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Effect of heat treatments on the corrosion behaviour of Al-5Mg layers deposited on Al6061 by wire-arc additive manufacturing

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In the present work, an Al-5Mg alloy was deposited on an AA6061-T6 substrate in the form of a block by robotic wire-arc additive manufacturing. The structure was subjected to two different heat treatments with the purpose to reduce the number and size of the second phase particles present in the as-manufactured material. The as-prepared and heat-treated blocks were electrochemically tested (cross-sections, two different planes) by cyclic polarization in 3.5 wt.% NaCl. The objectives were: a) to identify any different electrochemical behaviour between the various deposited zones and b) to determine, which heat treatment was more effective in mitigating the corrosion responses between the various deposited zones.

In the as-manufactured material, the deposited layers and the interlayer boundaries presented similar anodic polarization behaviour but small yet distinct differences in the cathodic polarization behaviour. Corrosion degradation in both the substrate and the deposited layers was mainly due to the presence of AlFeSiMn precipitates. The corrosion resistance followed the sequence: substrate < substrate/deposited alloy interface < interlayer boundaries < within an individual layer. Small differences were observed in the polarization performances of the two different cross-sectional planes.

Both heat treatments were successful in the refinement of the deposited alloy microstructure. Corrosion experiments on specimens heat-treated by the optimum treatment regime revealed a mitigation of the differences in the polarization performances of the deposited layers interior and boundaries.

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Effect of pH and fly ash on the electrochemical performance of 316L stainless steel concrete reinforcement in saline environments

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The employment of AISI 316L stainless steel as reinforcement of the architectural members in the ancient theater of Dodona in Greece is a common practice. However, even 316L is susceptible to localized corrosion in chloride containing environments [1]. Therefore, the partial replacement of traditional Ordinary Portland cement (OPC) with industrial byproducts with corrosion inhibition abilities, such as fly ash (FA), could present an important economical and ecological alternative. The beneficial role of FA on the corrosion resistance of reinforced concrete has been manifested in several studies. The pozzolanic reaction of SiO_2 with $Ca(OH)_2$ (the main cement hydration product) leads to the formation of calcium-silicate-hydrate (C-S-H), which is more corrosion resistant than $Ca(OH)_2$ [2].

Following previous works studying the effect of fly ash on the corrosion performance and structural integrity of stainless steel concrete rebars in acid rain and saline environments [3,4], the present study investigates the effect of fly ash as a corrosion inhibitor on the electrochemical behavior of 316L concrete reinforcing bars in a simulating concrete pore solution exposed to a coastal environment that is polluted by acid rain. The corrosion performance of 316L stainless steel is examined by cyclic polarization in a highly alkaline solution simulating fresh concrete exposed to the combination of chlorides and acid rain (pH≈12) and a mildly alkaline solution simulating corroded concrete cover that exposed the reinforcement to direct acid rain and chloride attack (pH≈8). Both solutions contained 1.8 g/l of $Ca(OH)_2$, fly ash at different contents (0 - 25 wt.% of the dry mixture), an acid rain simulating solution of pH=3.1, 3.5 wt.% NaCl, and appropriate amounts of 95% H_2SO_4 to regulate the pH of the solution.

All polarization curves at pH≈12 presented passivation within a broad range of anodic potentials and at low current density values (<0.1 mA/cm^2). However, the large negative hysteresis loop and the repassivation occurrence in the middle of the passive range several hundred of mV below the breakdown potentials showed that the breakdown of the passive films was partially due to pitting and partially due to oxygen evolution. In all cases, pitting initiated at potentials very close to the oxygen evolution potential.

At pH≈12, the beneficial effect of fly ash up to 20 wt.% content on the corrosion resistance of 316L rebars was manifested. However, this trend was reversed at 25 wt.% content as a deteriorating effect was demonstrated. This is attributed to the agglomerates of FA that do not interact in a pozzolanic manner with $Ca(OH)_2$. The above findings were confirmed by SEM/EDX examination of cross-sections after cyclic polarization. The experiments are continuing at pH≈8

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Comparison and combination of dynamic optical measurement systems for in-situ structural assessment of high-speed composite rotors

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Novel materials expand the design capabilities of multi-material structures, especially of composite structures. In view of increasing requirements regarding the structural integrity of high-speed composite rotors, new testing methods are prerequisite to capturing new phenomena and occurring interdependencies. Such novel optical measurement systems can provide valuable in-situ information regarding the structural integrity, especially when combined in a testing method. To achieve a combined method, they have to be compared with each other and with state of the art systems, in order to identify advantages and limits. Such a comparison is performed in the example of a high-speed glass-fibre reinforced epoxy disc rotor under rotation up to approximately 10,000 RPM [1]. Four optical measurement systems are compared regarding their ability to capture the structural dynamics. The systems are the Laser Doppler Distance Sensor LDDS [2], the Diffraction Grating-based Method (DGM) [3], the Optical Coherence Tomography (OCT) [4] and the Laser Doppler Scanning Vibrometer mounted on an optical derotator (LDSV) [5]. These systems, when combined, are able to capture both the dynamic radial and axial deformation and strain fields as well as the damage propagation near the surface of translucent rotors in µm accuracy.

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Adding remote sensing capabilities in fibre reinforced polymer composites through magnetoelastic sensor integration by 3D printing

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This study examines the potential of embedding magnetoelastic agents in otherwise passive composite structures, thus inducing remote sensing capabilities. The structures are carbon fibre reinforced polymer composite slabs, created via 3D printing procedures. During slab printing, magnetoelastic strips are inserted [1] in (rather than attached [2] onto) the slab. Owing to the magnetoelastic principle, mechanical vibration of the slab causes changes in the strip magnetisation. This, in turn, triggers the passive induction of electrical signals in reception coils placed at a distance from the slab. Since these signals are intrinsically linked to the slab's vibration characteristics, one may obtain a low-cost means of monitoring the slab dynamics, e.g for health monitoring purposes. The key question regards the possibility of receiving meaningful (with respect to noise) electrical signals, despite their contact-less passive reception. Vibrating slabs of different sizes at both high and low frequency-amplitude settings and using a specific data analysis framework, the slab remote sensing abilities are successfully demonstrated.

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Long Fibre Thermoplastic Composite Subjected to Impact: Experimental and Numerical Investigation

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Abstract. A combined experimental and numerical investigation was conducted of long fibre thermoplastic composite beam. Nylon 6 beam specimens were subjected to a low velocity impact. Three different glass fiber reinforcements have been tested (20%, 40%, 50%) and compared with the additional finite element results, while the temperature was constant at 23oC. A three-dimensional (3D) finite element analysis (ABAQUS/Explicit) has been employed to determine the deformation and failure of Nylon 6. The numerical predictions were in satisfactory agreement with experimental results.

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Fabrication aspects of hot structural aero engine components

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Fabrication and welding of structural components for the hot section of gas turbines continues to be of high importance to the manufacturing industry within this discipline. Weld cracking and specifically hot cracking as well as strain age cracking, is a serious concern during fabrication of these structural components. The aforementioned cracking phenomena can occur during welding or subsequent heat treatment of precipitation hardened Ni- based superalloys and can be influenced by i.e. chemical composition in terms of hardening elements and impurities, microstructure of base material and weld zone, together with welding processes and corresponding parameters and heat input. This presentation will shed some light on cracking susceptibility of wrought, cast as well as superalloy parts produced by additive manufacturing.

Air-coupled ultrasonic measurement of in-plane elastic properties of a non-uniform MICA paper

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MICA is a naturally occurring mineral, based on a group of silicate minerals composed of varying amounts of aluminium, potassium, magnesium, iron and water having thin sheet-like or plate-like structure with different composition and physical properties. MICA's unique properties as a thin, durable insulation material with excellent electrical resistance make it ideally suited for a variety of aerospace applications. MICA composites contribute to interior aircraft equipment such as parts of the galley, cabin, black boxes or data recorders in planes. The black boxes or data recorders, aircraft flight recorders are the crucial recording devices. MICA's flexibility as an insulating material will help ensure that the black box is fully compliant with manufacturing standards.

The tensile strength of the MICA is very low, therefore it is reinforced according to the product with some backing like glass cloth or polyethylene film. According to a manufacturer most important parameters of the MICA paper are density, tensile strength, porosity, humidity and uniformity of elastic properties. On-line measurement of those parameters, especially of elastic properties and thickness during a manufacturing process are not solved up to now.

The objective of this work was development of an ultrasonic contactless measurement method suitable for on-line measurement of spatially non-uniform elastic properties of MICA paper.

For solution of this problem we proposed to exploit a subsonic A_0 mode ultrasonic guided wave and to measure its velocity. The elastic properties were found from the measured ultrasound velocity. Ultrasonic guided waves in the MICA sample were excited by a contact and air-coupled PMN32%PT strip-like piezoelectric transducers operating in the frequency range 43-48 kHz. The normal displacements of the A_0 mode guided wave were picked up by the POLYTEC laser interferometer. Propagation of guided waves in the MICA sample was simulated by a finite element modelling. In order to separate the sub-sonic A_0 mode from the direct ultrasonic wave propagating in air we proposed to use the 2D spatial-temporal filtering of the recorded B-scans. This method is based on exploitation of different propagation velocities of those waves. From the 2D filtering follows that in the MICA sample propagate two A_0 modes with different phase velocities - c_1=98 m/s and c_2=117 m/s at 47 kHz, which correspond to two regions with clearly different elastic properties. The experimental and simulation results revealed that the proposed method is suitable for measurement of spatially non-uniform elastic properties of the MICA paper.

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The Influence of Concrete Cracks on the Chloride Penetration and Corrosion Damage of RC Elements in the Short Term

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Evident superficial cracking of concrete has engaged attention the last years, not only as an indication of severe corrosion damage of steel reinforcement but also as an aid factor in promoting corrosion in Reinforced Concrete structures.
In many studies, in the field of Construction Engineering, the cracks characteristics (such as width, length and density) have been identified as the main parameters that probably impair the Durability and consequently the service life expectancy of RC structures exposed to corrosive environment.
Moreover, the span of exposure (since the crack formation) is being considered as an important factor that influences the extent of cracks effect both on the stage of corrosion initiation and on the stage of reinforcement degradation as well.
Being grounded on aforementioned observations, in this study is examined the impact of superficial concrete cracking on the performance of RC elements against laboratory corrosion after a short-period of exposure. The chloride ions penetration in concrete was examined by means of colorimetric method on two types of cement (CEM I and CEM II), and a diffusivity index of crack was extracted. Furthermore, the mechanical performance of reinforcement was examined carrying out tensile tests on corroded steel rebars. The results of this study showed that, after short-periods of exposure, the Chloride ion ingress is promoted by the presence of cracks. Additionally, the diffusivity in the cracking area was increased with the increase of crack width. Finally, the mechanical performance of corroded rebars showed an intense degradation, mainly on ductility properties, even after a short exposure period, which was also confirmed by the severe pitting corrosion of steel reinforcement.

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Influence of the material volume of a lattice structure on bending properties

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In recent years, a few new fields which change the approach to life might be observed. Within the area of manufacturing, the most rapidly developing is additive manufacturing techniques. A special area of the components that can be produced by the 3D printing technique is so-called lattice structures. The article deals with the experimental investigation of the influence of material volume of a lattice structure on bending properties. FDM (Fused Deposition Modelling) technique and ABS (Acrylonitrile Butadiene Styrene) material were selected for the samples production. Five types of samples with the same simple lattice structure and the same size of a basic cell, but differ in a material volume ratio, were analyzed experimentally. Minimally five pieces of the samples of each volume ratio were produced and tested using the ZWICK 1456 testing machine at an ambient temperature of 22 °C and at a relative humidity of 60 %. The stress-strain diagrams have been plotted, the important values have been tabled and based on the results, the influence of volume ratio on the behaviour of the structure has been mathematically described.

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Experimental characterization of fabrication effects on the shear properties of thermoplastic composites in high and sub-zero temperatures

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Nowadays, as the world is steadily looking for green solutions, composite materials consisting of thermoplastic matrix are increasingly catching the attention. They are already being used in several industrial fields thanks to their recyclability, their performance and adjustability to mass production. Still, there have been noted many issues regarding the relation between the fabrication process and their mechanical characteristics. Among them, the shear properties are directly related to the quality of the matrix of the produced composite material while other parameters influence, such as the textile waviness, is quite unknown. A relatively high number of standardised methods are available for characterizing composite experimentally. In the present work, the effect of specific fabrication parameters on the shear performance of short and textile glass fibre reinforced thermoplastic composites is investigated using the modified V-Notched Rail Shear test method. Four thermoplastic-based composite materials are characterized, one containing short and 3 containing textile glass fibres. In addition, the characterization is expanded in a temperature range between sub-zero and higher, than the ambient, temperatures. The results reveal a strong dependency of the in-plane shear properties on the in-service temperature while a detailed report of the relation between parameters such as the injection molding direction and the shear performance is reported.

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Design approach for the development of a digital twin of a generic hybrid lightweight structure

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The innovation potential of lightweight design in its scientific and technical foundations lies in the systematic, i.e. integrated and cross-material consideration of the process chains. This consideration is one of the main goals of dahlia project - Digital Technologies for Hybrid Lightweight Structures. The end-to-end digitalisation of the development, manufacturing and validation process provides a first understanding of its process parameter-structure-property relationships, which is essential for the creation of a representative digital twin. To investigate these aspects in the design phase, a generic hybrid profile made of aluminium alloy and fibre-reinforced thermoplastic is exemplarily studied combining the advantages of each respective material [1]. The deformation and failure behaviour is analysed under typical thermal and mechanical loading conditions. Furthermore, important aspects for the development of a digital twin are considered, such as a knowledge-based selection of design and simulation tools, their respective parametrisation and interface communication [2]. First results are presented as well as the development aspects of a digital twin from its nominal offline form up to its specific application at a generic lightweight structure.

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Quality improvement through process and learning approach in failure investigation and root-cause analysis

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Process and product improvements in industry have been realized through the systematic investigation of failures, following a deterministic and rigorous approach, aiming to the identification of the major root cause(s) and the implementation of corrective actions and optimization modifications. The outline of the failure analysis, as a comprehensive and diligent process, requires deeper understanding and assessment of the expected benefits, in conjunction to the process stages and resources which are needed to achieve them. Therefore, the planning and organization of the failure investigation is a necessary condition for successful results and it is almost identical for any type of failure and industry related process, see also Ref. [1, 2].

This presentation is mainly constructed in a way to underline the significance of the quality tools and techniques that could be used in the frame of a failure analysis procedure. This perspective is further elucidated through the connection with specific case histories that provide a clearer background and insight of the succeeded benefits, through quality improvement and risk prevention.

The analytical methods employed, refer mainly to the investigation of material properties and identification of fracture/failure mechanisms, from a microscopic and fractographic origin (light microscopy, SEM/EDS), as well as from a continuous mechanics approach (mechanical testing; static, dynamic, cyclic). Numerical simulation can be also performed to obtain more quantitative information concerning the service loading conditions (stress and strain fields) in order to get a better interpretation of material/component behaviour.

Moreover, the organizational aspects of failure investigation, dominated by the systems-thinking, evidence-based and risk minimization principles or elements are discussed from a wider and a holistic perspective, which is reflected by the established quality management frameworks and modern manufacturing systems pursuing to continuous learning and business excellence.

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Autofrettage of component-like ultra high Strength Steel Specimens with intersecting Holes

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This work is primarily concerned with the fatigue life of high-pressure bearing components with intersecting holes, typically used in Diesel engine fuel injection systems. The investigation focuses on specimens with orthogonally intersecting holes that have undergone the process of Autofrettage (single mechanical overload), which is typically used to extend the fatigue life of components loaded by cyclic internal pressure. The Autofrettage process induces advantageous, life-time prolonging residual compressive stresses in the highly stressed areas of the components. The resulting residual stress distribution thus influences the fatigue failure and especially the crack propagation behavior of the components.

In previous works, the increase in endurance limit for autofrettaged specimens made of the quenched and tempered steel 42CrMo4 was investigated. Results showed that besides crack initiation, crack arrest behavior has to be taken into account when calculating fatigue lives of autofrettaged specimens as the endurance limit is otherwise underestimated. As efforts are made to increase the injection pressures of fuel injection systems, in this work, the benefit of using ultra high strength steel for the application described is investigated.

In order to achieve reliable results, material testing with samples made of the ultra high strength steel W360 was performed. The resulting test data were used to describe the initial loading and cyclic loading behavior of the material with a suitable material model. Finite element analysis was then performed to simulate the Autofrettage process. The resulting residual stress distribution was used to determine at which levels of subsequent cyclic loading crack initiation would occur. For predicted crack initiation, the simulated residual stress distribution was used to investigate the crack propagation behavior with fracture mechanics based approaches of different complexity in order to identify possible crack arrest or crack propagation. Calculated results were compared to experimental test data from component-like specimens. Similar to previous works, specimens subjected to Autofrettage showed a much higher endurance limit. The comparison to the test results showed an overestimation of the predicted fatigue lives. The modelled material behavior and consequently the residual stress distribution from the simulation models was identified as the decisive factor for the deviation. Still, the comparison showed that the fracture mechanics based approaches are capable of describing the crack arrest and propagation behavior reliably. Further investigation regarding the modeling of the material behavior with focus on the Autofrettage process is still required.

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Influence of discontinuities on fatigue strength using the example of additively manufactured specimens made of AlSi10Mg

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Fatigue strength is largely affected by the influence of discontinuities: geometric notches like holes and corners in components, surface notches (roughness), pores and inclusions in the material. Therefore fatigue of structures and materials is a local problem and fatigue strength calculations are best carried out using local approaches such as local stress concept, local strain concept or fracture mechanical concepts.

For high strength components and materials the influence of discontinuities on fatigue strength becomes more important because of the higher notch sensitivity of the material itself. With additively manufactured components, 3D-printing creates more pores in the material than a conventional process.

In this work, the influence of discontinuities on low cycle and high cycle fatigue strength of materials was examined on the example of additively produced material specimens made of aluminium by using a fracture mechanics parameter.

Hourglass-specimens with a diameter of 6 mm were made by turning and finish turning from 3D-printed round bars of 18 mm diameter. The bars were printed in longitudinal direction using Selective Laser Melting (SLM) technology. Four different process parameter sets (H1 to H4) were used for printing.

Fatigue tests were performed under total strain control in the range from ε_a = 0,07 % to 1,19 %. Crack initiation life was defined at 5 % sudden change of maximum load. Damage almost always started from pores near the specimen surface. Test results show a nice scatter (Fig. 1) due to the variation of geometry, size and position of these pores.

The investigation of the crack-initiating pores was done using a light-microscope equipped with digital camera and measurement software. The area of these pores was calculated using either ellipses or pore boundaries.

The influence of pores on fatigue strength was investigated by using a modification of Murakami's $\sqrt{area}$ parameter [1] to approximate the stress intensity factor for an arbitrary shaped crack. The approach was extended to low cycle fatigue by introducing El Haddad's strain based crack tip parameter K_ε [2] together with a geometry function from Shah and Kobayashi [3] to take the position of the pores relative to the specimen surface into account. A re-evaluation of the test data using this approach then leads to a significant reduction of the scatter (Fig. 2).

Therefore, this modification of the $\sqrt{area}$ parameter can be used to improve the fatigue strength estimate of materials containing discontinuities, if appropriate information is available.

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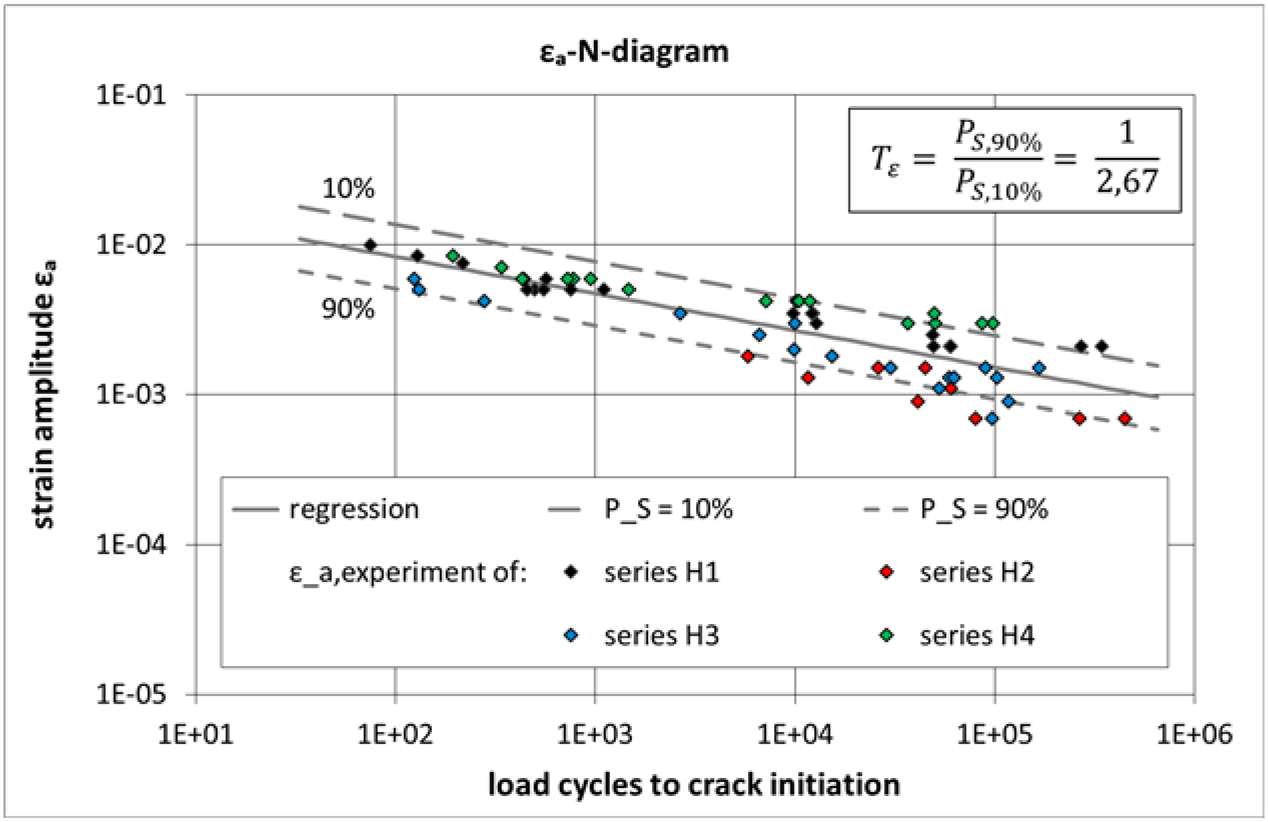
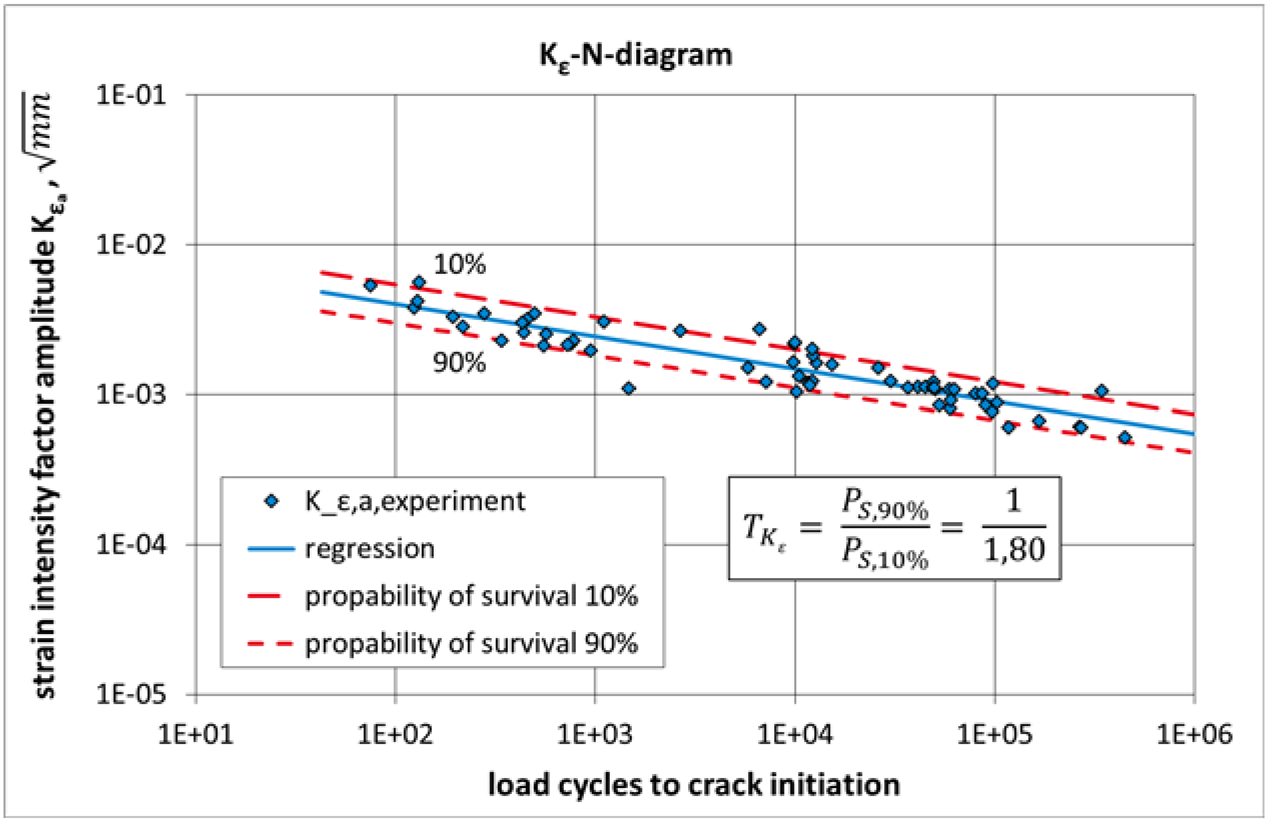


Results of fatigue tests on 3D-printed hourglass specimen made from printing series H1 to H4. Total strain versus number of cycles to crack initiation.



Results of fatigue tests on 3D-printed hourglass specimen made from printing series H1 to H4. Strain based intensity factor versus number of cycles to crack initiation.

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A Leakage Problem in Hot Water System of a Building

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A big building experienced water leakage through the nipples in the system not long after a decision made to decrease the water temperature for 90 C to approximately 80 C due to financial reasons. Threaded nipples in some areas started leaking and one nipple connecting a valve fractured catastrophically. Nipples, made of plain carbon steel, with low hardness and ferritic-pearlitic structure had corroded significantly. Pitting colonies had infested the internal surface of the nipples. Further tests indicated that the decrease in temperature had allowed the bacteria in the colder regions of the system to colonize and cause pitting and subsequently causing leakage.

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Thermomechanical and microstructural simulation of the AM process of 316L austenitic stainless steel

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An integrated thermomechanical and microstructural simulation of additive manufacturing (AM) process, as applied to an AISI 316L austenitic stainless steel, is presented. A finite element technique is employed to evaluate the temperature evolution as well as residual stresses and distortions in the processed part, due to the successive material deposition. The heat transfer and mechanical problems are solved in sequence. The material deposition is modelled using “quiet elements”, which are activated as the added material solidifies. These elements are present from the start of the analysis but, until activated, are assigned properties that do not affect the analysis. The thermal history generated by the heat transfer analysis is essential in determining the resulting microstructure. CALPHAD-based computational thermodynamic and kinetic modelling, implemented in the Thermo-Calc software, is employed to study the microstructural evolution during AM. Material properties required for the heat transfer problem, such as the specific heat and the liquidous and solidus temperatures, were calculated according to Thermodynamics. The thermal cycles obtained from heat transfer calculations are used to study solidification and solid-phase transformations upon cooling via multi-component diffusion simulations in a representative microstructural section. A distinction between eutectic and peritectic solidification modes is made, as both have been observed in AM studies. Phase fractions and composition profiles are calculated as a function of time, allowing for the determination of the non-equilibrium solidus temperature, the freezing range, as well as the presence of elemental segregation, which are parameters crucial for the mechanical and corrosion behaviour of the manufactured part. The ensuing microstructural properties, including phase fractions and constitutions, are then provided as input for the mechanical analysis. In the mechanical finite element analysis, the local mechanical properties are estimated based on the calculated microstructural properties by using non-linear homogenization methods, and residual stresses and distortions are calculated.

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Towards Cyberalloys: computational alloy and process design

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The development of new metallic alloys is traditionally a very tedious process, involving extensive experimental investigations by which composition and processing conditions are varied in a more or less erratic manner until the desired properties are achieved. This situation has a tremendous negative impact on alloy development time and costs. Alloyneering is a generic term, developed over the years in the Laboratory of Materials of UTH, which combines the words Alloy and Engineering and describes a concise knowledge-based methodology leading to the development of engineered alloys. Alloyneering encompasses the application of computational alloy thermodynamics, kinetics, and precipitation models, which can describe the microstructure evolution, with strength models, which link strength with microstructure, for the computational design of metallic alloys with tailored properties or cyberalloys. The procedure is integrated with genetic optimization techniques for the selection of optimal alloy composition or processing parameters. Three examples illustrate the alloyneering approach. The first example is concerned with the computational design of 6xxx Al-alloy with high extrudability. The evolution of iron intermetallics during the homogenization process as well as the precipitation of the strengthening phase Mg2Si during homogenization cooling were simulated. This enabled the design of optimal alloy composition and homogenization parameters to achieve a 40% increase of extrusion speed over conventional alloys. The second example is concerned with the design of Medium-Mn steels (MMnS) with tuned retained austenite stability for optimum TRIP interactions which lead to enhanced strength/formability combinations. CALPHAD based thermodynamic and kinetic calculations, coupled with evolutionary and gradient based optimization techniques enabled the design of optimal compositions and processing parameters that satisfy certain design criteria. The third example is concerned. The third example is concerned with the optimization of the thermomechanical control process (TMCP) of niobium-microalloyed HSLA steels for oil & gas pipeline applications. A mean-field model integrated with a Kampmann-Wagner numerical (KWN) precipitation model was developed for the description and interaction of static recrystallization kinetics of austenite and the strain-induced precipitation kinetics of niobium carbonitrides during the multipass hot-rolling. Genetic programming was again used to identify optimum processing parameters for the hot rolling process such as reduction per pass and interpass times. The examples illustrate that the alloyneering method could be used for the development of cyberalloys, which are the result of a computational alloy design process.

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Verification and application of bird strike analysis for the design of high-speed helicopter composite cowlings

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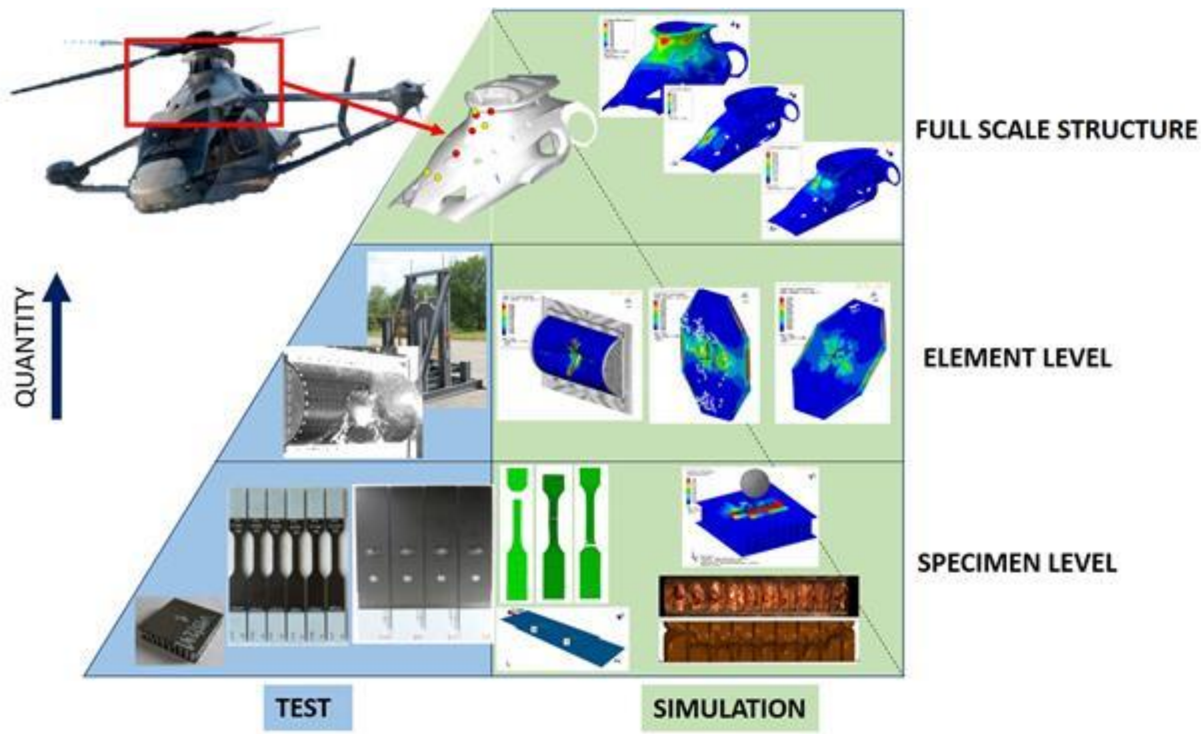
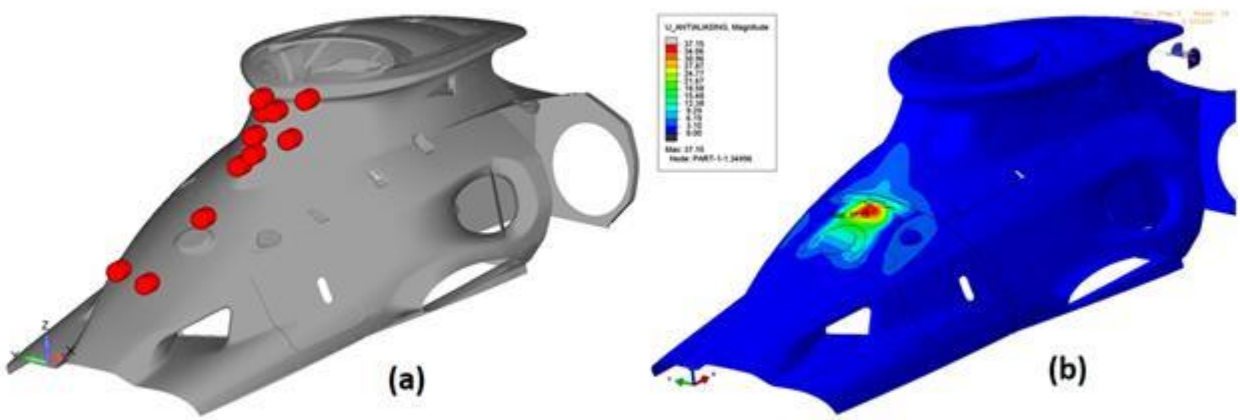
Bird strikes are an important phenomenon that must be taken into consideration when designing aircraft. A bird impact experiment provides a direct method to examine the bird strike resistance. However, the design of the aircraft structures usually involves many iterations of design-manufacturing-test and conducting bird impact experiments is not only time consuming but also costly. The aim of this work is to show the application of test verified numerical simulation for the design of composite cowlings of the high-speed helicopter. The standard block building approach (figure1) was used to verify the numerical model.
The first step was the experimental determination of the basic material properties of the evaluated structure. In the case of composite structure, average material properties determined by standard quasi-static material tests (tension, compression, in-plane shear, ILSS) are used in numerical models. Application of fiber dominated material properties measured at high strain rates is not necessary due to brittle behaviour of CFRP materials leading to a minor dependency of mechanical properties on strain rate. Additionally, to basic elastic and strength parameters crush strength of the sandwich core is measured by quasi-static flatwise compression test. Matrix dominated and sandwich core properties with higher dependence on load strain rates must be correlated later based on flat/curved panel test results.
Test plan of flat/curved panels was defined in dependency on the preliminary design of the final part, bird mass and impact speed. The test results are compared to numerical simulations and the correlation of the models is performed. Altered parameter of bird model is mostly porosity and geometry (length) of the projectile.
The FE simulations were performed using the ABAQUS software. The particle elements (SPH – Smoothed Particle Hydrodynamics) with the hydrodynamic material model was used for bird projectile simulation. The general contact of ABAQUS/Explicit was used for contact analysis between all parts of the FE model during impact analysis.
The global FE model of cowlings assembly was created on the base on the verified model of test specimens. The FE mesh of cowlings was created on CAD geometry model in Hypermesh SW and transform to ABAQUS/CAE.
The analyses of full-scale composite cowlings were performed according to CS29.631 airworthiness requirements for cruise speed and bird mass 1 kg. The design of composite cowlings and integrated part of a structure such as frames, antennas, fasteners were analysed for 11 bird trajectories and two lengths of the bird projectiles (figure 2). The analyses parameters for each trajectory were displacement, contact with inner parts mainly in rotor area, composite damage criterion (tensile fibre), a load of fasteners and weight of penetrated parts of the projectile in case of cowling failure.
The results from numerical simulation were used to improve and optimisation of composite cowlings design.
The work was performed under project "DREAM – Design and Realization of equipped engine compartments including cowling for a fast compound rotorcraft". This project has received funding from the Clean Sky 2 Joint Undertaking under the European Union's Horizon 2020 research and innovation programme under grant agreement No 737955.



Building block diagram for bird strike resistance analysis of composite cowlings



Trajectory of bird projectile (a) and example of displacement analysis during bird projectile impact (b).

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Process Design and Optimization of HSLA Steels using Mesoscale Modeling

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The design of the Thermomechanical Control Process (TMCP) of HSLA steels and the identification of the optimum processing parameters constitute a challenging problem in the industrial pipeline applications, especially for heavy plate rolling. The TMCP of a microalloyed steel consists of a two stage multipass hot rolling in austenite region (roughing and finishing), followed by controlled accelerated cooling during the austenite to ferrite phase transformation. Understanding the phenomena which control the microstructure evolution with respect to processing parameters is the key to process design. In the present study, a mesoscale physically based recrystallization model integrated with a Kampmann-Wagner Numerical (KWN) precipitation model was employed to describe the interaction of the strain-induced precipitation kinetics of niobium carbonitrides Nb(C, N) and static recrystallization kinetics of austenite during the multipass hot-rolling of an X70 HSLA steel, with an initial plate thickness of 60 mm. The variation of the volume fraction and particles size distributions of Nb(C, N), as well as the recrystallized fraction and the average austenite grain size were obtained at each pass of the process as a function of the interpass time, the thickness reduction per pass and the temperature drop at each pass. The industrial processing bounds were taken into account in specifying the design space. After applying specific process design criteria, which aim to minimize the final ferrite grain size, maximize the Nb content in solution, and the degree of pancaking during the finishing stage, a multi-objective non-dominated sorting genetic algorithm was used to determine a list of optimum processing routes. Then, for the selection of the final optimum processing route, hierarchical clustering methods and constraint functions were employed as a measure of the sensitivity and robustness of the decision variables on the processing parameters.
Based on the desired microstructural features, a processing route was chosen from the list and its effect on the microstructure during the controlled accelerated cooling was investigated, using a mesoscale multi-phase field model (MICRESS) coupled with Thermo-Calc thermodynamic and kinetic databases. Clustering analysis and neighbor nearest index were employed to characterize the microstructural homogeneity, while a non-parametric kernel density estimator analysis and a bootstrap procedure were used to derive the equivalent circular grain diameter distributions and their 95% confidence bands. A selected processing route was carried out at laboratory scale, and the final microstructure was characterized by SEM and EBSD analysis, while Charpy V-notch and BDWTT tests were performed on the produced specimens. A homogeneous distribution of a fine bainitic ferrite structure was observed, indicating that the applied process design criteria were satisfied. The effect of other parameters on the toughness, such as the texture or the precipitation of aluminum nitrides and titanium carbonitrides should be considered in achieving improved mechanical properties. The ability of the above method to connect the microstructure with the processing parameters, makes it an effective integrated tool for material process design.

Robust optimization for alloy and process design of medium Mn steels

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In recent years, the demand for highly formable and lightweight alloys for automotive applications, drives the development of the 3rd generation of AHSS, primary candidates of which are medium Mn TRIP-TWIP steels, containing 4 to 10 wt% Mn. Medium Mn steels aim to improve on formability, uniform elongation and strength to weight ratio, over existing steel grades, via retained austenite stabilization by means of C and Mn partitioning during intercritical annealing. The successive activation of TWIP, ε- and α΄-Martensite TRIP upon forming, improves uniform elongation, total strength and workhardening rates, by stabilizing plastic flow and delaying necking. Addition of Al and Si reduces material density and stabilizes δ-Ferrite, allowing for pre-partitioning of C and Mn to occur during solidification, accelerating austenite growth kinetics during intercritical annealing. Although significant progress has been made over the years on the field of medium Mn steels, material development still heavily relies on empiricism and trial and error approaches.

In the present study, an ICME approach for alloy and process design of δ-Ferrite containing medium Mn steels is presented. CALPHAD based thermodynamic and kinetic modeling was employed, coupled with robust and reliable multi-objective optimization, considering the uncertainties arising during material production. Phase fractions and compositions as well as austenite stability, expressed via the particle size dependent Ms temperature and Stacking Fault Energy (SFE) of austenite, were determined at equilibrium using thermodynamic calculations. Composition and annealing temperature were considered as Gaussian random variables with given variance, obtained from production data and a second order uncertainty propagation method was employed to efficiently determine the marginal distributions of model outputs, as retained austenite fractions and stability. Specific alloy design constraints were defined in terms of the probability of forming undesirable microstructural features and incorporated into a stochastic a multi-objective optimization problem formulation, aiming to maximize retained austenite fractions, stability and annealing temperatures, along with process reliability and robustness, given the uncertainties during production. The optimization problem was solved efficiently via genetic programming utilizing the Non-Dominated Sorting Genetic Algorithm (NSGA-II), to determine a list of Pareto optimal compositions and annealing temperatures. Multi-component diffusion calculations followed on a selected optimal steel, to simulate solidification, hot rolling, accelerated cooling, and quenching, providing the initial conditions for the isothermal intercritical annealing simulation that followed. The temporal and special evolution of phase fractions and austenite stability were calculated, and an optimal heat treatment time was identified by solving a temporal optimization problem under specified constraints. The presence of δ-Ferrite, due to increased Al and Si, was found to accelerate austenite growth during intercritical annealing, by taking advantage the elemental segregation occurring during solidification. The modelling approach was experimentally validated on several δ-Ferrite containing medium Mn steels by means of quantitative metallography, optical, scanning electron and atomic force microscopy. Good agreement with model predictions was observed, indicating that the proposed approach can be deployed to accelerate the development of novel alloys with optimized microstructural properties under uncertainty, crucial for an effective industrial adaptation.

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Microstructure properties relationship in low carbon microalloyed steel bars

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The work sheds light in the interactions between chemical composition and metallurgical processing on the developed microstructure and eventually the mechanical properties of microalloyed steel bars for automotive, hydraulic and agricultural applications. Here two separate case-studies of low carbon microalloyed steel bars produced via the continuous casting – reheating - hot rolling route are presented and discussed. The first case focuses on the interpretation of different impact strength values obtained by using Niobium and Titanium (Nb, Ti) instead of only Vanadium (V) in the production of S355J2 rounds under similar casting and rolling conditions. In the second case, several critical microstructural features that contribute to the compromise among strength, elongation and impact properties in 20MnV6 steel bars, with variable chemical composition are studied. The microstructure characterization of the samples was performed by means of optical microscopy, SEM/EDS and EBSD, utilized as principal analytical techniques.

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Estimation of the fatigue strength of ultra-high strength steels

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Ultra-high strength steels are being used in an increasing number of applications in mechanical engineering, which is due to some of the advantages of these materials. In the automotive industry, for example, sustainability can be increased by using ultra-high strength steels in car body construction to maintain the same strength while reducing vehicle weight and thus consumption and emissions. Likewise, in the manufacture of bearings and transmissions, ultra-high strength or case-hardened steels are mostly used.

For the dimensioning of components made of low- and medium-strength steels, there are established estimation methods for material parameters as well as transfer functions to transmit these parameters to components. However, this level of knowledge is still insufficient for ultra-high strength steels and has not yet been specified in guidelines. This often leads to over-dimensioning when using these materials and thus to a waste of resources or to a high dimensioning risk in lightweight construction. The aim of an ongoing research project is to develop a validated method for calculating the fatigue strength of components made of ultra-high strength steels up to a tensile strength of 2400 MPa. Especially the estimating of cyclic material behaviour for the local strain approach is to be extended to include the coverage of ultra-high strength materials.

In the present publication, three ultra-high strength steels are examined in more detail. The results of tensile and fatigue tests as well as the determination of cyclic material characteristics are presented. In addition, the estimation of the cyclic material behaviour based on a minimal amount of input data (only tensile strength) is presented. These studies serve to determine input values for the local strain approach, which will be extended to include suitable parameters for ultra-high strength steels.

This publication is part of the ongoing research project “Ultra-high strength steels” which is funded by the German Federal Ministry for Economic Affairs and Energy (IGF-Nr. 19667 BG).

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Approximation of elastic-plastic local strains in surface-hardened notched components

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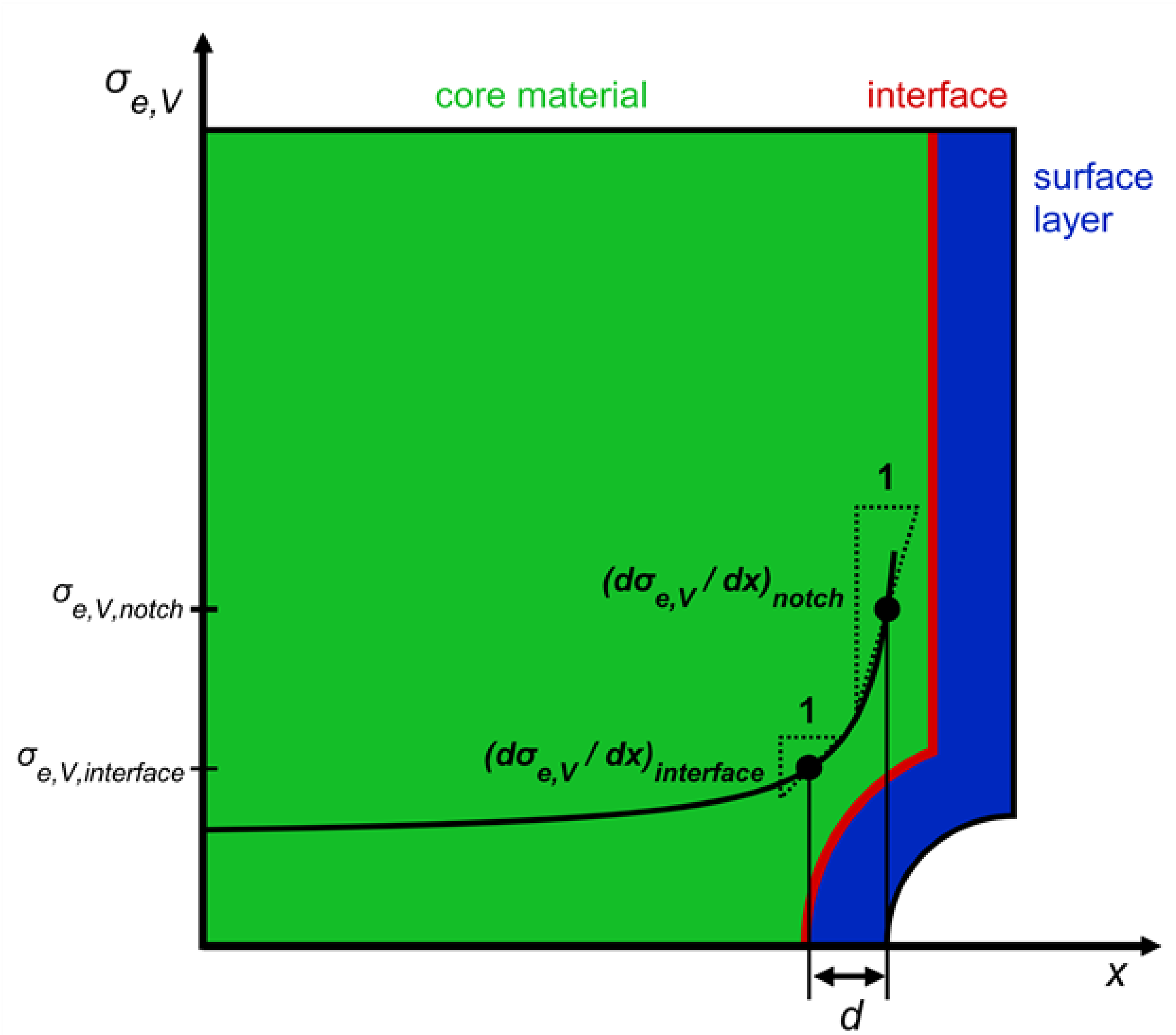
Highly stressed components in mechanical engineering often require the use of surface layer strengthening techniques to ensure their resistance against wear and fatigue. The hardened surface layer then exhibits better mechanical properties than the core material in its original state. This results in a structure with inhomogeneous material properties.

While the elastic material properties of various areas do not differ significantly, the surface layer shows considerably higher resistance to plastic deformation. Compared to a structure with homogeneous material properties, inhomogeneity only has an effect when the yield point is exceeded. Depending on the component and load introduction geometry, plastic deformation can first occur in the surface layer and in the area of the core material.

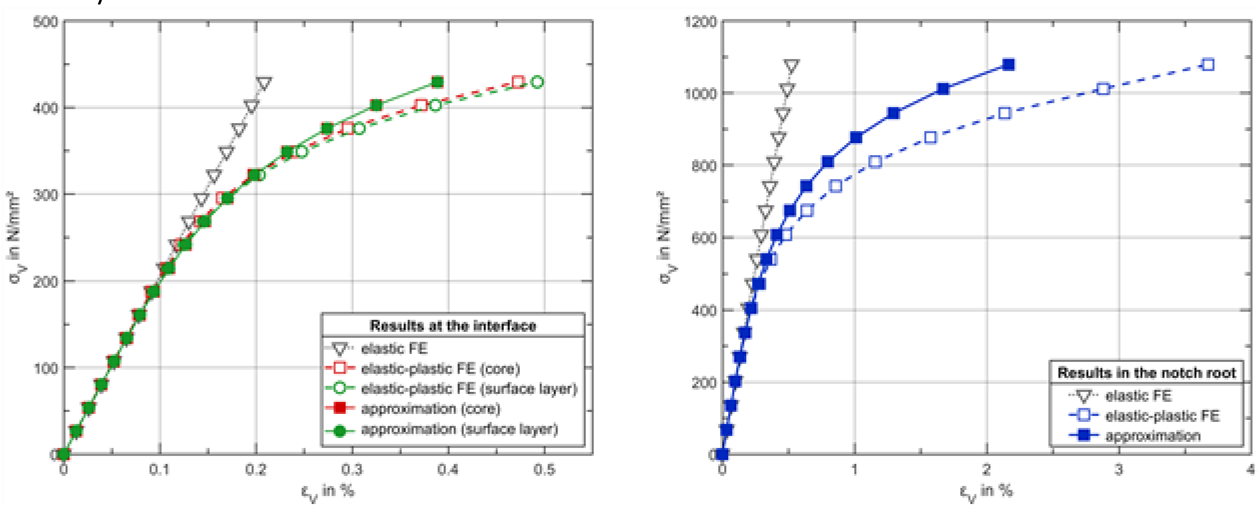
When performing proofs of structural durability based on the local strain approach, the elastic-plastic strains at the failure-relevant points (notch root) are estimated with approximation formulae based on the stresses determined by elasticity theory. E.g. the "Guideline non-linear" of the Forschungskuratorium Maschinenbau (FKM) allows the application of the Neuber formula. This Guideline is currently only approved for homogeneous components. The aim of an ongoing research project is to make the proof of fatigue strength based on the local approach also feasible for components reinforced by surface layers. A prerequisite for this is the identification of approximation formulas and algorithms, which can be used to estimate elastic-plastic stresses in such inhomogeneous structures, which is the subject of the present publication.

Part of the procedure is a strong simplification: The structure consists of only two, in itself homogeneous areas, namely the low strength core material and the high strength surface layer. At the interface exists deformation compatibility. On both sides of the interface, three of the six components of the strain tensor are identical. In contrast, the approximation method postulates that the equivalent strain on both sides of the interface is the same. By comparing these values with FE calculations, it is shown that this leads to only minor inaccuracies, whereas the ease of use is impressive.

The approximation algorithm starts with the calculation of the interfacial equivalent strain using the Neuber formula and a special virtual stress-strain relation. The latter is obtained from the stress-strain relationships of the two materials involved by means of a kind of mixing rule, taking into account geometry-related influencing variables. With the corresponding stress-strain relationships of the materials, the stresses at the interface are determined. They are included in the evaluation of the fatigue strength for this location. From the stresses and elastic-plastic strains at the interface, surface layer-side, the pseudo-elastic strains there are determined again using the Neuber formula. They are larger by a factor than the elasticity-theoretical ones for homogeneous structures. It is precisely by this factor that the elasticity-theoretical notch stress is increased. A third application of the Neuber formula to the increased notch stress, now in conjunction with the stress-strain relationship of the surface layer, leads to the notch strain. A second evaluation of the fatigue strength must be performed for the location of the notch root.



Schematic sketch of the underlying geometry and stress distribution according to the linear theory of elasticity



Comparison of strains calculated with the finite element method and with the presented approximation method, left at the interface and right in the notch root

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Phase-field simulation of the evolution of retained austenite during processing of low alloy TRIP steels

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Low-alloy TRIP steels exhibit excellent combinations of strength and formability and are currently used for automotive applications. The enhanced formability is due to the strain-induced transformation of retained austenite (RA) during forming. The associated TRIP effects depend on the amount and stability of the retained austenite, which in turn depend on processing. A two-stage thermal process, consisting of intercritical annealing and followed by isothermal bainite transformation at a lower temperature, has been simulated in the present study using multi-phase field modeling (MPF). The required thermodynamic and kinetic data are derived by coupling the phase-field model with the Thermo-Calc databases. 2D multi-phase field calculations are performed on an initial ferrite-pearlite structure, and the simulations during the intercritical annealing are carried out in two steps. In the first step, the rapid transformation of pearlite to austenite takes place under non-partitioning local equilibrium (NPLE) conditions. The second step starts after the complete dissolution of pearlite, where the ferrite to austenite transformation occurs until the end of intercritical annealing. The phase fractions, composition profiles, and microstructure obtained at the end of intercritical annealing are implemented into the MPF model, for the simulation of the isothermal bainite transformation. Carbide-free bainite is considered to form through diffusional nucleation and displacive transformation. A phenomenological approach incorporating the anisotropic properties of the interface is employed to simulate the displacive growth of bainite. The spatial distribution of retained austenite, the RA fraction and its composition are computed at the end of the process. The simulation results were validated experimentally with a Al-containing TRIP 700 steel under different processing routes by varying the bainite isothermal transformation temperature and time. With the processing routes used, different microstructures have been obtained with variation in initial retained austenite volume fraction and stability. The retained austenite volume fraction was determined using the saturation magnetization method, while the RA stability was assessed with the critical $M_{s\sigma}$ temperature, using the SS-TV-TT experimental procedure. Also, the size and distribution of the RA phase after processing were evaluated using metallographic techniques. The experimental data obtained was used for the evaluation of the simulation results with the multi-phase field modeling method. The present model enables to study the influence of the processing parameters on the variation of the microstructural features and constitutes an effective tool towards material design.

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Development of a multipurpose test rig and validation of an innovative rotorcraft vertical tail TAILTEST

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TAILTEST ninth call of programme Clean Sky 2 project is aimed to development of multipurpose test rig for validation of an innovative rotorcraft vertical tail has started in 2019 year and is conducted in Czech Aerospace Research centre (VZLU) as coordinator cooperating with Greek Athena Research centre (Athena RC) as participant. This project was initiated by Fokker Aerostructure Company and as part of project chain is contributing into conceptual aircraft type of Next Generation Civil Tiltrotor with the reduction of fuel consumption and CO2 emissions by lowering the structural weight of a rotorcraft tail through application of thermoplastics. The project is resolved in 6 Workpackages.

WP1 – Management. It concerns the project management and coordination activities including the prompt periodical reporting as well as creation the certification strategy for damage tolerant bonding joints.

WP2 - Design and manufacture of the multipurpose test rig where the main objective is the design and manufacturing of a multipurpose test rig including the test plan development to be used for certification structural tests of a thermoplastic vertical tail fin as well as for testing of representative structural joints, see Figure 1. Based on definition of fin loading and joint stiffness requirements the preliminary design of test rig focusing on variable joint stiffness and innovative load application capabilities will be optimized through detailed FE analyses of the complete testing facility. Consequently the test rig will be equipped by test article and completely instrumented.

WP3 – Test execution. The V-tail will be tested together with rear part of the fuselage. Only the one deck of the V-tail will be part of the tested structure. The second deck will be compensated by dummy when the real stiffness of the second deck will be simulated and experimentally verified. The test article will be instrumented including usage contactless optical systems, see example in Figure 2. The static tests will be completed up to ultimate load. The test will be monitored by cameras and measured data will be remotely monitored and evaluated. The final test report will contain the test setup, test rig and the test articles descriptions, test process, strain gauges and deflection measurements.

WP4 - Numerical validation & correlation is devoted to numerical simulation of fin structural behaviour and validation of the respective FE model. Consisting of two tasks it deals with the fin FE analyses under the loading conditions during testing and with the correlation of calculated and measured data and the validation of the FE model.

WP5 - Interface debonding propagation simulation test and analysis of a spar-to-skin joint. The aim is development and validation a numerical model for debonding simulation in hybrid joints and material damage for static and dynamic loads. Validated model will be based on spar-to-skin joint and used for virtual testing of the vertical tail and the design optimization of the fuselage/fin joining.

WP6 - Exploitation, dissemination and communication is aimed to establish a close cooperation with the aeronautical manufacturers in the project’s results exploitation based on dissemination and exploitation plan.

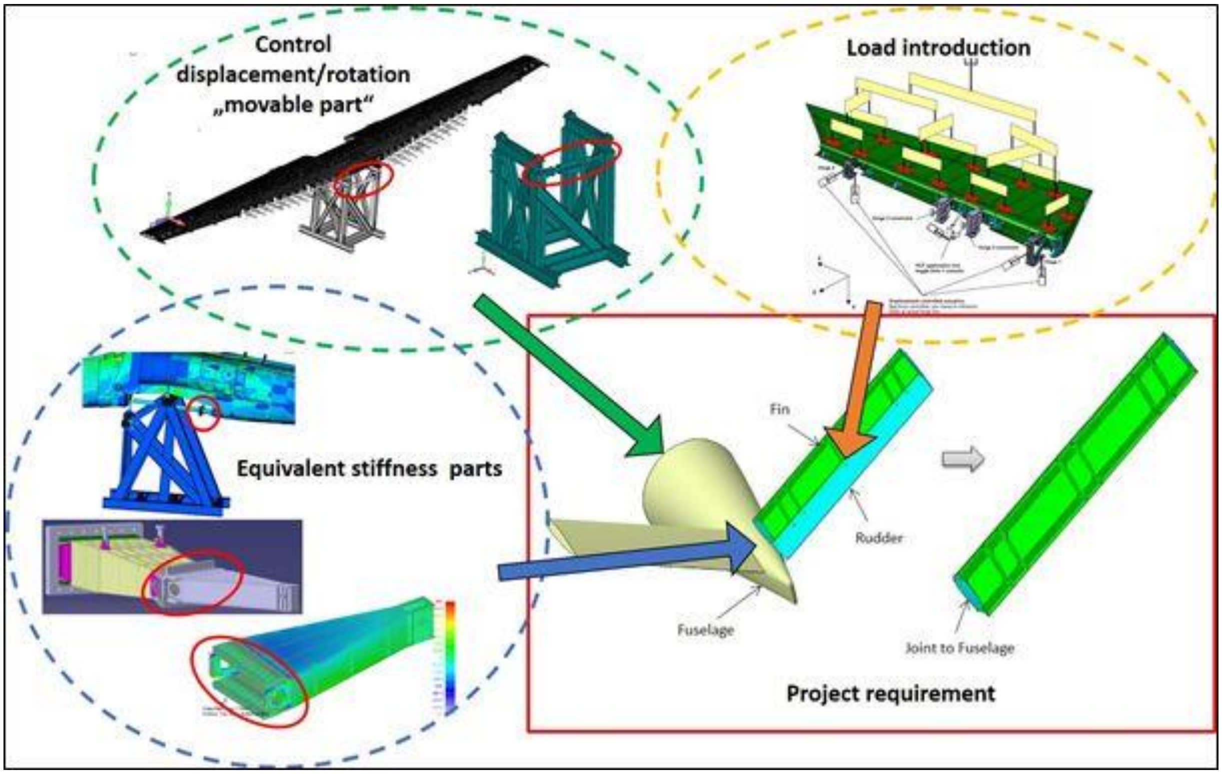

Figure 1: Schematic representations for the design of the variable stiffness test rig based on VZLU previous applications

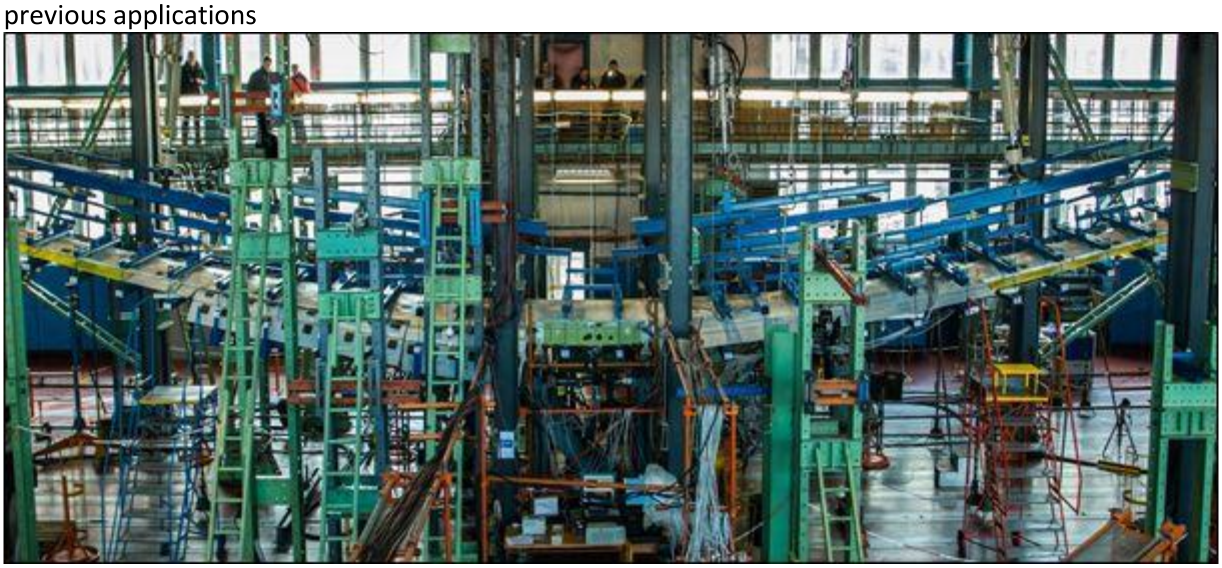

Figure 2: Example of test rig - Wing static test (national project) with simulation of variable stiffness of fuselage

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Influence of multiaxial cyclic loading on the fatigue behavior of defective friction stir welded joints

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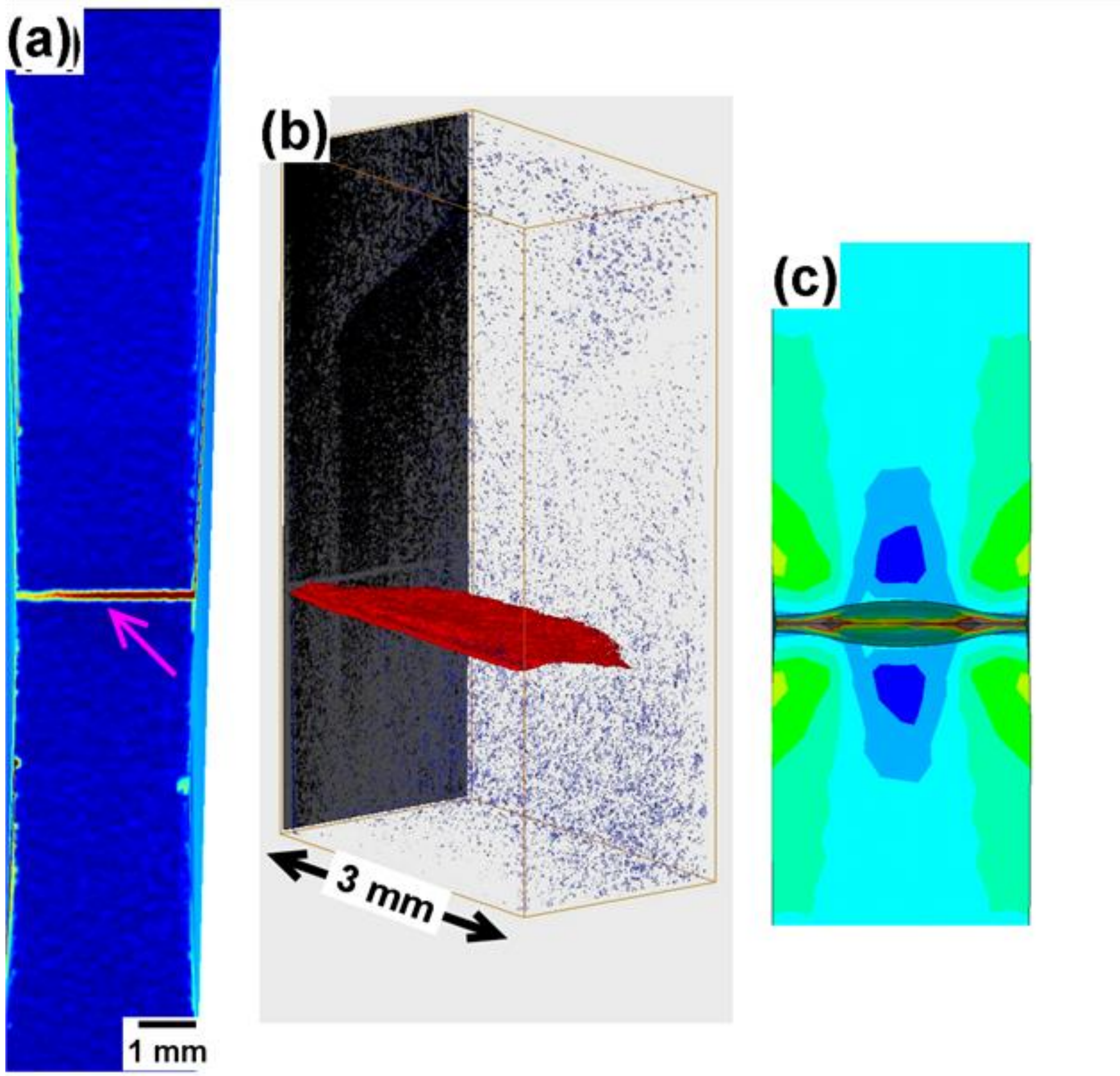
In this work, the influence of the lack of penetration (LOP) on the fatigue performance of friction stir welded AA2024-T3 joints was examined under multiaxial loading conditions to meet representative conditions of an aircraft fuselage. Biaxial specimen with a gauge area of 380 x 380 mm², as well as dog bone samples with a width of 3 mm were investigated under cyclic loading in a multi-scale approach. Ultrasound scans, digital image correlation (DIC) and computed tomography were used prior and during the experimental program to reveal the damage evolution. Especially the influence of shear stresses was investigated with both types of specimen at different orientations of the friction stir welded (FSW) seam with respect to the loading axis. Therefore, the principal stress component perpendicular to the seam was kept constant. The tests with the small dog bone specimens were carried out on defective friction stir welded joints oriented at 90° and 45° degrees. The orientation of the weld seam influenced the fatigue response of the defective friction stir welded joint. For the 90° specimen, the crack initiated at the tip of the LOP and grew through the weld nugget perpendicular to the loading axis, as revealed by computed tomography scans and scanning electron microscope images. Conversely, for the 45° oriented specimen, the crack initiated at the heat affected zone and grew perpendicular to the loading axis exhibiting a longer fatigue resistance. The biaxial tests lead to similar results, as the FSW seam subjected to shear had a significantly longer duration. The higher fatigue resistance of the weldment subjected to additional shear can be attributed to complex strain redistributions in the vicinity of the FSW seam. Additional finite element analysis supported these results.



(a) DIC results showing fatigue crack (pink arrow) at the LOP, (b) 3d visualization of the fatigue damage (red) through the FSW seam (c) FEM-analysis showing the von Misses stresses.

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Mode-I fatigue crack growth analysis based on crack tip cyclic strain hardening

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Fatigue crack growth modeling used in damage tolerance design usually relies on empirical observations and assumptions of material behavior at the zone of the advancing crack. Characteristic assumptions that are often used consider low cycle fatigue behavior at the tip of the crack, incremental or cycle by cycle crack advancement, and potential microstructural influences at different stages of fatigue crack growth. Furthermore, the microscopic scale and complex nature of occurring fatigue damage phenomena, demand for the use of appropriate fitting parameters in fatigue crack growth simulations. Therefore, reliability of analytical models depends usually on the calibration of such material parameters, which do not provide any physical background of the fatigue damage process. In the present investigation, a new analytical fatigue crack growth model is proposed, for prediction of mode-I crack propagation, based on the strain energy density criterion (SED), which provides a physical interpretation of the material scale at which fatigue damage occurs at the crack tip. The critical distance ahead of the crack tip used as failure criterion in SED, is correlated to the critical material length parameter, which is the striation spacing during fatigue crack growth. Fatigue crack growth analysis considers low cycle fatigue behavior and takes into account material cyclic strain hardening at the tip of the crack, thus relying on the use of mechanical material properties for crack growth prediction, rather than the use of fitting material parameters. The analytical results obtained with the model, are compared against experimental data on the commercial and widely known aeronautical aluminum alloy 2024. For this purpose, fatigue crack growth experiments have been performed on 2024 T3 alloy to determine stage-II fatigue crack growth rates under a stress ratio R=0.1. Comparison of analytical results to experimental data showed good agreement, indicating that the model using physical material parameters is capable for predicting satisfactory the rate of a growing crack under mode I loading.

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Influence of pre-straining on the fatigue crack growth rate of S355 and S460 structural steels

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Cold-formed structural steel sections used in racking systems of logistics warehouses, are subjected to in-service alternating loads, which eventually lead to fatigue damage cracking. Potential damage sites are corner section locations that have been subjected to cold roll rolling process, in order to produce specific geometrical configurations. The cold forming process induces significant plastic deformation, resulting in material strain hardening as well as the development of residual stresses, factors which influence the fatigue resistance and damage tolerance behavior of the steel section. In order to evaluate the amount of residual strain and stress imposed in the cold formed section, numerical analyses may be employed. On the other hand the effect of existing plastic deformation on fatigue behavior is material dependent and requires experimental research. The present work is part of European project FASTCOLD “FAtigue STrength of COLD-formed structural steel details”, sponsored by the European Commission, through the RFCS programs, with the support of the European steel industry. In the present research, an experimental program has been carried out, in order to evaluate the effect of pre-straining on the fatigue crack growth resistance of two structural steels, S355 and S460, which are used in such structural applications. In the experimental investigation, the current knowledge on damage tolerance behavior of these steels [1-3] is extended. A comparative study is performed, which considers the influence of various parameters (material, thickness, orientation) on fatigue crack propagation behavior for both virgin and pre-strained material. Fatigue crack growth tests have been performed [4] and evaluated by means of fatigue crack growth rate (da/dN) vs stress intensity factor range (ΔK) diagrams. The experimental results reveal that fatigue crack growth rates of the prestrained material are slightly higher compared to the rates of the virgin material, specifically in the lower ΔK region and for stress ratio R=0.1. With increasing value of stress ratio, the observed effects of prestrain diminish. Material orientation with respect to the rolling direction and the thickness of the plate may not have a significant impact on fatigue crack growth rate. Finally, it is found, that S460 steel exhibits higher crack growth rates and, hence, inferior damage tolerance behavior compared to S355 steel, for all examined stress ratios.

Keywords: Structural steel, pre-strain, fatigue crack growth, damage tolerance

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Laser induced breakdown spectroscopy (LIBS) for extended non-destructive testing (ENDT) – latest advancements and current research

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In order to enable the full potential of adhesive bonding as a joining technique for primary aircraft structures, reliable and mature quality assurance tools for adherend surfaces are indispensable [1]. In the last years, Laser-induced Breakdown Spectroscopy has shown high potential as a very surface-sensitive method for extended non-destructive testing of metals, plastics and fibre-reinforced plastics [2, 3]. Advancements in LIBS, especially regarding detection limits, reduction of impact on the adherend and automation, could be achieved in the frame of several national and international research projects [4, 5]. In the present work, we present examples of possible LIBS applications with focus on the surface quality assessment of adherends.

The surface state of CFRP adherends prior to bonding is of major importance for the reliability of the bonded joint. Even low residues of e.g. release agent may have a major impact on the bond strength, especially if ageing is considered. We show the capability of LIBS as a fast and in-line capable measuring tool to detect residues of contaminants on CFRP surfaces. Here, LIBS can not only differentiate between clean and contaminated surfaces, but is also able to detect different levels of contamination due to different concentrations of the contaminant.

Concerning the promotion of adhesion properties of Aluminium, a shift to chromate-free conversion coatings was necessary due to REACH regulations (Annex XVII). For these new, very thin (< 70 nm) conversion layers, there is up to date no reliable quality assurance method available. We show the potential of LIBS to detect and quantify the conversion coating weight with simple and fast measurement, which is capable for in-process application [6].

We further provide an overview of current LIBS research activities. For a more flexible use of LIBS in production environments and for quality assessment of complex structures there is an ongoing research project [7] where a robot-guided LIBS measuring head is developed. Within another research project [8] LIBS is adapted for measurements of aqueous solutions. To this end, a completely new LIBS setup is required. The successful work within these projects will open up new fields of application and thus further improve the capability of LIBS as a tool for in-line quality assurance.

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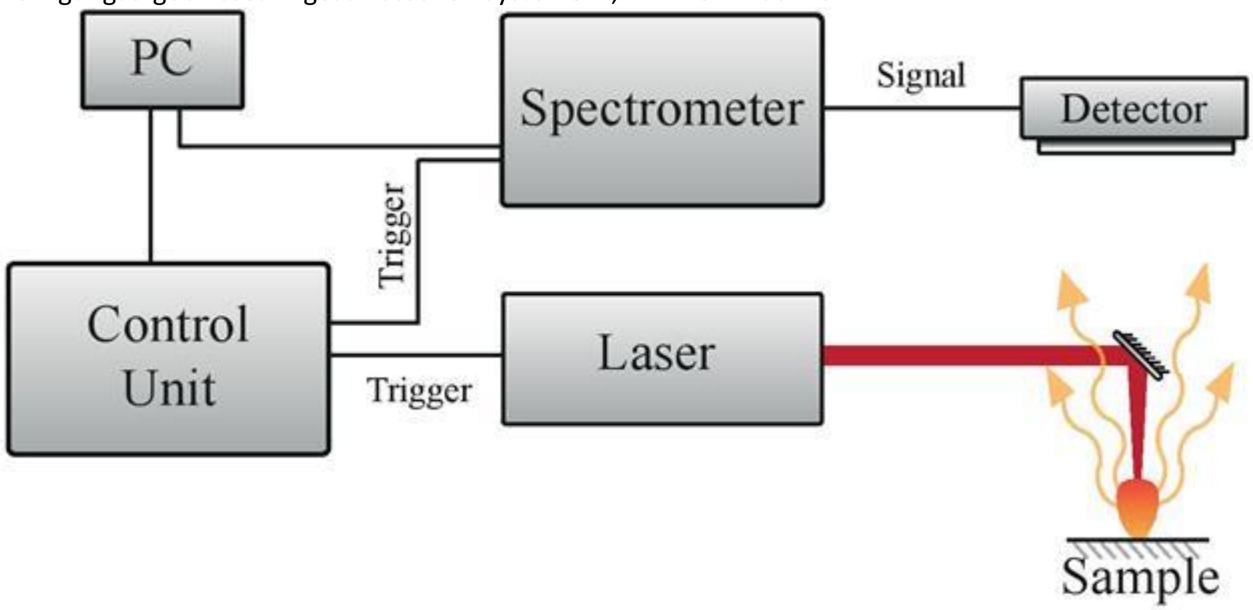
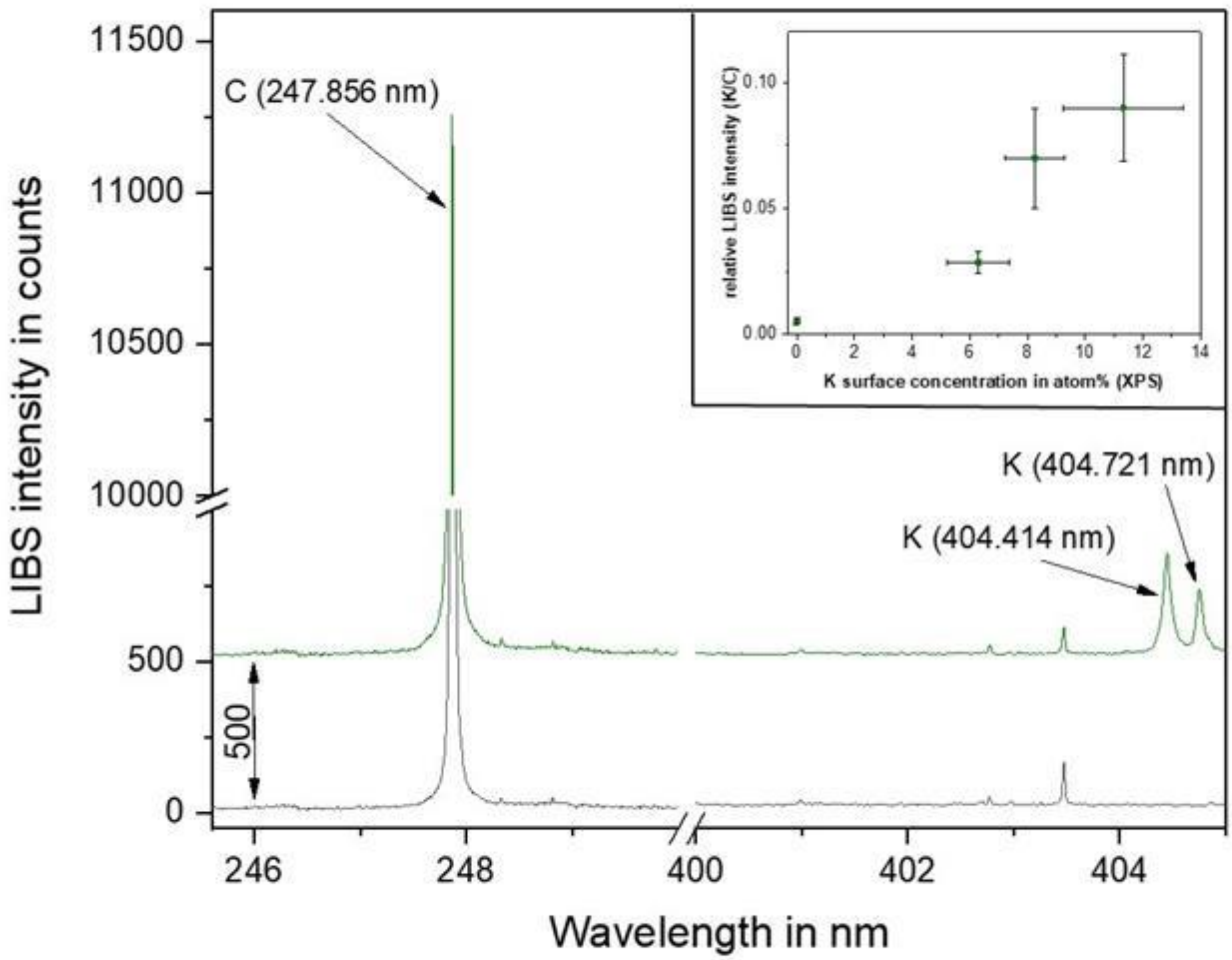
[4] FP7 ENCOMB „Extended Non-Destructive Testing of Composite Bonds” (FP7, AAT-2010-1.1-2.AAT.2010.4.1-2. TPT, 2010-2014).
[5] Horizon2020 ComBoNDT “Quality assurance concepts for adhesive bonding of aircraft composite structures by extended NDT” (H2020 — H2020-MG-2014, 636494, 2015-2018.

[6] Imlau, M.; Toschke, Y.; Rischmüller, J.; Schlag, M.; Brüning, H.; Brune, K. Vorbehandlungsprüfung mit dem Laserpointer. JOT Journal für Oberflächentechnik 2019, 59, 46–49. doi:10.1007/s35144-019-0171-9.
[7] LUFOV-3 ALASKA „Qualitätssicherung mittels robotergeführter laserinduzierter Plasma-Spektroskopie", FKZ: 20Q1718B.
[8] BMEL SensoRein "Sensorbasierte Überwachung des Reinigungsbedarfs und des Reinigungsergebnisses in geschlossenen Systemen", FKZ: 281A106116.



Setup of LIBS. The laser beam is focused onto the sample surface inducing a plasma that is detected and analysed by the Spectrometer.



LIBS spectrum of a CFRP sample contaminated with de-icer contains elemental emissions from Potassium. The K/C ratio is employed for quantitative analysis of de-icer. LIBS results correlate with XPS measurements.

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Investigation on the influence of different testing methods and parameters on the determination of fatigue crack growth data

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The correct determination of fatigue crack propagation data is of great importance for the damage tolerance design of engineering components, especially with regard to the calculation of residual lifetime and the establishment of inspection intervals. The fatigue crack propagation threshold ΔK_{th}, in this respect, is a crucial input parameter for simulating crack growth, since it corresponds to the stress intensity factor range at which a non-growing crack starts to propagate. However, the experimental determination of ΔK_{th}, as well as its application, is still confronted with few issues related among others to the load ratio (R) dependency of ΔK_{th}, the testing procedure, and environmental effects. These can lead to large scatter and significant errors in the prediction of component failure. In this context, the use of the intrinsic fatigue crack propagation threshold $\Delta K_{th,eff}$ in component assessment is a promising alternative, since it does not depend on a number of factors that affect ΔK_{th}, but only on the elastic properties (E-modulus) and the lattice (Burger's vector $\|b\|$) of the material. The aim of the present work is therefore to investigate different experimental procedures for the determination of $\Delta K_{th,eff}$, namely: (a) conventional load reduction (LR) procedures, (b) the K_{max} procedure and (c) compression pre-cracking load reduction and constant amplitude (respectively CPLR and CPCA) methods. Furthermore, the determination of ΔK_{th} has been carried out varying some testing parameters, such as test frequency, ΔK at the beginning of the crack propagation test (ΔK_0) and stress ratio (R). The results are statistically analyzed and a discussion about the use of ΔK_{th} and $\Delta K_{th,eff}$ for the component fatigue assessment is presented.

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Influence of cutting parameters on surface integrity in BTA deep hole drilling of steel components

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Boring and Trepanning Association (BTA) deep hole drilling is a process that is used to drill bores with large length-to-diameter ratios, which usually feature excellent straightness and roundness. Typical lengths of such bores are in the range of L = 1.5 to 4.5 m for diameters of D = 6 to 125 mm [1]. Applications of the process include the production of drill collars, hydraulic cylinders and landing gears of aeroplanes. These components have to withstand high loads in operation, while at the same time they are required to guarantee long service lives and be as fail-safe as possible for security purposes. For this reason, tailoring surface integrity during production, to prevent failure of components, is vital and there is a high demand for reliable characterization of the surfaces of deep hole drilled bores. Up to this day, however, research on BTA deep hole drilling remains far from conclusive and further research is required to investigate e.g. the coherence between the design of the machining process and the resulting surface integrity inside the bore.

The impact of the cutting parameters feed f and cutting speed vc on the surface integrity of BTA-deep hole drilled AISI 4140 and AISI 304L was analysed. Three feed rates, in combination with three cutting speeds, were used to drill bores with a length of L = 250 mm and a diameter of D = 60 mm. The occurring process forces Fa (axial force) and Fn (normal force) while levelling and burnishing the surface as well as the drilling torque Mb, were measured to assess their impact on surface integrity. The microstructure and the hardness in the surface edge zone were analysed. Micromagnetic investigations were conducted, based on results of previous studies, in which it was found that Magnetic Barkhausen Noise (MBN) analysis proves to be an adequate means for characterising the residual stress state in the surface edge zone of deep drilled specimens (Figure 1) [2]. To validate the results of these investigations, X-ray diffraction measurements were performed (Figure 2) and they showed that depending on cutting parameters, favourable compressive residual stresses between σaxial = -200 and -700 MPa can be build up in the subsurface area and that they can be assessed by micromagnetic techniques as well.

Acknowledgements:
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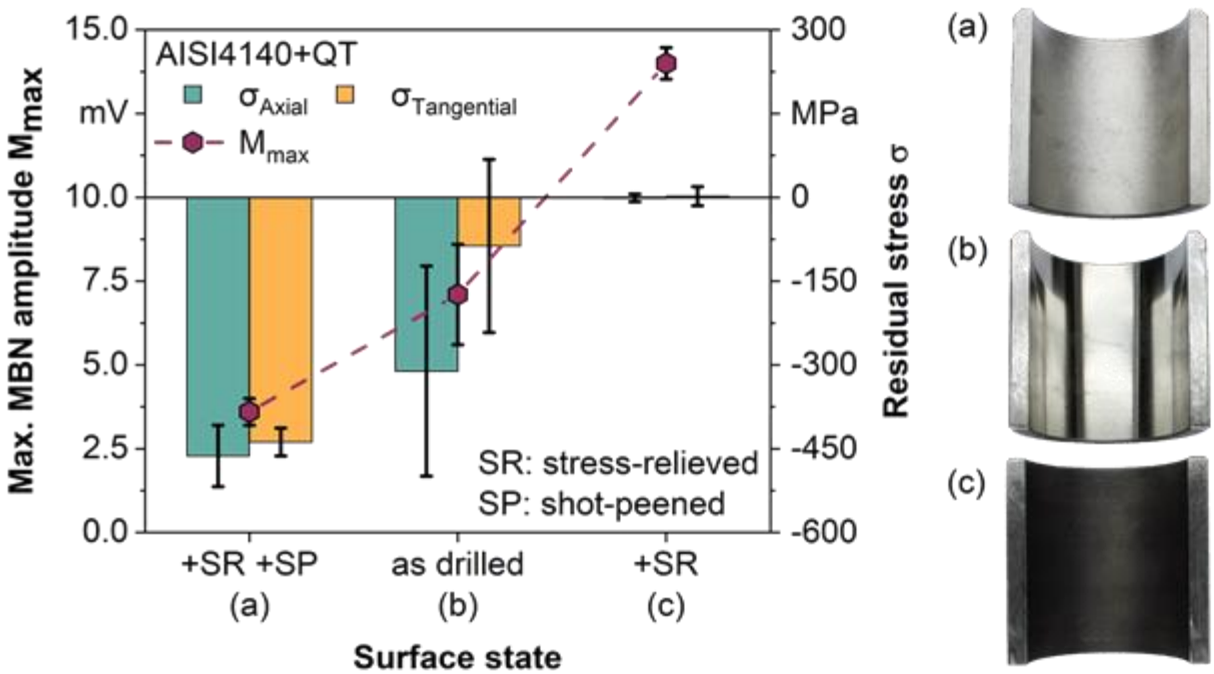
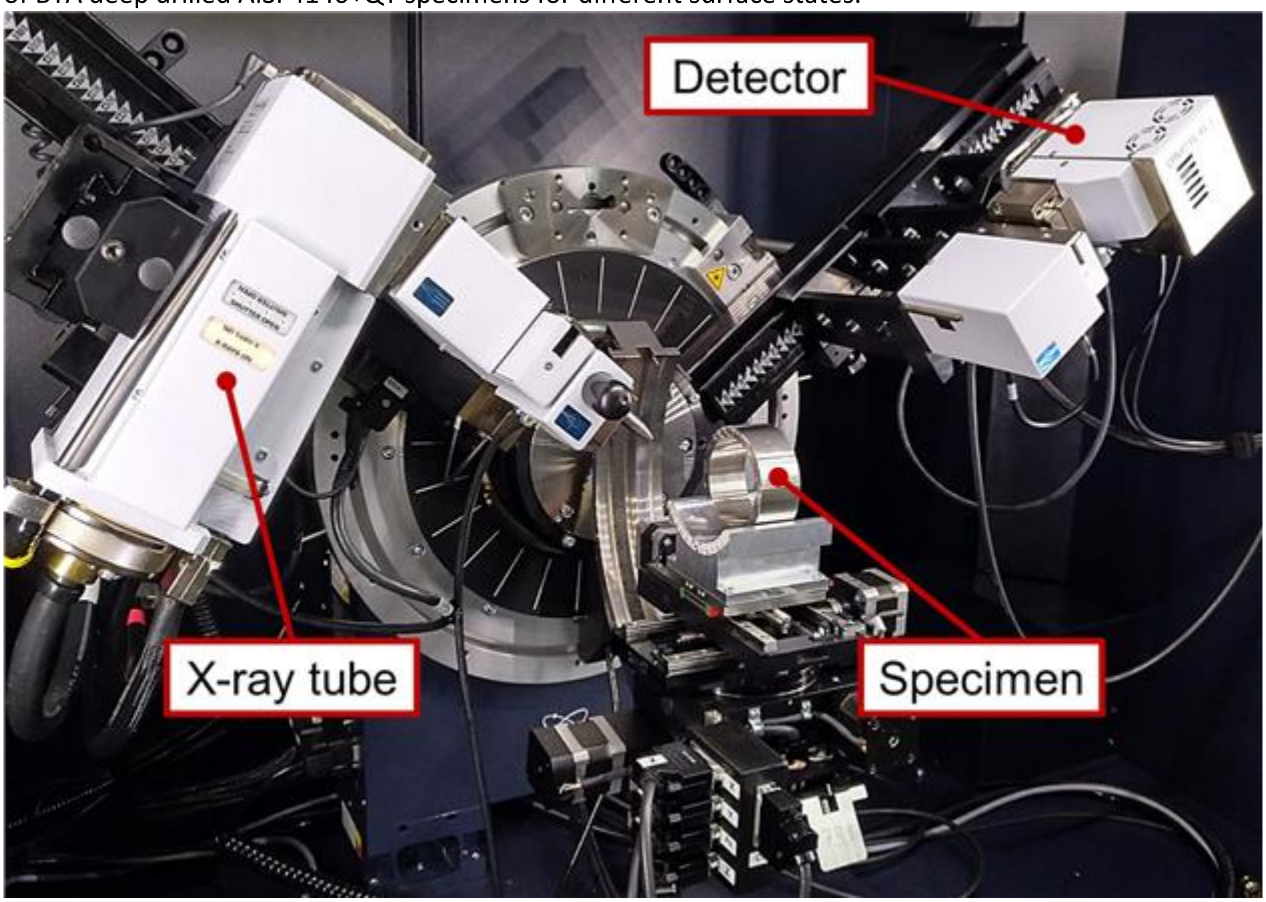


Correlation between the Magnetic Barkhausen Noise (MBN) amplitude Mmax and the residual stress state of BTA deep drilled AISI 4140+QT specimens for different surface states.



Experimental setup, used for X-ray diffraction analysis.

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Multiaxial Testing Bench for the Durability Assessment of High-Strength Automotive Axle Suspension Systems

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Axle suspension systems of commercial vehicles must fulfill highest requirements regarding functionality, durability and safety. They are composed of several components like leaf or air springs (or combination of both), antiroll bars, guiding arms etc., all made of high-strength materials, especially high-alloyed steels. In addition to the durability approval of the individual suspension components, which occurs on appropriate fatigue test rigs by the individual manufacturers, testing of the complete axle suspension system is an indispensable task to check both the functionality and durability of all connecting parts and subsystems, e.g. the mutual interactions between the steering and suspension subsystems. The present paper settles at this point: It deals with the multiaxial fatigue load assumptions, their mutual interactions and their damaging effects on the individual suspension components. Furthermore, it deals with a universal, six-channel servohydraulic test bench designed to apply all operational, multiaxial fatigue loads with constant and/or variable amplitudes on complete axle suspension systems. All significant events, from the point of view of durability, resulting from straight-ahead driving over potholes and obstacles, forwards- and backwards braking, driving torque can be reliably realized. The test bench is designed to cover the complete range of commercial vehicle axle suspension, from very light to heavy ones. The developed test bench is fully suitable for cost-effective and reliable the fatigue/durability assessment of individual suspension systems. The test rig can be easily modified for durability testing of other load-carrying chassis components and for type approvals of vehicle structural systems.

Acknowledgement:
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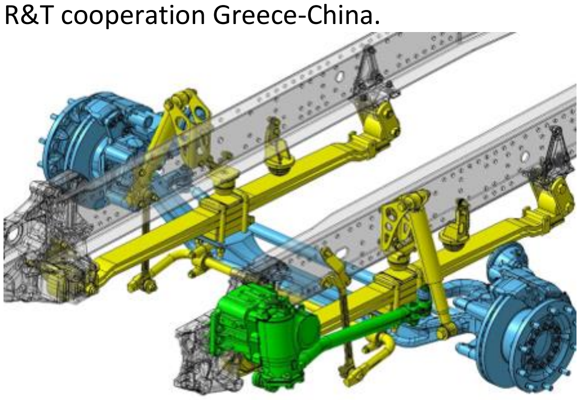
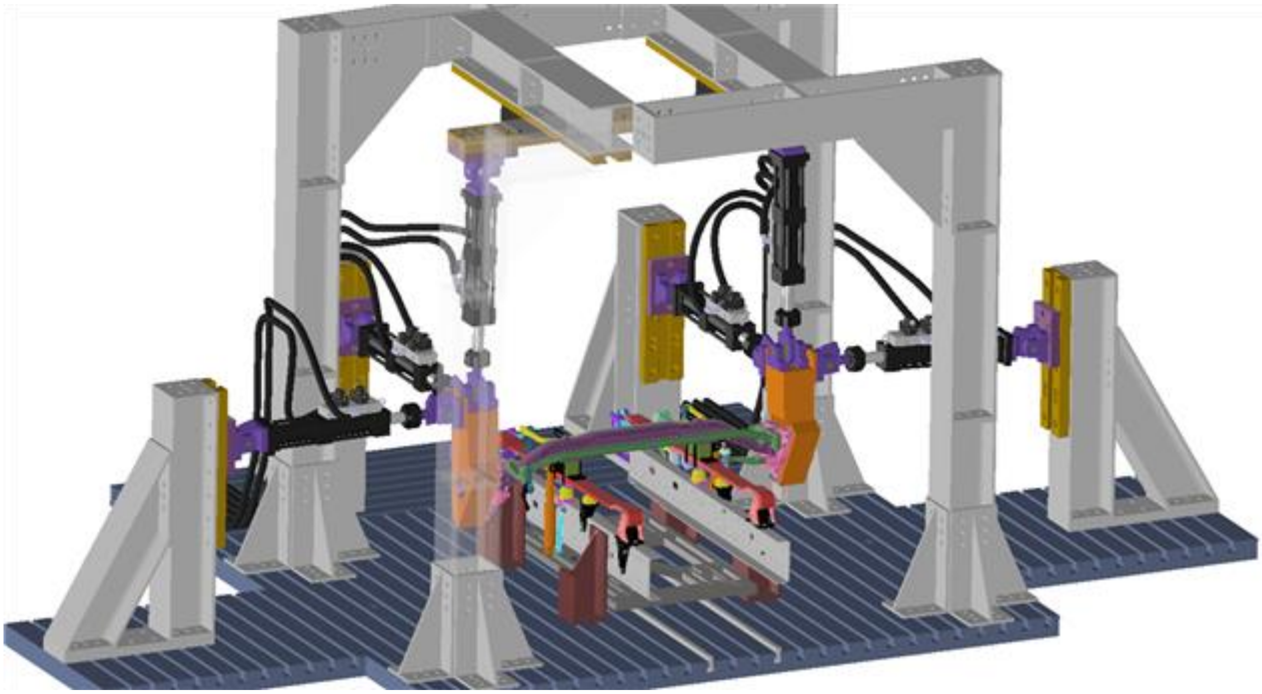


Front axle suspension system of a heavy truck



6-channel test bench

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On the effects of heat and surface treatment on the fatigue performance of high-strength leaf springs

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Leaf springs constitute the most effective suspension way of commercial vehicle axles from the point of view of costs and maintainability. Especially in the case of front axles, they have to overtake both the guidance and the suspension. Due to their multi-function, leaf springs are regarded safety components of vehicles and pre-mature failure should be prohibited. The safety aspect rises more pronounced in the case of front axle springs, where failure of a main leaf may significantly affect the steering behavior of the vehicle.
The present paper deals with parabolic leaves made of the high alloyed spring steel 51CrV4 under serial manufacturing conditions. It focuses on the influence of the major manufacturing process steps, i.e. the heat treatment and the subsequently applied stress shot peening, on the fatigue performance.
The effectiveness of the applied heat treatment regarding the extent and quality of the martensite formation from the initial (raw) ferrite-pearlite microstructure as well as the degree and extent of surface decarburization has been determined by means of optical microscopy and corresponding microstructural analyses. Comprehensive series of fatigue tests (3-point bending) with constant amplitudes have been executed on parabolic leaves before and after the applied stress shot peening to quantify the effectiveness of the stress shot peening process to the fatigue performance. The tests cover two different stress ratios R=0 and R=0.5, which constitute the most significant ones for automotive applications. Hereby, the complete range of interest has been experimentally investigated, from the Very Low Cycle Fatigue until to the engineering endurance limit. In addition, measurements of the residual stresses in the surface-near area combined with micro- and macro-hardness and roughness before and after the stress shot peening have been executed on selected specimens to expose and analyze the influence of each individual technological effect on the overall fatigue performance.

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Characterization and performance of high-strength steel 51CrV4 under cyclic loading

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Heat treatment of spring steels may greatly affect their fatigue life by increasing the number of cycles sustained before failure. Heating, quenching and tempering of spring steel increase its fatigue limit, as tempered martensite formation with an appropriate hardness, is achieved from an initial ferrite/pearlite microstructure. Fatigue design of engineering components is often based on guidelines such as the FKM-guideline. Therein, the corresponding mechanical properties referring to high-strength materials (UTS>1200 MPa) are not yet accurate, so that the responsible engineers still need comprehensive experimental methods to verify the components' design. Regarding the high alloyed spring steel 51CrV4 it should be further noticed, that the international literature contains very few and isolated data regarding its cyclic behaviour, while corresponding cyclic material properties are totally missing, even though it is widely used in engineering applications, espcially for manufacturing automotive springs.
The present paper contains comprehensive experimental results regarding the characterization and the mechanical behaviour, especially, the fatigue life of 51CrV4. Two batches of specimens have been investigated: (a) raw material and (b) thermally treated (quenched and tempered) one. The influence of the applied heat treatment on the microstructure has been acquired by means of optical microscopy. Macro- and micro-hardness measurements reveal the significant upgrade of the mechanical properties caused by the applied heat treatment. Fatigue tests at uniaxial cyclic loading and three different stress ratios, R=-1, R=0 and R=0.5, reveal the significant fatigue life increase that can be achieved due to the applied heat treatment. The results cover the whole R-area of practical interest for engineering applications. Furthermore, the comparison of the fatigue lives determined at the various R-ratios investigated here yields the mean stress sensitivity factors for the heat treated condition, which is of practical interest. Strain measurements performed during the tests exhibit the stress-strain behaviour under monotonic and cyclic loading. Therewith the corresponding elastoplastic cyclic material properties could be accurately determined. They can be directly implemented in material databanks and used for the fatigue design of engineering components made of 51CrV4 in the as-here investigated conditions. Finally, fatigue tests at fully-reversed rotating bending reveal the influence of stress gradient on the fatigue life for both material conditions.

Acknowledgement:
This project has received funding from the Research Fund for Coal and Steel under grant agreement No 799787. The authors would like to gratefully acknowledge the Research Fund Coal and Steel.

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Cavitation shapes measurements in piston-rig lubrication and their link to lubricant properties

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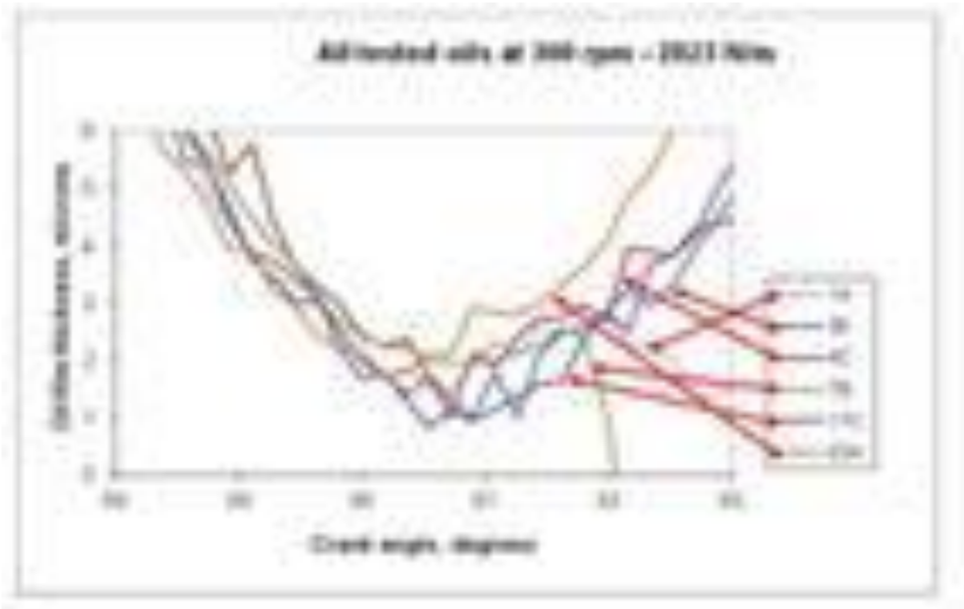
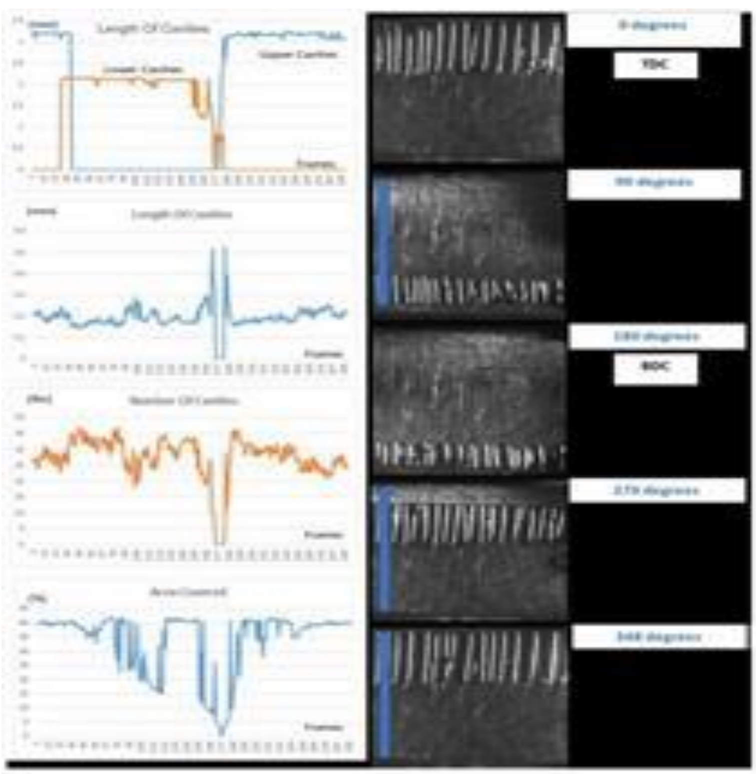
[1]*Aspete*

The emissions control regulations introduced by governments are set to improve the quality of the engines and reduce the impact automobiles have on the planet. The regulations imposed on the manufactures have proven very difficult to meet. Te effect of this development pushed some of the leading names in the industry to invest significant funding in research and development and optimisation of the combustion processes, powertrain and tribology inside the internal combustion engine. Their goal is to reduce the fuel consumption and exhaust emissions while increasing the engine performance and durability. The piston-ring and cylinder-liner interaction is the major source of frictional losses for reciprocating internal combustion engines and so, it is important to avoid any failure of the piston-rings to effectively control lubricant transport from the sump onto the cylinder walls and further to the combustion chamber. This amount of lubricant will participate in the emissions through absorption and desorption of fuel in the oil film at the cylinder walls. This process results to lubricant contamination and consumption. The objective of this project is to assist with the investigation of phenomena that occur in the cylinder liner and piston ring interaction under different operating conditions. To achieve these the following investigations have been carried out, flow and cavitation visualisation in a model lubricant rig and cavitation visualisation in a newly designed optical engine.

Video images captured with two high speed cameras coupled with three high intensity light sources were analysed. The images were post-processed with the aid of a custom build algorithm. The basic function of this algorithm is the extraction of matrices with elements of cavity length, cavity width, area of cavitation and number of cavities present under the piston-ring and the cylinder liner. In this instance, after the initial evaluation of cavitation visualised through quartz sections in a Lister-Petter engine and the attempt to compare the imaging findings to the ones already identified in a simulating single-ring test rig, a more detailed and controlled experiment was carried out, with new visualisation tools and a specially made optical internal combustion reciprocating engine. Lubricant cavitation was visualised and assessed for different sets of lubricants. Visualisation experiments are a quick, efficient and effective way to test different lubricant samples and compare their performance in terms of physical, chemical properties and cavitation initiation and development throughout the stroke. This parametric study offered valuable results enabling the performance of each lubricant to be assessed. Direct link between the lubricant formulation and the operating conditions could be established.
In previous research, the effect of different lubricant properties was evident in lubricant film thickness measurements with the Laser induced fluorescence technique. Different sets of lubricants were measured in the simulating single –ring test rig and the results showed that for same testing conditions, with lubricants that do not degrade through a piston engine combustion process, the film thickness varied according to the lubricant properties.



LIF tests comparison for 6 different oils, 300 rpm - 2823 N/m load



Correlation between processing software and raw data, 600RPM, 70C, 0-180 Degrees (Vasilakos, 2017)

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The contact mechanics and switchable adhesive properties of polyelectrolyte brushes

Geoghegan M[1]
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Polyelectrolytes, the original "smart" polymers offer the possibility for enhanced adhesive and tribological properties, including switchable adhesive properties. In this presentation I shall outline how switchable adhesion can be controlled, improved, and also how smart adhesive coatings can be created to design "one-pot" pH-controlled switchable adhesion. All of these technologies require grafted polymers, so-called brushes, and their contact mechanics is very dependent upon environmental properties, be they due to pH or added salt.

One method of switchable adhesion is to use oppositely charged polyelectrolytes. The pH-switchable adhesion between a brush and a hydrogel and two brushes is presented and compared. Hydrogels are brittle and are known to cohesively fail. The use of more robust double-network hydrogels is an effective means of ensuring that adhesive failure is the dominant detachment mechanism, and it is shown that a brush-double-network system can effectively be detached and reapplied even without a pH switch.

The underlying mechanisms of the adhesion between oppositely charged components is discussed in the context of polymer brushes, and contact mechanics reveal that the dominant mechanism of interaction is electrostatic.

Finally, a self-assembled layer is designed whereby polyelectrolytes are grown from a calixarene. These calixarenes have self-assembling qualities and show some promise for a "one-pot" coating that can exhibit reversible adhesive properties.

The polycations used in this work are poly[2-(dimethyl amino)ethyl methacrylate] and poly[2-(diethyl amino)ethyl methacrylate]. The polyanion used is poly(methacrylic acid). Macroscopic adhesion is measured using a low-load mechanical tester and contact mechanics (tribology and adhesion) using friction force microscopy.

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Modern Tribological Trends in the Rolling-elements Bearing's Industry in Terms of Materials, Heat Treatments & Coatings

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This talk intends to give a current overview of the latest developments and material practices in the REB' industry : compositions, Types, heat & surface treatments and mechanical properties will be discussed in details based on the point of view of the main damaging phenomenon occuring in industrial applications. A review of the important trends for improving corrosion, electrical insulation, wear resitance, superficial or rolling-contact fatigue behaviour (for application at room T° as at hight T°) but also to reduce as well the frictional losses in accordance to the principes of the "Industry 4.0" will be presented. A full review of the existing "high tech" coatings helping for solving the precedent issues will also be exposed.

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A customized electrical potential difference method for in situ monitoring of propagating cracks using a stochastic algorithm

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In this paper, a modified direct current potential drop (DCPD) method for real-time measurement of the length, the inclination and the position of cracks is presented. Based on the proposed configuration it is possible to process the data acquired by continuously measuring the change in the electrical resistance (potential drop), between specific points on the specimen, in real time and correlate them with the propagation of the crack. Furthermore, the effect of strain, temperature and sensors' positioning in the detection of the electromagnetic field inside materials has been identified. In that way noise can be significantly reduced but also a better understanding of the relation between the implemented voltage values and the fracture itself is obtained. Therefore, conclusions are drawn about the structural integrity of any given specimen through a risk assessment after the crack characteristics have been calculated. In order to achieve this, special techniques were implemented including the development of a stochastic algorithm along with a customized experimental layout to accomplish high accuracy for the prediction model and robustness towards other parameters such as temperature and humidity.
Keywords: DCPD method, Crack detection, Real-time monitoring, Non-destructive inspection

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Experimental testing of polyether ether ketone (PEEK) under vibration-induced heating

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Dynamically loaded structures made of thermoplastic materials are widely used in automotive industry, aerospace industry as well as medical technology. The thermoplastic polymers are applied here in the form of neat polymers or as matrix material for composites. Due to their viscoelastic and thermal properties, self-heating effects occur, especially during dynamic deformations at high frequencies. Thermoplastics with high temperature resistance and high specific strength, such as of polyether ether ketone (PEEK), are primarily suitable for these dynamic loaded applications. An experimental analysis of the vibration characteristic and the vibration-introduced heating effects of flat-sheet specimens made of PEEK was performed. The specimens were excited at its clamping by means of a displacement-controlled test configuration using a piezoelectric actor at a high order resonance frequency at around 13 kHz. The specimen's normal velocity and the resulting surface temperature of the whole specimen were determined by means of the non-invasive testing methods laser scanning vibrometry and infrared thermography, respectively. For the highest investigated excitation, a maximum temperature increase of approximately 4 K was measurable. With decreasing displacement amplitude of the excitation, the temperature increase was reduced.

The quasi-static crack growth and analysis of interlaminar fracture toughness of layered composite

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An improved version of the energy description of quasi-static crack growth [1] is briefly presented. Finally, it gives an ordinary first-order nonlinear differential equation for the load / crack size function. In the case of a small-scale cohesion zone of a crack, this equation is invariant with respect to the configuration of the sample or structural element, which, together with the stability conditions of the equilibrium configurations, opens up wide possibilities for the practical analysis of various aspects of the growth of crack-like damage.
In particular, statistical properties of interlaminar fracture toughness in a quasi-brittle layered composite was done. A standard test using DCB specimen [2] was implemented to obtain the interlaminar fracture toughness of a layered carbon fiber composite.
It is known that at the load control, the process of delamination growth should theoretically be stable. However, in many cases, an intermittent unstable growth of delamination is observed. Based on the proposed model, it is shown that this is possible only at variation of the local crack resistance of the material.
The report discusses the technique of testing and processing measurement results, and also presents the implementation of random changes in the interlaminar fracture toughness. Obviously, statistical parameters of the interlaminar fracture toughness allow to judge the homogeneity of the structural material.

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Casting and solidification of magnesium alloys

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Magnesium alloys have a high specific strength with their good castability and machinability which are interesting for lightweight construction applications. However, they have a poor room temperature formability and low high-temperature strength. Microstructural modifications such as refining and precipitation were popularly used to improve their ductility and strength. Regarding the subsequent microstructural optimizations, the first step casting and solidification plays a key important role because the quality of initial microstructure directly influences the subsequent one. The present paper introduces some recent investigations on the casting and solidifications in MagIC. First, the influence of alloying elements on the hot tearing of magnesium alloys is simply summarized, including the elements Al, Zn, Y, Gd and Ca. Among them, the addition of Ca results in the most severe hot tearing, while the additions of Al or REs have a lower hot tearing susceptibility. With the increment of alloying element content, the hot tearing susceptibility increases till to a maximum, and then reduce with further increasing the content of alloying element. Second, the applications of synchrotron radiations in the in-situ observations of solidification is introduced for magnesium alloys. It was found that synchrotron radiations could identify the solidification process, the solidified phases and also the casting defects.

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The influence of exposed to corrosion length of rebars on fatigue life of RC elements

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Deterioration of reinforced concrete is a main factor on estimation of structures' service lifetime. As it is well known, both corrosion of steel reinforcement and earthquake events, have detrimental effects on structural integrity of RC elements. In this study, the fatigue life of corroded reinforcement is investigated. Bare and embedded (in concrete) specimens of rebars are tested in low cycle fatigue conditions after accelerated corrosion experiments using impressed current technique. Corrosion damage, in terms of mass loss, and the mechanical tests of fatigue are taken account in function of the exposed to corrosion length of reinforcement. The outcomes attained from the experimental study indicate higher mass loss values of specimens with short exposed to corrosion length than the corresponding mass loss values of specimens with long exposed to corrosion length at the same tested corrosion time; subsequently resulting in their reduced fatigue lifetime. Extrapolating the abovementioned results on RC elements in marine environment located in seismic prone areas, issues are raised concerning the assessment of structural integrity and the parameters which are taken into account on monitoring of high importance structures.

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Practical Experience with the Methodology of Prediction of Corrosion-Fatigue Failures of Steam Turbine Rotating Blades

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[1]*Research And Testing Institute Pilsen*

Corrosion fatigue fractures initiating from corrosion pits are one of the most serious problem during service of rotating blades of the low-pressure parts of steam turbines. A methodology for fatigue failure prediction, originally based on the knowledge obtained by EPRI (Electric Power Research Institute), using corrosion pits parameters assessment and local stresses calculation was adapted to the conditions of ČEZ a.s. power stations. This contribution deals with the evaluation of the corrosion state of blades of two low pressure rotors after long service. Measurement was done in two power stations equipped with turbines of power 200 MW and 110 MW respectively. Possibilities and uncertainties (influence of filling of pits with oxides, cyclic stress calculations, and the selection of the geometric factor Y) and their elimination are discussed.

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Mechanical behavior of steel reinforcement before and after flame spray coating in marine environment

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Corrosion of steel reinforcement, and subsequent the degradation of reinforced concrete, is a major concern for infrastructure durability. In particular, corrosion of reinforcement raises important issues for reinforced concrete design and assessment, since it can impair not only the appearance of the structure, affecting the cross sectional area of reinforcement with the subsequent degradation of strength and ductility properties of steel and, ultimately, structural integrity of each structure.
As it is widely known, international scientific community up to date, used various methods so as to increase the corrosion resistance of steel. In this context, in the present study, specimens of steel reinforcing bars - B500c class- were examined after flame spray coating with an alloy of aluminium and zinc, without any interference in the chemical composition or in the production mode. More specifically, bare rebars of 12 mm nominal diameter were subdivided in two groups, in reference - as delivered - conditions and after flame spray coating; both groups of rebars were subjected to accelerated corrosion experiments, using impressed current technique, and subsequently their mechanical behavior in uncorroded and corroded conditions.
The outcomes attained from the experimental study indicate a positive contribution of this method compared with other studies. Moreover, a comparison is presented between the present study on flame spray coating and our recent studies on application of anticorrosive coatings, such as shot peening treatment.

Energy Balance-Based Numerical Method for Turbine Blade Cooling Analysis during Preliminary Design of Aircraft Engines

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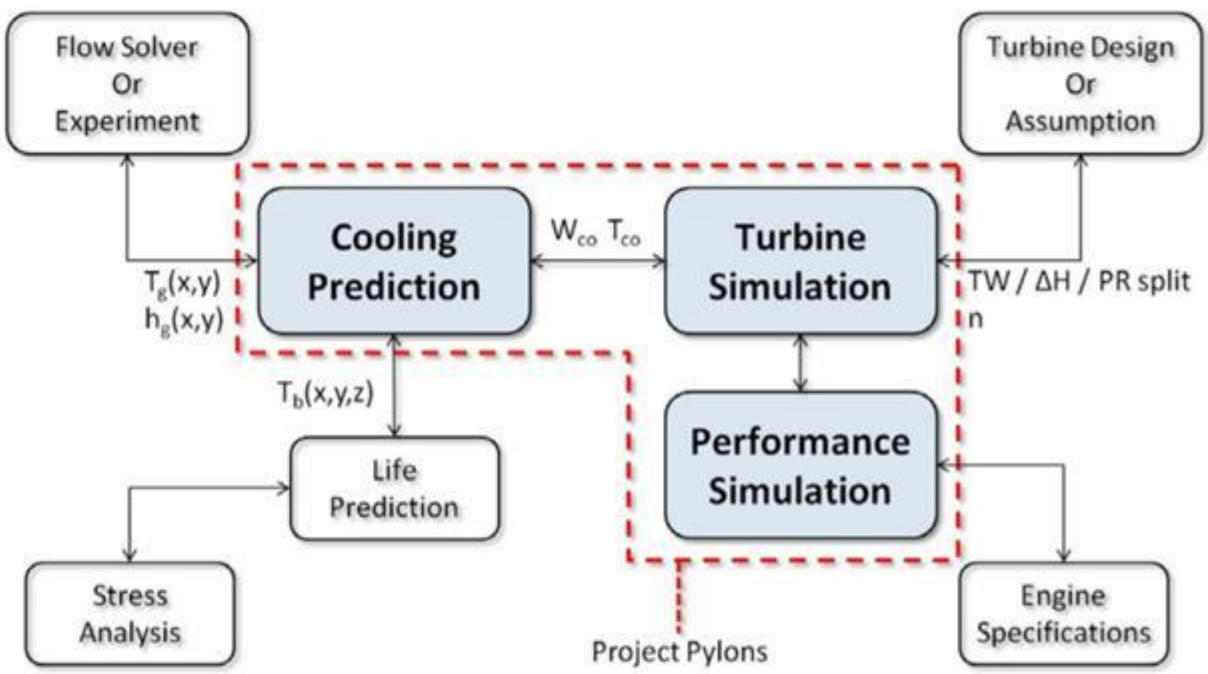
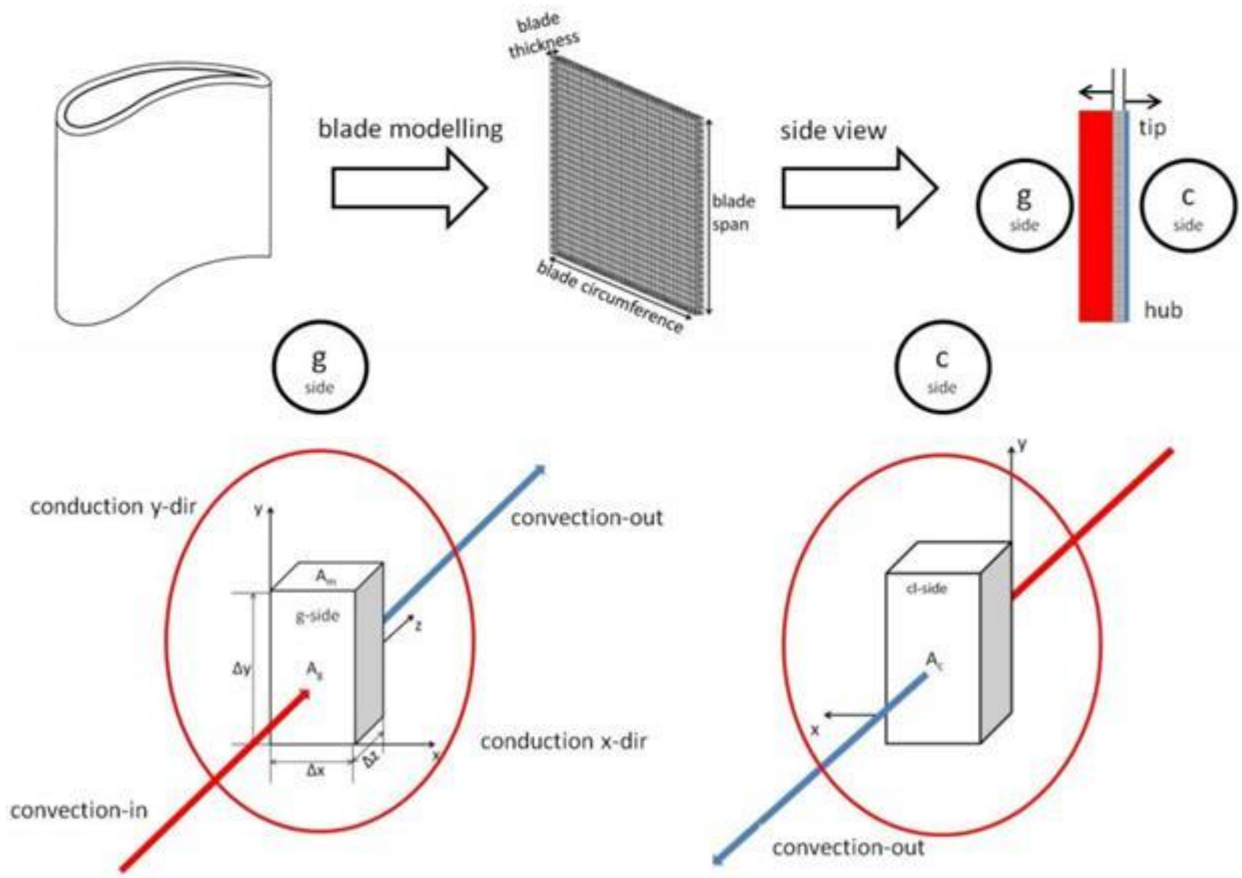
A numerical method for the modelling of heat transfer in cooled turbine blades and vanes of aircraft engines is presented. The method divides the part into a finite number of nodes along the span and chord. This modelling approach can be used during preliminary design, when little knowledge exists about the cooling geometry. It can be considered as a hybrid approach, being differentiated from analytical methods, which provide little spatial resolution and no conduction analysis, but it does not require the geometrical complexity of higher fidelity methods. This way, designers can predict the cooling requirements of turbines and calculate the engine cycle, with a minimum number of input data. Moreover, preliminary temperature and life calculations of turbine parts can be performed. Both advancements can eventually accelerate the design process of high pressure turbines. Validation provides good correspondence with experimental data. Results show that conduction modelling is important, as thermal diffusion moderates temperature gradients that may be misleading when calculating the cooling requirements or part life. Results show as well that an axial blade resolution is essential, as gas acceleration and expansion along the turbine has significant effects on local static and total temperatures, which may lead to life prediction errors.



Turbine Simulation Framework



Two-dimensional turbine blade modelling

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Experimental and FE – based analysis of the mechanical performance of high porosity gyroid lattices with thin walls.

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Lattice structure design has emerged nowadays on the one hand because of the appearance of demanding applications such as lightweight components and bioengineering scaffolds and on the other hand because of the manufacturing convenience that 3D printing provides, especially in the case of lattices where their geometries are complex and difficult to materialize using other technics. In lattice structure design, two different cellular arrangements are commonly introduced; ordered and stochastic one. The geometry of random lattices (metal foams) consists of irregular, non-periodic cells which form a network of interconnecting walls or struts. Regular lattice structures (honeycomb) are formed by the repetitive placement, at the same distance in 3D space, of a representative cell.
One of the regular lattice structures that has gained attention the last years is the gyroid one which belongs to the triply periodic minimal surface (TPMS) lattice structures family. In this work, various gyroid lattices where modelled and manufactured aiming to the investigation of their mechanical behavior. An effort has been made to manufacture the specific structures with a wall thickness of less than 0.5mm. In fact it was possible to reduce wall thickness down to 200μm with a 3D printer which uses the stereolithography (SLA) printing method. The produced lattice specimens had four porosity values (70, 75, 80 and 85%) and three maximum cell numbers per axis (9, 11 and 13). The apparent moduli and strength of lattices depends on the ratio of the specimen size to the cell size, so the modelled structures should have at least eight cells per direction. With the specific parameters cell sizes varied between 1.5 and 2.2mm. After post – processing, the sample lattices were subjected to compressive testing. Since the mechanical behavior understanding is the key parameter for the proper adoption of cellular materials to various applications, the experimental testing was combined with finite element analysis which proved to provide precious insight for the characterization of the mode of failure.

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Evaluation of the effect of shot size on the residual stresses of shot peened high strength steel 51CrV4 specimens through a 2D FEA model.

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Shot peening is a surface treatment commonly used to improve the fatigue performance of various metallic parts. This process consists of projecting a large number of tiny particles at high velocity onto the surface of a component. Each impact plastically deforms the material and repeated impacts lead to a beneficial compressive residual stress state near the surface. Process optimization is complicated since many variables are involved, with the most important being shot velocity, shot size and shot size distribution, shot material and impact angle. Within this scope, the use of finite element analysis methods can provide precious insight regarding the effect of the aforementioned shot peening parameters on the material behavior and surface roughness of the part under treatment. Due to the high velocity of the shots, it is necessary to use an explicit FE code for the conduction of the analytical calculations. The developed FE model implements all the process variables as well as elastoplastic material properties for part and shots.
The shots are modelled through an algorithm which employs the Voronoi tessellation technic or Voronoi diagram. A Voronoi diagram is a partition of a plane into regions close to each of a given set of objects. In the simplest case, these objects are just finitely many points in the plane (called seeds, sites, or generators). For each seed there is a corresponding region consisting of all points of the plane closer to that seed than to any other. These regions are called Voronoi cells. The Voronoi diagram of a set of points is dual to its Delaunay triangulation. This work focuses on the effect of the size of the shots, given specific nominal values and statistical distribution. Shot rate is also calculated considering the homogenization of the developed stresses. After relaxation, the residual stress fields are calculated, and the effectiveness of the tested process parameters is evaluated.

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The effect of knocking combustion on a turbocharged diesel engine emissions and top compression ring friction

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Abstract
Turbocharged engines with direct injection have a significant position in the downsizing technology. However, there remain many unsolved and ambitious issues concerning knocking and pre-ignition. Therefore, detailed understanding of the top compression ring lubrication and fuel economy is critical. This paper focuses on the tribological performance of top compression ring under fully flooded and starved conditions caused by knocking combustion in a turbocharged diesel engine. A mixed-hydrodynamics model was built including multi-phase flow and asperity interactions with realistic boundary conditions. The study shows that frictional power losses in the compression ring-liner contact increased owing to the knocking combustion and starved conditions in a turbocharged gasoline engine. This finding indicates that the control of knocking combined with the inlet flow conditions can help to mitigate fuel economy and emissions in compression ring-liner conjunction.

Keywords: knocking combustion, top compression ring, inlet flow conditions, power loss, emissions

Introduction
One opportunity to reduce fuel consumption and to increase engine peak power of SI engines is downsizing. Turbo charging in conjunction with gasoline direct injection are the key aspects for enabling this technology [1]. Therefore, the development of a high-performance powertrain is of prime interest. Nowadays, it is widely known that the piston-cylinder system is a major contributor to the overall parasitic losses [2, 3]. It is clear that an increase in chamber combustion through inlet flow conditions would result in a plethora of problems, including power loss, increased emissions and engine damage. Therefore, the current paper attempts to address the issues of frictional losses particularly in the top compression ring- liner contact. The geometric dimensions of the compression ring-cylinder model were obtained from a turbocharged gasoline engine with a focus on engine knocking. Realistic engine running conditions were used. Flow simulations were performed solving the 2D Navier-Stokes equations and asperity interactions. The present study also combines fully flooded and starved conditions with knocking combustion, thus providing a more realistic analysis.
Results
Fig. 1 shows the minimum film thickness variation at 2000 rpm. Fully flooded and starved conditions show very thin films at the TDC reversal, where the in-cylinder pressures are high due to knocking. On the other hand, lubricant starvation has a dominant impact during mid-stroke. This is obvious at the higher piston speeds. Actually, at power stroke, the minimum lubricant film varies between 0.5 μm to 2 μm for fully flooded conditions, while for the starved lubrication the values varies around between 0.5 μm to 1.2 μm for the certain engine running conditions.

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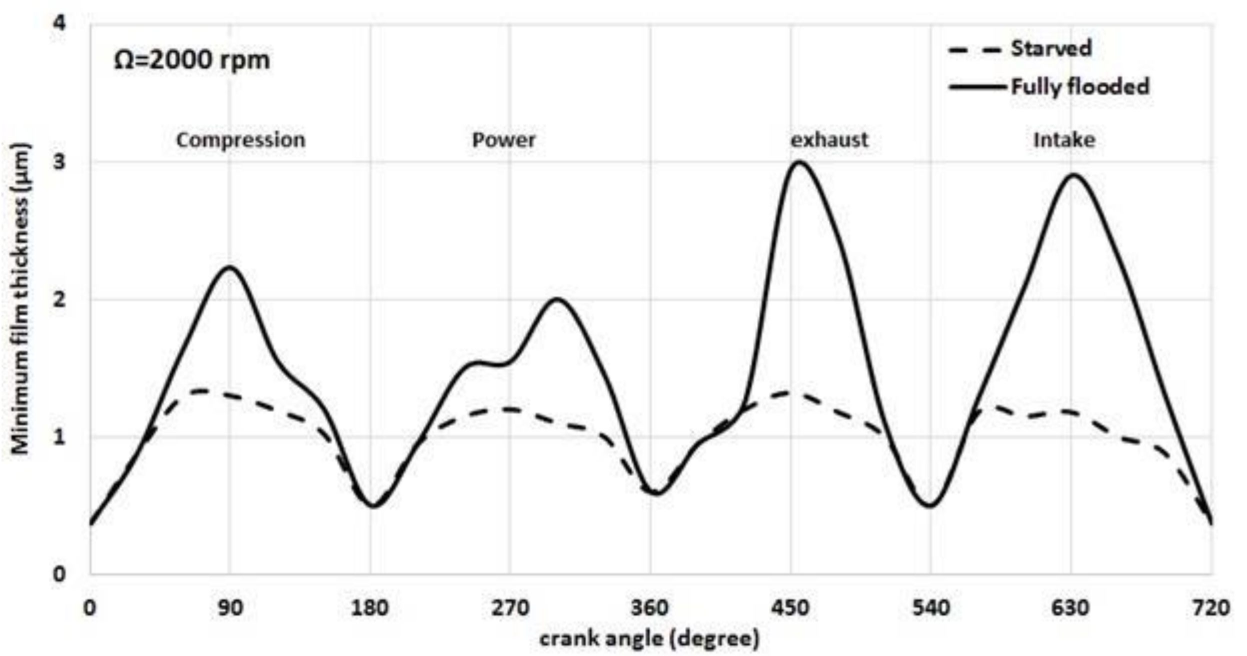

Effect of inlet flow conditions on the minimum lubricant thickness at 2000 rpm

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Effects of shot peening on tribological and fatigue behaviour of LPBF AlSi10Mg

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Laser powder bed fusion (LPBF) as an efficient technology of additive manufacturing (AM), can be used for fabrication of mechanical components with complex geometries such as notched parts. Generally, as built surface of the LPBF parts have poor quality with various irregular features. These features vary based on the processing technology, processing parameters, material, geometry, build direction, etc. Applying surface post-treatments such as shot peening as a mechanical surface treatment can play critical role to overcome this issue. Shot peening, as a mechanical surface treatment, can not only improve the surface morphology but can also induce compressive residual stresses in the top surface layer. These residual stresses can contribute to enhanced fatigue performance by delaying crack initiation and propagation. In the present study, the effects of two different shot peening treatments performed using steel and ceramic shots with different Almen intensities were investigated on microstructure, surface morphology, hardness, residual stresses, wear and corrosion behaviour as well as fatigue behaviour of LPBF AlSi10Mg samples. The results indicated considerable improvements of mechanical and tribological properties and fatigue performance caused by modification of surface morphology, surface layer hardening and compressive residual stresses.

Keywords: Laser powder bed fusion, AlSi10Mg, Shot peening, Tribological properties, Fatigue

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Numerical Prediction of Residual Stress in Cold Spray Deposition for Additive Manufacturing and Repair in Tool Industries

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In recent years, ability of cold spray technology for bulk manufacturing has initiated its consideration as an additive manufacturing process with the prospect of offering a wide range of options, including surface functionalization and structural repair. Unlike high-temperature additive manufacturing processes, e.g. laser powder bed fusion process, cold spray additive manufacturing (CSAM) is capable of producing oxygen-free deposits at high production rates. This results in retaining the original properties of the feedstock, which makes CSAM a very interesting additive manufacturing method for innovative solutions and achieving high performance deposits. However, to employ cold spray like other conventional AM methods, it is necessary to predict some of mechanical characteristics of final deposit, such as residual stress.
In this study a finite element model was developed to simulate the thermal and mechanical constituents of residual stress during the cold spray deposition of SS316 steel. This was followed by introduction of a 3D finite element model to evaluate the possible effect of toolpath strategy on the accumulated residual stress in consecutive layer depositions. The finite element outputs are in good agreement with the experimental results. The comparison of some conventional toolpath strategies confirms the difference in residual stress for various toolpaths, which can be attributed to the discrepancy in maximum achievable coating thickness with different strategies.

Keywords: Cold Spray, Additive Manufacturing, Residual Stress, Finite Element Modeling, Toolpath Strategy.

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Experimental-numerical validation of the curing reaction of snap-cure polymer systems for component families of small batch sizes and high diversity

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The efficient production of component families of small batch sizes and high diversity requires numerical analyses of manufacturing processes, especially for complex shaped components made of fibre-reinforced thermosets. In the case of snap-cure systems, curing takes place in a very short time and the exothermic reaction can lead to accumulation of heat and inhomogeneous curing. In order to achieve a reliable production of composite components, a numerical analysis of the curing process is necessary. Especially the practice-oriented and timesaving determination of the thermal conditions during the curing process is essential for the industrial application. Therefore, an experimental-numerical approach to predict the curing process was presented, which includes the analytical as well as the experimental determination of numerous thermal and thermochemical material parameters and models for snap-cure thermosets. The experimentally determined material parameters and models for the description of the material and structural behaviour are validated and evaluated by numerical simulations. In addition, the developed finite element models were used for the manufacturing process design of a complex component demonstrator.

System reliability as a key for ecological and sustainable products

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Data-driven methods have shown great potential for the acceleration and augmentation of existing physics based models. Surrogate models allow for fast and accurate predictions from a known dataset of physics based simulations or experimental data. These properties make them ideal for situations in which a high number of similar problems have to be solved, e.g. statistical studies [1] or optimization [2].
The proposed method applies an artificial neural network to predict stresses at arbitrary coordinates of structural components. This results in a very flexible formulation that can be parameterized using differently structured data. As a consequence, simulations with changing mesh topologies and data from experimental measurements can be combined in this surrogate model.
This approach is demonstrated for computational models with different levels of complexity. First, specimen with simple geometric features are used to solve benchmark problems from structural mechanics. Afterwards, the approach is applied to a fibre reinforced injection molded thermoplastic bicycle frame, where
different load cases are imposed in finite element simulations. Furthermore, a life time estimation is conducted using the nominal stress concept.
While the surrogate model is restricted to the parameter space of the dataset, it achieves a significant reduction of runtime in comparison to the finite element solution and can be adapted when new data becomes available.

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Experimental and numerical analysis of the defects induced by the thermoforming process on woven textile thermoplastic composites for automotive applications

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In the recent years, thermoplastic based composites are gaining the interest of many industrial sectors. Among them, the automotive has been using them incrementally due to their recyclability and the existence of know-how regarding the available equipment for achieving mass and high-quality production. Needless to mention that, even though initially the components consisting of thermoplastic composites were parts of low load-carrying capacity structures, the research is oriented to the implementation of such type of materials to more critical components. Among the most frequently used production methods, thermoforming is applied in many components made of thermoplastic-based composites which exploits the high formability of, mainly, textile composites. Nevertheless, several defects may be introduced to the produced component mainly due to the intense fibre deformation caused by the stamping pressure as well as thickness non-uniformity and wrinkles. All these defects contribute significantly not only to the aesthetical appearance of the products but also to their mechanical performance while in service. In the present work, a case study of an automotive component produced using the thermoforming process is presented. A numerical analysis of the product is conducted a priori using a commercial finite element software, developed for this specific process. Moreover, measurements of the component characteristics such as the fibre relative deformation of the textile is conducted. Consecutively, a comparison between the finite element process simulation and the measurements' output is conducted in order to investigate the validity of the process simulation and to assess the problematics of the thermoforming process.

Comparative Study of Microstructural Evolution and Mechanical Properties of Inconel® 718 and Waspaloy® Welds

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This research work focuses on the mechanical behaviour comparative assessment in conjunction with microstructural evolution characterization of Waspaloy® and Inconel® 718, following TIG (Tungsten Inert Gas) and EB (Electron Beam) welding. Both of the forth-mentioned alloys are Ni-based superalloys, precipitation strengthened and widely used in chemical, petrochemical and aerospace industries. More specifically, Waspaloy® is strengthened by the precipitation of the ordered fcc gamma prime intermetallic phase, γ΄ - Ni3(Al,Ti), while Inconel® 718 is mainly hardened by the ordered bct gamma double prime phase, γ΄΄ - Ni3Nb, in addition to γ΄. After both welding processes, various samples of the above superalloys were subjected to appropriate post-weld heat treatment, according to SAE Aerospace Material Specifications. The mechanical response of the tested specimens is assessed via uniaxial tensile tests, combined with fractography, as well as Vickers microhardness tests. Furthermore, the microstructural characterization of TIG and EB welds is conducted by Scanning Electron Microscopy (SEM), coupled with Energy Dispersive Spectroscopy (EDS), while phase identification was performed through X-Ray Diffraction (XRD). The main objective of the present research work is to examine the influence of post-weld heat treatment on the Waspaloy® and Inconel® EBW and TIG welds microstructural evolution features, correlating them with their corresponding mechanical behaviour.
Keywords: Ni-based Superalloys, Waspaloy, Inconel 718, EBW, TIG, Post Weld Heat Treatment, Electron Microscopy, Mechanical Properties

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An addition to the Local Strain Approach of the FKM guideline nonlinear for calculating the fracture fatigue life of steel components

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The FKM guideline nonlinear [1] was published in Germany in 2019 and presents a description of the Local Strain Approach for fatigue life calculations of components under constant or variable amplitude loading for failure criteria crack initiation. By applying the Local Strain Approach, the fatigue life calculation considers the cyclic elastic-plastic material behaviour described by the Ramberg-Osgood-equation, the Masing law and the memory effects based on a simple linear-elastic FE calculation. The transformation from the linear-elastic FE-calculation to the elastic-plastic material behaviour is realised by flow curves. For variable amplitude loading the HCM algorithm by Clormann simulates the stress-strain-path in the notch and counts the closed hysteresis loops. Damage parameters evaluate the damage potential of each hysteresis loop and a damage accumulation allows an approximation of the fatigue life of the component. All cyclic material parameters and the damage parameter Woehlercurves can be experimentally determined or approximated by the FKM method [2] based on the ultimate tensile strength and the material group.

This paper presents the U-Concept [3], an addition to the FKM guideline nonlinear to approximate the remaining fatigue life from crack initiation to fracture for steel components under constant or variable amplitude loading. The concept transfers the advantages of the Local Strain Approach from crack initiation to fracture. It consists of 1.) a shift of the damage parameter Woehlercurve, 2.) a correction of the slope, 3.) an additional mean stress factor and 4.) a correction factor of the Miner sum. All factors and correction terms were derived from a large structural database for steel specimens and requires no additional material parameters.

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Investigation of hardness behavior after carburizing and hardening of 15CrNi6 steel

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Surface heat treatment is widely applied to improve the working life and performance of engineering components. Carburizing is a common method used to modify the chemical and mechanical properties on the surface. It is usually implemented in applications that require high friction and wear properties while maintain satisfactory levels of ductility in the core of the part. It is a high temperature technique in which the surface of low-carbon steels is enriched in carbon. Final results are strongly determined by the treatment parameters [1]. The present work examines the microstructure and the mechanical properties of 15CrNi6 steel after progressive carburization and martempering in a modified process of double quenching. DIN 15CrNi6 is a low alloyed case hardening steel, suitable for machine elements as shafts and crankshafts. The material is case-hardened through carburization and then quenched. The objective of this study is to investigate the effect of carburizing time on the microstructure and hardness of the steel after a modified double hardening process. Part of heavy dimensions need to be hardened by isothermal quenching. On this context, the study was conducted according to the technical data sheet of the material manufacturer, modifying the cooling stages and tests were implemented according to the related standards.
Four sets of samples of identical chemical composition were subjected to heat treatment sequence, including: salt bath carburizing at 900oC for one, two, three and four hours respectively and air cooled. All samples were reheated at 840°C for 30min., martempered on salt bath at 180°C for 15min. and cooled on air at room temperature. After martempering, samples were tempered in salt bath at 180°C for 2h. Each case hardened set was comprised of four randomly selected samples.
Nondestructive testing (hardness measurements) and destructive testing (microhardness, light microscopy) were conducted. Case microhardness and core hardness were measured. Case hardness profiles were acquired (Fig.1). The effective case depth was determined for the different holding times. Microstructure examination was performed under an optical microscope.
The optimum carburizing parameters for achieving the optimum case depth were defined. Under these conditions, optimized combination of case and core properties was acquired.
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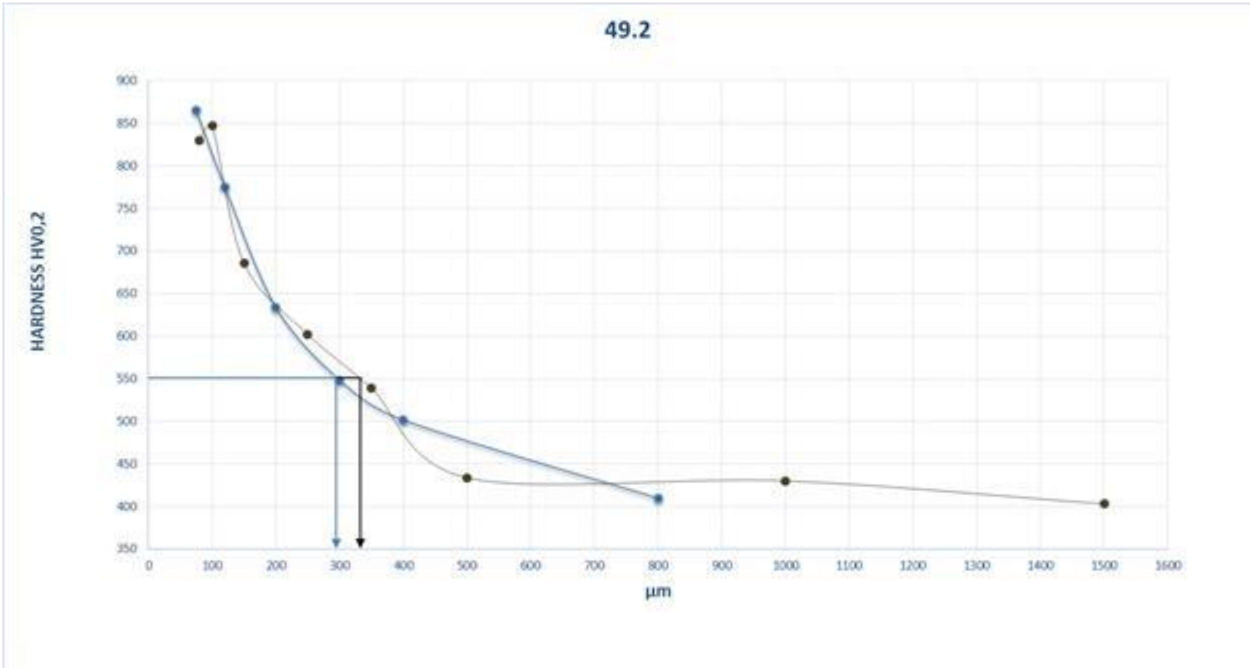

Hardness profile on two opposite sides on a sample carburized for one hour at 900oC. Effective carburization depth is denoted.

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Hardness behavior of W. Nr. 1.7709 steel, oil quenched and tempered between 475oC and 575oC

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Mechanical properties of steels are mostly determined by their chemical composition and strongly influenced by their microstructure. The microstructure depends on the applied heat treatment. On these context steels hardening through quenching and tempering is a usual method to upgrade steels. W. Nr 1.7709 is a high temperature structural steel frequently used in fastener industry. It is commonly selected for mechanical or assembly components suitable for operations resistant to high temperatures; in energy industry, in automotive and shipbuilding industry, in arm industry and machine tools. In order to meet the working conditions, the components are delivered after quenching and tempering. In the hardened condition, the steel acquires high creep and fatigue strength, and presents high-pressure resistance, high wear resistance, as well as heat and corrosion resistance [1].
Tempering process is the reheating of steel to a certain temperature, holding for a definite time, and cooling on air at room temperature [2]. The tempering conditions depend on the predicted hardness of each piece. Manufacturers offer facts that contain recommendations regarding tempering sequence of the produced steels. A tempering diagram is usually offered, where the hardness is plotted as function of tempering temperature, for recommended soaking time. Despite of it's wide applications, the tempering diagram of 1.7709 steel hasn't been provided yet.
The paper is a part of a project which analyzes the tempering resistance and plot a tempering diagram at 1.7709 steel. It focuses on the steels hardness behavior after oil quenching and tempering on specific interval of temperatures. Row material was acquired in bars of the same melt, in the as delivered condition, in order to assure identical chemical composition of samples during experiment. Groups of ten specimens were quenched in oil and tempered at selected temperatures between 475oC and 575oC (Fig.1). Rockwell (HRC) and Vickers (HV) hardness measurements were carried out after quenching and tempering respectively [3]. The results were statistically processed and the influence of tempering temperature was discussed. The resistance of the steel to tempering back was assessed and the tempering diagram was plotted for the specified interval of temperature.
The results are a benefit for heat treatment shop, enabling them to achieve intended mechanical properties through the predicted component hardness.

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Images showing the oil quenching of samples.

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Polymers on surfaces: structure, wetting and adhesion at the nanoscale

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Polymers on surfaces play a major role in many applications ranging from composites and nanocomposites to tribology and adhesion. The prediction and determination of materials properties at the nanoscale regime is not a trivial task and unexpected deviations from bulk behaviour are not uncommon. The atomic force microscope (AFM) has played a critical role in the nanoscale analysis of such systems. No other instrument is so versatile to be able to measure the structural, mechanical, frictional and adhesive properties of polymer nanostructures in dry state and in liquids with an unprecedented spatial and force resolution at the sub-nanometre and sub-nanonewton scale, respectively. In this talk, I will present AFM investigations of nanostructures formed on surfaces by the self-assembly of various polymer systems concentrating on recent work on homopolymers and random copolymers [1–4]. The phenomena studied include the differences in the morphological, wetting and adhesion behaviour when different substrates were used (silicon wafers, mica, graphite) and the increased elastic modulus of polymer nanodroplets due to surface 'pinning' [5]. The results demonstrate the critical importance of the substrate properties on the formation of the films and the emergence of dewetting phenomena. The AFM experiments were complemented by (and discussed in terms of) scaling theory, continuum theory and computer simulations. Single polymer chain droplets were found to lie flatter and wet the substrate more than chemically identical multi-chain droplets of the same size (same total number of monomers), which attain a more globular shape and wet the substrate less. This marked difference in the wetting behaviour is associated with conformational arrangements within droplets, which affect wetting behaviour. Furthermore, the adhesive behaviour of the polymers with the substrates is quantified at the single polymer chain level by performing a systematic study with AFM force-distance curves. The results reveal the single chain polymer-polymer and polymer-substrate interaction contributions allowing a detailed discussion of single chain pull-out phenomena from their films on different substrates. Finally, an investigation of the sizing of carbon fibres will be presented. Results [6] showed that the amount of sizing on the fibre surfaces influenced the mechanical and chemical interlocking phenomena occurring at the fibre/matrix interface.

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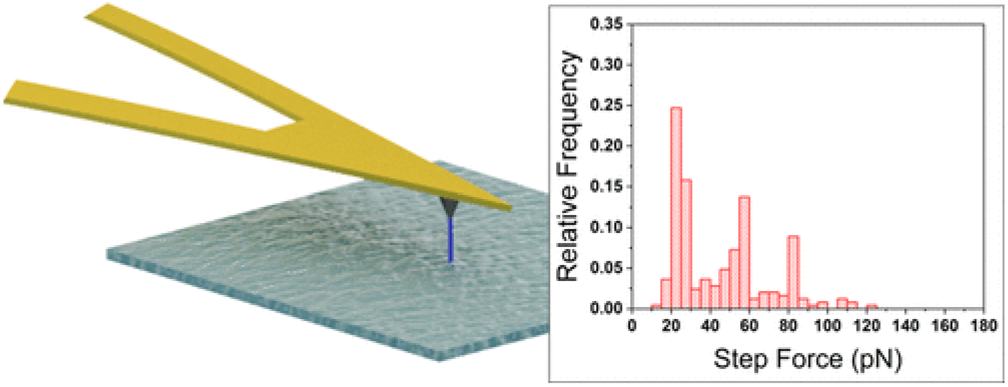

Schematic drawing of an AFM pulling experiment and a histogram of typical forces measured. [4]

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Flux-driven and external-pressure-driven finite element models replicating pressure-volume hysteresis of small airways and daughter branches in the lung.

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Introduction: In normal, healthy human lungs there exists a hysteresis loop in the relationship between volume and intrathoracic pressure [1] – a consequence of the surface tension forces emerging over the lungs' large surface area. To replicate this, a finite element computational model was developed to represent a small airway (bronchiole) and its subsequent daughter branches post-terminal-bronchiole (the 15th branch of the conducting airway), the point at which alveoli (tiny balloon-shaped air sacs) emerge anatomically and therefore encompassing the site of greatest surface tension in the lungs.

Methods: A spherical geometry was constructed in COMSOL Multiphysics® Modeling Software to occupy the approximate volume (63 mm^3) of one transitional bronchiole and its subsequent daughter branches. A spherical flux boundary of 0.25 mm radius (the same size as the lumen radius of a transitional bronchiole) was built into the geometry's core to replicate air flow. The pressure drop between the trachea and the terminal bronchiole was considered and estimated mathematically to decrease from an initial 1471 Pa [2] to 947 Pa; the latter being the magnitude used for the inner boundary of this flux-driven model. In another model using the same geometry, external pressure was used to drive volume change, with the inner flux boundary remaining for passive flow to occur. For this, a pressure range of 1471 Pa was used under the assumption that intrathoracic pressure will be uniform within the chest cavity. Both models used expansion/contraction cycles of approximately 6.3 second periods to approximate normal human breathing rates.

Results: For both models, a volume-pressure hysteresis emerged, with the range of pressure and proportional volume of comparable magnitude to a set of reference data [1] for air inflation of lungs using a controlled pressure chamber. For the flux-driven model, the following parameters were found as best-fitting the behaviour of the small airway as identified from literature data [1] (see Fig. 1): Young's Modulus of 3 kPa, permeability of 10-5 m^2, and Poisson's ratio of 0.2. These parameters were carried over directly to the external-pressure-driven model with only the Young's Modulus altered to 4 kPa to find the best-fitting results (see Fig. 2). It would appear that both models are therefore comparable in their behaviour despite the contrasting methods used to drive a pressure-volume cycle.

Discussion: The material parameters found in the two studies can now be utilized under physiologically-accurate conditions (i.e. pressure and air flow) to investigate changes to lung structure that underlie lung pathologies such as asthma or pulmonary fibrosis. Both the flux-driven and external-pressure-driven models' Young's Moduli of 3 kPa and 4 kPa, respectively, lie within the expected magnitude for a soft tissue of this nature, and in fact lie directly in the middle of a 1 kPa to 5 kPa range found through atomic force microscopy [3], indicating these results to be valid.

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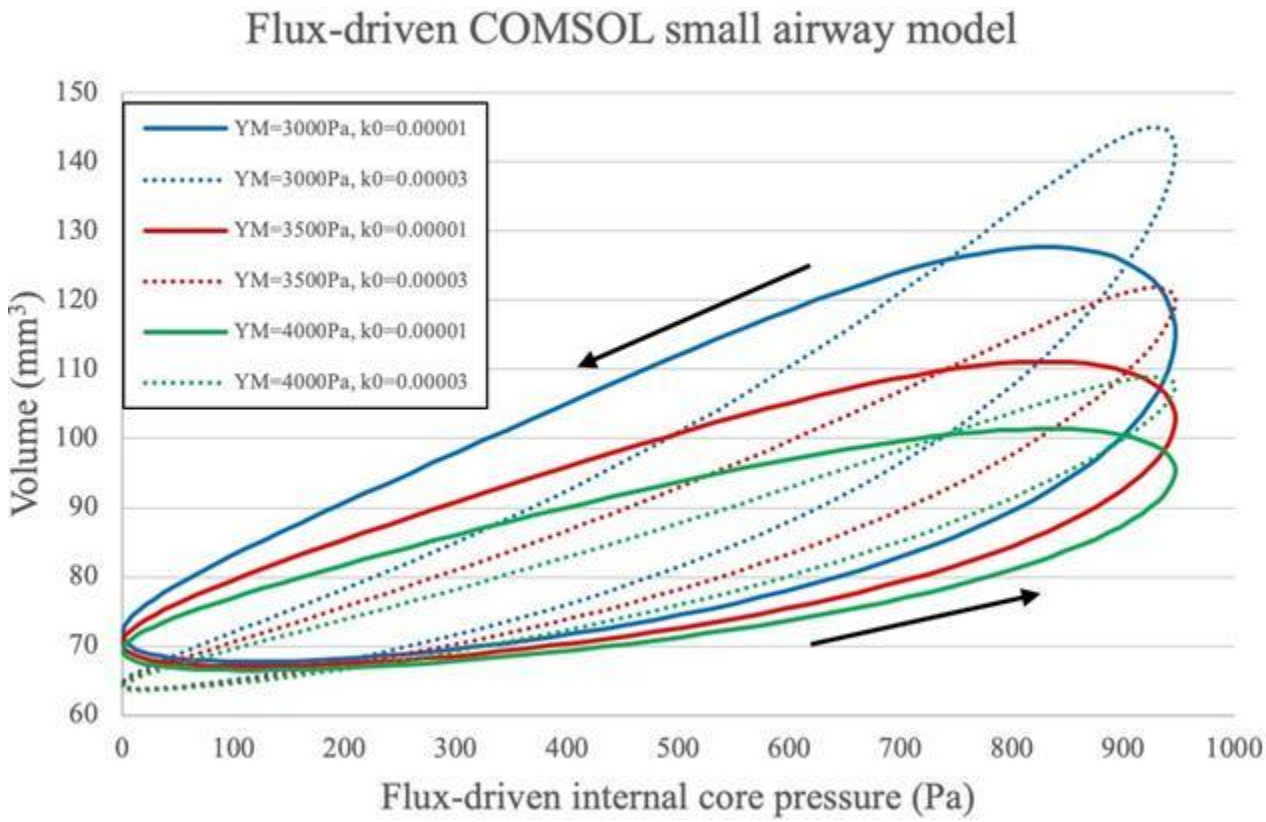

Figure 1: Flux-driven COMSOL model over appropriate Young's Modulus (YM) and permeability (k0) range with direction of cycle annotated by arrows.

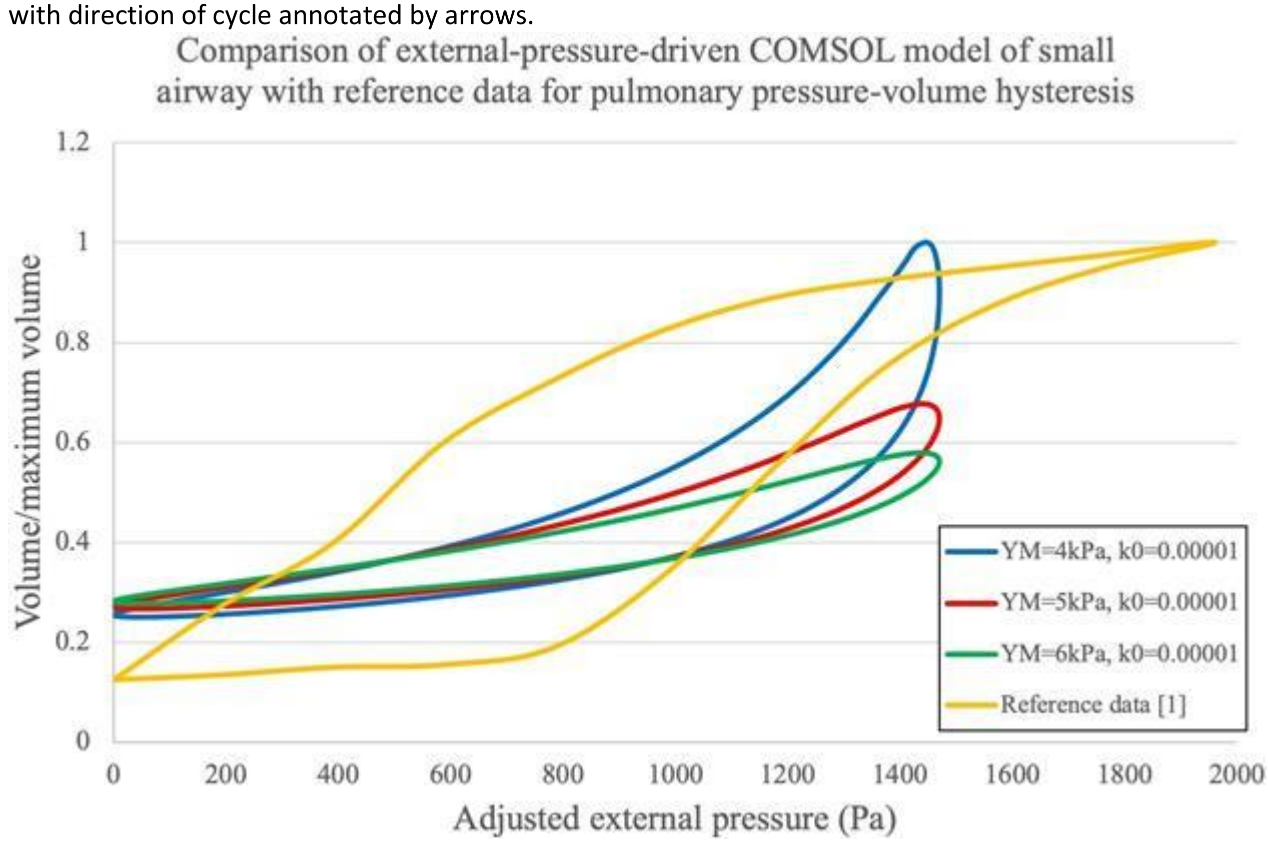

Figure 2: External-pressure-driven COMSOL model over appropriate Young's Modulus (YM) range and constant permeability (k0) directly compared with reference data [1] for pulmonary pressure-volume hysteresis.

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Structural and magnetic performance of soft magnets based on FeCoNiMnAl additively manufactured high entropy alloys

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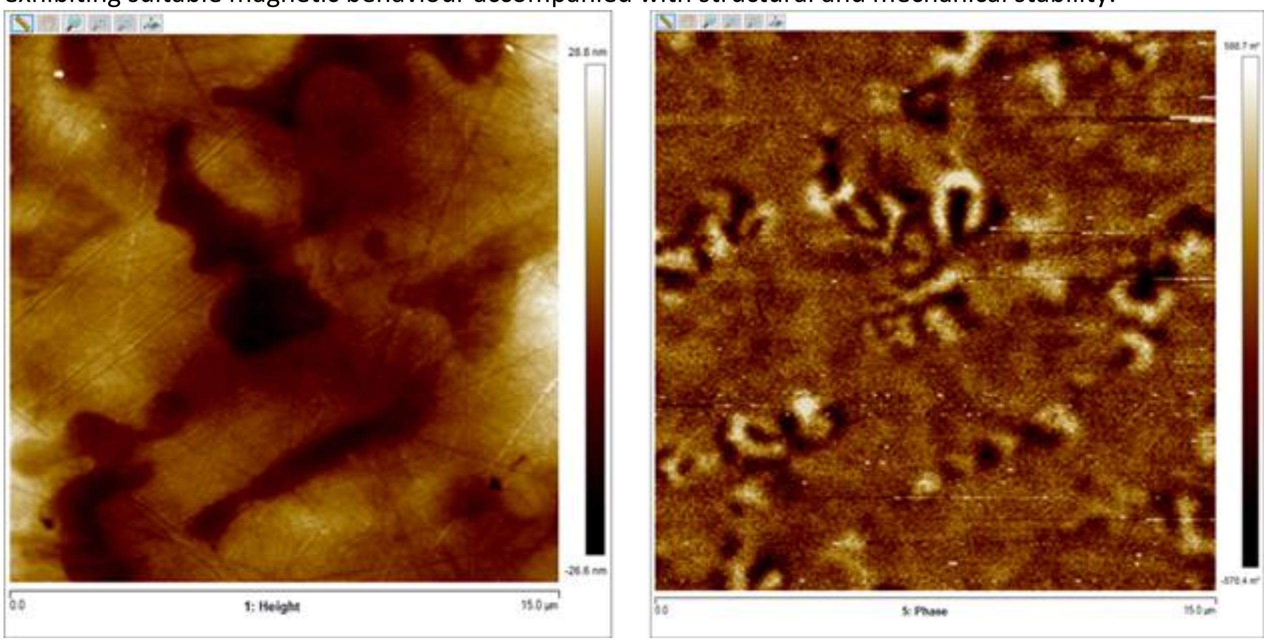
High entropy alloys (HEA), were produced by laser metal deposition as a high throughput synthesis tool. The produced material consisted of phases having different crystal structures and compositions exhibiting different magnetic properties. After compositional and magnetic screening, single phased materials showing promising soft magnetic properties were produced with laser powder bed fusion and subsequent heat treatments. We will demonstrate the employment of high throughput micro- and nano-level characterisation and testing, as well as atomic scale modelling, to accelerate the development of materials exhibiting suitable magnetic behaviour accompanied with structural and mechanical stability.



Left: Atomic force microscopy image of the surface of a low Al,Mn content HEA
Right: Corresponding magnetic force microscopy image showing Fe-rich magnetic domains

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Examination of reduced graphene oxide aqueous dispersions with electrical impedance spectroscopy

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Carbon-based nanomaterials – CBN (e.g. carbon nanotubes, graphene) are novel materials possessing excellent electrical properties. Currently they are exploited as filler material in different composite materials (e.g. epoxy resin, cementitious materials) so as to enhance the reinforced matrix with self-sensing capability. To this end, the matrix itself can be used as a strain sensor by exploiting the measurements of electrical resistance through the material lifespan.
In cement-based composites, these CBNs are first incorporated in aqueous solution, efficiently dispersed and then mixed with cement. Electrical Impedance Spectroscopy (EIS) technique was exploited to study the dispersion level of the CBNs in aqueous solution. Through this method, external voltage of variable frequency is applied and the current flowing in the circuit is measured. EIS can be applied for any kind of electrochemical cells, both solid and liquid systems.
In the present study, EIS is applied in order to investigate the possibility of reduced Graphene Oxide (rGO) to be efficiently dispersed in aqueous solutions. Dilute rGO aqueous dispersions (0.07 to 0.30 g per 100 mL) are studied in frequencies ranging from 0.1 to 100,000 Hz. The real and imaginary parts of the complex electrical impedance are obtained by the experimental data and are used to extract the appropriate Equivalent Circuit Model (ECM), which is in good agreement with the experimental data. The proposed ECM depicts all phases present in the dispersion, namely the dispersed particles, the soluted particles and the electric double-layer.

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The effect of artificial ageing on the corrosion-induced mechanical properties degradation of aeronautical aluminum alloy 2198

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Abstract
The increasing demand for improvement in energy efficiency and performance in the aviation industry lead to the development of new, lighter metallic structures. Third generation Al-Cu-Li alloys were developed to replace the conventional aluminum alloys since they can offer approximately 5 % weight reduction of the structure as well as improved property balance and corrosion resistance. Their improved mechanical properties are often attributed to their precipitation hardening system including δ (Al3Li), θ (Al2Cu), T1 (Al2CuLi) and S (Al2CuMg) phases. Nevertheless, these precipitates may influence the electrochemical behaviour of the alloys and therefore increase their corrosion susceptibility. The formation of such IM phases can be significantly accelerated by the artificial ageing heat-treatment. Heat treatment is usually performed in order to change the metallurgical structure, the mechanical properties, or even the residual stress state of the metal sheets. Artificial ageing heat treatment also affects the corrosion behaviour of the aluminum alloys due to the different electrochemical behaviour of the precipitated intermetallic phases and the matrix [1]-[3]. The 2xxx aluminum alloys were found to have higher corrosion resistance when artificially aged at certain tempers, such as T6 or T8, than at T3 [4]. Hence, it is of major importance to investigate the effect of artificial ageing on the corrosion behaviour Al-Cu-Li alloys.
The material used was a wrought aluminum alloy 2198-T3 which was received in sheet form of 3.2 mm nominal thickness. Machined specimens were exposed to artificial ageing heat-treatment for different ageing times in order to simulate the different ageing tempers named as under-ageing (UA), peak-ageing (PA) and over-ageing (OA). Exposure of the specimens to exfoliation corrosion solution (EXCO) according to ASTM G34 specification was performed for different exposure times in order to investigate the effect of artificial ageing on the corrosion evolution. The corroded specimens were examined with light optical microscopy in order to measure the depth of corrosion attack for the evaluation of corrosion-induced mechanical properties degradation. Finally, tensile specimens with prior heat treatment and corrosion exposure were tested to quantify the degradation on the mechanical properties. It was found that the corrosion exposure caused a significant degradation of the mechanical properties of AA2198 specimens that was correlated with the distribution of the depth of attack of the exposed surfaces to the corrosion environment.

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Optimal Designs of Tilting-Pad Thrust Bearing operation with the combination of numerical and machine learning techniques

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Thrust bearings are machine elements used to support axial loads of rotating machinery. Many studies, both experimental and numerical [1,2] can be demonstrated around the hydrodynamic lubrication of tilting pad thrust bearings. The aim of this study is to optimize the lubrication of a pivoted pad trust bearing, in terms of minimum friction and maximum load carrying capacity, using multi regression methods as simple machine learning techniques. For this purpose, the Finite Difference method is used to solve the Reynolds equations on a 2-D pad.
The basic hydrodynamic and tribological characteristics are identified for monograde and multigrade lubricants, in different operating conditions. The pressure field, the film thickness, the load capacity, the friction forces as well as the balance parameters of the pivoted pad are calculated with a parametric, iterative algorithm build in Matlab. A viscosity model based on Sutherlands' Law is taken into consideration [3]. The linear regression method is used to identify the optimum operating conditions from a simulation dataset that includes all the cases studied.

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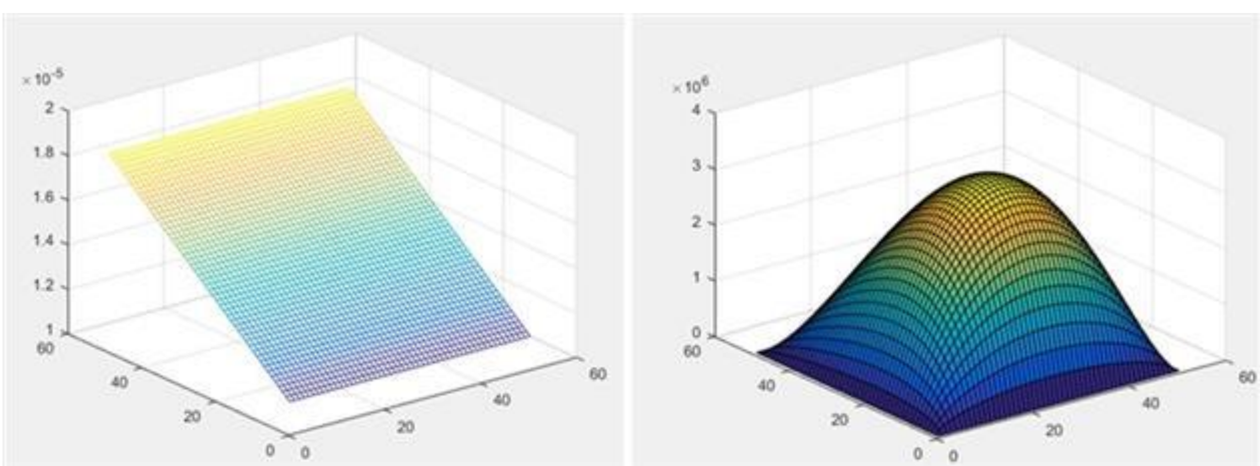

Pivoted Pad Finite Difference Grid and Pressure field calculation

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Electrochemical Corrosion of 2707 Hyper-Duplex Stainless Steel

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Hyper-duplex stainless steels (HDSS) have raised the scientific community's interest due to the properties of the characteristic two-phase microstructure (ferrite – austenite). Thanks to their microstructure, which renders higher corrosion resistance in chloride environments and higher mechanical properties as compared to other common steels, the HDSS are suitable for aggressive, acidic and/or chloride process environments that exist in various industries. Thus, this work focuses on the study of the behavior of HDSS 2707 in a chloride environment and its susceptibility to pitting corrosion, as well as the determination of the critical pitting temperature.
In order to evaluate pitting susceptibility, cyclic potentiodynamic polarization tests (CPP) were conducted in 3.5 wt.% NaCl solution at 25 oC, which simulates sea water. For the measurement of the critical pitting temperature (CPT), potentiostatic polarization at a 5 wt% NaCl solution was performed. The electrochemical tests were supported by Stereo-Optical microscopy, Scanning Electron Microscopy (SEM), Energy Dispersive X-Ray Analysis (EDX), Atomic Absorption Spectroscopy (AAS) and X-ray photoelectron spectroscopy (XPS) to identify the corrosion mechanism and products.
The corrosion rate was calculated by the Tafel equation. Also, a comparison of the results of two different types of cyclic polarization (anodic and cathodic-anodic) was made and the influence on the pitting corrosion was established.The results of this study highlight the characteristics of HDSS, its low susceptibility to pitting corrosion and its very high resistance to general corrosion. In more detail, only one quarter of the replicate potentiodynamic polarization tests revealed susceptibility to localized corrosion. Moreover, the corrosion rate was found lower than that of other stainless steels used in similar corrosive environments.

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Phase-Field Modeling Of Nugget Zone in Friction Stir Welding

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This work presents simulation of microstructure evolution in the nugget zone (NZ) of a AZ31-Mg-alloy friction stir weld (FSW). The process parameters (tool geometrical characteristics, rotational speed, travel speed, applied load) have been correlated with the resulting microstructural features in the NZ of the weld (grain size and population) with the aid of the MICRESS software, which provides the ability to simulate both nucleation and grain growth during dynamic recrystallization phenomena (DRX) evolving in the NZ during the weld thermal cycle. The input parameters of the developed model include the tool geometry, the welding conditions as well as the recrystallization energy, the grain boundary mobility and specific material properties. NZ microstructure obtained by simulation shows good agreement with experimental measurements for both grain population and size.

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The corrosion-fatigue performance of conventionally and additively manufactured Maraging steel after various surface and heat treatments

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Additive manufacturing offers the ability to quickly and economically manufacture complex geometric products. Among the methods developed, selective laser melting (SLM) has attracted the major interest. SLM can deliver very good manufacturing quality by optimally adjusting production parameters for a specific alloy. This adjusting could affect the grain structure, phase formation, microstructure, roughness and porosity, compared to conventionally manufactured parts. Among them the surface integrity, such as distorted subsurface microstructure and roughness are determinant of the functional life, especially in a corrosive environment. The present study highlights and compares the fatigue life of maraging steel 18Ni-C300 with a superior strength and toughness, between conventionally manufactured specimens from a rolled bar and different post-treated SLM-fabricated specimens of the same geometry. The post-treatments refer to surface polishing, glass-blasting and heat treating. Experiments were performed in corrosion free and in a 3.5% wt. NaCl aqueous solution. Metallography, microscopy, surface scanning, FEM and hardness measurements were employed to help understand the results obtained. There is a clear superiority of the wrought material both in pure fatigue and in corrosion-fatigue, because of its dense and homogeneous microstructure, as well as its lower resulting surface roughness compared to the SLM. The as received SLM specimens, due to the distorted microstructure and more dominantly the higher roughness, has an inferior fatigue and corrosion-fatigue performance that acts positively in neutral environment with combination of glass-blasting and polishing, because of the imposition of residual stresses and improvement of surface integrity. On the contrary, glass-blasting has a negative impact in a corrosive environment, whereas heat treatment does not seem to have a positive effect in all cases.

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Percolation Threshold Sensors for reducing complexity in Structural Health Monitoring (SHM) of engineering structures

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Sensing principles for interrogating the structural integrity of engineering structures aircraft frequently operate in a quasi-linear mode. However, although quasi-linear-sensing is a prerequisite for versatile, high-end devices in applications where only one or two thresholds are monitored, other concepts could provide more appropriate solutions. An interesting alternative is offered by percolation threshold sensors that are characterized by a sharp sensor response depending only on one outer parameter that is related to a certain damage threshold. Moreover, the sensor response usually ranges over many orders of magnitude and this is ideal to filter out baseline variations and thus, the probability of detection is superior with respect to many other technologies.
In literature, there are a couple of highly non-linear sensing devices reported and some are even used in operations, such as the alarm wires in bleed air systems for aircraft providing information on overheat, or crack propagation gauges in fatigue testing.
The present paper is providing an introduction into this research field in a more systematic way and provides a couple of recent sensor applications developed at the Department of Materials Engineering, KU Leuven, such as the detection of corrosive liquids in aircraft (Boeing 737-500, Boeing 747-400), the detection of hydraulic liquids and fuel as well the detection of moisture ingress in composite materials. Moreover, long term results obtained from chemical installations where moisture accumulation in pipelines insulation were detected are presented and illustrated.

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Safety assessment for the power train integration of the hybrid-electric e-Genius HPH

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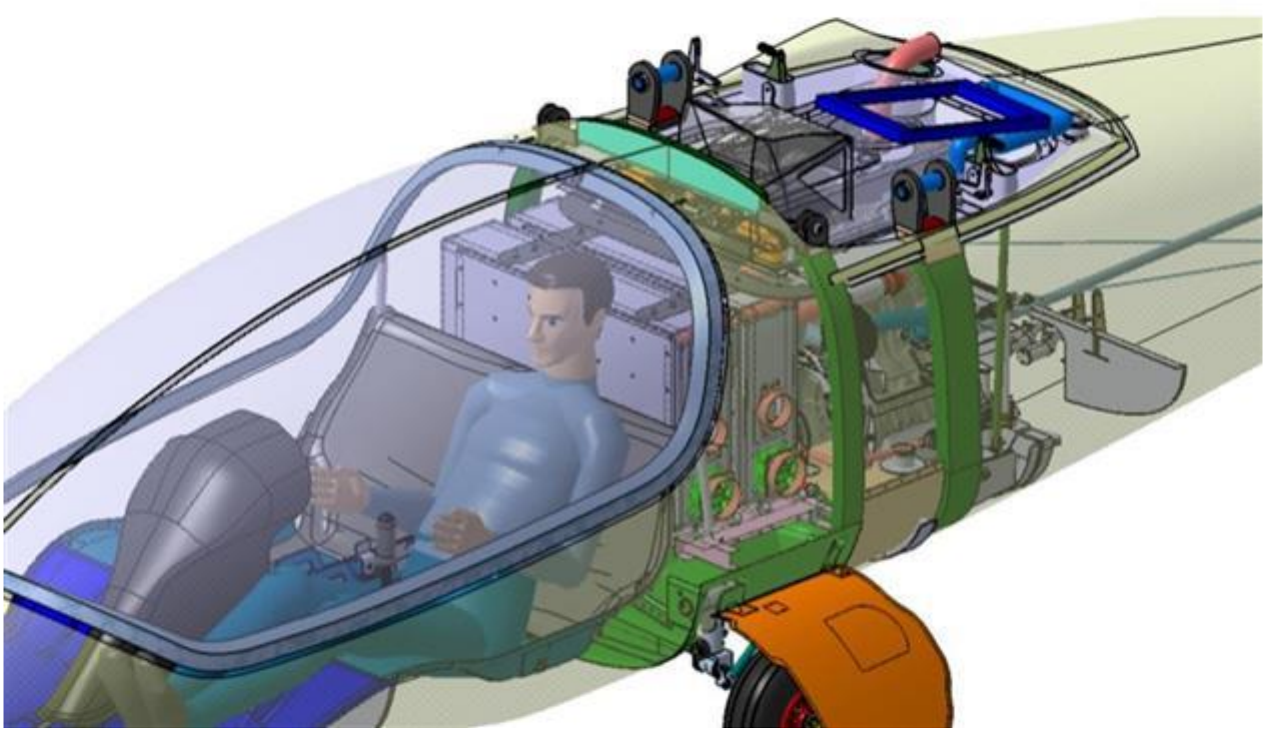
University of Stuttgart's e-Genius had its first flight in 2011 as a fully battery-electric two-seated aircraft. Designed and built as a test and demonstration platform for electric flight it holds several world records and is a valuable tool for research in this field. In 2016/17 it a first step towards hybrid-electric flight was taken with the integration of a Wankel-powered range extender in the electric system. Since 2018 the Institute of Aircraft Design converts its e-Genius to a high performance hybrid-electric test platform ('e-Genius HPH), integrating an internal combustion engine-generator system ('GenSet'), powered by the 50 kW OM660 3-piston engine of the Smart car. With this modification the battery-electric range of more than 400km can be extended to about 1200km.
The GenSet, together with a 30 l fuel tank and power-density optimized 400V lithium ion battery packs holding 23 kWh, is integrated in the center fuselage just behind the pilot seats and below the wing main spar connection. The integration of the components of this new power train concept in this sensitive location requires a thoroughly elaborated safety concept which will be laid out in the presentation. Based on the applicable standards this concept covers inter alia (a) cooling and ventilation, (b) battery system safety, ranging from cell type selection to contact-proof integration and outgassing precautions, (c) thermal management and temperature control, (d) GenSet fire protection and (e) validation of structural modifications. Finally operational safety and system redundancies are assessed.


GenSet integration in the e-Genius HPH of University of Stuttgart

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Preliminary examination of a tool used for sectioning steel reinforced concrete pillars

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Keywords: sectioning reinforced concrete pillars, cutting knives, shear blades, failure analysis, multi-layer chipping.

Abstract

A local organization is engaged in recycling reinforced concrete pillars. The round columns are demolished by the use of excavators. Initially, assembled tooling on the arm of the bulldozer crush the aggregates so to bare the steel bars. Subsequently, the bars are cut off in random length, so to be effortlessly transported (Fig.1).

The single arm of the excavator features a hydraulic system comprised of two bearded jaws. Two different kinds of interchangeable tooling are used (aa and ab in Fig.2) to exert the shredding and cutting loads. Compressive stresses are exerted by the conical tooling so to smash the concrete. Shear stresses are applied by the rectangular knives in order to cut the reinforcing steel bars. The shear blades are failed repeatedly (Fig.2b). These tools are operating for just 5% of their estimated service life. The present study referred to their preliminary failure examination. Eight damaged cutters and one M16x25mm screw were received (Fig. 2b).

Historical background was collected. The failed blades were exanimated by naked eye. Each cutting tool has four available cutting edges. The knife is rotated when an edge wears out. All cutting edges were failed. Material detachments on the edge the tool, total breakage as well as flaking around the countersinks of the holding screws were observed. The fractured surfaces were cleaned and examined under stereoscope. Multi-layer chipping as well as improper machining were observed.

Chemical analysis was performed using optical emission spectrometer which showed that the blades were manufactured by different tool steel grades [1].

Hardness measurements were carried out away from the fracture areas. The tools have different hardness ranging from 52-55HRC and 56-57 HRC respectively. The hardness is considered too high for the specific application, since the cutting tools under examination are subjected to impact, shear as well as to multiaxial loading [2]. The tools' critical property chosen by the manufacturer was hardness in order to assure increased wear resistance.

The preliminary examination conclude that poor design contributed to the failures of the cutting knives. Both material selection and heat treatment caused the low productiveness of the components. Furthermore, microscopic examination of the knives is recommended in order the primary findings been verified as well as the corrective actions to be drawn.

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Fig.1 General aspect of the excavator used for crushing the concrete pillars as well as for cut off the steel bars.

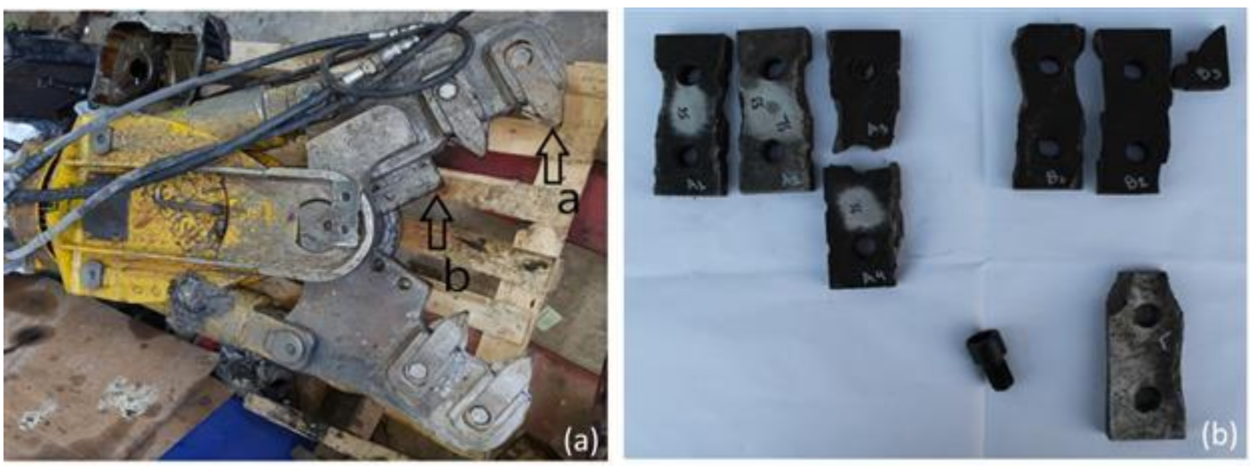

Fig. 2 (a) General aspect of the cutting assembly; (aa) conical shredding fittings, (ab) rectangular shaped cutting fittings, (b) fractured shear blades.

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Additively Manufactured FeCoNi(AlMn)x High Entropy Alloys: Mechanical and Magnetic Properties Investigation

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Recently, a brand-new category of materials has dynamically entered the scientific field, opening an unexplored path in metallic materials characterization. Named as High Entropy Alloys (HEAs), these systems consist of at least five principal elements with a concentration between 5-35 at.% , and they ideally form simple solid solutions. Because of their exceptional properties suitable for diverse high-tech applications, such as high mechanical properties, wear and corrosion resistance, as long as their unique microstructural features, this new type of alloys finds application in both low and high temperature fields.
In the present work, the Additively Manufactured FeCoNi(AlMn)x systems were evaluated in terms of structural, mechanical and magnetic properties. In particular, the microstructural features and crystal structures of the alloys were characterized, in both as received and heat-treated conditions. Hardness tests, under various indentation loads and dwelling times, were performed to assess the mechanical properties of the prepared samples. The work highlights a process-structure-property (PSP) relationship through creating hardness neural network profiles as a function of constituent elements concentration. Regarding the magnetic properties, the alloys exhibited good soft-magnetic behavior, being easily magnetized to the saturated state with coercivity values of <1000 A/m. Magnetic screening through Magneto-Optical Imaging (MOI), Magnetic Force Microscopy (MFM) and Vibration Sample Magnetometer (VSM) confirmed the importance of the structure evolution in defining the magnetic properties of the alloys. The trends in the magnetic behavior, as a function of the alloy composition are revealed.

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Integration and evaluation of a meander-shaped fiber-optical sensor in a GFRP leaf spring

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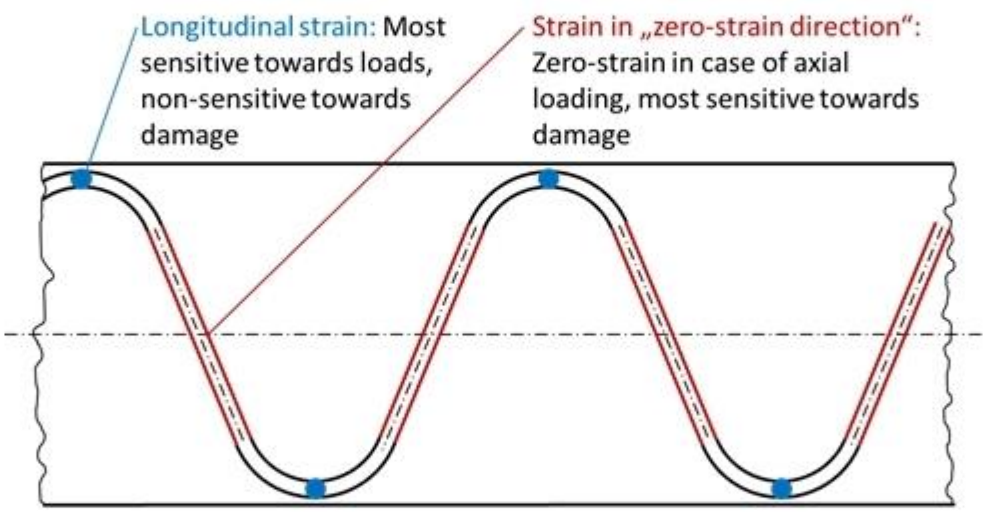
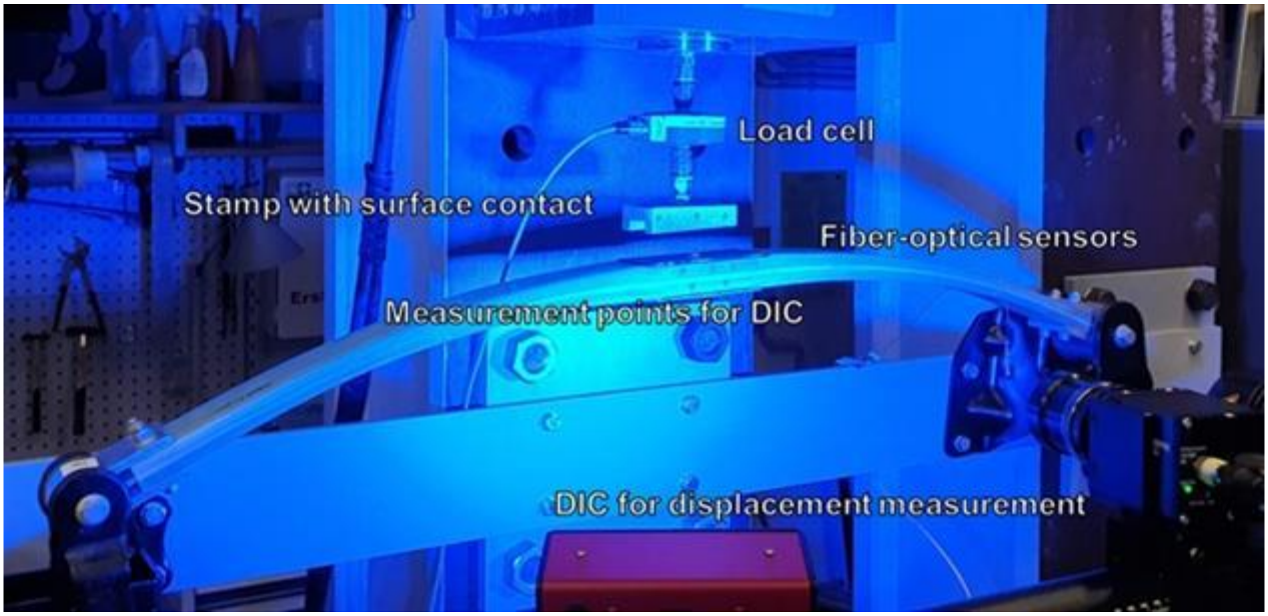
Structures made of carbon-fiber and glass-fiber-reinforced plastics (GFRP) are attracting more and more attention also in non-aviation sectors due to their good strength-to-weight and stiffness-to-weight ratios. However, possible internal damage (such as delamination or matrix damage) is a significant challenge, as it cannot be readily detected from the outside. This lead to a need for structural health monitoring (SHM). Here, fiber-optical sensors possess an enormous potential. Due to their fiber-shape and the possibility of a quasi-continuous measurement along the fiber, they enable a wide range of measurement and placement possibilities.

In previous work, the so-called zero-strain direction was derived for an efficient damage detection and assessment. In this direction, longitudinal strain due to the external loading and the transverse strain due to lateral contraction cancel each other out. Thus, zero-strain is measured in this direction as reference state. In case of damage, additional shear is present, leading to a significant change in the stress and strain state and thus to strain in the former zero-strain direction. In order to enable comprehensive monitoring, previous work proposed the use of a meander-shaped sensor layout (see attached Fig. 1): measuring points in longitudinal direction provide loads monitoring while distinct measuring sections in zero-strain direction are used for SHM. This approach was validated in numerical studies and during coupon tests.

In the present work, the proposed meander-shaped sensor layout was integrated within an unidirectional GFRP leaf spring, leading to a close-to-application validation. In this demonstrator test-setup a realistic three-point bending test setup was aimed at using the real mounting elements as bearings (see attached Fig. 2). The evaluation of the demonstrator tests showed the principle function of the proposed sensor layout. Different load levels and the presence of artificial damage could be detected. Challenges exist, however, in the handling of measurement noise and in preliminary damage to the sensor fiber due to the integration and manufacturing process.



Proposed meander-shaped sensor layout.


Load cell
Stamp with surface contact
Fiber-optical sensors
Measurement points for DIC
DIC for displacement measurement

113

Assessment and rehabilitation of a deteriorated heat pipeline overpass

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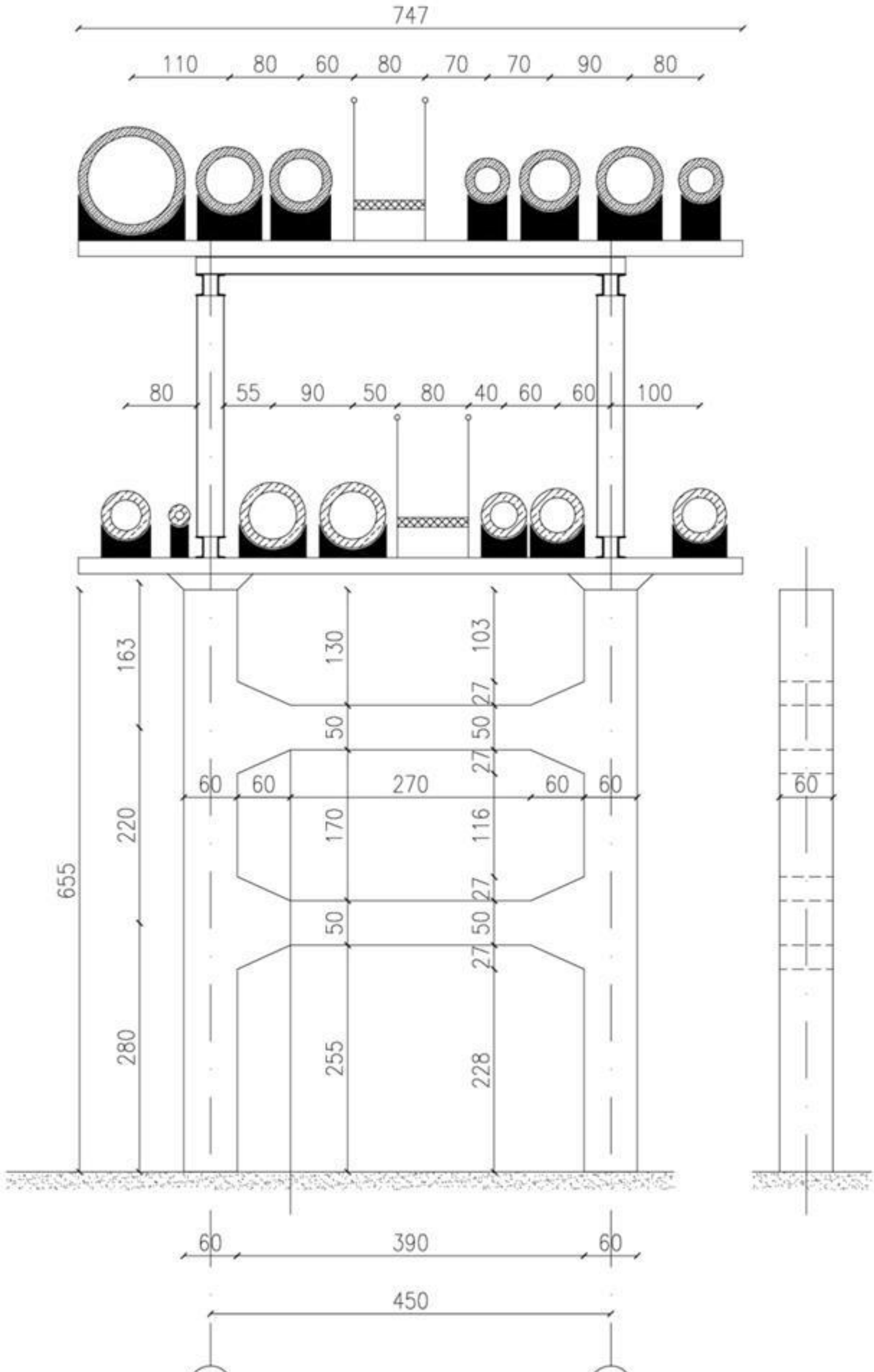
Assessment and rehabilitation of existing structures are very often more challenging than constructing a new structure. Access to complete technical documentation is highly valued, however not always possible. Moreover, as-built documentation may not be reliable and it has to be compared with the existing structure taking into consideration materials used, quality of workmanship, and manner of exploitation. The localization, type, magnitude and origin of damages have to be identified to provide the optimal solution for rehabilitation.
This research paper deals with a heat pipeline overpass. The overpass consists of a 265 meter long spatial truss, which rests on supports made of steel profiles and reinforced concrete frames. During sixty years of use the structure of the overpass was subjected to deterioration resulting from exploitation. The loading of the overpass had been increasing by addition of new pipelines, which was not always accompanied by adequate strengthening. The objective of this paper is to discuss the magnitude and origin of damages to the steel and reinforced concrete structural elements, present verification of resistance of the structure, as well as methods applied for its rehabilitation.
The overpass was inspected to identify the damage to the structure. The structure was found to have undergone corrosion. A very high level of corrosion was observed at the bottom parts of the overpass, where the closed zones in the truss did not allow for fast drainage of rainwater. The zones of connections of the truss elements were found to be corroded due to insufficient and inappropriate anticorrosive protection. Factors accelerating the corrosion process were localization of the structure at a chemical plant and leakages from the technological installations. Temperature changes due to the transported steam and environment resulted in changes in the length of the pipelines and excessive displacements on the supports. The “U”- shape compensations turned out to be inefficient.
The assessment of the overpass constituted a complex problem due to the lack of technical documentation, and inconsistent codes requirements. The codes used at the time of design of the structure vary from the codes valid at the times of strengthening of the structure, and are different from the current codes. The codes significantly differ in the approach to the structural design. While the oldest codes were based on the permissible stress design method, the newer codes are basing on limit state design. Requirements of all the codes were taken into consideration, which resulted in significant discrepancies in evaluation of the resistance.
After numerical modelling and analysis of the resistance of the structure, the optimal solution for rehabilitation was chosen. Strengthening was added to some of the truss elements. Additional strengthening was welded to gusset plates and connected by battens to existing steel profiles. The anticorrosion protection to steel elements was applied. Reinforced concrete frames were cleaned using the hydromonitoring method. A passive cathodic protection for reinforcing bars was applied. The defects in concrete were refilled and reprofiled using polymer cement concrete and protected with a paint coating.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60 390 60
450

Cross-section of the overpass

Damage to one of the supports

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Repair of local damages to precast prestressed slab elements at a parking garage

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Structural precast elements are characterize by achieving very high quality owing to high quality control during the production process, which can be more easily obtained in factories than on construction sites. However, the durability of precast structures is also sensitive to quality of execution and proper exploitation of the structure. In particular, the potential risk zones influencing structural integrity are the connections of precast elements. Over the years, precast producers have developed a variety of connection details to fulfil design code requirements and provide optimal solutions. Despite that fact, they tend to provoke problems of complex/compound origins.

The subject of this research paper is the repair of a precast slab in a two-story parking garage of a shopping center. The precast structure consists of prestressed double tee slab elements supported on prestressed inverted T beams/girders, which transfer loads to columns and foundation pads. The effect of a monolithic slab structure was obtained by filling the gaps between the double tee elements and adding a reinforced concrete slab at the top of the precast elements. The connections between double tee elements and the inverted T girders were designed as simple supports on one side and pinned supports on the other side. For simple supports sliding elastomeric pads were used, while for pinned supports sliding elastomeric pads and dowel bars were applied.

In the research paper presented, the type and magnitude of damages as well as methods used for repair are described. During exploitation of the structure at the connection zones with pinned supports local damages occurred to the double tee slab elements and inverted T girders. Numerous cracks, concrete spalling, efflorescence, and surface rust stains were observed. If was found that during execution the girders were forced to fit dowel bars which resulted in their initial deformation. Moreover, those connection zones were subjected to excessive loading from the top. The unloading zone for delivery trucks was located unfortunately directly above them. This type of loading was not taken into consideration during design. It resulted in the crushing of the elastomeric pads, uncontrolled rotation of double tee precast elements, and deformation of dowel bars.

The assessment of the state of the existing structure led to a statement that it was at high risk of failure. The project for repair was elaborated. The first stage of the repair process was the unloading of the structure, which facilitated further evaluation of damages. The slab was lifted up with the use of a jack to provide necessary space for work. In order to avoid damage of the continuous slab reinforcement, the spans adjacent to the damaged ones were also lifted up. Damaged dowel bars and elastomeric pads were removed. The concrete surface of double T beams and inverted girders was cleaned, refilled, prepared and strengthened with FRP wraps. Additionally, angle steel profiles were used to protect the edges of the inverted T beams. In this paper, the description of the performed work is illustrated with figures.


Lifting up the slab structure

Damage to connection of the precast elements

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Homogenization of Unidirectional Composites with Brittle Fracture Modeled by the Phase-Field Approach

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This study is concerned with the linear homogenization of unidirectional composites (UD) having heterogeneous microstructure with brittle fracture. The micro-model of the UD composite undergoing brittle fracture is modeled by the phase-field approach. To the best of authors' knowledge, the phase-field failure model has not been applied to a homogenization study of the heterogeneous microstructure of composites yet. Instead of assessing the failure via macro failure theories, like Hashin [1], this study aims to evaluate the damage by homogenizing the micro-model thereby extracting the equivalent stiffness/stress information. In this context, there are other studies such as the one by Kästner et al. [2] who implemented the XFEM in a microscale model.

For this purpose, a representative volume element (RVE) model is generated for a simple UD configuration comprising of fiber and matrix domains. The phase-field model is based on Miehe's isotropic brittle failure [3], which is modified by the tension dominant failure characteristics applied with the energy model as suggested by Wu [4]. The verification of the phase-field model through the benchmark problems employed in the literature is presented. Beginning with two main loading scenarios, lateral tension and transversal shear, combined loading conditions along with the periodic boundary conditions are considered. The results obtained through the homogenization (equivalent stress/strain curves) are compared with the experimental results and the implications of the phase field-based modeling of damage in the microstructure are discussed.

It should be noted that even though the classical composite failure theories can adequately predict the initial failure in composites, the phase-field model has the advantage of tracking the non-linear post cracking behavior of the material. With the proposed approach, a material-specific failure can be tracked for various types of composites, especially the ones with complex textile configurations.

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A Review of Computer Vision Techniques in the Detection of Metal Failures

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This paper considers and contrasts several computer vision techniques used to detect defects in metallic components during manufacturing and in service. As technology has evolved within the sensor, image processing, and vision algorithm domains, industry and service of components have begun to leverage computer vision to perform high speed, non-destructive inspections for large volumes of product and in service of structures. Methodologies include statistical analysis, weighted entropy modification, Fourier transformations, neural networks, and deep learning. Manufacturers use such systems to perform non-destructive testing and inspection of components at high speeds [1]; they provide better error detection rates than traditional human visual inspection, can lower costs [2], and may operate in a broader range of the electromagnetic spectrum than human vision. These techniques have varying abilities to differentiate defects from the background, computational requirements, cost, granularity, and complexity.

This review will explore the computer vision system and will compare the different mathematical analysis to illustrate the strengths and weaknesses relative to the nature of the defect. The presentation will include exemplar that histograms and statistical analysis operate best with significant contrast between the defect and background, co-occurrence matrix and Gabor filtering are computationally expensive, structural analysis is effective with repeated patterns, Fourier transforms, applied to spatial data, need windowing to capture localized issues, and neural networks can be utilized after training.

This article examines different modes of failure, including cracks, inclusions, impurities, as well as chemical effects, such as corrosion. It discusses the current literature on the detection of such defects and suggests the appropriate ways to better address the non-destructive detection and prevention of failure.

Computer vision is an evolving technology. It has the potential to improve product quality, to perform industrial inspections, and to detect defects such as surface scratches, hits, stains, corrosion, and impurities in metals.

Keywords: computer vision, defect detection, statistical analysis, transforms, neural networks

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Uncertainty identification of composite properties via inverse approaches: methods and virtual setups

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Material characterization of microscale composite properties is a challenging task, which becomes even harder in the presence of the inherent uncertainties of lower scales. The application of inverse approaches is a smart solution, allowing the uncertainty quantification of microscopic parameters from a relatively small data set from standard macroscale composite tests (tensile, compressive, buckling etc.). However, there are several numerical challenges, including an efficient model suitable for repeated evaluations and a clear perspective on the sensitivity of each input parameters within the design space. This work consists of several examples of inverse uncertainty quantification for both destructive and non-destructive test data. The methods used for the inverse identification (optimization and Bayesian inference) and the necessity of a global sensitivity analysis beforehand are discussed. A use-case for an acceptable defect tolerance identification of stiffened panels manufactured with automatic fiber placement (AFP) is also presented. Furthermore, an investigation regarding appropriate non-destructive simple test cases is presented towards a successful identification of parameters with low sensitivity.

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An evaluation of various damage models for thermoplastic composite materials subjected to quasi-static tensile loading

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In the present work, damage propagation in thermoplastic composite laminates subjected to quasi-static tensile loading was numerically simulated using different damage models. The simulation was performed using the commercial finite element suite LS-Dyna, where various material models were evaluated based on their ability to simulate the thermoplastic composite behavior. More specifically, material models based on Tsai-Wu failure criteria, progressive damage, micromechanical material modeling and continuum damage were implemented, comparing the output failure strength and load – displacement curve with experimental data available in the literature. The approach of damage evolution and failure type for each model was taken under consideration as well. The progressive damage model presented the most accurate prediction of the material's failure behavior. As a second part, a woven composite laminate, fabricated by polypropylene matrix and reinforced with 2/2 twill glass fiber weave was tested under tension. The damage model with the optimal performance from the first part was utilized for the simulation of the tested laminate.

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A Health Monitoring Modelling Case Study: Humidity Effects on Engine Deterioration Prediction

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Engine health monitoring is a crucial function for aircraft operators and Maintenance, Repair and Overhaul (MRO) providers, for two main reasons: First, to secure a safe and reliable operation and second, to identify the maintenance needs of individual engines. Timely and efficient maintenance is becoming of greater importance for MRO companies, driven by competition, as a total of $69 billion has been spent on MRO in 2018, which represents around 9% of an airline's annual operational cost . Under this frame, the accurate assessment of the condition of a large turbofan engine is paramount.

It is known that the operational profile of aircraft has a distinctive signature in the deterioration modes of its components. However, the exact mechanisms that link the operational environment with deterioration of aircraft parts are not considered in MRO programs, a practice that can underestimate the maintenance needs of assets.

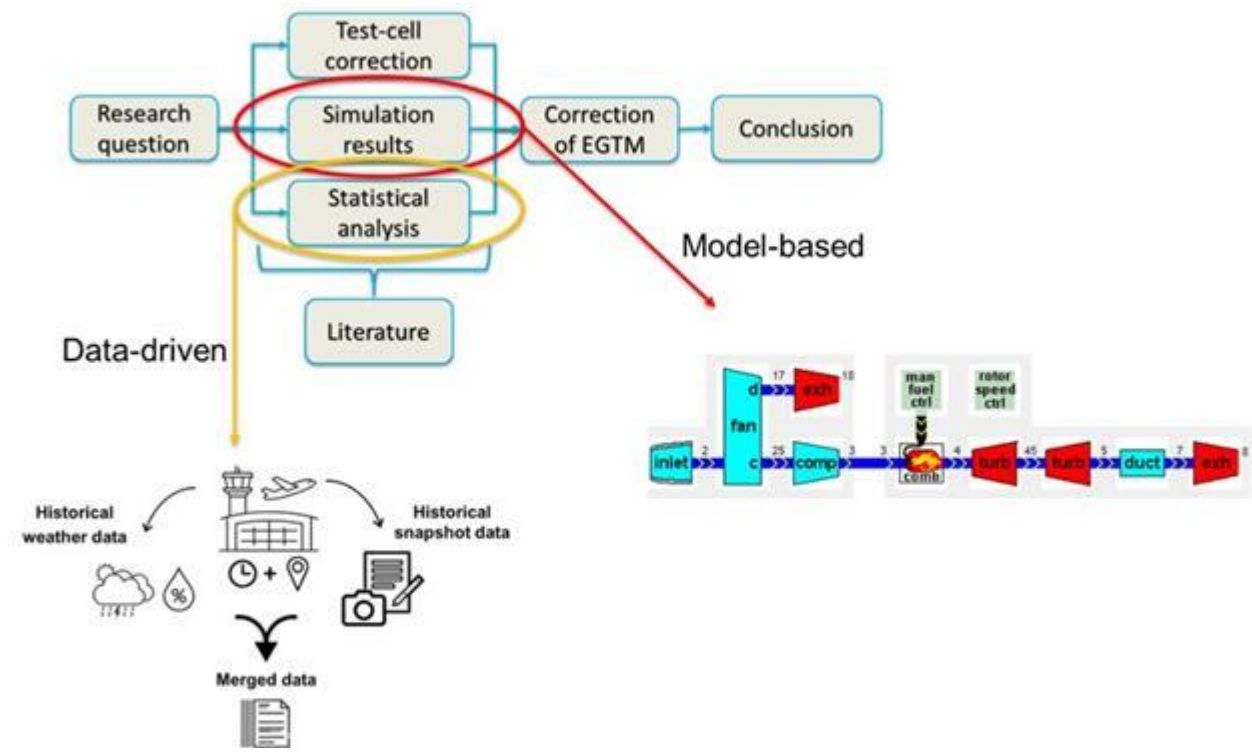
The main key performance indicator of an engine is the Hot Day Exhaust Gas Temperature Margin (EGTM). EGTM acts as a measure of the overall thermal efficiency of engines, since deteriorated components are characterized by reduced isentropic efficiencies and increasing gas temperatures along the gas path. However, as the composition of the air as working fluid varies with ambient conditions, the reported EGTM might also be partially inaccurate with varying absolute humidity. The reason is that humidity is not measured by the aircraft and therefore EGTM is not corrected for it.

This work focuses on humidity effects of turbofan engines, in order to identify the magnitude of the error in operational conditions and the implications on MRO decision support. More specifically, this paper employs a set of different methods, including semi-empirical corrections used in engine testbeds, performance simulation models and analysis of historical data, in order to investigate the effects of humidity. In literature, component corrections assume flow field similarity, which implies a constant specific heat ratio. However, this last condition is not met with unknown absolute humidity, leading to indicated EGTM inaccuracies.

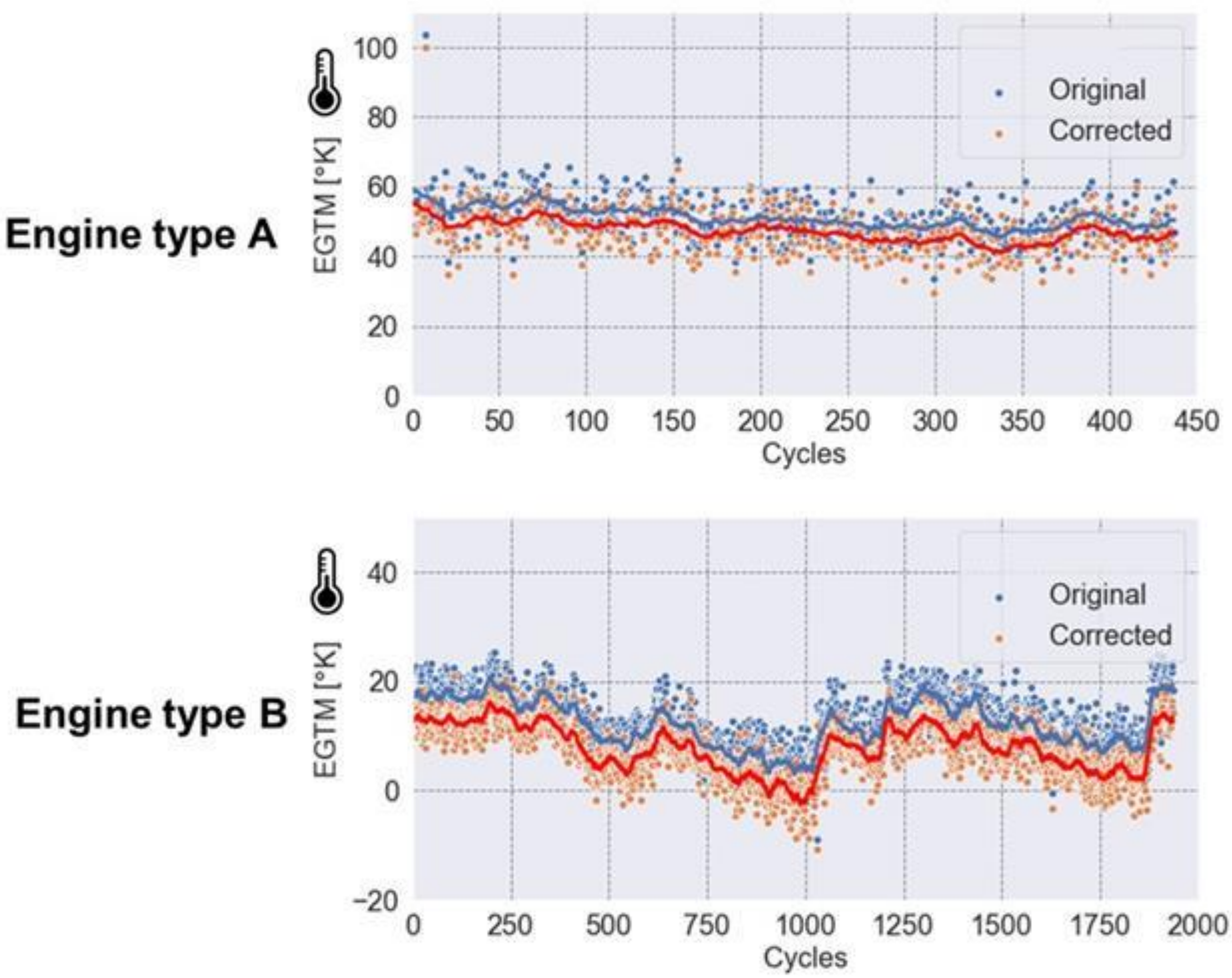
We show that varying humidity can have a noticeable influence on the performance of the engine. These discrepancies cannot be currently quantified by health monitoring systems. Simulation and testbed correlations indicate a decrease of EGT of ≈0.35% per 1wt% of absolute humidity, which varies worldwide between 0 and 3wt%. Consequently, deviations in EGTM can be up to ≈1%, a figure which can be up to 12K for a modern civil turbofan. Simultaneously, thrust is found to diminish by ≈0.65% per 1wt% of absolute humidity. In practice, variations in ambient humidity have the potential to conceal possible deterioration in engine components.

Following, the flight historical data were corresponded to historical humidity data. The two methods were identified to provide comparable results, indicating a higher EGTM for increasing ambient humidity. Next, three correction methods are suggested.

Overall, it was concluded that EGTM corrections for ambient humidity is an area of significant interest, especially for newer engine types where accurate diagnostics are of increasing importance.



Modelling strategy



EGTM Correction

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Historical buildings prevention of failure by technical condition testing and revitalization

Krentowski J[1], Knyziak P[2]
[1]Bialystok University of Technology, [2]Warsaw University of Technology

Introduction:
The paper presents problems related to the operation of historic buildings in terms of their modernization. The stage of renovation, reconstruction or modernization of such facilities should be preceded by detailed research. The most important criterion for correctly implemented modernization is the safety of contractors conducting construction works and future users, as well as the preservation of the historic substance in a stage that best suits its historical form.
Methods
Residential and public utility buildings, e.g., schools, universities, theaters, or industrial facilities in the 18th, 19th and early 20th centuries were most often realized in the so-called traditional way, made of ceramic bricks, based on concrete, stone or ceramic foundations, using brick vaulted ceilings, floors based on steel beams, with a wooden attics and roof truss; cf. Fig. 1.
The different stages of the destruction of structural elements, different design solutions and the materials used in the historic buildings, built and exploited for many years, determine the selection of appropriate research methods. During diagnostic works, the authors investigated the actual state of the historical material, analyzed complex stress states in degraded structural elements, formulated and verified study concepts of protective structures. It was assessed whether the condition of materials and structural elements at the present moment, and also after further destructive processes, could lead to potential failure.
Results
The final effect was the implementation of the developed solutions, which enabled many years of failure-free operation of several facilities.
Historic buildings are a visible testimony to the craftsmanship of architects and builders of the past centuries. However, with the passage of time, the parameters of the buildings in use are significantly degraded. In historic buildings, the identification of damage and determination of the method of repairing defects should be preceded by an analysis of the structure modelling and determination of the actual aggressiveness factors of the external environment.
Due to the unique nature of historic buildings, it is essential to select the appropriate scientific and diagnostic methods, primarily in the field of non-destructive testing, ensuring that the assessed objects remain intact, Fig. 2. During the conservation works, it is necessary to stabilize the propagation of destructive phenomena and protect the structural elements of walls and ceilings against degradation processes.
Discusssion
As a result of an in-depth analysis collected during the research works, the following useful limitations, were formulated:
- the shape of structural elements of historic buildings should be left in their original form;
- during reconstruction of historic buildings, it should be forbidden to treat the existing elements as load-bearing structures, the loads should be transferred by an independent structure;
- the progress of destructive processes should be predicted and assessed;
- the main structural elements of the modernized facility should be subject to constant monitoring.

It should also be remembered that any interference with a historic substance, even the one whose safety has been confirmed by detailed research and calculations, can always create a risk resulting from hidden defects of historical materials or connections between them.

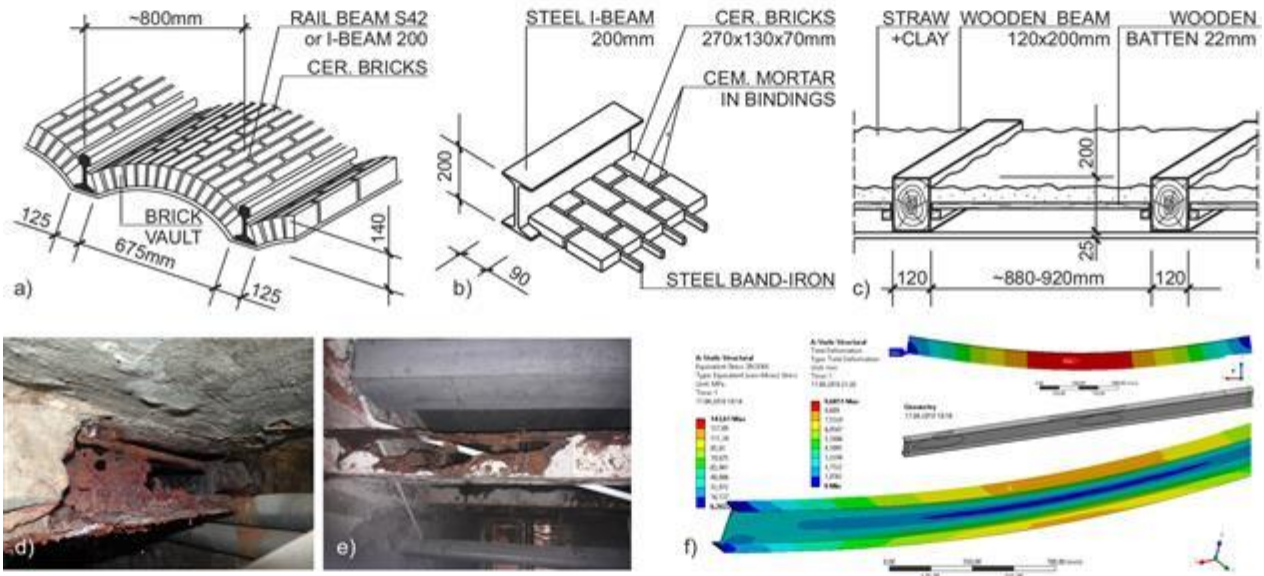

Fig. 1. Typical solutions of historic ceilings, a) brick vault, b) brick slab on steel beams, c) wooden ceiling, d), e) faults of steel beams, f) results of numerical calculation

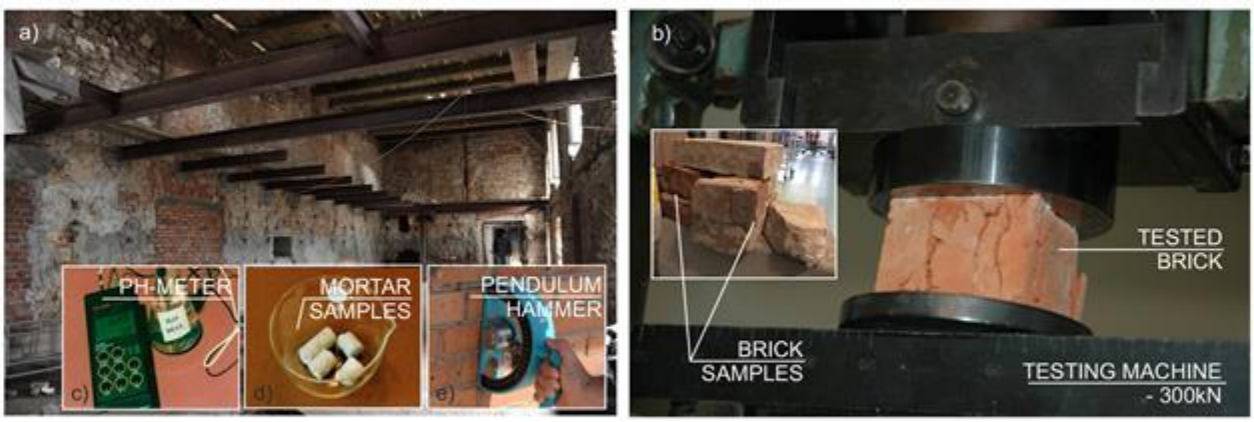

Fig. 2. Masonry structures: a) 18th-century interiors during renovation works, b) destructive masonry strength tests, c) pH level tests, d) mortar samples, e) estimation of the wall structure strength

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Methodology of testing and strengthening endangered roof structures by suspending

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Introduction

Building structures used for several dozen years require constant monitoring and assessment of their current condition. The consequence of the activities carried out is the possible repair or strengthening of elements threatening the safety of users. In extreme cases, it is necessary to make a costly decision to demolish the facility. The decision concerning safe operation of the building must be preceded by detailed tests, calculations and analyses.

Methods

The authors of the study conducted many years of research works on the deformation state of steel, reinforced concrete and prestressed roof structures. The result of the research was the development of the methodology of the implementation of works, different for each type of structure, with the use of non-destructive technology. The authors also proposed the concept of strengthening the existing structures with an additional steel frame located above the existing cover.

The efficacy of the concept presented in the paper was confirmed by an example of the diagnostics of a steel spatial roofing with the dimensions of 30x30 m, used for 50 years, Fig.1. The structure was excessively deformed under the influence of snow load. The layer thickness and snow weight exceeded the values specified in the standards effective at the structure design time. However, the change in climatic conditions, including the so-called global warming, has prompted lawmakers in many countries to increase the limit values for impacts caused by snow. The snow layer identified during the tests corresponded to the current standard conditions.

Results

As a result of the computational analysis, it was confirmed that the elements of the cover structure did not meet the current codes requirements. The occurrence of the phenomenon of plasticization of the cross-sections of both tension and compression bars was confirmed by computational analysis. Experimentally, during the tensile test, permanently deformed bars were identified. A unique concept of repairing a deformed structure by suspending it to a newly designed steel structure located above the existing roof was presented, Fig. 2. The concept has been implemented and the stages of its implementation are described in the paper. During the operation of the strenghtened structure, the deformation state was measured at intervals of several years.

Discussion

The experience gained during the stage of suspending the structure and its safe operation afterwards for more than twenty years prompted the authors to develop a unique concept for strengthening the existing roof coverings.

As a summary of the work, the concept of strengthening the used prestressed girders using the method of suspension to an independent external structure, transferring both the environmental loads transferred to the existing elements of the cover structure, as well as the loads caused by the self-weight of the girders, was presented.

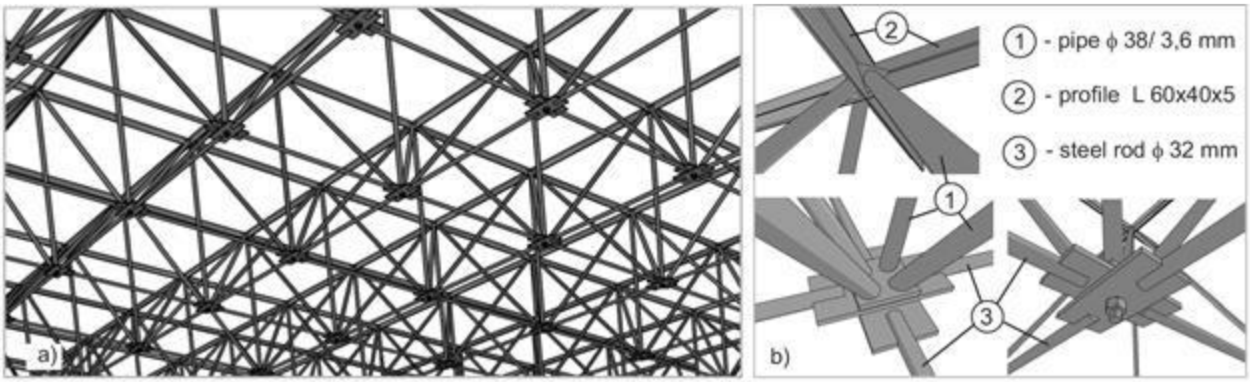

Fig. 1. Structural roof covering: a) layout of the elements, b) connection details

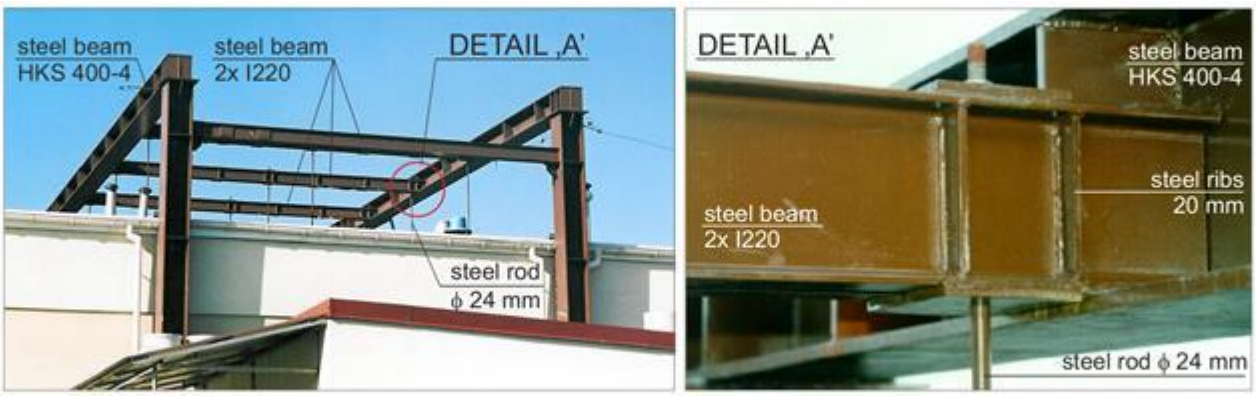

Fig. 2. Reinforcing steel structure: a) view of the steel frame, b) construction details

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Preventing damage to the reinforced concrete cylindrical shells due to temperature load

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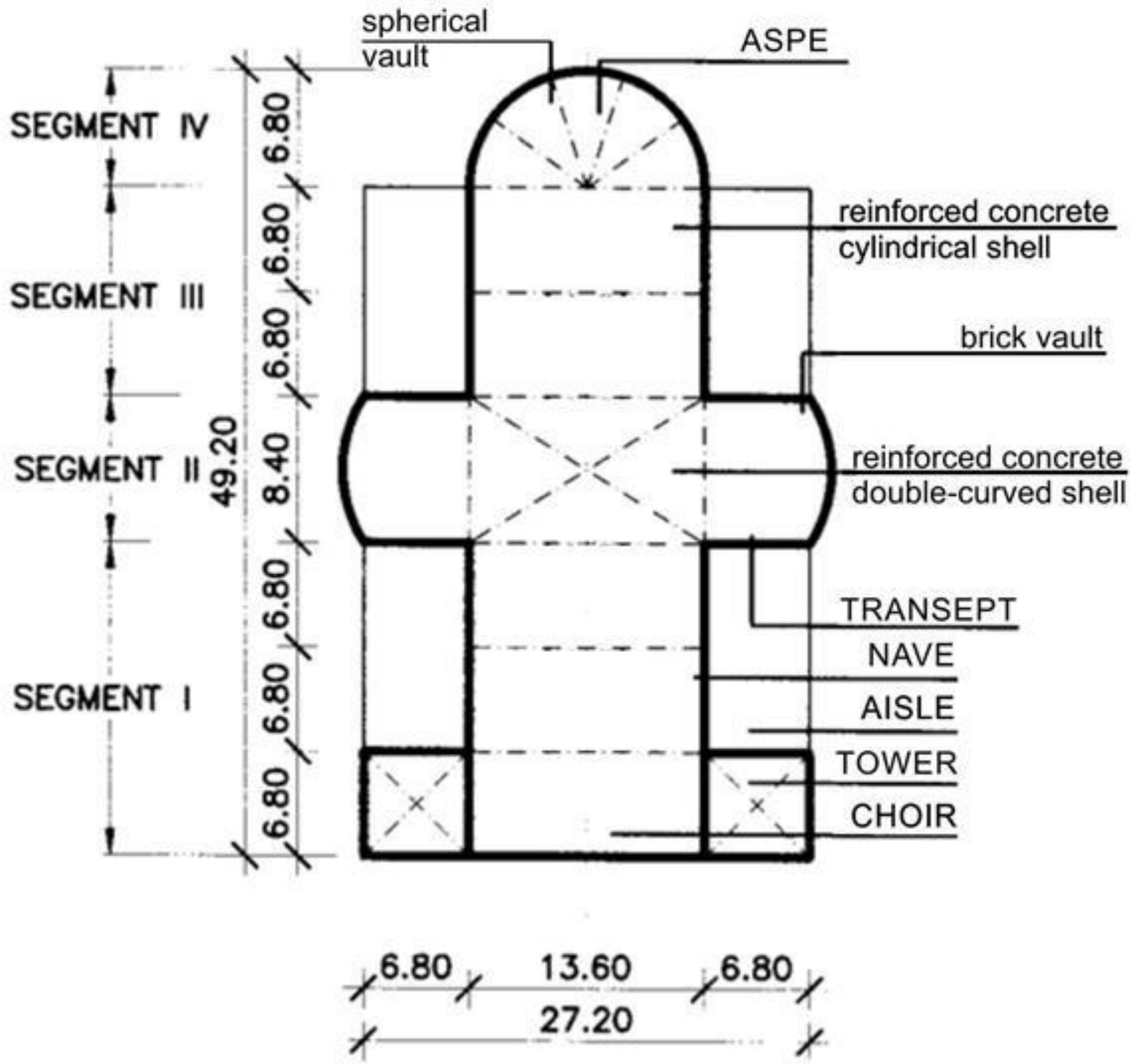
The extended period of buildings covers realization requires taking into account, among others, temperature effects in the calculation process. The paper analyzes the problem of the implementation of covers due to the emergence of additional non-static stresses resulting from variable processes of temperature loading, also taking into account the effect of insolation. The shape and span of the shell structure will be one of the elements determining the achievement of the limit parameters considered acceptable due to stresses and accompanying deformations. For such a technical problem, solutions will be developed that will allow to indicate the directions of action in the event of the need to limit stresses caused by thermal influence. This is important due to the temperature load conditions, when in the summer period, when the building is erected, it is open and exposed to direct sunlight. In turn, the object left for the winter period is exposed to negative temperatures. The variability of impacts during the construction of the structure turns out to be the most critical due to thermal loads. In the final stage, the applied thermal insulation and the execution of outer layers on the covering stabilize the thermal effects at much lower variability values. For this reason, it turns out that this problem is sometimes overlooked by those responsible for the proper course of the investment process, which is sometimes due to limited resources and lack of proper awareness of the impacts associated with these processes. In the aspect of variable values of interactions, code entries will be analyzed based on Eurocodes, which will also be verified by actual measurements of thermal interactions. The final effect will be supported by a practical numerical example showing the elongation values of a reinforced concrete shell with a total length of about 50m, subjected to the action of a variable field of external temperatures, Fig. 1. Possible directions of proceedings limiting the negative effects of thermal effects will be indicated. The paper will end with conclusions resulting from the analyzes of temperature load, indicating that fulfillment only the requirements of the Eurocodes may lead to scratches in structural elements exposed to direct sunlight. Suggestions for the need to apply stricter requirements will also be indicated, which should be applied in the design phase of coating objects implemented in extended investment periods. Methods that can reduce the negative impact of temperature in summer and winter, both in terms of ad hoc measures and when making decisions about design solutions, will also be indicated. Methods that significantly reduce the thermal impact, resulting from the appropriate technology and the appropriate sequence of concrete works, as well as through the use of expansion joints, which enable compensation of the thermal deformations that arise, will also be indicated. Recommendations for construction works will be developed, taking into account the most favorable conditions of temperature differences in the implementation phases. The solutions discussed in the paper prevent or significantly reduce the appearance of scratches, damage or excessive deformation in coating structures thermally loaded.



Shaping the cover due to the temperature load

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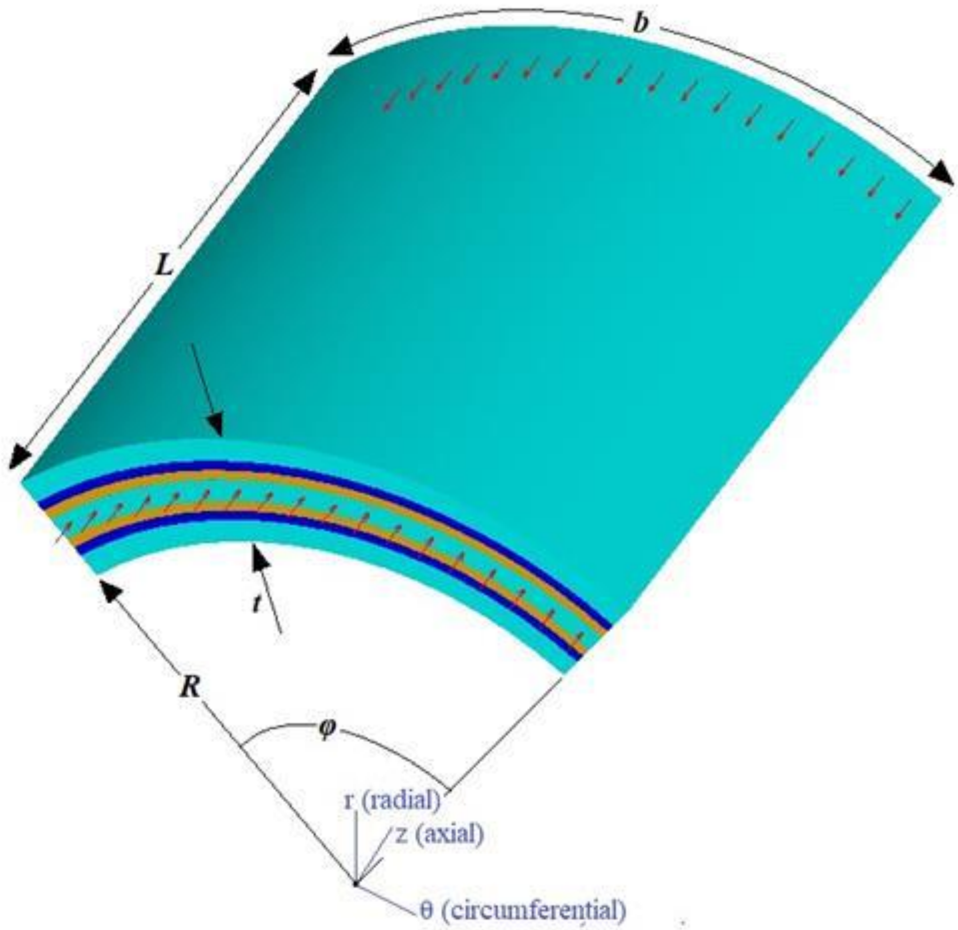
Buckling of simply supported GLARE cylindrical panels subjected to uniform compression

Kalfountzos C[1], Bikakis G[1], Theotokoglou E[1]
[1]*National Technical University Of Athens*

Fiber Metal Laminates (FMLs) are hybrid composite materials built up from thin metal alloy sheets bonded into one laminate with intermediate fibre/epoxy layers. The manufacturing of FMLs has been invented and developed at Delft University of Technology [1]. ARALL (Aramid Reinforced ALuminum Laminate) was the first candidate for aerospace applications, in the late seventies. Later, CARALL (CArbon Reinforced ALuminum Laminate) was investigated, which although it was much stiffer, flight simulation fatigue tests at elevated stress levels resulted in poor fatigue performance due to fiber failure. In 1990, high strength glass fibers were used creating GLARE (GLAss REinforced), which is the most successful FML up to now. GLARE laminates have been selected for many aerospace applications such as the upper fuselage skin material of the Airbus A380 and the cargo floor of Boeing 777 [2].
The elastic buckling of thin panels is a classical problem of the strength of materials with great practical importance and it must always be considered during the design of many engineering applications where stiffened thin-walled structures are employed. For example, the fuselage and wing skin of aerospace structures consist of stringer stiffened curved plates which have the shape of cylindrical panels between stringers. FMLs are mainly used for the construction of stiffened thin-walled fuselage structures and, as a result, the investigation of the buckling strength of FML panels is very important. The present study deals with the elastic buckling of thin FML cylindrical panels subjected to uniaxial compression on their curved edges, as shown in Figure 1. The main objective is the calculation of elastic buckling coefficients of FML panels and the construction of pertinent diagrams of the buckling coefficient versus the curvature parameter of the panels. The classical simply supported boundary conditions [3] are considered for the analyzed FMLs.
The calculation of the elastic buckling load of the panels is carried out using the eigenvalue buckling analysis of ANSYS FEM software [4]. Different material systems are considered: GLARE FMLs, unidirectional composites and monolithic aluminum. The convergence of FEM results is always verified by comparison of results corresponding to fine and very fine mesh density. The FEM results have also been compared with corresponding theoretical results obtained using previously developed analytical models and the FEM procedure is fully validated.
It is found that aluminum has a stronger impact on the buckling behavior of the FML panels than the composite layers. From the constructed buckling coefficient - curvature parameter diagrams in double logarithmic scale it is found that there is an approximately linear relation between the buckling coefficient and the curvature parameter of the panels. Based on this finding, appropriate regressions are implemented in order to derive approximate analytical formulas of the buckling coefficient as a function of the curvature parameter for the considered materials.



Geometry of cylindrical FML panel under uniform axial compression

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Impact of structural uncertainties on the buckling strength of cylindrical GLARE panels subjected to uniform compression

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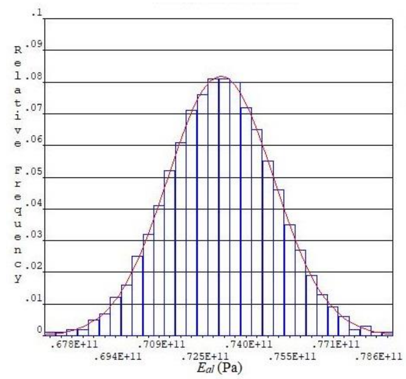
Fiber Metal Laminates (FMLs) are hybrid composite materials, which were originally developed for application in primary aircraft structures. FMLs combine significant advantages of metal and fiber-reinforced composites. Because of the intact bridging fibers, in the wake of the crack, which restrain the crack opening, FMLs demonstrate high fatigue resistance. They also have high fracture toughness which is higher than the fracture toughness of their constituent alloys and excellent impact resistance. Low density, excellent moisture, corrosion and fire resistance are some other significant advantages of FMLs, which make them ideal for multipurpose aerospace applications [1]. GLARE (GLAss REinforced) is the most successful FML, up to now.

The unstiffened cylindrical panels are employed in a large number of structures subjected to high compressive loads which are prone to buckling. Furthermore, the calculation of elastic buckling load of the unstiffened panels is necessary for the consideration of the local buckling modes in the analysis of the, more widely used, stringer-stiffened cylindrical shells [2]. Consequently, since FMLs are mainly used for the construction of thin-walled aerospace structures, the buckling strength of unstiffened FML panels is of great practical importance. There are several factors that affect the strength of a structural component such as its exact dimensions and the material used. However, it is known that the mechanical properties of a considered material vary, because of variations in the raw material and the processes used [3]. Moreover, there is uncontrollable variability in the manufacturing process of the component leading to undesirable deviations of the actual from the nominal dimensions [3]. These factors motivated the principal objective of this study, which is the investigation of the buckling strength of cylindrical simply supported GLARE panels subjected to axial compression using probabilistic analysis methods, so that the effect of uncertainties associated with material properties and dimensions of the panels on their elastic buckling load can be evaluated.

The employed eigenvalue buckling analysis and the probabilistic finite element analysis were carried out with ANSYS software. The Probabilistic Design System (PDS), along with the Monte Carlo Simulation and the Latin Hypercube Sampling method were used for the calculations. The convergence of PDS results is always verified by running a large number of simulation loops in combination with ANSYS convergence check recommendations. Since aluminum governs the elastic buckling response of GLARE panels, the variations of the mechanical properties of aluminum are considered, whereas the mechanical properties of composite layers have their deterministic values. Figure 1 shows the variations of aluminum Young's modulus. Additionally, the dimensions of aluminum and UD glass-epoxy layers are considered to be random input variables as well. The critical buckling load is defined as a random output parameter.

It is found that the thickness of aluminum layers has the strongest effect on the buckling strength, among the considered random input variables. It is also demonstrated that there is a considerable probability for the buckling load of GLARE panels to be overestimated when only the deterministic values of mechanical properties and dimensions are considered.



Histogram (blue color) with values of statistical measures and normal distribution function (red color) of 2024-T3 aluminum Young's modulus (Pa)

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A Novel Polymeric Composite Material for Thermal Shield Applications – Fabrication and Flammability Characterization

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As the use of composite materials by the aeronautical, aerospace and the automotive sectors is being increased, a particular demand has arisen for composite materials of polymeric base that can be used in applications in which the extremely low flammability is a required. Especially, in the avio industry, a structure of this kind should sustain thermal loads for more than 1 minute in order to be certified. In the present work, presented is a novel series of composite materials made up with inorganic resins, designed to serve as thermal shields with high flammability resistance. Furthermore, presented is the way these materials are interacting, their chemical nature and their fabrication. In addition, a burn-test is conducted for a period of 15 minutes for qualifying the composite plate as inflammable for aeronautical use.

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Monitoring of large-panel residential buildings elevations for prevention of failure

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[1]Warsaw University of Technology, [2]Poznan University of Technology, [3]Bialystok University of Technology

Introduction:
In all European countries, thousands of residential buildings, prefabricated large-panel reinforced concrete structure were made. Many of them have been in use for about 40-50 years. When analyzing the condition of buildings in terms of their service life, it is necessary to determine the manner of their further use to ensure proper durability and prevent future failures.
External elements of building elevations are particularly exposed to destructive processes. In their case, the technical condition monitoring and conducting NDT tests are necessary. It is also necessary to modernize them, because the requirements have been changed eg. regarding thermal insulation.
Methods
Long-term visual observations supported by NDT studies were carried out in three cities with a population of over several hundred thousand, located in a medium-sized country in Central Europe. Specialized research equipment was used, such as ultrasonic or electromagnetic condition analyzers of concrete, or the number and arrangement of reinforcing bars. The technical condition of over 100 buildings and their elevations elements was assessed.
The course of renovation and modernization works was also monitored. The obtained results were compared with the examples and conclusions published in specialist and scientific publications.
Results
The tested large-panel buildings were made on the basis of solutions in force at the time of their design. When comparing the quality of the elements with the current requirements, in many cases it should be concluded that the elements used at that time are inconsistent with the current regulations and standards. From the point of view of the durability of the structure of large-panel buildings, the potential weak points were the joints connecting individual precast elements. The most sensitive to corrosion are always the connections in the partitions that are in contact with the external environment.
Currently, the main operational problems of large-panel buildings often result from the initial insufficient quality of materials and elements made of them, incorrect technical solutions, and assembly accuracy.
External walls, flat roofs, balconies, loggias, vestibules and roofs over the entrances to buildings are directly exposed to the intensely destructive influence of the environment: moisture, temperature and air pollutants - dust and gases.
Discusssion
Replacing the elevation panels and other external elements of the elevation is technically possible, but for economic and environmental reasons (large amounts of waste) it is not a correct solution, or at least it should not be considered as a solution for general use. It seems reasonable to use such renovation and modernization solutions as possible, which will isolate the external elements from the surrounding destructive environment. In practice, it was possible to achieve this in many buildings where, as part of the modernization, additional layers of thermal insulation cladding were installed, and the anti-moisture insulation of external elements was replaced. The external elements, i.e. balconies, loggias and vestibules, most often have not been insulated and are subject to the influence of an aggressive external environment during operation.
The condition of the elevation panels and other external elements must be monitored and reacted to any signs of wear.

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Characterization of single-lip deep drilled samples by means of in-situ eddy-current measurements

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To improve the performance of highly loaded deep-drilled parts, e.g. valves of plunger pumps (Figure 1 a) or common rails of injection systems, an optimization of the machining strategy is an economically meaningful opportunity, beside changes in the choice of materials and complementary processing steps like autofrettage, deep rolling or shot peening. Previous studies showed that single-lip deep hole drilling is capable of inducing an advantageous surface microstructure, residual stress and work hardening condition (Baak et al. 2018). This work shows the capability of eddy current measurements as a tool for the monitoring of the drilling process and subsequent the structural health monitoring during fatigue life of the parts.

For this purpose, specimens were drilled by varying cutting parameters, resulting in differing microstructures and work hardening states in the bores surface and subsurface region. In the first place the specimens were characterized by a custom-made eddy current sensor (Figure 1 b). The sensor can be placed inside the bore to detect changes in the electromagnetical properties at the crucial inner surface. Figure 2 shows the separation regarding the cutting speed. It can be seen that the investigated drilling parameter can be separated by the real and imaginary part of the eddy-current signal, whereas the phase angle remains constant. The findings were correlated to destructive testing methods like hardness measurements and microstructural investigations. Subsequently instrumented fatigue tests were performed. On the one hand well established techniques like strain and temperature measurements were implemented in the test setup, on the other hand the tailored eddy current sensor remains in the bore to detect in-situ the electromagnetic changes induced by the degradation process.

References

Baak, N.; Schaldach, F.; Nickel, J.; Biermann, D.; Walther, F. (2018): Barkhausen noise assessment of the surface conditions due to deep hole drilling and their influence on the fatigue behaviour of AISI 4140. In: Metals 8 (9), S. 720. DOI: 10.3390/met8090720.

Acknowledgment

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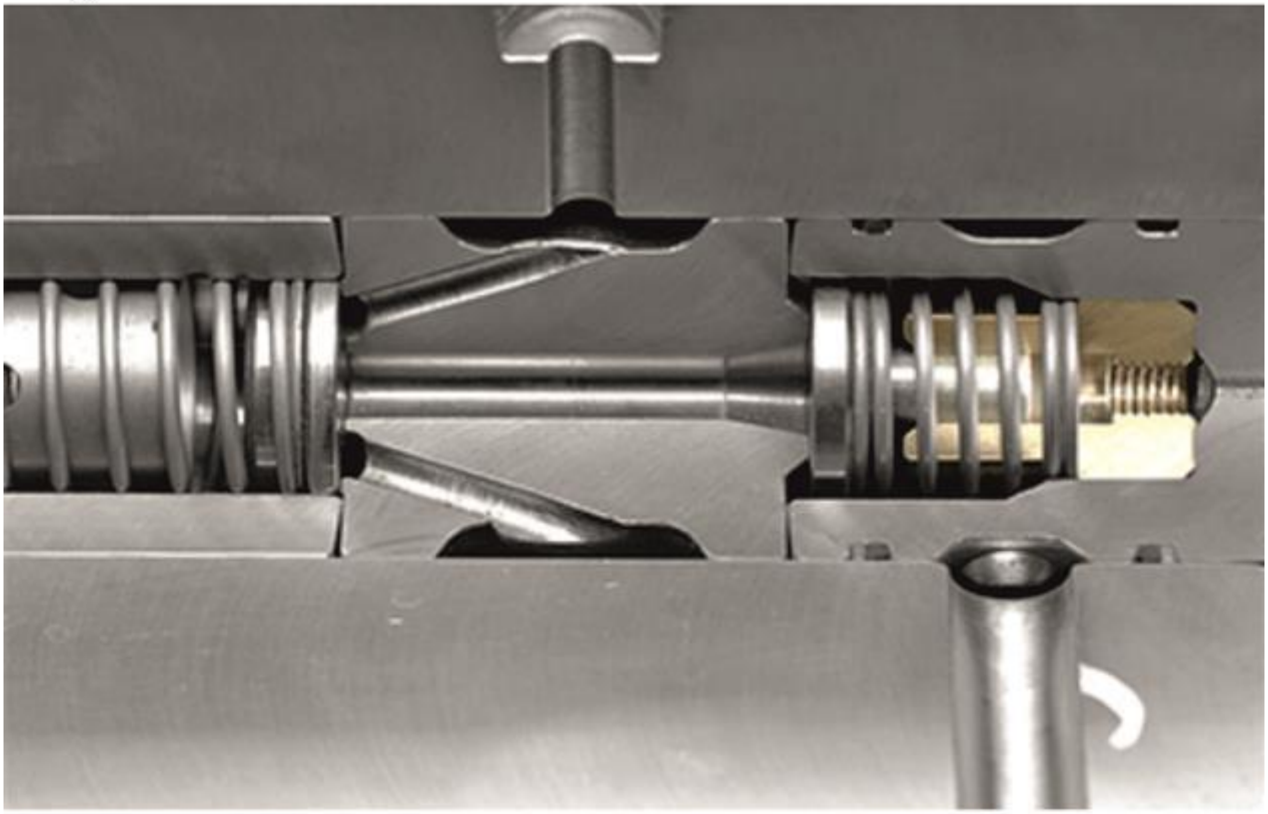
a)



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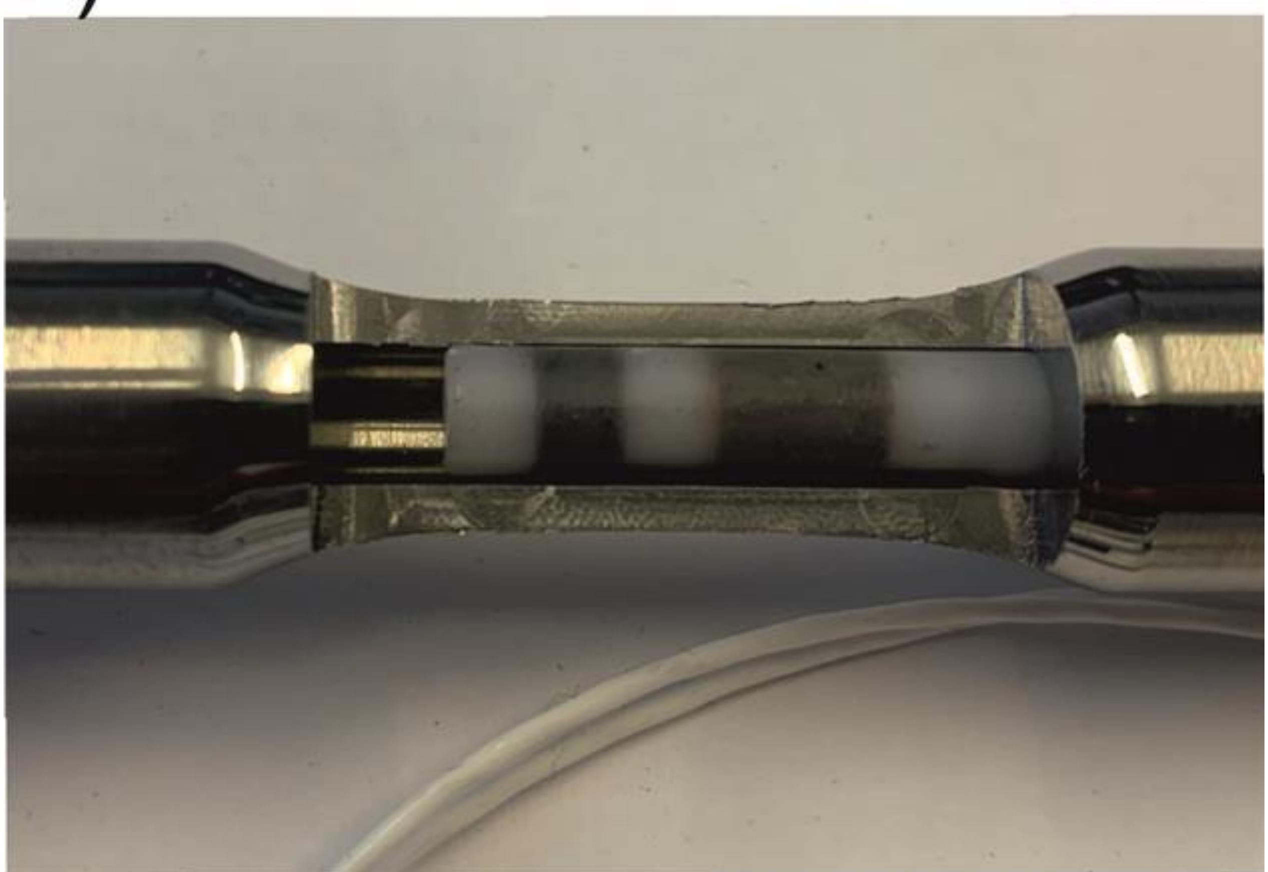
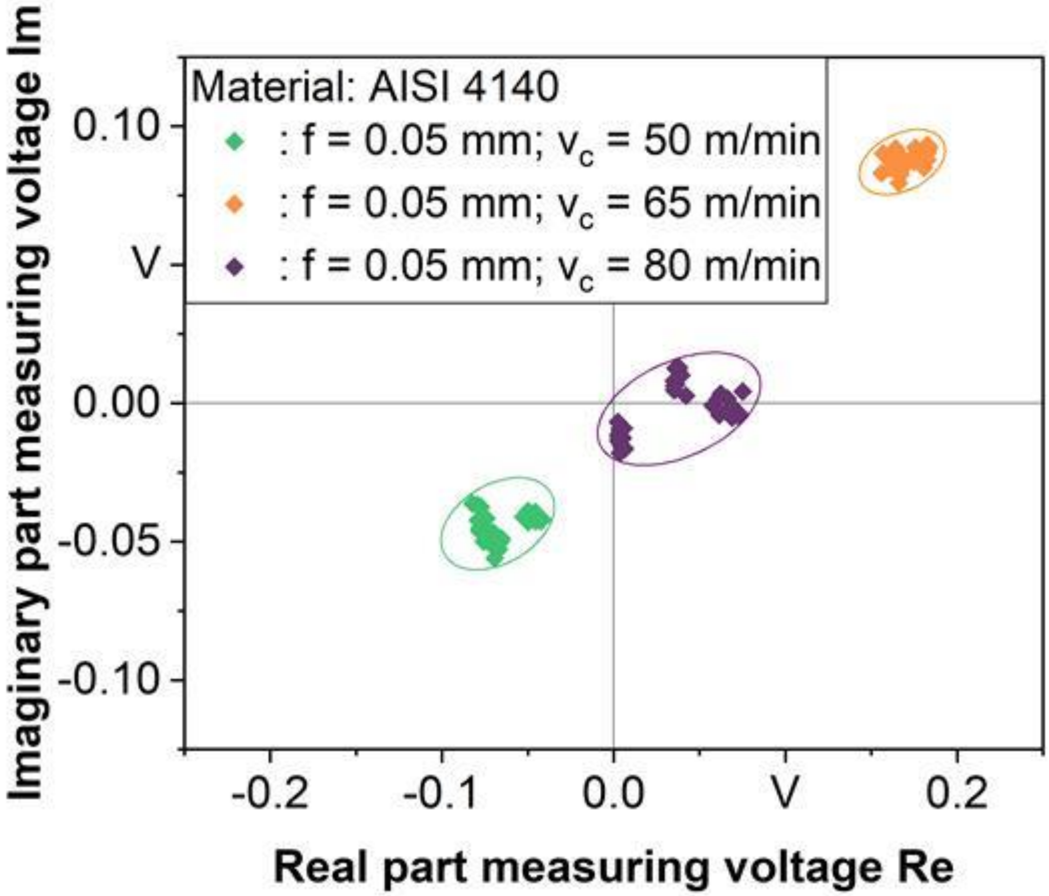


a) Valve of high-pressure plunger pump (KAMAT GmbH, Witten Germany);
b) Customized inner-surface eddy-current sensor;



Imaginary and real parts of the measuring voltage for specimen drilled by varying feed rates.

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Disproportionately wide range of fire in a RC building during construction stage

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Introduction:
Opposite to timber and steel structures, which are usually completely destroyed in a fire, reinforced concrete structures are characterized by good fire resistance. They usually might be damaged by fire but are rarely completely destroyed.
In recent years, in developed countries, the level of the required fire protection for structures has increased. However, in a temporary situation during construction, fire protection is often not sufficient. The requirements in this respect have not yet been included in the regulations and the problem of fire resistance of the structure during construction is not taken into account during designing.
Methods
The article analyzes the effects of a fire that occurred in a small room of an electrical switchboard in the underground garage of a multi-storey residential building. The building was in the final stage of construction, but many of the "passages" of the installation through the walls and ceilings were not yet fire-protected, ie. the fire integrity requirement was not met. It results that a spread of fire was much larger than could be expected.
The research carried out in order to assess the condition of the structure after the fire were presented, in particular the selection of members that: (1) had to be dismantled, (2) required significant strengthening or repair, (3) could be used after only minor cleaning works. Due to the short time to carry out the assessment, it was mainly based on non destructive tests (NDT) results.
Results
The conclusions from the conducted assessment and analyzes were presented. A small and seemingly easy to control fire, which started in the underground garage, spread up to 12 storeys above ground level. The fire was difficult to control due to incomplete works in the field of securing installation passages through the partitions. These works were to be carried out in the final stage of the construction of the building, while the electrical installation was already in use.
Damage to reinforced concrete members had an unexpectedly large extent due to thermal spalling of the concrete. Significant intensification of this phenomenon was caused by the high moisture content in "young" concrete (short drying time from casting the members) and the close location of the burning electrical wires in relation to the structural members. The possibilities of estimating, but still sufficiently reliable, assessment of damage to members using NDT was pointed out.
Discussion
Buildings under construction are in a condition that does not meet the requirements regarding protection against fire spread. Much more intense spread of fire is possible in buildings during the construction stage, when the passages through the partitions are not yet secured and the electrical installations are already in use. The fire resistance of reinforced concrete members soon after construction is lower than the target one, due to the greater susceptibility of "young" concrete (with higher moisture content) to the phenomenon of thermal spalling. The fire in the electrical installation may locally damage the structure to the extent that it is necessary to replace/strengthening structural members, e.g. ceilings.

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Thermo-fluidynamic analysis of composite metallic coating on metal foam.

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Metal foams are a rather recent material, featuring interesting characteristic for the aeronautical and automotive fields because of their low specifics weight, high thermal properties and mechanical performance. In particular, this paper deals with thermal and fluid dynamics study of open cell metal foams produced by indirect additive manufacturing. A study of foams behaviour as a function of the morphological (pores per inch (PPI), line width (r) and morphology), features was performed. Also, the influence of a composite coating composed of copper and graphene was analysed.
The samples produced were tested in an open circuit wind gallery to measure the fluid dynamic properties (pressure drop, inertial coefficient and permeability), in an air forced convection flow. The thermal characterization was performed evaluating the heat transfer coefficient (HTC) with different air flow rates. The paper shows how the morphology and a composite coating affect the metal foam thermo-fluid dynamical behaviour.

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A Machine Learning Based Approach for Fast Impact Damage Analysis

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1. Introduction

Several approaches for high fidelity impact simulations have been developed in the last years to accurately predict the damage in fibre reinforced composites under low velocity impact loading. The underlying goal is to determine the residual strength in compression after impact (CAI) tests to design damage tolerant structures. However, with increasing accuracy of the simulation models the modelling effort and computation time also increase. This work proposes a data-based methodology to obtain equivalent results compared to time consuming finite element simulations by means of machine learning (ml). After training a ml-algorithm once, it has generalised the relation between the simulation results of fast computing macroscopic models and detailed mesoscopic models. The schematic approach is illustrated in figure 1. As a result, the algorithm can prognose interlaminar damage within a few seconds.

2. Methodology

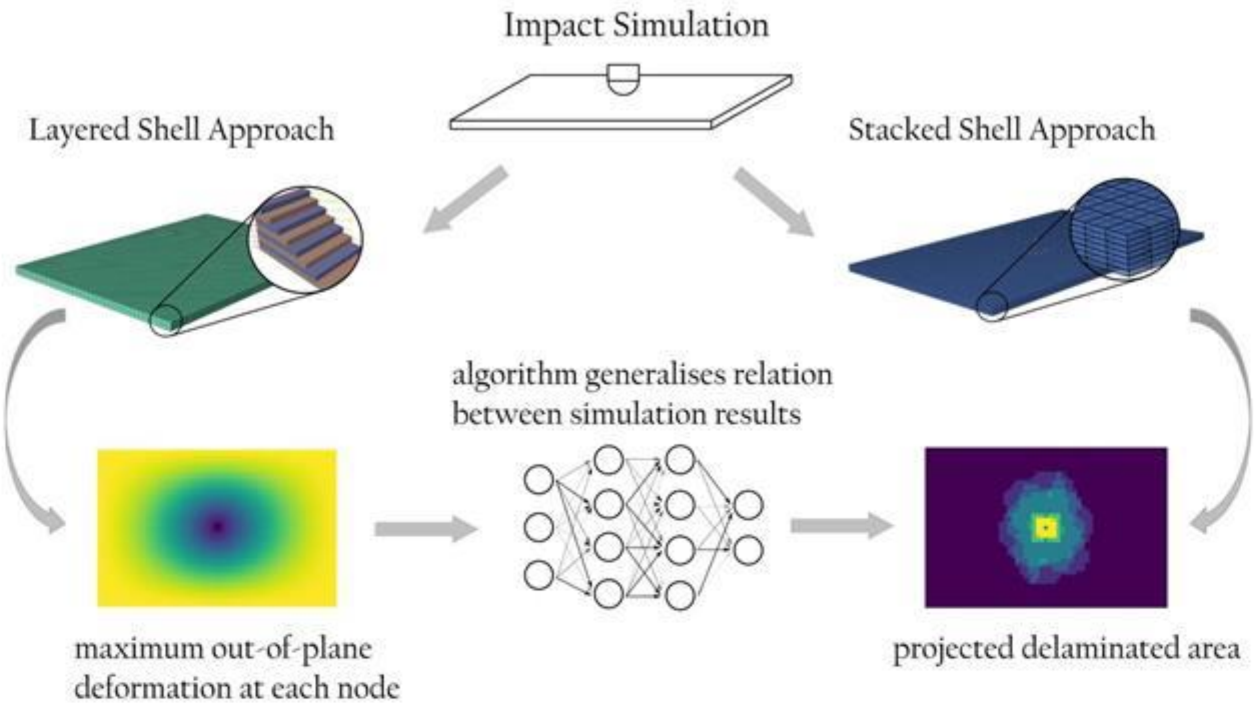
A multiple input convolutional neural network (MI-CNN) is trained on a labelled dataset to predict delamination of high-fidelity impact simulations. Each data point in the labelled dataset consists of simulation results from corresponding impact simulations. The laminate of these models is built using a layered shell approach (LSA) and stacked shell approach (SSA). While the simulation results of the LSA serve as input values for the algorithm, interlaminar damages from the SSA simulations are the target values. Different parameters like the fibre angle or impact energy are varied for each data point to generate the dataset. During training on the dataset, the algorithm generalises the relation between the input data which is the laminate deformation and its stacking sequence and the interlaminar damage as output data. Thus, the input for the MI-CNN consists of two data types, namely a matrix containing the maximum out-of-plane deformation of each node during the impact and an additional vector describing the fibre direction of the laminate. The output of the MI-CNN is an image in which each pixel represents a finite element labelled as “damaged” or “undamaged”.

3. Simulation method for dataset generation

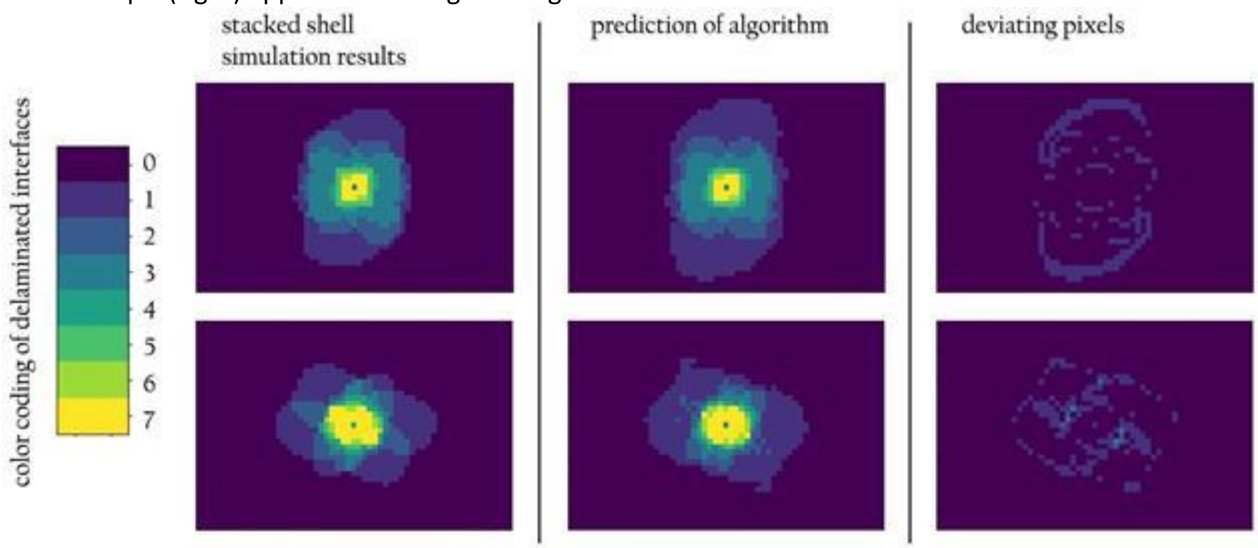
The impact simulations are performed using Abaqus/Explicit. In order to decrease computational effort, a coarse mesh is used in all simulations to reduce the degrees of freedom. This allows the generation of the dataset in an acceptable time. In the LSA simulations, the laminate is modelled by continuum shell elements with reduced integration (SCR8). The SSA model uses conventional shell elements (S4) for each ply and cohesive zone elements (COH3D) between the plies to model delamination.

4. Analysis of predictions

Different approaches are presented to analyse the accuracy of the trained algorithm on new datasets. The errors of these predictions are evaluated in terms of size and shape of the interlaminar damage. Figure 2 illustrates a predicted projected delaminated area and the corresponding simulation result. The results show a good correlation between the predictions of the MI-CNN and the SSA simulation results. Considering the computational time of the ml-approach, a significant reduction of over 50% is achieved compared to classical SSA simulations.



Schematic approach of the proposed method; an impact simulation is modelled by a macroscopic (left) and a mesoscopic (right) approach. The algorithm generalises the relation between the simulation results.



The projected delaminated area of two different stacked shell simulations (left), are compared to the predictions of the algorithm (middle). The deviations are visualized in the right column.

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Alumina-Forming Austenitic (AFA) steels and aluminium-based coating on 15-15 Ti steel to limit mechanical damage in presence of liquid lead-bismuth eutectic and liquid lead.

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The corrosion resistance and the mechanical behaviour assessment of structural alloys (steels) is crucial for the durability and the safety of the lead cooled Fast Reactor (LFR) and accelerated driven systems (ADS). Moreover, it is well-known that the presence of a liquid metal may compromise the performances of a metallic alloy due to liquid metal corrosion or liquid metal assisted mechanical damage, in particular liquid metal embrittlement (LME). Though tough and ductile metallic alloys are selected, they may become brittle when stressed in liquid metal exhibiting thus LME.

To avoid LME sensitivity and to increase corrosion resistance of some steels in contact with lead or LBE, different materials were selected, developed and then tested in contact with Pb or LBE. One of the solutions is the presence of aluminium at the surface of the materials in order to allow the formation of an oxide layer, permanently and whatever the content of oxygen present in the liquid metal. This oxide layer (alumina) aims at avoiding the contact between the steel and the liquid metal, limiting all steel / liquid metal interactions and therefore reducing the corrosion phenomena, in particular dissolution or selected dissolution of one element of the metallic alloy. Furthermore, the wetting of the steel by the liquid metal is one of the conditions of the occurrence of LME. Thus, the presence of alumina on the surface of the steel should limit the sensitivity to LME.

The results presented in this communication concern two types of materials: 2 Alumina-Forming Austenitic (AFA) steels and the 15-15 Ti steel coated by aluminium-based material. For the considered steels (for the 15-15Ti steel: with and without coating – for the AFA steels : according to an aging at 650°C for 1000 to 5000 hours), the influence of the presence of the liquid metal was investigated by performing monotonic tests (Small Punch Tests and tensile tests) in air and in liquid LBE or/and liquid lead. After tests, cracking and fracture surfaces were analysed by SEM (scanning electron microscopy), EDX-SEM (energy dispersive X-ray) to characterize and understand the effect of the liquid metal. The effect of the presence of liquid metal (Pb or LBE) will be discussed according to the microstructure of the steels as well as to the strain rate and the temperature (between 350°C and 500°C). The contribution of the presence of the alumina layer to limit the damage in presence of the liquid metal is discussed.

The results presented in this paper is a part of the contribution obtained in our lab, for the GEMMA (Generation IV Materials Maturity) H2020 program.

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Effect of the small punch test sample geometry on the liquid metal embrittlement of Cu-30 %Zn by the eutectic Ga-In

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The liquid metal embrittlement (LME) consists of a loss in ductility in metals and alloys when they suffer plastic deformation while in contact with a liquid metal. The apparition of this phenomenon depends, among other factors, on the physicochemical characteristics of the metals involved and on the conditions of the mechanical solicitation. In this sense, stress concentrations, which change the fracture behavior of the tested sample, can change the apparition of LME. The Small Punch Test (SPT) has been used to study LME on different solid/liquid couples. Furthermore, different specimen geometries have been developed to promote different stress concentrations, however, these specimen geometries have not been used to study LME.
In this study, three different sample geometries of Cu-30 %Zn were studied. SPT was done both in air and in contact with the liquid eutectic Ga-In (eGaIn) at room temperature. The fractures of the tested samples were observed by SEM to identify if they were either ductile or brittle. The stress during the test were calculated and compared by a finite element analysis (FEA) using the ABAQUS software.
We observed brittle fractures, which indicate LME, in the samples with a longitudinal notch tested at a displacement speed of 5 mm/min. However, we did not observe this behavior at slower displacement speeds nor in the other specimen geometries. Indeed the samples that not presented LME in contact with eGaIn did not present differences when comparing with those tested in air, i.e. they have similar load-displacement curves, similar fracture surface, and cracking. However, the samples that did present LME had changes mostly on the fracture behavior, since the load-displacement curves presented differences only at the end of the curve. Furthermore, the SEM observations showed that the samples that presented LME had a ductile fracture before the brittle fracture. Finally, we correlate our experimental results with different stress distributions calculated with the FEA.

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On the Phenomenon of Impact

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Aerostructures such as plates are commonly used in aircraft structures due to their advantageous weight to stiffness ratio. Plates are susceptible to lateral forces that occur during impact. Such impact events are caused by falling tools, bird strikes, collisions of objects, and more. Several researchers have studied impact events, but not yet the behavior of the plate and impactor shortly after impact due to various factors.
In this paper, Karas' semi-analytical approach is used to calculate and analyze an impact. Karas derived this approach to calculate an impact for a simply supported plate that is impacted in the center. Here, this approach is extended to calculate the impact event at any location on the plate. The linear semi-analytical approach is written in a Python routine to obtain fast results. In a code-to-code analysis, this Python code is verified with a commercial FE solver.
Various parameters are varied and investigated to analyze and describe the impact phenomenon. In addition to the influence of the initial velocity of the impactor, the mass ratio of the two bodies and the impact location are also investigated. The analysis shows that the impact behavior of contact force and maximum displacement varies as a function of impact location, while all other parameters are held constant. Depending on the impact location, the contact force between impactor and plate can be nine times higher than the lowest value.

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Discussion of hardening effects on phase field models of fracture

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Phase field models have been successfully applied in recent years to a variety of fracture mechanics problems, such as quasi-brittle materials, dynamic fracture mechanics, fatigue cracks in brittle materials, as well as ductile materials. The basic idea of the method is to introduce an additional term in the energy functional to describe the state of material bodies. This term contains a new variable, the so-called phase field, and makes it possible to calculate the surface energy of the crack. This approach allows to model phenomena such as crack initiation, crack branching and buckling of cracks, as well as the modelling of the crack front in three-dimensional geometries, without further assumptions.

The numerical implementation of the phase field method is based on the introduction of an additional degree of freedom for the phase field variable and is carried out within the framework of the finite element method either with a monolithic approach or with the help of a "staggered" strategy. The latter particularly favours the numerical implementation in the case of incremental plasticity, since the boundary value problems for the displacement and for the phase field are solved decoupled from each other. The required time integration for the classical displacement problem is based on the elastic predictor and plastic corrector method for elastoplasticity.

It must be noted that an investigation of the influence of strain hardening within the phase field method on crack development has not yet been carried out. However, it is reasonable to expect that this will be significant. The aim of this paper is to investigate this influence. The hardening mechanisms considered here are kinematic and isotropic hardening.

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Numerical and experimental study for AM50 magnesium alloy under dynamic loads

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AM50 alloy is used in the automotive industry, in the passive safety sector. This paper highlights the behaviour under impact tests for the AM50 magnesium alloy. Both a numerical simulation method with FEM (Finite Element Method) with explicit integration, and a Charpy impact test method, is used. The Charpy impact test method is a standardized test, which is performed at high speed, which highlights the energy absorbed by a specimen during breakage. The specimens, were tested with a hammer: CEAST 9050 Pendulum Impact System. The LS-Dyna solver, under the Ansys Workbench interface, was used to numerically model the Charpy impact test. Four types of specimens were simulated numerically, and the one without concentrator was used to calibrate the material model, from the results of physical tests.
The results of the numerical simulations are in good agreement with the experimental tests, thus giving the possibility to extend the virtual testing to engineering applications in real life.

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Advanced Scanning Transmission Electron Microscopy investigations of FeCoNi(AlMn)x high-entropy alloy: nanoscale structure and impact on magnetic properties

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High-entropy alloys (HEAs) are a new class of materials exhibiting a superior combination of magnetic, mechanical and electrical properties. FeNiCoAlMn is a promising candidate for a soft magnet, important for applications in electrical systems such as power generation, electromagnets and transmission. However, the high entropy effect is partially true, since other thermodynamic properties can also play a role in phase stability, making the alloys vulnerable to phase separation that could affect their magnetic behavior. Here, we report on the first nanoscale investigation of FeNiCo(AlMn)x processed by Laser Metal Deposition, by applying (Scanning) Transmission Electron Microscopy ((S)TEM) combined with Energy-Dispersive X-ray spectroscopy (EDX) and Electron Energy-Loss Spectroscopy (EELS). Experiments were performed on an FEI Titan G2 60-300 kV equipped with a CEOS DCOR probe-corrector, monochromator and Super-X EDX detectors.
A gradual change of the FCC phase towards BCC by increasing x was observed. A thorough analysis employing STEM-EELS revealed a more complicated structural picture on the nanoscale. A coexistence of Full-Heusler L21 and B2 ordered structures was detected in the BCC phase, and ordered nano-percipitates were detected in the FCC phase. Low-loss EELS revealed a plasmon-peak splitting in FCC indicative of two valence electron densities. This finding in combination with intense Moiré fringes and high-defect density indicate that FCC exhibits intense phase separation tendency. However, ordering and phase separation trends did not have a severe impact on the magnetic behavior of the alloy. All samples exhibited good soft-magnetic behavior since they were easily magnetized to the saturated state with coercivity values of <1000 A/m. This finding indicates that the magnetic properties of ordered B2 or Heusler alloys with similar compositions to HEAs, are more associated with the specific chemical environment of the segregated atoms. Finally, in-situ experiments in STEM revealed that ordering is suppressed with increasing temperature.

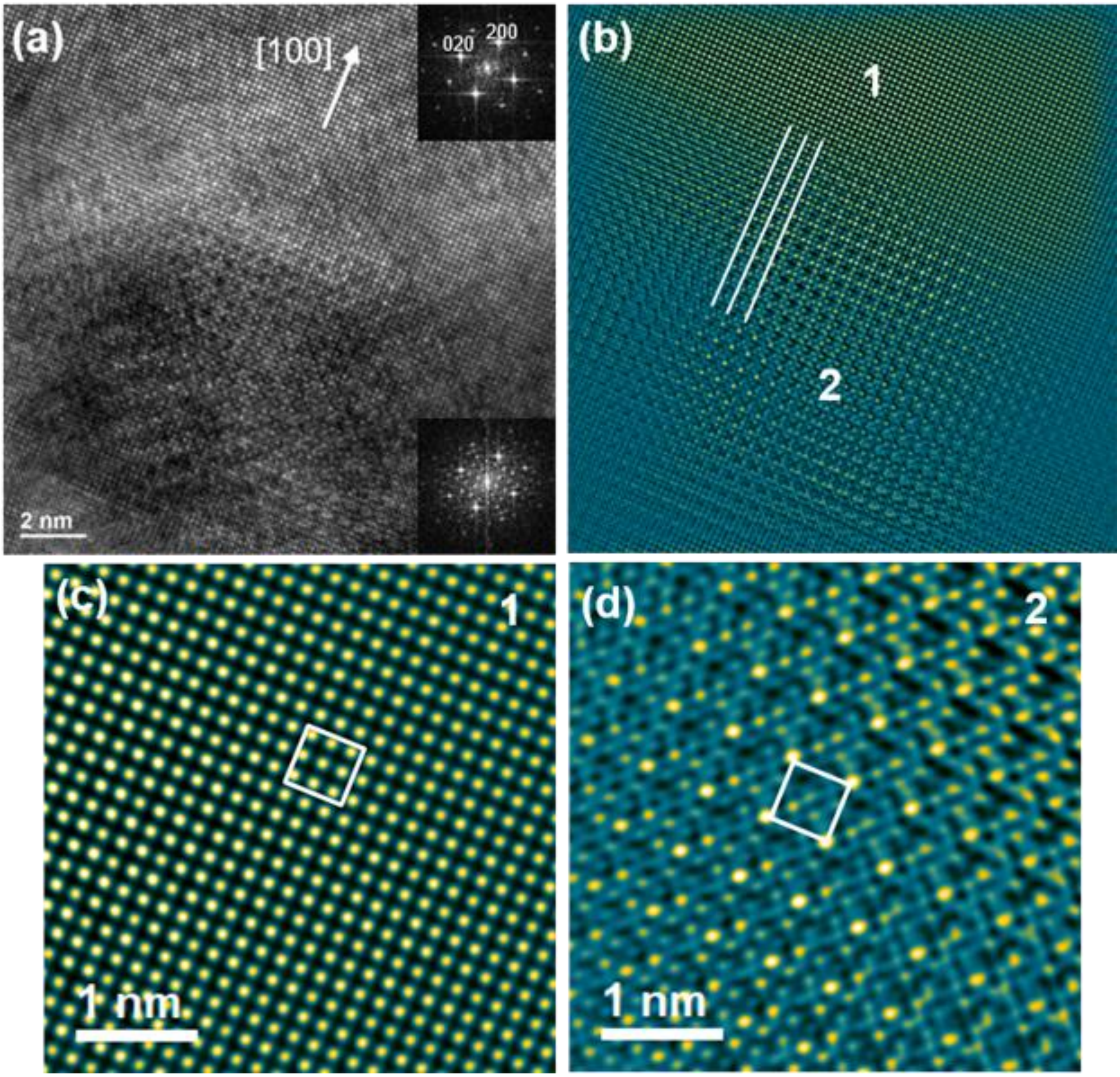

Figure 1. (a) High-resolution TEM image with the corresponding FFTs, showing nano-scale ordering. (b) Corresponding IFFT image and (c) and (d) close-ups of the FCC and the ordered region respectively.

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Reliability Design of Mechanical Systems Subject to Repetitive Stresses

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The basic reliability concepts - parametric ALT plan, failure mechanism and design, acceleration factor, and sample size equation were used in the development of a parametric accelerated life testing method to assess the reliability quantitative test specifications (RQ) of mechanical systems subjected to repetitive stresses. To calculate the acceleration factor of the mechanical system, a generalized life-stress failure model with a new effort concept was derived and recommended. The new sample size equation with the acceleration factor also enabled the parametric ALT to quickly evaluate the expected lifetime. This new parametric ALT should help an engineer uncover the design parameters affecting reliability during the design process of the mechanical system. Consequently, it should help companies improve product reliability and avoid recalls due to the product failures in the field. As the improper design parameters in the design phase are experimentally identified by this new reliability design method, the mechanical system should improve in reliability as measured by the increase in lifetime, LB, and the reduction in failure rate,λ

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Crack propagation in metal-ceramic and metal-metal nanolaminates

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Nanoscale multilayers or nanolaminates are nanostructured materials made up by alternating layers of two or more materials with a layer thickness below ~100 nm. These nanolaminates present very high strengths at ambient temperature. Their unique properties, typically measured by nanoindentation and/or micropillar compression are mainly a result of the high density of interfaces, which change the standard mechanisms of deformation when the layer thicknesses are below ~100 nm. The combination of dissimilar materials together with the small dimensions of the layers are also expected to significantly affect the fracture behavior. However, fracture properties have not been studied in detail so far, mainly due to the lack of appropriate testing techniques to determine fracture toughness at small scales. With the current development of novel nanomechanical testing techniques, it is now possible to test these materials under tension and/or bending, and to determine the fracture behavior of these heterogenous materials Examples will be shown in three different nanoscale multilayer systems, combining metallic and ceramic layers: Cu/Nb and Al/SiC.

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Consequences of excessive deformation of structural elements in large-panel buildings

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Introduction

Large-panel buildings have been a typical solution that has been widely used in European countries. Defects of structural connections or layer connections in panels of facades were repeatedly subjected to research. A neglected aspect of the large-panel buildings operation are the consequences of excessive deformations of structural elements progressing over time. In addition to an aesthetic effects, cracks result in falling of wall fragments, which is a significant threat to the health of room users.

Methods

Damaged wall structures, as well as the method of connecting partition walls elements, were tested. The extent of damage, identified visually or as a result of destructive testing, usually took into account the structure of all internal partitions in the rooms.

Results

Identified damage appeared after approximately thirty years of use. As a result of tests in several buildings, it was found that deflection of precast floor slabs with a span of 5.40-6.00 m during many years of operation achieve about 20 mm. The conclusions resulting from testing the zones of wall support directly on floor slabs or floor layers were also significant.
As a result of vibrations transmitted to the foundations of buildings through the subsoil, the strength of gypsum masonry elements was exceeded locally, which caused their violent cracking, combined with high-intensity acoustic effects. In the case of a building on other housing estate, the failure in an incorrectly made corner of precast partition walls was determined by the increase in service loads and progressive rheological changes.

Discussion

Rigid wall panels remained only supported at the edges in structural wall zones. Masonry partition walls can be treated as shear elements. The safety of building users is determined not only by the fulfillment of the conditions of limit states by basic structural elements. Emergencies can also be generated as a result of defects in partition walls.

Partition walls - damages (scratches) and restoration.

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Damage mechanisms appearing in a cross-ply composite material under uniaxial tension: a mutliscale simulation study

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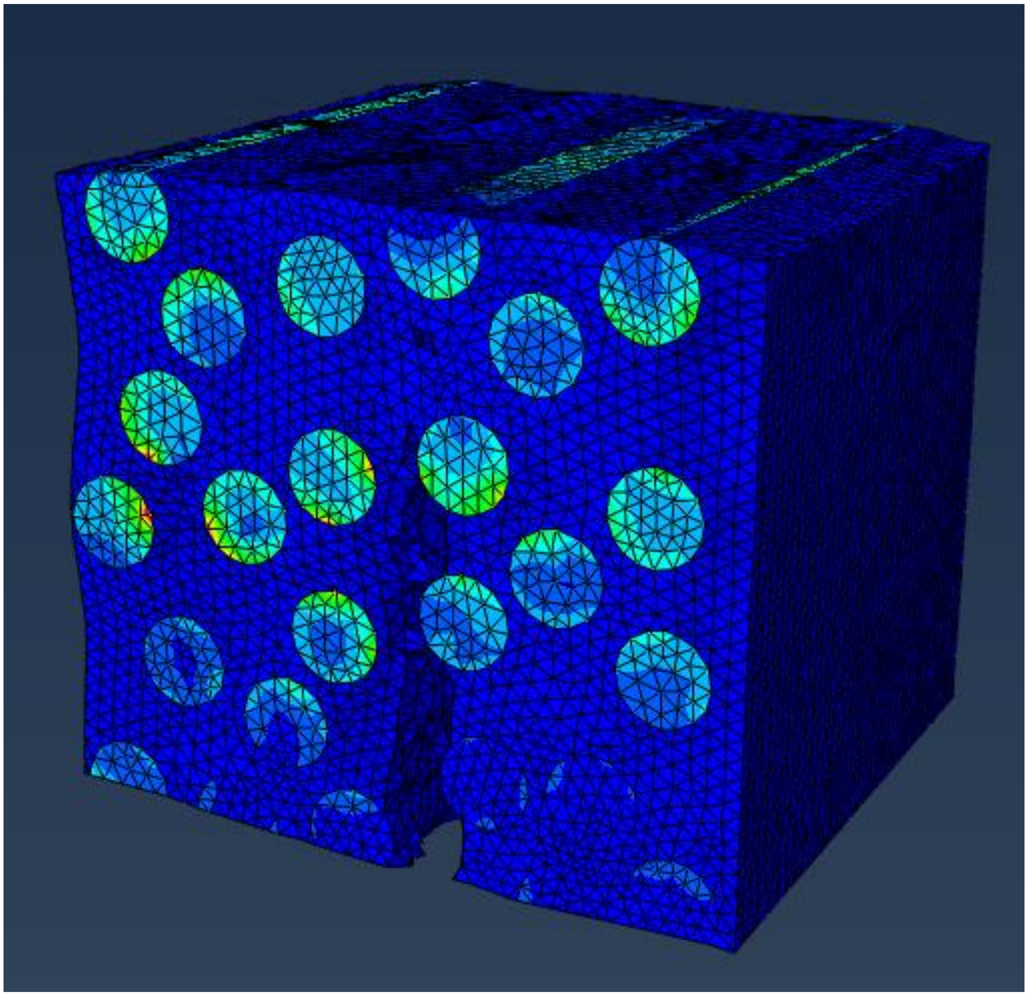
In this study, a meso and a micro scale model of a glass fibre - epoxy cross ply composite material are proposed that allow the accurate prediction of damage and failure mechanisms at multiple scales. In the meso scale approach, the proposing model adopts mean field homogenization methods to predict the response of a composite material with viscoelastic matrix and elastic continuous fibres along with cohesive zone modeling to simulate the interfacial delamination and the transverse matrix cracking, and was built with the consideration of the shear lag effect, determining the stress transfer through the interface. For the latter damage mechanism, numerous cohesive contacts are placed at predefined positions on the middle layers, whose strength follow a normal distribution, to avoid the development of a uniform stress state and simultaneous activation of multiple cracks. The crack density results obtained from the simulation are compared with experimental results of the same composite material sample. Furthermore, a mesh sensitivity analysis is presented that prove that the proposed model is mesh independent. For the micro scale model, a representative volume element (RVE) of the middle layers at the position of a crack is generated and the appropriate boundary conditions are applied. In this RVE a more complex nonlinear material model developed by the authors is used to simulate the matrix material, taking advantage of the user material interface provided by the finite element solver. The matrix follows a visco-elasto-plastic with Chaboche damage material with failure criteria and element deletion activated in case where the failure criterion is satisfied. The glass fibres are considered as elastic in this explicit dynamic analysis. The cracking initiation and propagation are successfully simulated at the micro scale.



Damage and crack propagation in the microstructure of the composite material

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Numerical simulation of debonding of a composite-to-metal adhesive joint subjected to centrifugal load

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The centrifuge test is considered as a promising alternative to the expensive and time-consuming mechanical tests of adhesive joints mainly due to its limited testing time and multi-sample testing capability. The present paper reports the first attempt to simulate the centrifugal loading of adhesive joints. To this end, a composite-to-metal adhesive joint was modeled and analyzed using the LS-Dyna explicit finite element software. Debonding was simulated using the cohesive zone modeling approach. The model was capable to predict the adhesion strength of the joint. Using the model, the effects of computing parameters (mesh density, loading rate) and geometrical parameters (adhesive thickness and diameter) on the adhesion strength were evaluated. The predicted adhesion strength values of the joints agreed very well with experimentally measured values obtained from a previous work of the authors. More specifically, simulating smaller adhesive diameters led to strength reduction so did the alternation of the standard film thickness. The model can be potentially used to optimize the centrifuge test of adhesive joints and for virtual testing.

Numerical Evaluations of Strain Field Modification Induced by Production Flaws in Loaded Composite Structures

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Structural health monitoring (SHM) involves observation and analysis of a system over time using periodically sampled response measurements to monitor the initiation and propagation of a flaw. To detect the flaw initiation, many approaches, techniques, and detection systems can be used. One of the possibilities is to analyze the strain field of the loaded structure because damage or defects to loaded composite structures cause their strain field to be modified. In this case the SHM aim is the diagnostic of the presence of damage or defects on the basis of the measurement of the induced strain modification. Specific software has been developed suitable to create such correlation.

This work is focused on modelling of strain field modification induced by flaws in loaded composite structures.

Frequent and very dangerous production flaw is a delamination, interlaminar separation of two plies. The considered flaw size depends on non-destructive detection possibilities. The flaw shape was idealized as square with a length of 1 inch. One flaw per laminate in several positions in the layup was considered.

For finite element (FE) model numerical simulation, a plate as 2D model was adopted with the current, linear, 4-node, full integrated plate elements (Nastran label QUAD4). Only linear, elastic solutions were executed. The element size and mesh quality were verified in order to be FEM computing error negligeable in comparison to the flaw strain field modification.

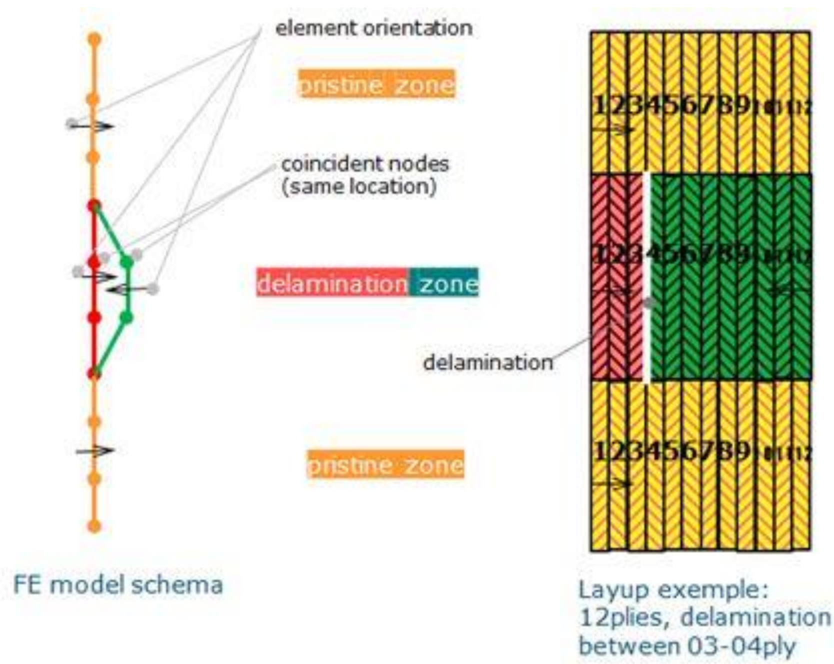
The pristine structure was modeled with one element per thickness. For delaminated zone in the center, the twin coincident elements per thickness were adopted: first element to simulate the lay-up from bottom to delamination, second from delamination to top (Fig.1).

The loads and the boundary conditions of the FE model were issued from the tests, based on the ASTM standards: tension test – ASTM D3039, compression after impact test – ASTM D7137 and 4-point bending test – ASTM D7264. The standardized tests configurations were chosen to facilitate comparison with future experiments. To integrate the results of different tests, the same specimen gage section with dimensions of 100 mm by 150 mm was chosen.

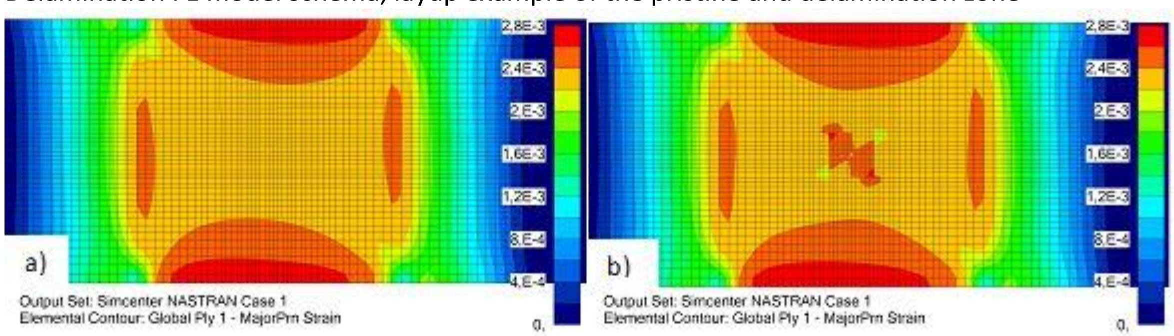
The numerical simulations of various loads for the three tests were systematically executed for all delamination positions in the layup. A typical example of the strain field modification, due to the delamination flaw, is demonstrated in Fig.2. In this case, 12-plies laminate was loaded in 4-point bending. The field of the major principal strain was compared for the pristine structure and for the structure delaminated between ply 1 and 2.

Generally, for all used standardized tests and for both laminates, the strain modification is stronger for the delamination near the surface (near the top or the bottom) then for the delamination deep in the structure. Consequently, the flaw near the surface is much easily detectable then the flaw deep in the structure. Considering usual measuring equipment (DIC, strain-gauge), the flaw is detectable at maximum under third ply under surface.

This project has received funding from the European Union's Horizon 2020 research and innovation programme MODIFLAW under grant agreement No886703.



Delamination FE model schema, layup example of the pristine and delamination zone



Major principal strain field modification due to the delamination flaw – comparison between a) pristine structure and b) structure with delamination between plies 01-02, 4-point bending test, 12-plies laminate.

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A holistic assessment of a stiffened panel production using a novel thermoplastic material and implementing the induction welding process

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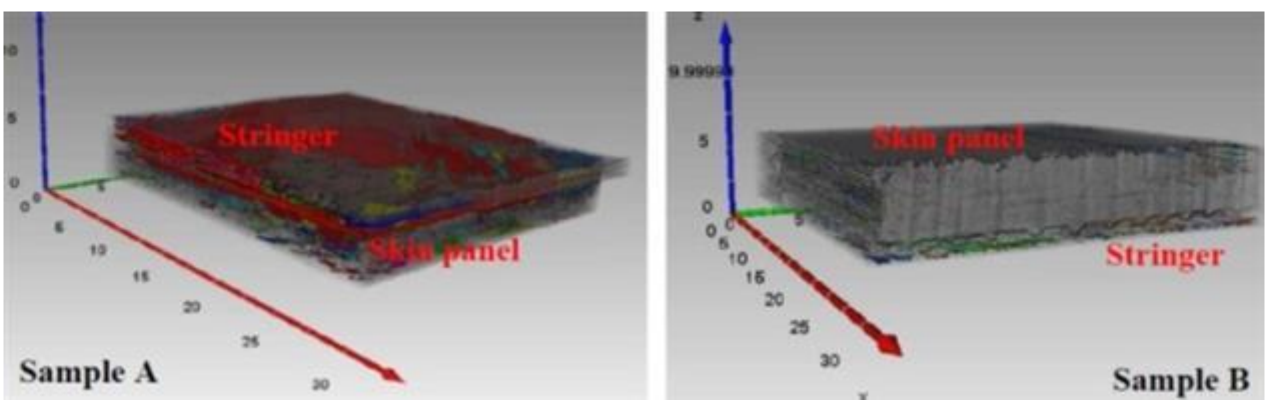
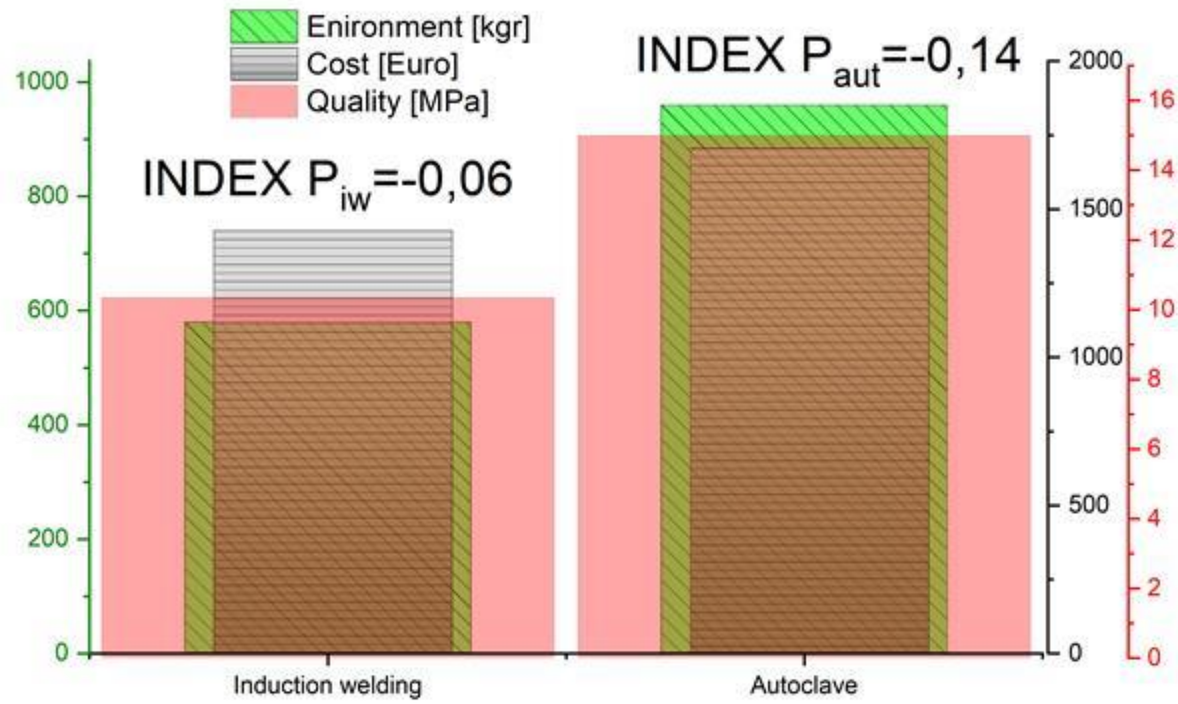
In this work, the investigation of the feasibility to produce a novel aircraft stiffened panel is presented. The full thermoplastic composite panel has been fabricated using entirely a new hybrid thermoplastic composite material allowing for appreciably lower processing temperatures as compared to conventional structural thermoplastic composites. For stiffening the fuselage skin panel, the out of autoclave welding of four composite stringers was obtained using a modified induction welding process For the feasibility evaluation of the application, the quality of the welds was investigated using micro-tomography and the mechanical strength of the lap joints was assessed by means of single-lap shear strength (SLSS) tests. Moreover, a holistic design Index was implemented as a decision support tool for selecting the optimal set of induction welding process parameters. Based on the index utilized, the quality of the application as well as its entire life cycle cost and environmental impact are accounted for. The quality is interpreted herein as a critical mechanical property, while the life cycle cost and environmental impact were assessed by means of Life Cycle Costing (LCC) and Life Cycle Analysis (LCA) models, respectively.
Low values of porosity as well as no material deconsolidation were observed at the investigated application by means of the non-destructive tests, as well as the average measured SLSS, even found lower, lies within the range of the respective values encountered in other similar high performance applications (e.g. Aeronautics, Automobile etc.). The optimized application is also compared against the conventional processing way, namely using the autoclave-based process. From the comparison it is exhibited that after the optimization the Induction welding process offers significant potential to replace the Autoclave process in welding applications, and thus it paves the way for reduced cost and increased sustainability, while still meeting the predefined quality constraints.



3D pores reconstruction in the overlap area of sample A (a) and sample B (b)



Quality, Cost and Environmental footprint terms of the Index P for both processes studied

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Model-Based Structural Health Monitoring of Box Girders

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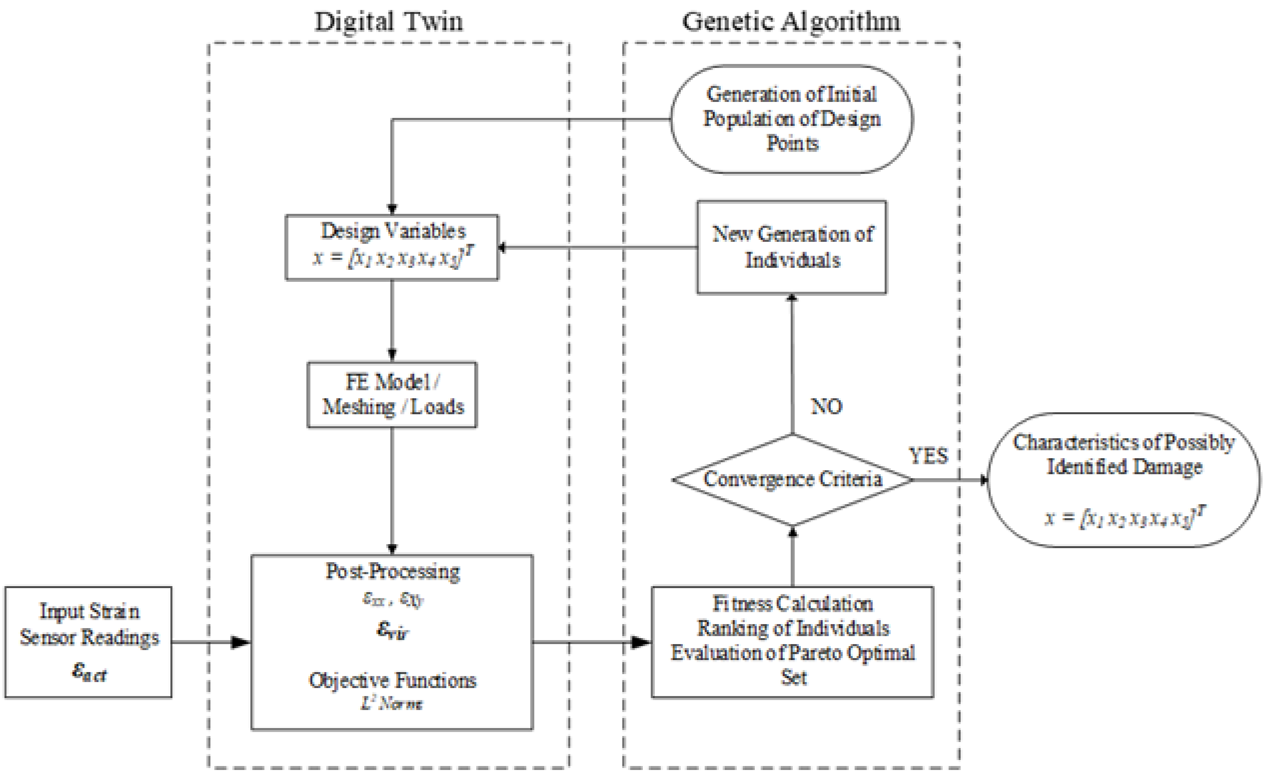
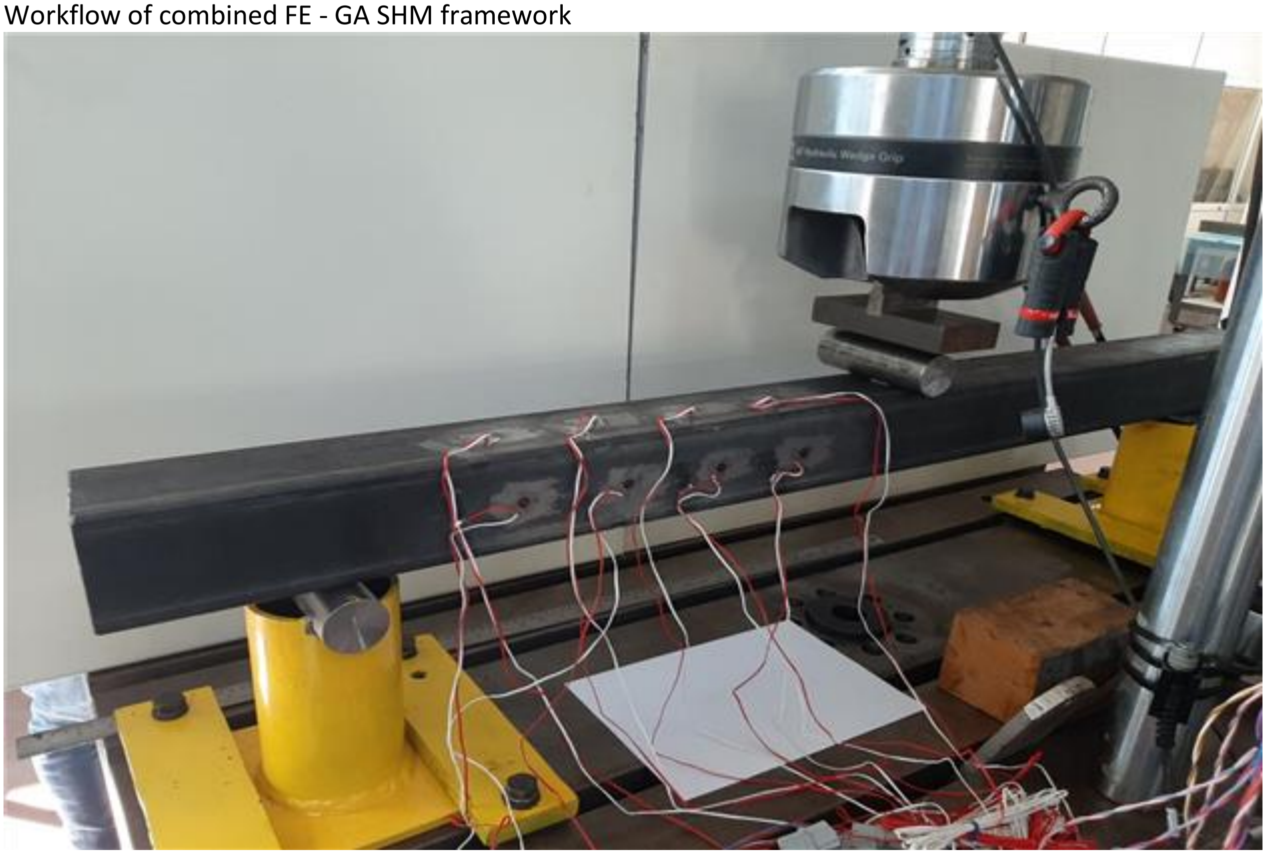
Maintenance procedures for ship hulls are currently dictated by rules and guidelines imposed by IMO International Maritime Organization), IACS (International Association of Classification Societies) and individual classification societies. According to these, vessels must undergo a strict schedule of planned surveys to assess their structural integrity. However, these cannot provide information on structural integrity in real time. Therefore, instances of structural degradation that may potentially lead to catastrophic failure (e.g., MOL Comfort accident), cannot be addressed in time. This highlights the need for the introduction of Structural Health Monitoring (SHM) systems for ship hulls, a sentiment echoed in the strategic goals of major classification societies. SHM refers to systems which enable the automatic and on-line observation of the structural integrity of any given component or structure during service. Two main approaches to SHM are widely accepted, the “model-based” one and the “data-based” one. In the former, which is the one adopted in this work, a physics-based model of the structure of interest is built, which can then be updated using in-situ measurements resulting in an updated model which has accurately captured the presence of damage.
In the present work the physics-based model used was not an accurate representation of a ship’s hull. Rather, an abstract simplified geometry was chosen to investigate the capabilities of the proposed method, both in a virtual and more importantly an experimental setting. Ultimately, a simple box girder geometry was employed subjected to three-point bending. This abstraction was meant to constitute a building block for future large-scale implementation of the proposed SHM system. Here, the objective was to design a system capable of detecting large-scale, global stress redistributions corresponding to failure of extensive areas in the hull, e.g., an entire frame. Therefore, to model the effect of this type of damage in the selected abstract geometry, while keeping in mind the possibility of laboratory tests, a circular hole was introduced to act as the nominal feature causing strain disturbance. The SHM system was then developed using a combined Finite Element – Genetic Algorithm method. The problem of damage identification was treated as an optimization problem. The design variables were identifying parameters of damage (e.g., location and magnitude), while the objective function was a measure of distance between strain measurements obtained from the in-situ sensors and those obtained by solving the FE model. By minimizing this objective function, it is expected to obtain as a solution the identifying parameters of the damaged structure from which the in-situ measurements were obtained. The basic workflow of this approach is provided in Figure 1. The proposed method was initially validated in a solely numerical environment, with the in-situ measurements being supplanted by FE data corresponding to indicative damage scenarios, yielding promising results. In a second stage, a laboratory test was set up (see Figure 2) to verify the method using actual strain data, which in turn showcased reduced accuracy.



Workflow of combined FE - GA SHM framework


Laboratory Test Set-up

Multifunctional polymer composite materials with Self-healing & EMI shielding properties

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Multifunctional polymer composite materials with Self-healing & EMI shielding properties

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Multi-functional composites represent a state-of-the art materials due to their enhanced structural performance. This improvement can be achieved via the incorporation of self-healing properties into the composites. The restoration/healing of the initial properties can be extrinsic or intrinsic with the incorporation of capsules inside the material (extrinsic approach) to be the most promising technique. Capsule based materials provide one-time healing but their easy applicability, mass production and high healing efficiencies with small knockdown effect, exceed this disadvantage. Concurrently with the self-healing properties multi-functional conductive polymer composites should have desirable properties such as EMI protection. The rapidly increase of various high frequency electronic devices demands the development of materials that can absorb or reflect the electromagnetic radiation.
In this study, the effect of the addition of Multi-Walled Carbon Nanotubes (MWCNTs) at three percentages into the urea-formaldehyde (UF) shell-wall of microcapsules on the healing efficiency is reported. Microcapsules thermal stability was also evaluated via Thermogravimetric Analysis (TGA). Healing efficiency was evaluated in terms of fracture toughness, while EMI shielding properties was measured in free-space with two rectangular horn antennas and a vector network analyzer. The derived results indicated that the introduction of 0.5 % w/v CNTs did not affect the healing efficiency, while it increased the initial mechanical properties by 27%. The measurements of the EMI SE was carried out in the frequency range of 7-9 GHz. The experimental results showed that the SE increases on average 5 dB or more after the introduction of conductive microcapsules.

"This research is co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Programme «Human Resources Development, Education and Lifelong Learning 2014- 2020» in the context of the project "Smart, multifunctional, advanced composites with EMI Shielding and Self-Healing capabilities for the recovery of mechanical and electromagnetical properties- SHIELD" (MIS: 5047645)."

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The Integration of a CNT-based Organic Thermoelectric Generator within a Carbon Fiber Reinforced Polymer Composite

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Advanced fiber-reinforced polymer (FRP) composites, can be engineered at the nanoscale to achieve significant multifunctional macroscopic properties through versatile design approaches with significantly enhanced specific mechanical, thermal and electrical properties [1-5]. In this work, organic and non-acidic semiconducting carbon nanotube CNT inks with a specified architecture were printed onto fibrous laminated aerospace materials, in order to achieve thermal energy-harvesting enabled structural composites, with emphasis on scaling and application pathways during the fabrication of multifunctional hierarchical composites. Herein, the fabrication of a highly efficient Organic Thermoelectric Generator (OTEG) via a versatile and fast printing technique, and its integration within an FRP structural part is demonstrated. The OTEG device, consisting of serially interconnected p- and n-type CNT-based thermoelements, is fully printed on the fibrous reinforcement of the composite. The produced TE power exhibited great stability over time with the “hot” side exposed up to T=125°C and the “cold” one at T=25°C (ΔT=100K), rendering the OTEG device as well as the multifunctional OTEG–enabled FRP capable to generate 11.6μW as shown in Figure 1. This power output has the ability to activate low-consumption electronic devices (e.g. Internet of Things) via a commercial step-up converter.

Acknowledgements
The study leading to these results has been part of research activities carried out at University of Ioannina to support the European H2020-MG-2017 program under the Grant Agreement No 769140 (HARVEST: harvest-project.eu). This project has received funding from the European Union’s Research and Innovation Action programme Horizon 2020.

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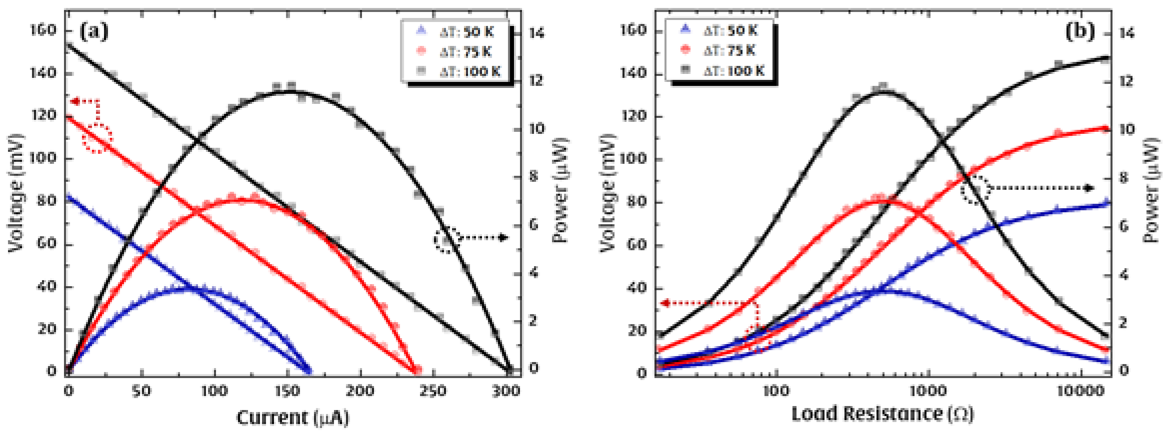

Thermoelectric performance of the CFRP-OTEG in various temperature differences (ΔT). (a) Voltage-current (V-I) and power current (P-I) curves, and (b) voltage-load resistance (V-RLOAD), power-load resistance (P-RLOAD) curves.

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A Carbon Fiber-Reinforced Polymer Composite with Embedded Photo-Thermal Energy Harvesting Capabilities

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In this study, we investigate a method for the development and integration of dye-sensitized solar cells (DSSC) and thermoelectric generators (TEG) into Carbon Fiber Reinforced Polymer (CFRP) composite materials. Carbon fibers, as a highly conductive material and an essential part of the CFRP, prove to be suitable for use as counter-electrodes in DSSCs, since they have an appropriate work function that gives them the ability to redox the electrolyte in a DSSC architecture. Moreover, a printed TEG has been integrated within the CFRP in order to investigate the collaborative interaction between the two technologies and the exploitation of the impact in the power output and the efficiency of the energy-harvesting CFRP device [1-5]. We have successfully achieved ~5 mW/cm2 power density under a luminance of a solar simulator at 100 mW/cm2 using the commercial dye N719 as a photo-sensitizer on a TiO2 semiconducting photoanode, iodine-based electrolyte and the carbon fibers as the counter-electrode. Furthermore, the simultaneous power generation from a Tellurium-based printed TEG on a CFRP is evaluated. The integrated TEG device is able to generate ~0.5μW/cm2 under the solar irradiation, rendering the multifunctional energy-harvesting FRP capable to activate low-consumption electronic devices (e.g. Internet of Things) via a commercial step-up converter.

Acknowledgements
This research is co-financed by Greece and the European Union (European Social Fund- ESF) through the Operational Programme «Human Resources Development, Education and Lifelong Learning 2014- 2020» in the context of the project "Advanced Composites for Power Generation in order to Supply Low Energy Requirement Electronic Circuits by Photo-Thermal Energy Harvesting (MIS 5047641).

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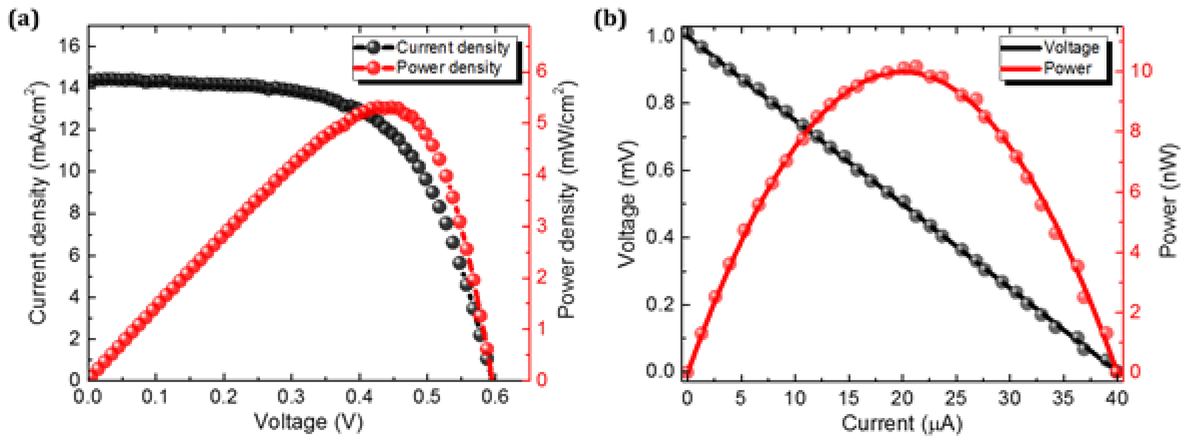

Figure 1. (a) Photocurrent density-voltage (J-V) and power density-voltage curves for the CFRP-DSSC device, (b) the thermoelectric current-voltage (I-V) and power-voltage curves for the CFRP-TEG device under solar irradiation.

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Effect of a coating type of a cutting tool on surface roughness of machined material during planing

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Machining is one of the classical technologies that are still widely used today, so increasing the efficiency of machining and the quality of the machined surface is still a current challenge for companies to become competitive. The article deals with the evaluation of the influence of the used coating of the cutting tool on the parameters of the achieved surface roughness Ra and Rz during machining and with the evaluation of the destruction of the coating layer of the tools during finishing planing. The experiments were carried out on a planing ma-chine type SJ 8A 181070313, which ensured sufficient rigidity of the technological system, stability of the feed frequency, sufficient drive power and sufficient rigidity and clamping range of the table. All tests were carried out without coolant due to the faster wear of the cutting tip. Steels ISO 630-80 (11 375), ISO 683-1-87 (12 050) and ISO 683 / 10-86 (17 240) were used as machined materials. The reference cutting tip made of high-speed steel Radeco - RO 19 830 was uncoated. The next cutting tips were coated with coatings AlTiN, AlTiSiN, TiN, while all cutting tips were of SOUN 250608-HSS type. The surface roughness was measured on a device SJ Mitutoyo Surftest and the measured values were statistically processed. The evaluation of the destruction of the coating layer was performed using a Carostest device. The aim of this experiment was to point out that during the machining process the coating is removed from the cutting edge by abrasion, which causes a significant deterioration of the surface roughness of the machined material. The achieved roughness varied in relation to the material being machined, but the results indicated that the most universal coating type for machining selected steels was AlTiSiN.

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Constitutive Modeling of BBC Single Crystals: Non-Schmid stresses and computational issues

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Abstract

Plastic deformation in metallic FCC single crystals obeys “Schmid’s law”, i.e., a slip system is activated when the resolved shear stress on that system reaches a critical value. Atomistic studies show that the traditional Schmid law breaks down in BCC single crystals ([1]). In particular, in BCC structures dislocation motion is controlled not only by the resolved shear stress on the slip system (Schmid stress) but also by non-glide stresses which affect the mobility of dislocations ([2],[3]). The non-Schmid stresses are of great importance especially in low temperatures in BCC crystals, where plastic deformation mechanisms such as twinning take place.

In this work, we use the model of Gröger et al. [4] to study in detail the mechanical behavior of BCC single crystals. The proposed theory leads to non-associative flow rule of plasticity, i.e., the plastic strain-rate tensor is not normal to the yield surface in stress space. This “non-normality” is known to enhance strain localization in the form of shear bands.

A methodology for the numerical integration of the constitutive equations is developed and the model is implemented in the ABAQUS general-purpose finite element program and several example problems are solved.

Also, a non-local (gradient-type) of the model is developed. The non-local model introduces a “material length” , which is related to the grain size. The evolution of plastic flow depends on a properly defined non-local “equivalent plastic strain”, which is identified with the average of the corresponding “local quantity” over a sphere of radius centered at the point under consideration.

Keywords: Crystal Plasticity; Yield criterion; Non-normality; Non-Schmid stresses; Finite Elements;

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On Lateral and Axial Crushing Response of Filament Winding GFRP and Modified GFRP Tubes

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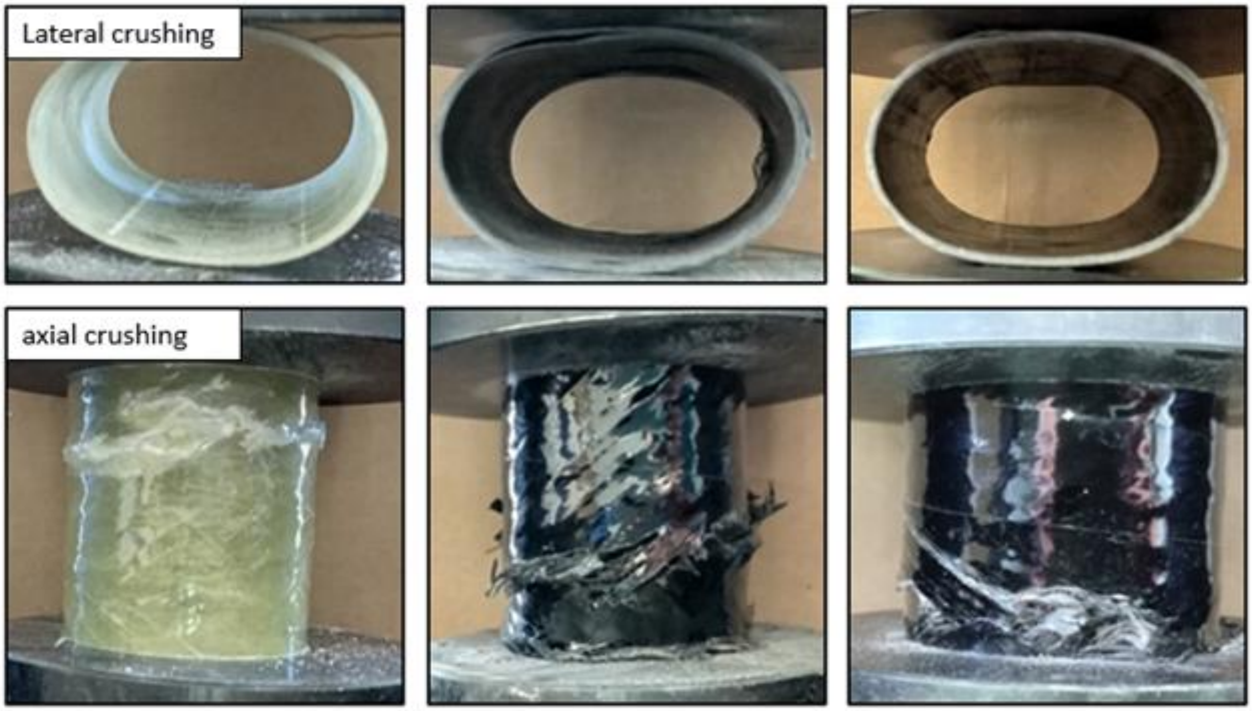
During the last decades, the use of composite materials has rapidly increased in various industrial and commercial fields owing to their excellent specific mechanical properties. Their applications may include among others piping and pressurized storage vessels, that require the structural element to be of circular profile. Although tubular composites could offer considerable energy absorption potential, their crushing behavior is a rather complex process, as it is governed by a combination of complicated failure mechanisms, involving fiber fracture, matrix cracking, and delaminations.
Filament winding technology has become the most prevalent technique in manufacturing of tubular composites as it presents a number of advantages. More specifically it is a well suited to automation method, that provides increased reliability and production efficiency, enabling therefore the fabrication of high performance yet low-price products.
“Smart” or multifunctional materials are a rapidly emerging and highly promising technology on the topic of structural composites. As such can be defined the materials, that apart from fulfilling their primary load-bearing purpose, they simultaneously demonstrate further functionalities such as electrical and thermal conductivity.
Taking the above into consideration, this work aims to characterize the axial and lateral crushing behaviors of circular glass fiber reinforced polymers (GFRP), fabricated with the filament winding process. For this reason, pristine GFRP tubes and tubes made of modified glass filaments were tested under compression. Regarding fiber modification two different Carbon Nanotube (CNTs) systems were adopted, with the one comprising a surfactant compound. In order to investigate the influence of fiber modification on the crushing response several crashworthiness criteria such as peak crushing force (PCF) and energy absorption (EA) were adopted. Modes of failure and energy absorption mechanisms occurring during the crushing process were studied by a series of deformation history snapshots and the respective videos.
Mechanical testing showed that regardless of loading direction the force-displacement diagrams can be divided into three distinct stages, namely linear elastic, progressive collapse, and densification. The loading direction does however significantly affect the size of the progressive deformation stage, where the majority of energy absorption takes place. The failure and energy absorption mechanisms during lateral compression involve initially the bending of the tube’s walls and subsequently the formation of a pair of plastic hinges at the left and right horizontal ends of the tube. Moreover, significant deformation recovery was demonstrated after testing. In the case of axial compression, the tubes failed in a progressive and stable crushing manner, dominated by brittle fracturing. Apart from the aforementioned failure mode, the specimens comprising modified fibers revealed progressive local buckling as well.
Finally, so as to explore the versatility and the multiplicity of potentials that smart composites may provide, electrical measurements were carried out. As expected, by modifying the fibers via the employment of a CNT-based ink, the initially insulator GFRP can be rendered conductive, manifesting in this manner the new capabilities that smart composites have to offer



Lateral and axial crushing of GFRP and modified GFRP tubes

Nanostructured inorganic polymer matrices for high temperature resistant fiber reinforced composites

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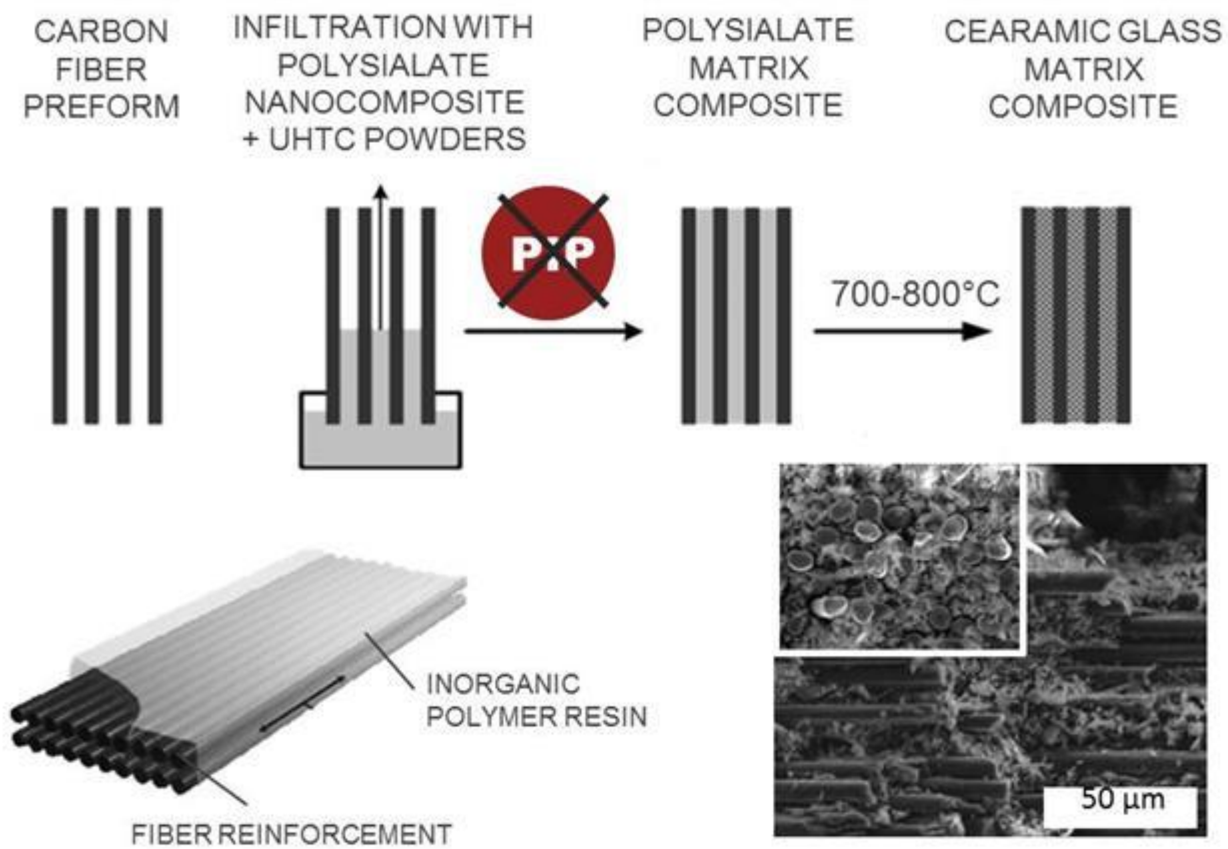
Nowadays the need to develop new materials able to combine lightness, mechanical strength and fire protection together with an easy and sustainable processability, has becoming an important challenge to face, especially in the automotive and aerospace industry. Current research efforts in the FRP sector, indeed, are increasingly dealing with reducing the emissions of volatile organic compounds from organic resins, and limiting the energy demand and the environmental impact of the manufacturing process, without affecting the overall performances of the materials.
In this framework, with the aim to ensure an optimal balance between performances, sustainability and costs, and allow for a viable industrial scale-up and distribution, an innovative fiber reinforced composite material based on a nanostructured inorganic polymer matrix has been designed. Such composite material shows properties and characteristics halfway between traditional FRPs and CMCs, and is particularly suitable to produce highly engineered structures through a simple, sustainable and low cost process. The hazard-free aqueous based matrix ensures the compliance with the most strict environmental legislations and codes of practice, granting at the same time the possibility of working with the same equipment and within the same process conditions of traditional FRPs. Also, the nanostructured inorganic matrix further boosts the thermostructural properties of the composite, protecting the fibers even in highly oxidizing environments and triggering self-healing mechanisms thanks to the introduction of specific nanostructured ultra-refractory charges. The designed composite might be used as a safe and lightweight thermal barrier with almost completely tunable properties, depending on the composition and the specific post-curing treatments. In general, it grants complete fireproofness and no-smoke emissions, high service temperatures (up to 800 °C), low thermal expansion and good mechanical properties (up to 200 MPa for tensile strength).



The water-based, low-temperature and one-step process for the production of sustainable nanostructured inorganic composites.

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Comparison of immersion and air-coupled ultrasonic testing techniques for evaluation of quality of the adhesively bonded joints

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Adhesive bonding known for its high performance to weight ratio, ability to join dissimilar adherends, and uniform load distribution, is an attractive alternative to other joining technologies. Despite the advantages, their usage is limited in the aerospace industry due to the lack of knowledge in reliable Non-Destructive Testing (NDT) techniques to inspect the bonded structures. This study aims to investigate an aluminum-epoxy-aluminum single lap-joint specimen using the immersion and Air-Coupled Ultrasonic Testing (ACUT) techniques and to measure the performance of each technique. In this bonded specimen, the debonding type artificial defects have been introduced in the form of thin release film inclusions. In case of immersion methods, through transmission, pulse-echo, and Scanning Acoustic Microscope (SAM) techniques were investigated. In case of ACUT, through transmission and Guided Wave (GW) methods were used. For both immersion and ACUT, the measurements were performed by using two different types of transducers i.e., focused and unfocussed transducers. The performance of each technique has been compared using the absolute error per wavelength of the ultrasonic wave.

From the results of the through transmission technique using immersion and ACUT it is observed that, the focused transducer can visualize the bonding quality with a better resolution than the unfocussed transducer. In case of ACUT for both through transmission and GW, it was observed that the losses due to the mismatch of acoustic impedances were extremely high which resulted in a low Signal to Noise Ratio (SNR). But this low SNR was improved by averaging the signals during data acquisition and by using bandpass filtering in the post processing of the signals.

The debonded areas are best detected using the longitudinal bulk wave. Particularly, when using higher frequencies (10–50 MHz) in the immersion testing, it performed significantly better than the air-coupled methods operating at 300 kHz. However, the immersion bulk wave testing requires immersion tanks and usually is performed in a lab. Therefore, investigations using air-coupled GW methods have advantages such as contactless measurement, possibility of a long-range inspection, and single sided access that can be attractive for in-situ evaluation.

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Probabilistic strength assessment through analytical modeling of pillars found in ship structures

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In shipbuilding, pillars are typically used to support large deck areas in car carriers, passenger ships and general cargo vessels as well as in the accommodation area in merchant vessels. Reliable design against their ultimate compressive capacity is therefore of high interest. Their typical scantlings are characterized by intermediate slenderness ratios that lead to elastoplastic buckling, which is a collapse mode that combines material and geometric non-linearities. Rule-based (e.g. Common Structural Rules-CSR) strength check involves the application of the well-established Euler-Johnson buckling formula with a maximum allowable utilization factor of 0.65 for static loads and 0.75 for dynamic loads [1]. Such a deterministic approach for strength calculation of compression members does not allow the incorporation of the uncertainty that is associated with geometric and material related parameters. In reality, there does exist a certain level of variability in the aforementioned design variables, which in turn have an impact on the real column resistance.

In this direction, the proposed work focuses on a probabilistic strength approach of compression, with a special interest in providing associations with the deterministic approach given by the standards of the shipbuilding industry. The main objective is to assign probabilities of failure for each pillar design. The Young's modulus, the yield stress and the initial bow imperfection were considered as random variables, with given statistical structures. These correspond to models that quantify the uncertainty associated with the design variables of the problem at hand. The pillar's resistance is calculated based on the Perry-Robertson formula, which is a purely analytical tool that has the advantage of explicitly including the initial geometric imperfection within the strength calculation. Uncertainty propagation was established through a Monte Carlo Simulation (MCS) assisted by a stratified sampling scheme, i.e. Latin Hypercube. Three typical cross-sections were considered, i.e. hollow circular, hollow square and "H" shape, in three different slenderness ratio levels (low, intermediate and high). MCS was employed for ten pillar cases per slenderness ratio per cross section type, resulting in 90 MCS in total. Following each MCS the probabilistic resistance per pillar was modeled by generating the probability density function that best describes the statistical nature of the sample data and by calculating its parameters from point estimates of the sample statistics. The column resistance was found in each case to follow the normal probability distribution (see Figure 1). The curves of interest are the ones defined by the 95% lower confidence bound (referring to the 95% lower bound of pillars having a given slenderness ratio) with a probability of failure of $1/10^3$ and $1/10^4$ accordingly (see Figure 2). Initial findings have shown that the design zone threshold suggested by the deterministic buckling resistance curve multiplied by the static utilization factor (CSR), is associated with a probability of failure that is very low (1.0e-8). By controlling this probability, the utilization factor may be fine-tuned so as to accommodate higher risk if required.

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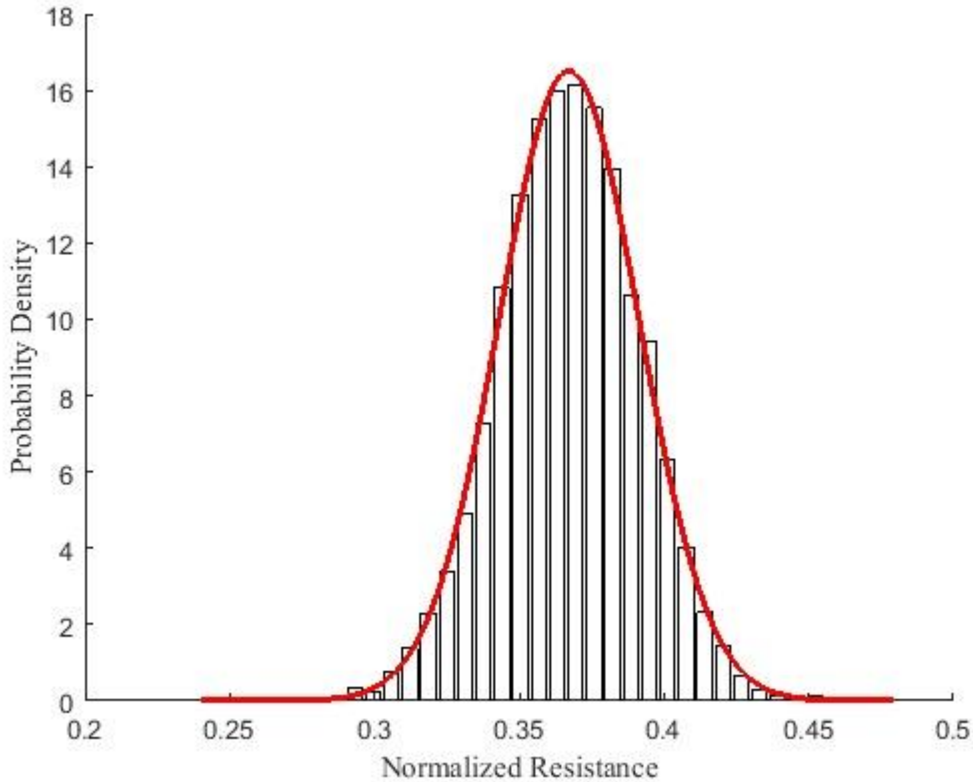

Figure 1 Normalized resistance pdf, (HEA, high slenderness ratio)

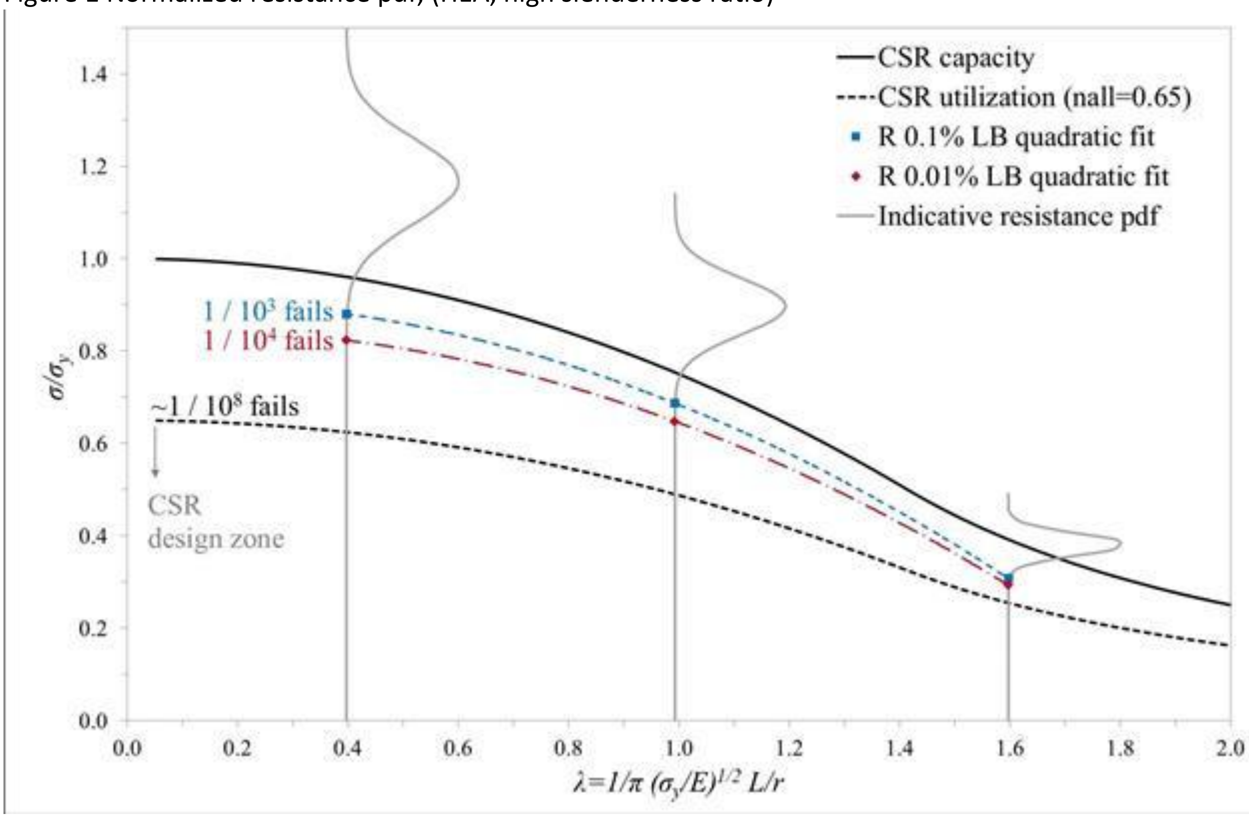

Figure 2 Ultimate compression column resistance curves (CHS, SHS, HEA)

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Methods of condition assessing of incomplete or temporarily out of service facilities

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Introduction

Typical diagnostic tests for assessing the condition of in-service facilities are known and widely described in the literature. Despite the development of testing methods, the assessment of the condition of unfinished objects is a problem. These issues bother specialists who assess the suitability of unfinished objects for modernisation. The authors have repeatedly assessed the condition of such buildings, and the final result of the work was to indicate how to strengthen the structure and enable safe exploitation. The analysis covered buildings with both reinforced concrete and steel structures, as well as with various functions, e.g. residential, storage and production.

Methods

The test methodology for assessing the condition of in-service facilities must be determined on an individual basis. The type and scope of planned research depends on the type, age and function of the object. The authors confirmed their conclusions resulting from many years of research on buildings in use.

Several buildings with prefabricated large-panel structure, which were commonly realised in Europe in the 70-90s, were examined. Even nowadays, there are unfinished and unoccupied buildings, which are subject to continuous degradation. Their attractive location and high demolition and new construction costs make it necessary to consider retrofitting and finishing the building as an alternative to new construction.

A pilot study was carried out on a large-panel building with 5 storeys above ground and 1 underground. Construction had stopped before the roof was put on. The building had not been protected from the external environment for thirty years. Visual evidence of degradation was found in the form of localised cracks in the precast elements, rebar corrosion, joint cavities, cracks in walls and floor slabs and algal aggressiveness. Subsequently, non-destructive tests and analytical calculations were carried out to determine the suitability of the building for the modernisation and operation process.

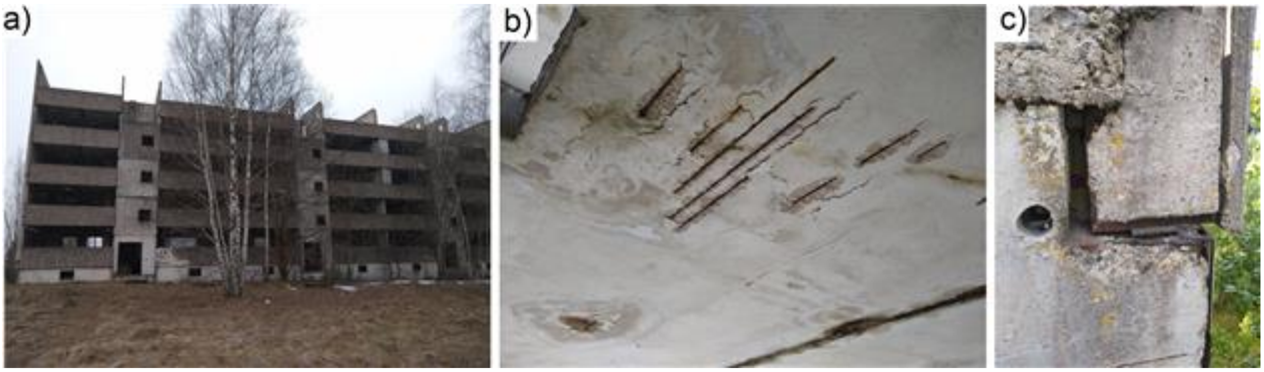
The reinforced concrete paint facility with curtain walls suspended to the steel structure was also tested. Degradation of the structural elements due to chemical attack caused the building to be out of use.

Results

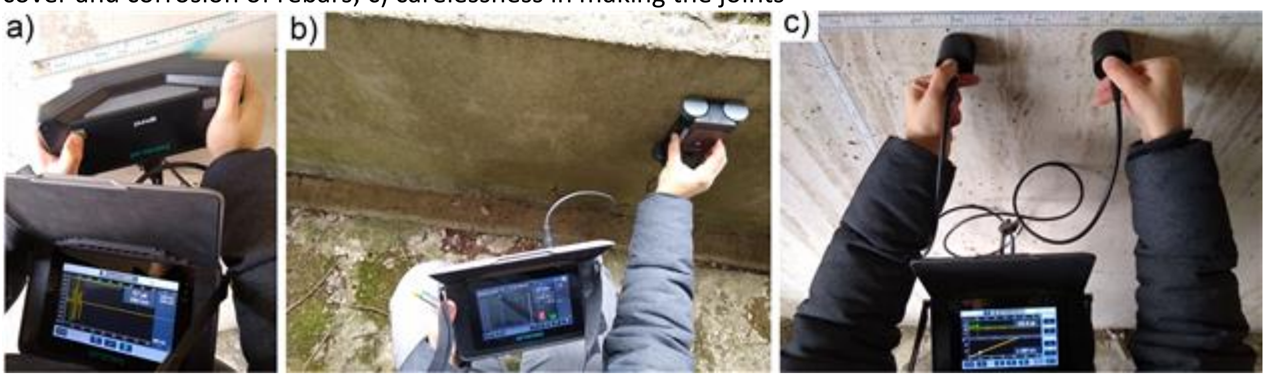
The development of digital technology and testing techniques allows minimising destructive testing. Non-destructive testing can be considered commonplace in assessing the degree of deterioration and the suitability of an object for upgrading. Modern testing equipment makes it possible to detect the distribution and diameter of reinforcement, depth and width of cracks and fractures, strength and homogeneity of concrete, and to detect defects, voids and delaminations. The experimental results should be matched with numerical analyses of existing degraded elements. Only the results of the tests and analytical calculations allow for a correct assessment of the suitability of the elements for further operation, their strengthening or demolition.

Discussion

Non-destructive testing can provide a lot of information about the degree of structural degradation. Calculations carried out using the results of NDT should provide guidance for the development of testing methodology and assessment of the technical condition of the structure. Restoration of the structure to use, or completion of the construction process, must be preceded by a detailed diagnosis of its condition.



Analysed degraded, unfinished large-panel building: a) large-panel building under investigation; b) lack of cover and corrosion of rebars; c) carelessness in making the joints



Non-destructive testing: a) wave speed estimation; b) locating reinforcement; c) estimation surface velocity

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Experimental and computational verification of precast large panel wall stiffness

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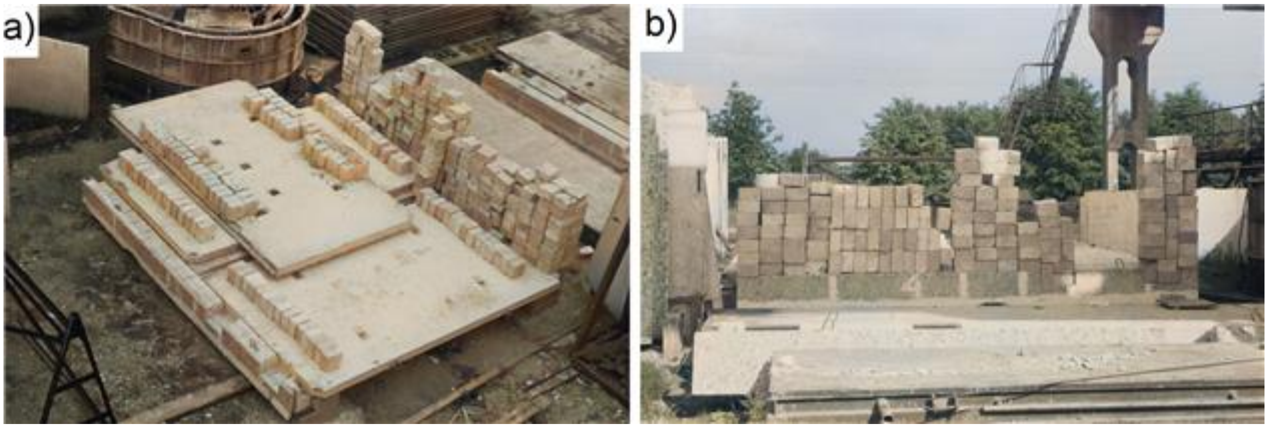
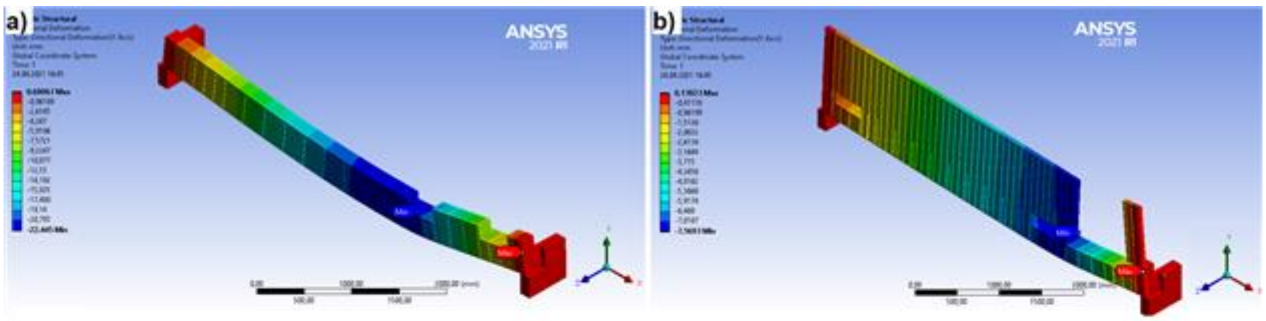
Introduction
In large-panel buildings, curtain walls were constructed as reinforced concrete elements in the form of a sub-window wall connected/monolithised with a lintel beam. The scale of large-panel building was associated with modifications of prefabricated elements. In the case of curtain walls, the function of the wall and the lintel was separated. The lintel remained in the form of a prefabricated beam, while curtain walls began to be made as brick. This improved the aesthetics and increased the thermal insulation of the walls. After years of use, cracks began to appear in the interiors of the flats constructed in this way. The result was a threat to the residents' feeling of safety.
Methods
An analytical model of the lintel beam was built to assess the structural failure risk. For comparison, an analytical model of a systemic beam-wall has also been made. The scale of the cracking phenomena, involving several buildings, led the authors to build a test stand to carry out test loads. The test stand was to model the real support conditions of the tested elements. Several precast reinforced concrete beams were constructed on a natural scale. The supports were concreted as cross joints of wall panels. Deflections were measured using dial gauges. The beams were loaded with a permanent load and a live load. As loads, prefabricated floor slabs and concrete blocks were used, which were carried by a crane.
Results
The calculations carried out showed that the conditions of limit states will be fulfilled in the case of an element made as beam-wall. In buildings constructed in this way, no defects were found in the beam-wall zones. Calculations performed for a lintel beam loaded with a masonry curtain wall confirmed the condition inventoried during test loads. Analytical calculations of the beam-wall confirmed significantly lower deflections in relation to the lintel beam.
Deflection measurements on the test bench showed that some of the tested beams exceeded the total limit deflection, defined in standards as equal to L/250. The results coincided with the analytical model, which also confirmed that the deflection was slightly exceeded. The effect of excessive deflections was the occurrence of scratches on the lower surfaces of lintel beams, and cracks visible on the surfaces of masonry curtain walls. Cracks were also identified in the façade layer of the beams, currently not visible as a result of thermal insulation and renovation works.
Discussion
The modified structural solution was designed to less restrictive standards than the current one.Calculations carried out in accordance with the Eurocodes confirmed that the SLS was exceeded in terms of lintel deflections.
Although deviations from the standard requirements were found, for social and economic reasons the authors recommended repairing the damage and allowed the buildings to resume use. During the renovation phase, consideration should be given to adding anchors to fix the scratched façade layer.
A requirement was made that structural elements must be monitored for deflection propagation and the building should be visually inspected at least every 6 months.



Test loads: a) view of floor slabs and concrete blocks loading the beam; b) view of load from masonry curtain wall



Analytical models showing deflection of beams: a) beam separated from the lintel; b) beam-wall (beam connected/monolithised with a lintel beam)

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3D imaging of cracks in composites and microchips using high-resolution XCT

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Fracture mechanical properties of materials in micro- and nanoscale dimensions have become an important area of fundamental research, including the development and introduction of new techniques for micro- and nanomechanical testing [1,2]. At the same time, there is an increasing need of industry to evaluate the risk of microcrack evolution at small length scales that can cause catastrophic failure in 3D-structured systems and materials such as leading-edge integrated circuits, advanced battery electrodes and composites. In this talk, we are presenting in-situ high-resolution X-ray computed tomography studies to image crack propagation in composites and microchips, with the goal to contribute to the understanding of small-scale fracture mechanics.

The combination of miniaturized mechanical tests with high-resolution imaging enables a precise control and monitoring of force and displacements in materials at the micro- and nanoscale. In-situ mechanical tests of 3D-structured systems and materials applying a micro double cantilever beam (micro-DCB) test in a laboratory X-ray microscope provide a unique capability for high-resolution 3D imaging of microcrack evolution while a force is applied [3]. Nano X-ray computed tomography (nano-XCT) is used to image microcracks in integrated circuits with sub-100nm resolution and to draw conclusions for the robustness of microchips [4]. A novel methodology for the determination of the local critical energy release rate Gc in 3D-patterned systems will be explained, and the ability of a controlled steering of microcracks into regions with high fracture toughness will be demonstrated.

Natural biocomposites, „designed“ according to their functionality in a long-term evolution process, outperform engineered materials and systems in most cases. As an example, a study at mollusk shells that consist of high-strength and high-stiffness building blocks (mineral phase) and ductile components (amorphous organic phase) will be presented. It could be shown that microcracks are steered into the organic phase where they are trapped [5].

The combination of micromechanical testing and high-resolution X-ray imaging opens the way for the development of design concepts for novel engineered materials systems based on their local mechanical properties.

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How can we successfully study tribological failures on the lab-scale?

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Unacceptable wear is identified as a frequent cause for the failure of materials and components. Typical examples of this tribological failure can be found in a variety of industrial and technological applications, ranging from aeronautical, automotive, biomedical up to micro-electronics. The diversity and uniqueness of each tribological contact, make it hard to reproduce the same failure mechanisms on the lab-scale. This is because different contact geometries, loads, motions, speeds, and environments are required in every case. Using a simplified approach or a standardized test poses a great risk, that the obtained results do not correlate to the actual application and thus cannot be safely transferred/extrapolated. Therefore, in this work we present an overview on the 'why' and 'how' we developed modified tribological methods to successfully simulate different applications, by recreating the occurring failure mechanisms. Indicative case studies are given to clearly explain our stepwise approach, and to highlight the added value and main outcome. We believe that the development of correct testing methodologies is extremely important for both Research & Development, Failure Analysis AND Quality Control processes.

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A novel approach for alloy design and composition screening for additive manufacturing

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Metal additive manufacturing (AM) has gained increasing attention in recent years. Among the AM methods, laser powder bed fusion (PBF-LB) can be considered as the most promising technology due to its capacity for processing complex structures. One of the biggest challenges with this method is the high temperature gradient exerted during solidification, which limits material selection. This work introduces a novel alloy design approach aiming to tackle solidification cracking in the AL7075 aluminum alloy, by demonstrating how alloy composition and microstructure can be tailored for laser powder bed fusion technology.

Using an advanced design of experiments (DOE) approach, a sample matrix with compositions close to the nominal AL7075 was developed. The DOE aimed to reduce the alloy solidification range via controlled silicon additions. A thermodynamical approach that includes multi-component calculation of the phase diagrams was deployed to find the columnar to equiaxed transition (CET) for the proposed compositions, as a prominent factor to predict grain morphology. To reduce the computational cost of thermodynamic calculations, an artificial neural network (ANN) model was developed based on a selective number of initial compositions. The ANN model was used to analyze the CET trends for arbitrary compositions enabling screening studies. Several computationally suggested compositions were then processed by arc melting, to verify the concept experimentally. The processed samples were metallographically prepared, etched, and observed with light microscopy, followed by an image analysis technique to study the grain size and morphology. The microhardness of all the processed samples was also measured. The imaging and microhardness results were re-introduced in the ANN model with the ambition to train and develop a master computational tool for designing and screening viable compositions.

As a result of this work, we found that the CET in the Al7075 system is highly dependent on silicon. A high silicon content promotes microstructural refinement and prevents solidification cracking that stems from the long grain morphology in the original composition.

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Role of Microstructure in Mechanics and Engineering of Soft Biological Materials

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Aortic disease (AoD) is a leading cause of mortality in developed countries. Worldwide, AoD affects approximately 600,000 people/year and the cost of aortic repair is in the order of €17 Billion/year. Two of the most common forms of AoD are aneurysm (widening) and dissection (tear in inner wall). Aneurysm and dissection often associate with bicuspid aortic valve (BAV) instead of the normal tricuspid aortic valve (TAV), and BAV aneurysms of ascending thoracic aorta have the tendency to bulge asymmetrically towards the greater curvature of aorta. Multiphoton microscopy can help us image collagen and elastin fibres (load-bearing components aortic fibre microstructure) in unstained samples of human ascending thoracic aortic aneurysm (ATAA) wall [3 locations across thickness: adventitia-media (ADV-MED), media (MED), media-intima (MED-INT); 3 circumferential regions: left coronary sinus (L), right coronary sinus (R), non-coronary sinus (N)], in order to investigate potential role of load-bearing fibre microstructure in BAV-ATAA or dissection propensity. Image-based analysis of fibre microstructure has demonstrated fewer radially-oriented fibres in regions N-R vs. L of BAV-ATAA when compared with TAV-ATAA. The regional differences in fibre microstructure may be driven by distinct mechanisms of vascular remodelling that contribute to asymmetric dilatation in BAV-ATAA, and, combined with dissection test, could improve our understanding of the biomechanical mechanisms of aortic aneurysm and dissection potential.

Should we wish to investigate the effect of microstructure in soft tissue formation and organ development (e.g., embryonic development, tissue regeneration), we would have to consider a rapidly growing process. In that process, connective fibres (e.g., fibronectin (FN), laminin) can’t be imaged without staining in multiphoton microscopy and are not load-bearing in the same sense as in adult tissues. The cells are the main load-bearing components, which cooperate to produce tissue-level forces that shape tissue formation. It is therefore important to create our own fluorescently-labeled matrix that can integrate into the tissue and enable tracking of these forces in-vivo. A new 3D optical nanomechanical biosensor (NMBS) based on fluorescent FN fibres (10μm wide × 100μm spaced, ~5nm thick) was developed based on integrated photolithography and micro-contact printing technology. NMBS was integrated into biologically relevant materials [Polydimethylsiloxane (PDMS, incompressible, isotropic), Fibrin (compressible, anisotropic)] and in-vitro validated under uniaxial tensile test. Fluorescence microscopy imaging analysis demonstrated agreement between microscopic strains of NMBS and macroscopic strains of both PDMS and fibrin. The measured stretch ratios also matched known material properties of fibrin.

In the future, biomimetic 3D scaffolds could be fabricated by assembly of 2D fibre constructs based on the NMBS technology, in order to analyse the effect of selected set of load-bearing microstructural components on the mechanical/functional response of soft biological materials. Advanced numerical techniques could be developed to integrate 3D image-based fibre microstructural parameters, patient-specific 3D geometry of tissue, and boundary conditions, in patient-specific microstructure-based disease predictors for soft tissues, which would be able to predict disease progression or mechanical stress fields in surgical anatomies, propose alternative optimal surgical procedures to alleviate stress fields, and help guide clinical decision-making for the further treatment of the patient.

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Design of smart resins for structural applications

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The growing interest in the development of composite materials arises from the need to satisfy fundamental requirements in the field of structural materials (aircrafts, ships, wind turbine blades, automotive components or electronic devices, etc.). These requirements are: a) weight reduction - to maximize the performance; b) control of pollution during the manufacturing process of the materials and their use in service; c) low consumption of fuel and resources; d) reduction of the manufacturing and operating costs (life cycle costs) etc.
The use of aeronautical thermosetting resins is still limited because of several drawbacks, such as the absence of electrical and thermal conductivity and the poor impact damage resistance (vulnerability of non-metallic materials to environmental hazards such as rain, storms, turbulence, icing, lightning, wind speed, etc.). These limitations can lead to the damage accumulation process, thus significantly compromising the integrity of the structure. An important contribution to increase the composite structural application can be achieved by designing smart materials through the implementation of the strategy of autonomous damage-repair and other specific functions integrated in the material structure.
Different innovative approaches have been considered to impart self-healing function to multifunctional resins. As an instance, for microencapsulated self-healing systems, a new ruthenium initiator for Ring-Opening Metathesis Polymerization (ROMP), which is able to tolerate reactive components, high temperatures during the curing cycles, and preserve its activity at very low concentration in combination with Diaminodiphenylsulfone (DDS) hardener, has been employed in aeronautical self-healing systems. Very recently, new relevant achievements have been obtained with different supramolecular chemistry approaches. The supramolecular systems are usually characterized by repeatable and autonomous self-healing capability, but they have been developed for applications where high mechanical performance of thermosetting resins is not required. Chemical strategies utilizing supramolecular chemistries for the design of self-healing functional materials, include dynamic covalent bonds and non-covalent interactions. Several attempts have also been made to extend these mechanisms to structural systems requiring high mechanical performance and integrated functionalities. In this context, hybrid materials or nanomaterials have been functionalized with hydrogen bonding moieties to activate self-healing mechanisms and introduce additional functionalities.
This work proposes a further successful strategy in the field of supramolecular chemistry, aimed at developing self-healing, load-bearing structures with all functionalities integrated in a single material able to meet many important industrial requirements.
In particular, the authors propose to use, as self-healing fillers, molecules having functional groups able to act as hydrogen bonding donors and acceptors at the same time, to add into a toughened epoxy resin in combination with pristine Multiwall Carbon Nanotubes (MWCNTs), with the aim to activate self-healing mechanisms and to impart electrical conductivity to the material, simultaneously.

Acknowledgements
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Development of anti/de-icing graphene-based epoxy systems

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The icing has relevant effects on the flying safety of an aircraft and the greenhouse gas emissions in the environment [1-3]. Usually, the de-icing of an aircraft is carried out through a sprayable chemical, in the case of aircraft stopped on the ground, before takeoff, or resorting to board mechanisms, specifically studied for the ice removal, which can be classified as mechanical, chemical or thermal. The latter exploits the power of engines conveying hot air from one of the turbine stages to heat the airfoil leading edges, resulting in high fuel consumption, and the increase of greenhouse gases in the Earth's atmosphere. Electro-thermal de-icing methods, at lower power, can be alternative leading technologies to contrast the adverse effect of current technologies. The employment of a heating film used as heating element among the layers of GFRCs or CFRCs used as structural materials in the production of an aircraft can be a different approach, which may fulfill requirements such as structural compatibility, flexibility, mechanical reinforcement, and adaptability in multilayered structures. In this work a system which follows this last direction, has been proposed, in particular the development of a 2D structure graphene-based films, with High-heating performance. Green processes have been employed through all preparative steps of the films. Two different grades of expanded graphite have been used for the production of heating films. The morphological and structural investigation highlight that an expanded graphite results to be composed of wider particle sizes, but characterized by thinner thicknesses, allowing to affirm that the two fillers strongly differ in their aspect ratio. The size of the graphitic blocks larger influences the electrical conductivity of samples; in fact, the film heater based on more expanded graphite presents an electrical conductivity value higher of an order of magnitude. Electrical heating analysis was carried out by applying different constant voltages at the environmental temperature of -20°C, in order to evaluate the applicability of the heater systems, considering the capacity of the generators on-board the aircraft and the large areas affected by the icing phenomenon. The system filled with the expanded graphite with a higher aspect ratio reaches higher maximum temperatures, applying the same voltage value. Finally, the de-icing tests have shown that the de-icing times are relatively low using low applied voltage values and the temperatures detected on the film are in the thermal stability range of the composite film. An increase in the voltage value allows an increase in the applied power and a consequent reduction in anti/de-icing times.

Acknowledgments
This research has been funded with support from the European Union (Horizon 2020 – G.A. EU Project 760940-MASTRO).

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Design of anti/de-icing bulk resins based on the joule heating

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Nanostructured carbon-based fillers dispersed in thermosetting matrices are able to confer them many required properties, such as anti/de-icing, lightning strike resistance and sensor properties [1-3]. This paper focuses on the design of structural resins which can be easily activated for the anti/deicing function. The possibility to integrate this function in epoxy resin makes these systems applicable in civil engineering (bridges, terraces, roofs, etc. exposed to adverse weather conditions) and in the aeronautical field. In particular, the efficiency of the Joule effect in the heating of bulk nanomaterials has been analysed for three different types of fillers : carbon nanotubes and two different grades of expanded graphite. An accurate characterization has been necessary before analyzing the properties of the nanofilled resins in order to correlate the performance of nanocomposite and the geometric and structural parameters of the used nanofillers. The morphological and structural investigations highlight that, while no relevant differences are detected in the structure of the crystalline phase of the two graphites, the aspect ratio of the fillers fall in different ranges, in particular between 1128 – 3541 for a graphite, and 286 – 984 for the second graphite. XPS investigation also highlights that the concentration of the oxygenated groups on the nanofiller surfaces is very low for the unidimensional filler (CNTs) and the expanded graphite characterized by higher aspect ratio. The aspect ratio of the filler affects the rheological behavior of the fluid formulations before the curing. The electrical and rheological data highlight a strong correlation between the electrical percolation threshold and the rheological one. The nanocomposites containing dispersed CNTs and the expanded graphite with higher aspect ratio achieve a similar electrical conductivity value (≈10-2 S/m) for a different concentration of the filler, 3% and 7% by weight for CNT and more expanded graphite respectively. The best deicing/anti-icing performance has been obtained by the resin containing MWCNTs and the more expanded graphite. For the highest value of applied power, which determines the achievement of a temperature value ranging between 88 and 109 ºC, the nature of the nanofiller affects the value of the plateau temperature. A CNT concentration of 3% wt/wt determines a nanocomposite able to achieve the temperature of 109 °C for an applied power of 8 W. A concentration of the more expanded graphite of 7% wt/wt determines the achievement of a temperature value of 98 °C. The lowest deicing performance, at the same applied power, is manifested by the nanocomposite with the 2D filler characterized by the lower aspect ratio (88 °C). In any case, the temperature of 88 °C guarantees an efficient deicing with the relevant advantage to work with very low values of viscosity during the processing steps.

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Acknowledgments
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Visualisation of Thermally Sprayed Coating Properties on the Surface of Complex Parts: Experiments & Simulations

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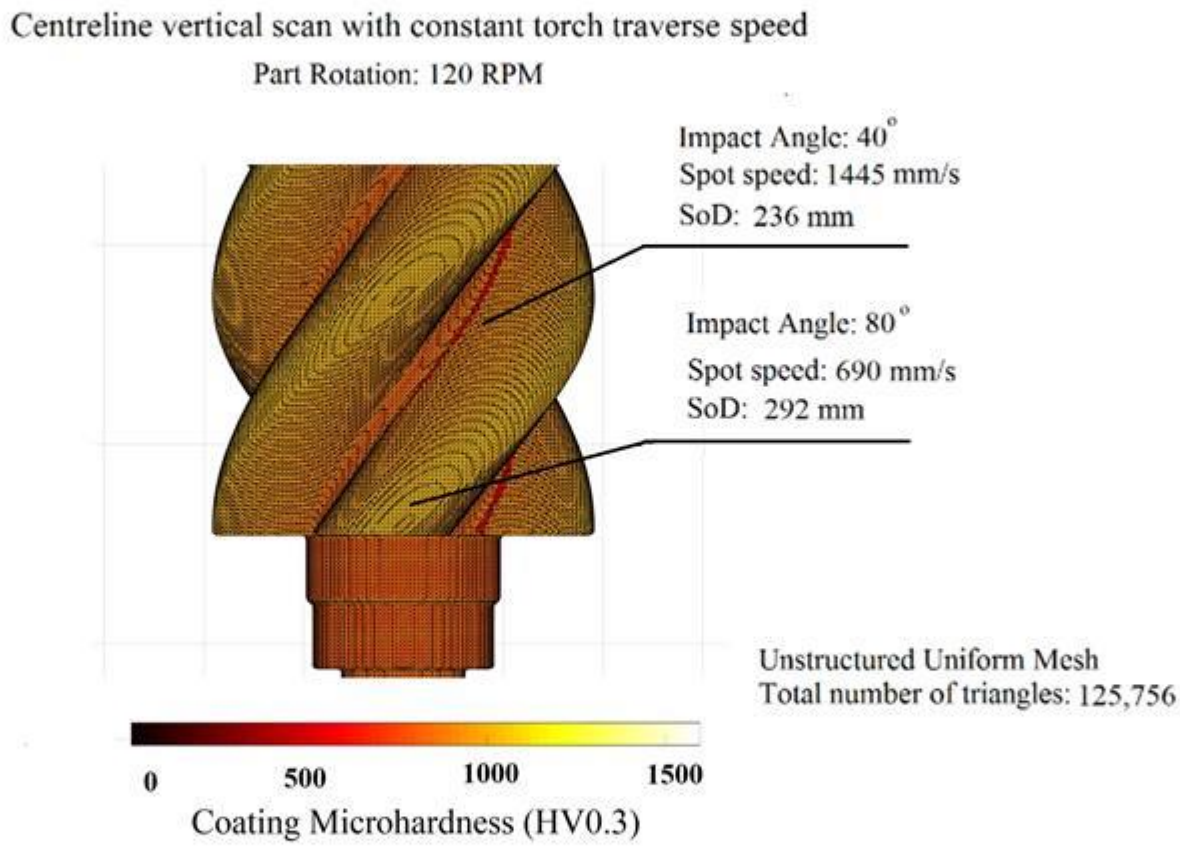
Surface engineering and advanced coatings technologies (SEAC) are employed to enhance surface properties and to add functionality to products. They are used by most industrial and manufacturing sectors and are deemed as vital to the success of their products. The last five years, SEAC technologies are under increasing pressure to support higher valued end-user manufacturing processes in increasingly competitive global markets. In this direction, despite the intense efforts, only few of the innovative materials discovered in the lab have earned their market place. More specifically, the thermal spray surface engineering sector is far from the comprehensive account of knowledge and technology transfer from the lab to real operating environments. This is mainly due to great variations in the application method of same materials, the deposition kinematic effects, the new complex part designs adopted by the original equipment manufacturers and the lack of information related to the mode of operation of the coated components. The tribological lab tests can provide the key material properties, however it is difficult to know whether the conclusions reached can be scaled up to more complex routines invoked when encountering a new coating application.
Our work aims to bridge this gap by offering a computational tool that can map the coating properties (wear rate, microhardness, thickness etc..) on the surface of any complex geometry sprayed under any possible kinematic condition. The models are derived analytically using the topological vector space theory and the coating properties are calculated from experimental data in the form of interpolated lookup tables from the deposition of HVOF WC-Co coatings under different spray conditions. In this work, the authors present the design-of-experiment approach, the experimental implementation, the tribological data, and the key software capabilities through two industrial case studies. The code has been developed in MATLAB from scratch and we anticipate that this development will allow for new coating materials and application ideas to be easily verified, communicated, and understood in a risk-free virtual environment.



Simulated coating microhardness on a complex industrial part: Oil & Gas mud rotor HVOF thermal spraying.

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Repair assessment of 3R composites using various NDE techniques and development of online SHM technologies

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Composite materials have become increasingly popular in the aeronautics industry as they have applications on numerous primary aerospace components during the last years due to their exceptional mechanical properties, such as strength to weight ratio, corrosion resistance, and the capability of manufacturing tailored structures. Beside the advantages, the anisotropic character of the structural composites involves more complex damage mechanisms than these of conventional materials.
For instance, a significant drawback of composite materials is that they are vulnerable to impacts. Impacts can cause various damage types, such as matrix cracking, delaminations between the plies and fiber breakages. These types of damage usually cannot be detected optically, as they occurred in the interior of the component. For the damage assessment, numerous Non-Destructive Evaluation techniques (NDE) can be implemented on the composites, providing crucial information about the structural integrity of the materials (i) after the manufacturing process, (ii) after mechanical loading, or (iii) simultaneously, as a Structural Health Monitoring (SHM) technique. Additionally, these techniques can also be utilized for the repair evaluation.
Many repair approaches have been studied in thermoset resins, i.e., micro-capsules, vascular networks, and intrinsic polymers [3]. The 3R resin is an innovative thermoset polymer that exploits the advantages of the thermoplastics. Over a specific temperature, the 3R resin is re-processable, repairable, and recyclable.
In this study, several NDE techniques were employed to assess the repair efficiency of the 3R composites, including IR-thermography, Electrical Resistance Change Method (ERCM), Impedance Spectroscopy, Acoustic Emission (AE), and phased array ultrasonic. These techniques were employed for the offline and the online assessment of the 3R specimens. The 3R resin was tested at (i) matrix level (Lap Shear), (ii) composite level (Double Cantilever Beam-Mode I, Interlaminar Shear Stress (ILSS), and Impact & Compression After Impact-(CAI)) and (iii) modelled level (Lap Strap). The results of the 3R specimens were compared with the conventional ones in order to assess the knockdown effect using NDE techniques. The NDE techniques were utilized to assess (i) the production quality, (ii) the damage during or after mechanical testing, and (iii) the repair efficiency.

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Knockdown effect assessment between conventional & 3R composites and their repair efficiency

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One of the most significant problem of the thermoset epoxy polymers and composites is the difficulty of the repairing. The chemical bonds that formed after the polymerization are irreversible thus, repair is problematic or even impossible. Moreover, thermoset polymers are non-recyclable, cannot be remolded or reshaped and dissolved in contrast to the thermoplastics. These properties can now be achieved thanks to a new and innovative epoxy resin which is re-processable, repairable and recyclable (3R) [1,2]. The "new" 3R composites preserve all the advantages of the conventional thermosets such as excellent mechanical properties and a minor knockdown effect. The repair takes place at specific temperature, which was 80oC above the Tg of the resin by applying heat and pressure. In this temperature, the dynamic chemical bonds of the epoxy can be reshuffled and repair resin/fiber delaminations and resin micro-cracks of the damaged part.
In this study, in order to assess the 3R technology, the fracture mechanisms of commercial and 3R-repairable epoxy polymers and composites were investigated and compared. Specifically, the knockdown effect assessment in relation to the mechanical properties was performed in several testing configurations. Initially, mechanical tests performed at matrix level using the Single Lap Shear geometry. Moreover, at composite level, ILSS and low velocity impact and compression after impact tests were achieved. At modelled structure level, the Lap Strap geometry that can simulate the stiffening of a composite panel was examined. The aforementioned tests were employed on both conventional and 3R Carbon Fiber Reinforced Polymers (CFRPs) for the knockdown effect assessment. For the evaluation of the repair efficiency, the above tests adopted before and after repair so as to estimate the ability of the 3R resin to regain its initial mechanical properties. Also, in order to examine the bonding technology, Lap Shear specimens with a 3R adhesive layer were manufactured and tested.

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Shape and Pattern in Biological System – Classifying Aortic Geometry from Clinical Data

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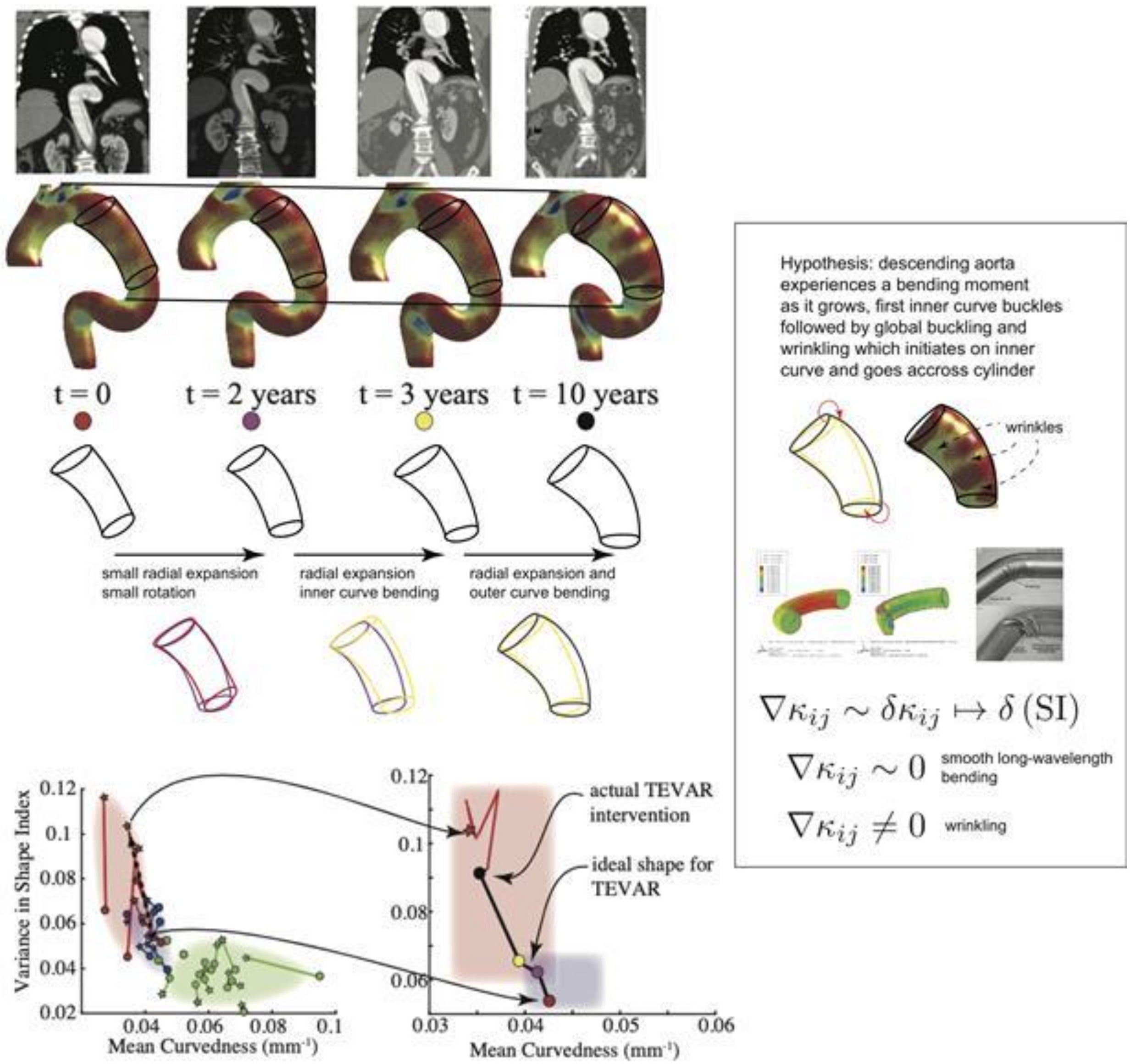
Size, in terms of a length scale, is often the dominant feature taken into account in diverse clinical problems from cancer treatment to aneurysm management. Aortic aneurysms, dilations of the largest blood vessel in the human body, are treated through surgery at a given size to prevent rupture, a catastrophic event of wall fracture that often leads to death. For any pressurized shell, the change in size over time provides information about strain and correlates to instabilities such as fracture. However aortas, normal or diseased, are not simple geometries. The established extreme linearization of aortic geometry to a single scalar measure is why aneurysm management has failed personalization, despite the immense amount of rich geometric data available from modern cross-sectional imaging. Utilizing a large data set of CTA images in longitudinally followed aortic aneurysm patients, we define their geometry by calculating local aortic wall curvatures. To allow optimal application of machine learning methodologies, the aortic geometry is mapped into a projected two-dimensional plane. An aortic feature space, the eigenaorta, is engineered using the dominant modes from a singular value decomposition analysis. This aortic eigenspace defines an optimal clustering of aneurysm patients allowing identification of high-risk geometric shape features.



Sequential CT scans of a patient with an aortic dissection. We monitor the progression of the geometry of the aortic wall in a newly defined feature space.

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Multifunctional Ceramic/Graphene Thick Coatings for New Emerging Applications

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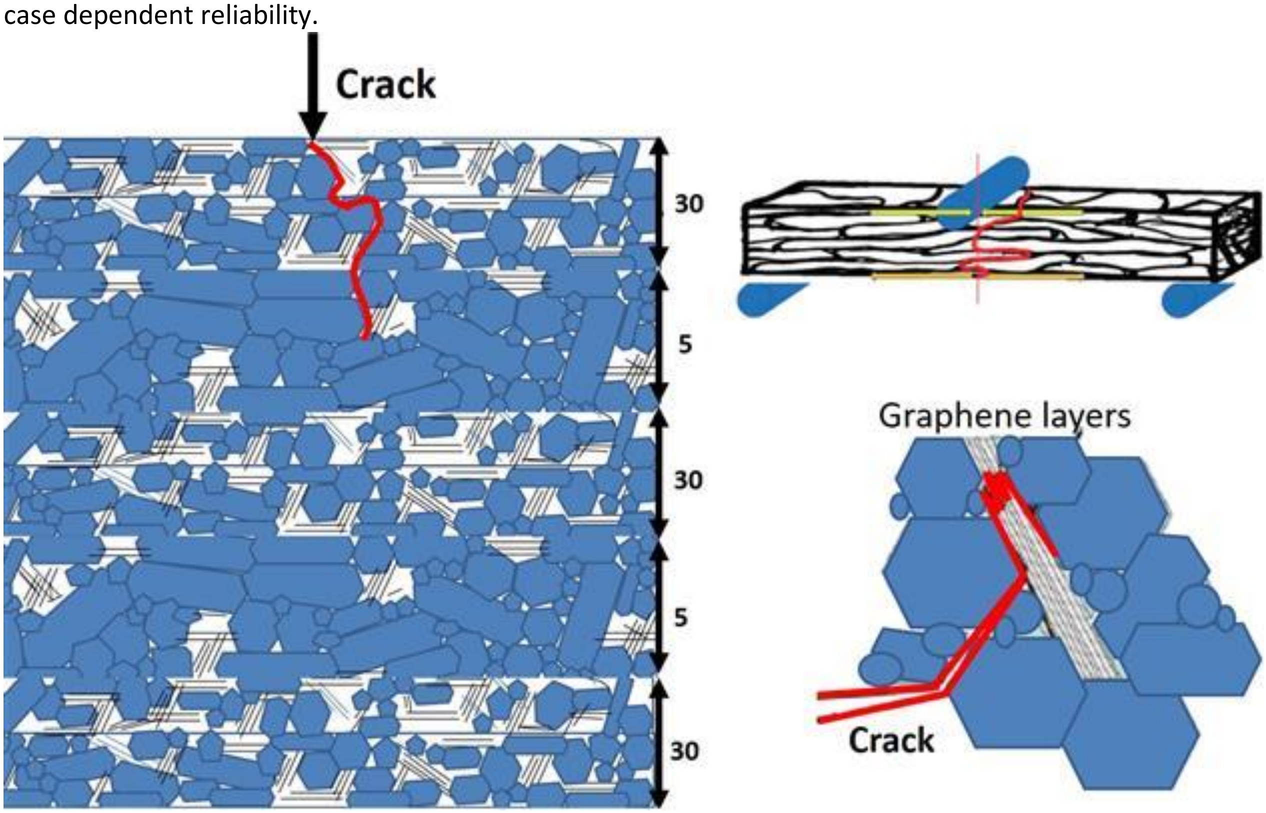
This study is focused on the development of new multifunctional conductive non-oxide multilayered ceramic/graphene thick coatings designed for electrical contacts and switches. The layered sample fabrication is realized using HIP/SPS technologies. Parameters for upscaling are defined simultaneously. Modelling of materials behaviour is done to understand the material behaviour and to identify possibilities for further optimisation and evaluation of functional properties with respect to possible applications, e.g. integrity sensors, ceramics for low cost electrical discharge machining, contacts, switches, electrically and thermally conductive ceramic parts. Since the properties of the multilayer coatings are significantly influenced by the interfaces, TEM studies are performed to characterize the interfaces and to provide input for interface engineering. The tailored materials will be used for energy technology, automotive, aerospace, railway and other transport industries as well as in electronics. The design of the multifunctional conductive non-oxide multilayered ceramic/graphene thick coatings will be adapted according to the requested use-case dependent reliability.



Crack propagation mechanism in ceramic-graphene layered composites

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Automated detection-classification of defects on photo-voltaic modules assisted by thermal drone inspection

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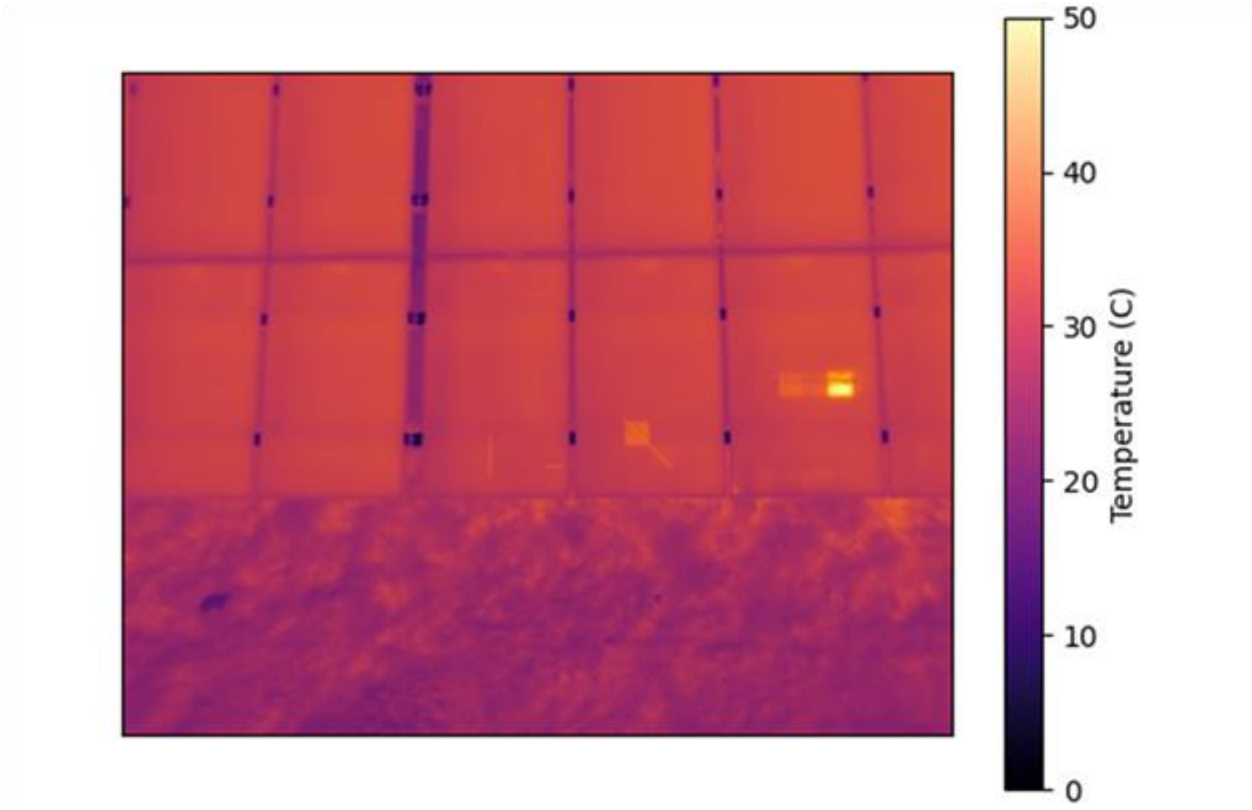
A new computational procedure is proposed for the automated detection-classification of defects on photo-voltaic (PV) modules-panels. Thermal imaging or IR thermography is an important and powerful non-destructive technique for the investigation of structural or operational defects on PV modules and when it is combined with drones can provide a fully automated inspection, detection and defect classification procedure. The aforementioned image processing approach adopts pre- and post-processing tools and methodologies assisting the infrared (IR) thermography for the evaluation of a photovoltaic (PV) module performance. In particular, the passive approach of IR thermography was adopted, a portable thermal imager was used for the in situ acquisition of images that show the distribution of infrared luminance of the PV panel surface. The acquired images are processed and analyzed for the detection and classification of defects and hot spots on the module's surface that are potential candidates for faulty operation. The proposed computational methodology adopts gaussian filters for the IR images, thresholding operations, morphological transformations and Artificial Neural Networks. The use of IR thermography assisted by Unmanned Aerial Vehicles (UAVs) - drones for the inspection of PV modules-panels proved to be a very reliable and efficient tool towards the automated detection-classification of defects.

Acknowledgment
This research has been co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship and Innovation, under the call RESEARCH – CREATE – INNOVATE (project code: PV-Auto-Scout-T1EΔK-02435)"

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Results for image 0.tiff there are| 1 |hotspots detected |Severity stage |critical fault | Possible Defect | shading |
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Results for image 3.tiff there are| 1 |hotspots detected |Severity stage |critical fault | Possible Defect | shading |
Results for image 44.tiff there are| 3 |hotspots detected |Severity stage |small fault | Possible Defect | Faulty interconnections |
Results for image 44.tiff there are| 1 |hotspots detected |Severity stage |critical fault | Possible Defect | shading |
Results for image 114.tiff there are| 0 |hotspots detected |Severity stage |-|Possible Defect | None|
Results for image 115.tiff there are| 0 |hotspots detected |Severity stage |-|Possible Defect | None|
Results for image 116.tiff there are| 0 |hotspots detected |Severity stage |-|Possible Defect | None|
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Automated detection-classification of defects on photo-voltaic modules assisted by thermal drone inspection

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Identification of defects in the eighteenth-century buildings in terms of their revitalization

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Introduction

Traditional methods of identifying defects in existing buildings may be unreliable during the condition assessment of facilities exploited over a period of several hundred years. Historic buildings are under the obligatory and official conservation protection, so decisions on their suitability for further use, methods, costs of repair and strengthening should be also made in the aspect of respecting / saving / preserving cultural heritage. Consequently, even very bad technical condition of the building or high costs of revitalization do not qualify it for shutdown or possible demolition.

Methods

Eighteenth-century residential buildings were usually built as brick structures with reinforced concrete slab-rib ceilings and also with ceilings in the form of slabs supported on steel or wooden beams. The buildings had a wooden construction of roof covered with ceramic tiles or bituminous roofing felt. Over the years, the owners of the facilities as well as the buildings utility functions have been changed. It was obviously associated with the modification of construction solutions. The buildings were devastated during shutdown and destroyed due to aggressive hostilities. The authors demonstrate the procedure of identifying the defects of the historic building on the example of two-story buildings complex of the palace back-up facilities erected in the years 1753-1755, Fig. 1.

Results

The degradation processes, identified during the tests, Fig. 2, compose in a symbolic chain of events. As a result of defects in the roof construction, structure elements like wooden roof truss, ceilings and walls of the lower storeys become damp. A humid environment causes the development of biological and chemical corrosion processes in the structure of wood and ceramic materials. These, in turn, result in the degradation of the support zones for the structural elements embedded in the wall, leading to the collapse of the ceilings. Damage of gutters, downspouts, and sheet metal work on the roof resulted in flooding of external wall surfaces, leading to destructions of external plasters on large surfaces. The uncovered structure of the brick wall was exposed to weather conditions and leaching of binder from the joints, as well as periodic freezing and loosening of material parts. Perforations of the walls without additional lintels caused cracks in the brick wall structure.

Discussion

The process of condition assessment of any historic object is an important stage in the development of engineering awareness. Exemplary aspects such as: the age of building, the degradation of the structure of construction materials over many years, the influence of an aggressive natural environment, periodic changes of water and ground conditions, previous low-quality modernizations must be taken into consideration. Regardless of existing conditions of facilities, the recognition of an object as a historic building requires its preservation and revitalization.
The results of the research, as well as conclusions regarding the methodology of identifying defects and permanent protection of historic buildings, should be disseminated during conferences and in professional and scientific publications in order to educate a group of responsible experts.

Visible defects of the facade: a), b) plaster losses and damp of the walls, c) crack in the arch, d) cracks in the wall, e) bricked up door opening

Tests of structural elements: a) opencast in the partition wall, b) opencast in the ceiling, c) borehole in the masonry

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Biomechanical testing of metaphyseal-fitting short stems in total hip arthroplasty; Digital image correlation Finite Element Modelling and Analysis Validation

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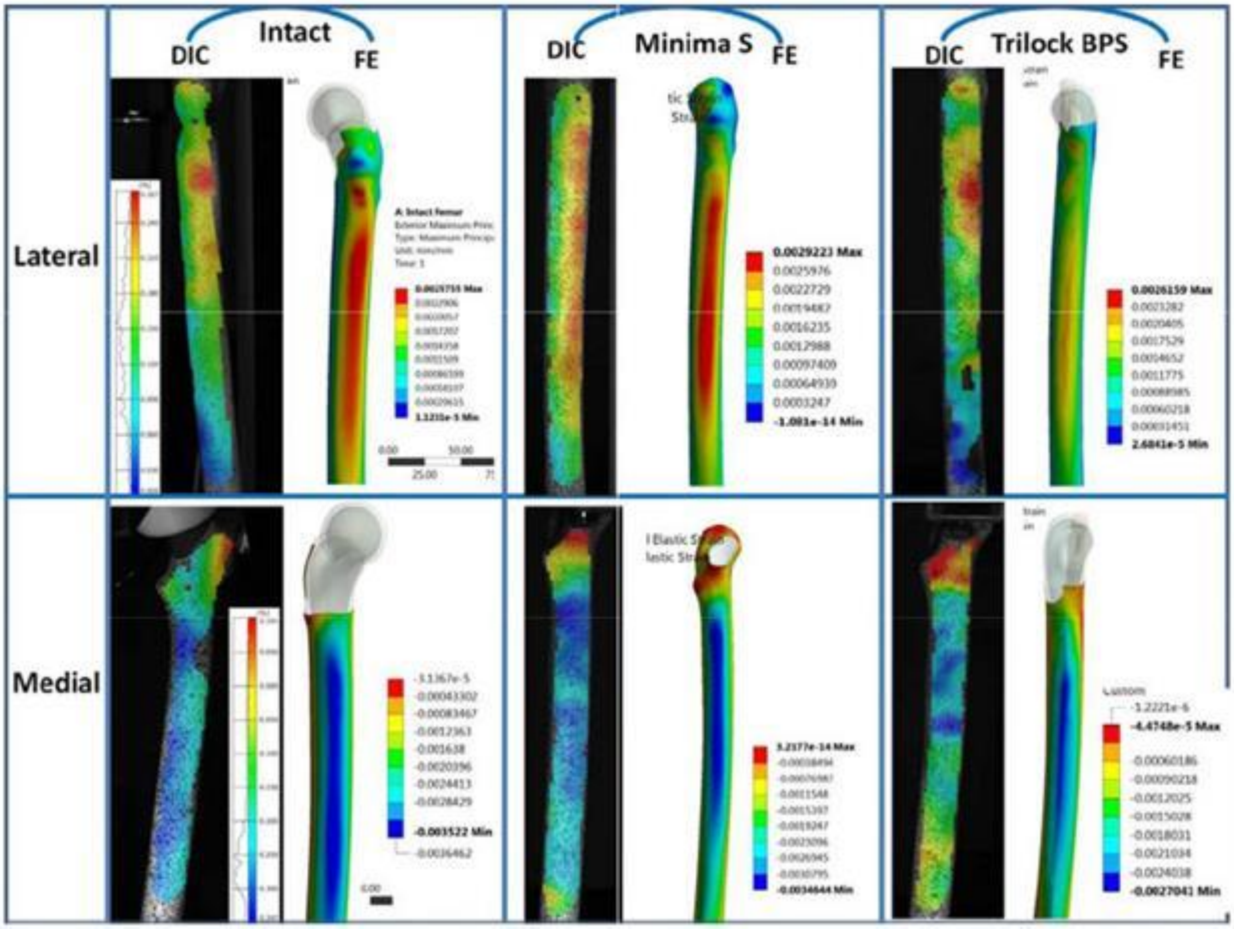
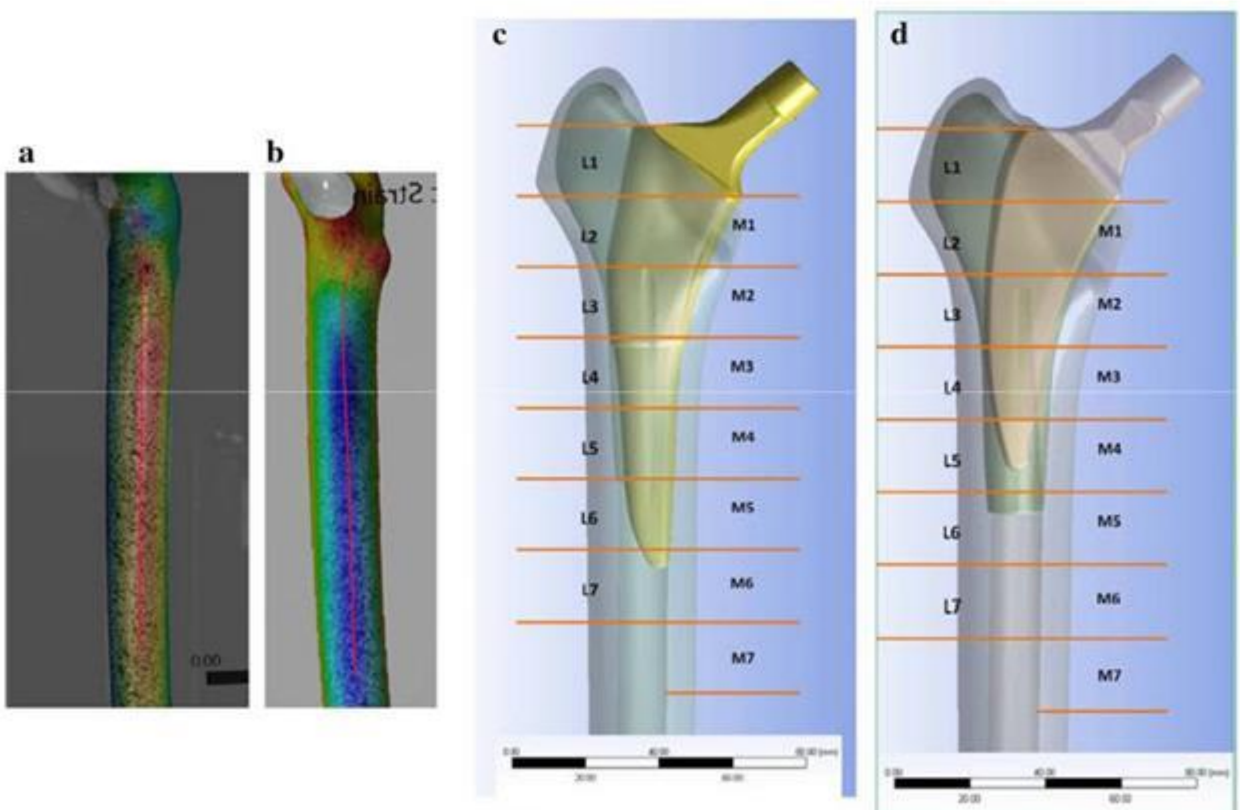
Background: The proposed study aims to investigate, through experiments and numerical simulations, the biomechanical properties of two distinctly designed metaphyseal fitting short stems, with an established performance record in short to midterm follow-up.
Materials-Methods: Cortical strain distribution was assessed via Digital Image Correlation (DIC) first on the non-implanted femur and then on implanted bones in a single-leg stance loading state. The latter configuration consisted of synthetic femurs implanted with the Tri-Lock BPS and the Minima S stem. The DIC full-field strain patterns in implanted femurs were then compared with those of the non-implanted femur. Finite element (FE) models of the implanted and non-implanted femurs were developed and evaluated for their validity against mechanical tests. The validation was performed via a direct comparison of the FE calculated strain fields with their experimental equivalents obtained using the digital image correlation technique.
Results: In the quantitative full-field stain analysis, the non-implanted femoral bone exhibited higher strain response to loading in the proximal medial area than any of the implanted femurs. A distally shifting load distribution pattern as a result of implant insertion and also an obvious decrease of strain in the medial proximal aspect of the femur was noted for both stems. At the medial femoral side, the percentage variance of strain in the Minima S implanted specimens ranged within -31.3% (P=0 .001) to +6.1% (P=0.001) compared to the non-implanted femur response while Tri-Lock BPS implanted specimens differed from the intact femur by -42.9% (P=0.00) to +1.6% (P=0.556). On the lateral aspect of the femur, a decrease in principal tensile strains was observed in the implanted femurs at almost all measurement zones compared to the intact bone. However, strain changes induced after the implantation of the Tri-Lock BPS stem at the lateral surface were more pronounced compared to the non-implanted femur response, as opposed to those exhibited by the Minima S stem. Specifically, using the intact femora as a reference, the percentage variance of measured strains in implanted femurs ranged from -12.5% (P<0.0001) to +0.3% (P=0.131) in the Minima S and from -42.2% (P<0.0001) to -7.4% (P=0.004) in the Tri-Lock BPS. Linear correlation analyses of the FE model-predicted strains against corresponding experimentally-measured strains revealed a strong correlation indicating that the developed FE models can be used for the calculation of stresses and strains at the implanted femurs.
Conclusions: The results of this study showed excellent agreement between the DIC measured and FE analysis calculated strain data, supporting DIC's potential for biomechanical FE model validation. An obvious decrease of strain in the medial proximal aspect of the femur was noted after the implantation of both short stem designs, demonstrating that proximal unloading of the femur could not be avoided even when using short stem implants. Furthermore, design differences between Tri-Lock BPS and Minima S were sufficient to produce dissimilar biomechanical behaviors, although their clinical implication must be investigated through comparative clinical studies.



DIC-measured and FE-predicted strains for each specimen in each of the two fields of view



Comparison lines depicted on the DIC prepared surfaces, superimposed by their corresponding FE fields

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Biomechanical testing and FEA of orthopaedic implants for fracture fixation

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Introduction.
Biomechanical studies of surgically treated fractures have been gaining in popularity in the past 20 years as a means to improve implant design and fabrication, and mainly, to decrease mechanical failure rates. However, unlike implant testing, biomechanical testing of instrumented bones has to overcome challenges relaying to complex bone geometries, multiple bone-implant interfaces and complex in vivo loading sequences.
Pertrochanteric fracture fixation has been an area of great interest owing to the frequency of these mostly geriatric fractures and the dire consequences in terms of morbidity, mortality and health costs of osteosynthesis failure.

Study aim.
Our aim was to define the effect of surgeon-controlled factors on the mechanical behavior of the fracture-implant system, namely the post reduction neck shaft angle and the hip screw angle of the implant used. The two most commonly used implant types were used, a cephalomedullary nail (Gamma 3 Stryker) and a plate-sliding hip screw device (DHS, DePuy) in stable and unstable fractures (AO A1 and A2).

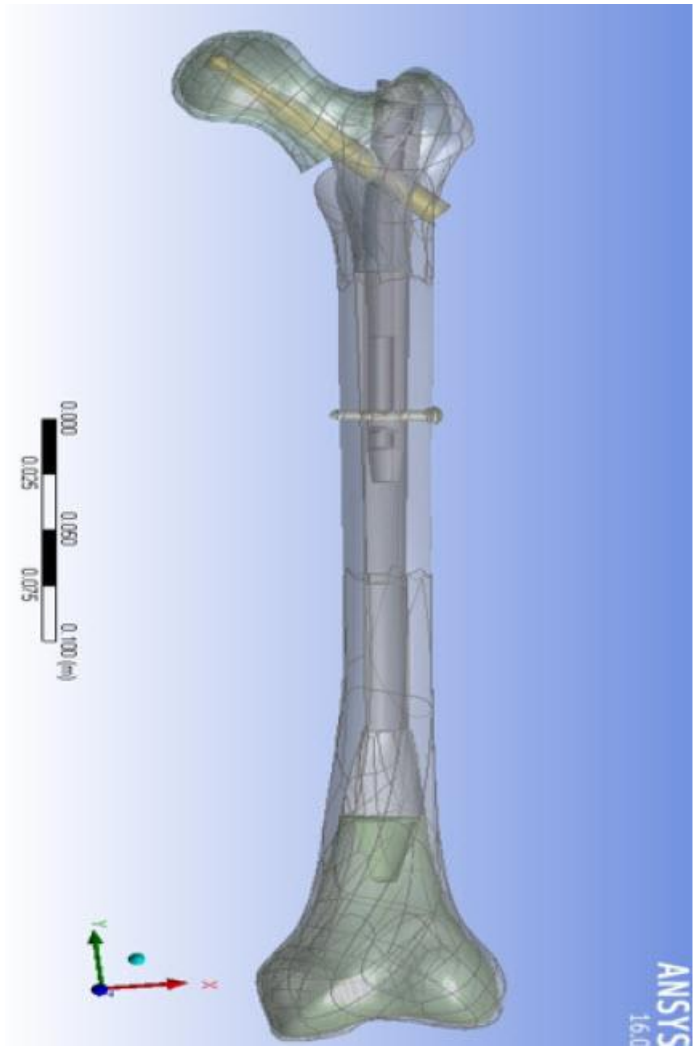
Materials and methods.
In order to create a validated FEA model mechanical testing was undertaken. We used synthetic sawbones (Sawbones, USA) because of model standardization and the availability of electronic image files. Two models were tested in static loading for each combination of implant and fracture (stable and unstable fractures with DHS and Gamma3 nail) and an intact femur. We retrieved data from the machine, strain gauges placed in areas of interest and Digital Image Correlation technique.
Consequently, the respective models were validated in FEA testing and the remaining scenaria designed and tested. The scenaria tested included a variation of fracture reduction angles and implant angles encountered in clinical practice.

Results.
In the biomechanical testing intramedullary nail osteosynthesis exhibited increased stiffness in comparison to DHS osteosynthesis in all fracture patterns. In unstable fractures the difference was more pronounced and there was a rotational element to the fragment translation. Stable fractures regardless of osteosynthesis were stiffer than unstable fractures.
In computational analysis (FEA) increasing post reduction neck-shaft angle in unstable fractures led to a significant increase in stiffness of the construct compared to anatomic and varus reduction angle in both DHS and Gamma osteosynthesis. In terms of implant angle we report increasing stiffness with increased implant angle, more pronounced in the DHS models, provided that the implant angle remained within a 5 degree range of the reduction angle. Stress distribution in the Gamma models resembled more closely that of the intact bone.

Conclusions.

Surgical technique and implant selection should be tailored to the fracture configuration and local anatomy. Based on the current data the surgeon should err on the side of increased neck-shaft and implant angle. Further testing of the hypothesis and clinical data will be required to empower the current study's recommendations.

Loading configuration in unstable trochanteric fracture



Unstable fracture finite element analysis model instrumented with Gamma3 (130/180/11).

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Bioengineering applications in Orthopaedics

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[2]*Orthopaedic Department, Patras University Hospital*

Introduction
Regenerative Medicine through bioengineering is a new frontier for medical practice. For the last 15 years there has been an enormous research on this field. The purpose of this study is to introduce the state-of-the-art methods of regenerative techniques as well as the most effective bioengineering products.
Material-Method
What makes stem cells special is that they can divide and duplicate themselves as well as develop into different types of cells. The hypothesis is that, when placed into a certain environment, stem cells can transform to meet a certain need. For example, stem cells that are placed near damaged tendon are developing into healthy tendon cells. The process of collecting stem cells is called harvesting. Physicians usually harvest stem cells from the patient's adipose tissue (fat), blood, or bone marrow. Fat can be collected through punch biopsy or liposuction. These cells are then cultivated by means of tissue bioengineering techniques, in order to produce multipotent stem cells. On the other hand, a blood sample from the patient can be used to harvest peripheral blood stem cells, which are found in the bloodstream and through special bioengineering protocols these cells are activated and primed for healing and regenerative use. Furthermore, bone marrow stem cells can be harvested from the pelvic bone or tibia using a needle and syringe. The process is called bone marrow aspiration. From then on with bioengineering methods, these cells are primed and activated for regenerative medicine techniques.
Results-Discussion
In degenerative joint disease, regenerative medicine treatments, through bioengineering process, and products are typically used to repair or replace damaged cartilage, tendon, and ligament tissues by: Amplifying the body's natural healing abilities, Enhancing the growth of new tendons, ligaments, or cartilage tissue. The goal is to reduce pain and improve function. There are three types of Regenerative Medicine Treatments enhanced by bioengineering: 1. Stem Cell Treatments, 2. Platelet Rich Plasma (PRP), 3. Operative Procedures for Cartilage Regeneration. Different techniques may be used for cartilage repair, including but not limited to microfractures, nanofractures or abrasions in the bone directly below the cartilage injury, implanting engineered tissue made from stem cells together with a bioengineered scaffold—a sort of microscopic netting that holds the cells until they mature and grow. The results of these procedures lead to promising combinations with proper rehabilitation protocols-always individualized.
Conclusion
Regenerative medicine through bioengineering, is a golden standard for musculoskeletal lesions treatment and can easily be used together with traditional nonsurgical treatments, such as rest, bracing, taping, and/or physical therapy to improve flexibility, strength and to optimize healing. Regenerative medicine is not limited to treating degenerative musculoskeletal conditions only. For example, tissue engineering allows skin tissue to be created for burn victims. Other applications, such as developing artificial organs, are being researched.

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Modelling and analysis of undulations and their influence on fiber-parallel compressive strength in unidirectional fiber-reinforced composites

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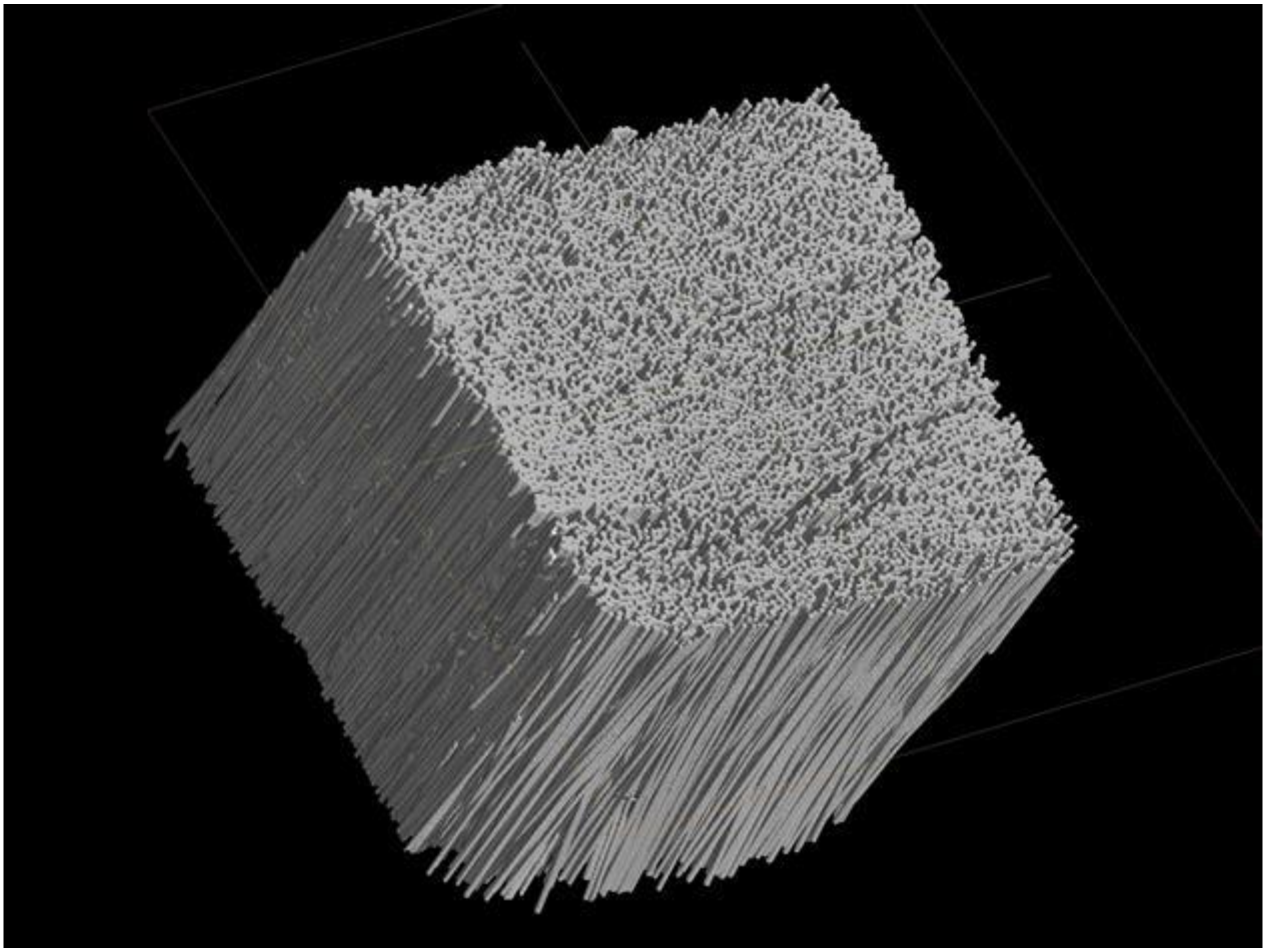
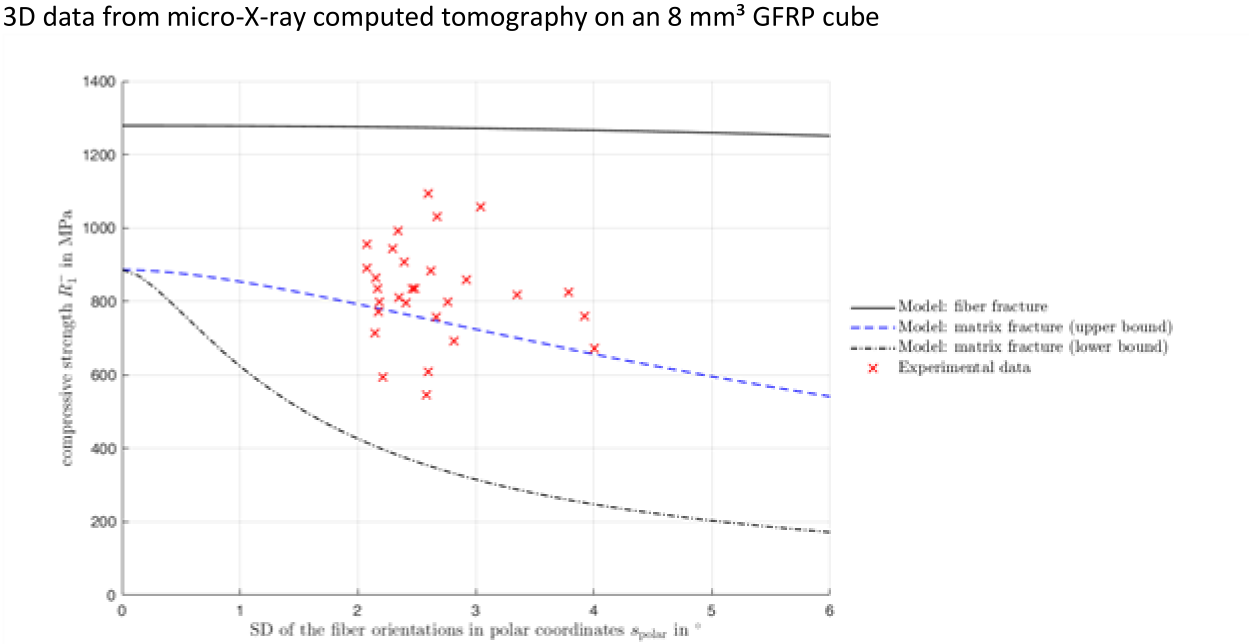
Fiber orientations represent one of the most important microstructural properties of fiber reinforced composites. Although they significantly influence the mechanical material behaviour as well as the damage development, varying fiber orientations have hardly been considered in micromechanical models for continuous fiber-reinforced plastic composites (FRP) so far.
This presentation focuses on the study of the influence of undulations on the fiber-parallel compressive strength of unidirectional continuous FRP. In this work, undulations are described using stochastic fiber orientation distributions (FOD) to give a probabilistic evaluation of the orientations of fibers in FRP. Based on this approach, a micromechanical material model was developed to calculate the undulation-related mechanical material properties and to analyse the influences of the fiber misorientations. This model shows a strong dependence of the fiber-parallel compressive strength on the extent of undulations. This correlation was investigated experimentally on normalized compression specimens and by means of X-ray computed tomography to validate the model.
To determine the influence of the undulations, normalized compression specimen from a unidirectional glass-fiber epoxy composite were analysed by micro-X-ray computed tomography (µCT) and then mechanically tested. This procedure allows direct comparison of the experimental results with the individual predictions of the model, considering the internal structure of each sample. To determine the fiber orientation distributions of each sample, the data from the µCT scans were analysed using the open-source image analysis software IMAGEJ.
In this presentation, the procedure for determining the fiber orientation distributions using the µCT scans and IMAGEJ software is described, and the accuracy of the methods is evaluated. Subsequently, the results of the mechanical compression tests are presented and the influence of the undulations on the fiber-parallel compressive strength is shown. The experimental results are then compared with the predictions of the analytical stochastic material model and discussed. Finally, an outlook on further investigations and material tests to validate the model is given and possible applications for the material model are discussed.



3D data from micro-X-ray computed tomography on an 8 mm^3 GFRP cube



Representation of longitudinal compressive strength as a function of the fiber orientation distribution: comparison between model prediction (with fiber volume fraction of 56%) and experimental data

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Grubbs-type catalysts at molecular level in self-healing epoxy resins for aerospace applications

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Self-healing materials are currently being considered for real engineering applications in the field of structural materials. The first self-healing system for thermosetting resins was proposed by White et al1. It consists of incorporating a microencapsulated healing agent and a ruthenium catalyst (Grubbs first generation catalyst, GI, at 5% by weight) within an epoxy matrix. An approaching crack ruptures embedded microcapsules releasing the healing agent into the crack plane through capillary action. Polymerization, through Ring Opening Metathesis Polymerization (ROMP), of the healing agent is triggered by contact with the embedded catalyst, bonding the crack faces.
In order to transfer this system for aeronautical applications, some critical points have been addressed: stability of the liquid phase of the monomer between -50 °C and 180 °C2; resistance of the microcapsules to the conditions of cure of the resin (180 °C)2; ruthenium catalyst stability between -50 °C (temperature reached in flight) and 180 °C and the reduction of its quantity in the matrix. Our research has overcome the various critical points. In particular, different strategies have been development to reduce the amount of ruthenium catalyst in the self-healing system:
1- some ruthenium commercial catalysts dispersed in powder in the epoxy matrix3 were used;
2- Hoveyda-Grubbs first and second generation catalysts, HGI and HGII, solubilized in the epoxy matrix2;
3- functionalization of carbon filler with ruthenium catalysts dispersed in the epoxy matrix4;
4- protection of the catalyst by means of a suitable shield5;
5- synthesis of new stable ruthenium complex solubilized in the epoxy matrix6.
All these systems have made it possible to get closer and closer to solving the problem, and the last solution has made it possible to achieve the set goal: to have a stable and active catalyst in the required temperature range and to use a modest quantity of it because it can be dispersed at molecular level in the composite material.

Refereces

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Thermomechanical Simulation of SLM process for Prediction of Residual Stress and Distortion Fields

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Selective Laser Melting (SLM) metal Additive Manufacturing (AM) process utilises a laser beam to selectively melt metal powder on a substrate to fabricate a layer-by-layer part with a desired shape. SLM technique offers superior design freedom, reproducibility and dimensional accuracy for part production [1]. For these reasons, SLM process has attracted the interest of research and industrial communities. One the challenges to the wide adoption of the technology for the fabrication of reliable and safe critical parts are process-induced residual stress and distortion fields. Residual stresses are inherent to thermal manufacturing processes such as AM processes and SLM parts are susceptible to build defects and failure associated with residual stresses during their fabrication [2]. Therefore, the prediction of residual stresses and distortions of an SLM part is critical to ensure the quality and the performance of a part.

In the present work, the development of a numerical modelling technique for the prediction of residual stresses and distortions of SLM fabricated parts is presented. A coupled thermo-mechanical analysis is utilized to simulate the building conditions of the SLM process. Most of the process parameters that significantly affect the thermal conditions are used as input parameters in the modelling method. The well-known element birth and death technique is utilized to simulate the layer addition during the SLM process [3]. To efficient simulate the process many layers are appropriately lumped to a larger one. Every lumped layer is gradually set to the melting temperature of the metal powder material to reproduce the temperature field during the SLM process. Consequently, the estimated thermal fields are imported into the mechanical model as predefined fields. Temperatures are automatically mapped between thermal and structural analyses and the thermal expansion drives the deformation of the building part. The residual stresses and distortions of the building part are estimated at the end of the analysis on each lumped layer and on the substrate. The numerical modelling approach is implemented on ANSYS Additive Systems Simulation package.

To test the accuracy of the proposed SLM numerical modelling methodology, comparisons with available experimental results was performed [4]. The comparison between numerical and experimental results successfully validated the numerical modelling method, making it a suitable and efficient modelling strategy for the simulation of SLM parts, towards the estimation of the level of residual stresses and distortions.

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Progressive Failure Analysis of Laminated Fiber Reinforced Composite Materials

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Laminated fiber reinforced composite materials have been increasingly used in applications of aeronautics, aerospace and automotive industry over the past decades. The growing use of composite materials is mainly due to their inherent advantages such as high specific stiffness and strength, high strength-to-weight ratio and superior corrosion resistance compared to traditional materials, such as steel and aluminium [1]. In order to take full advantage of the laminated composite materials properties, reliable numerical models must be developed for the prediction of their strength and damage accumulations. Composite materials can accumulate damage before their collapse and the use of failure criteria is not sufficient enough to estimate the ultimate structural failure. For this reason, the progressive failure analysis is more suitable for the prediction of the mechanical behavior of laminates under various loading conditions [2].
In the present work, the development of a modelling methodology for the progressive failure analysis of composite parts is presented. The developed progressive failure analysis methodology can be utilized for the simulation of composite structures under various loading conditions and the accurate prediction of their strength. The present progressive failure analysis simulates the damage initiation and evolution in conjugation with stiffness reduction [2]. In order to model the stiffness degradation, an instantaneous degradation factor is utilized when the failure criteria are met. Hashin failure criteria are utilized in the present progressive failure analysis. The value of degradation factor is appropriately selected, such that it accounts for the effect of residual stiffness of the lamina. This adjustment accounts for the nonlinearity associated with material damage. As the applied load increases, the degradation of the stiffness continues and the damage of laminate expands, until the final failure. The final failure is identified at the load level at which static equilibrium cannot be fulfilled [3]. The reliability of present modelling methodology was tested for the prediction of the mechanical behavior and strength of an open hole composite specimen subjected to tension. For the discretization of the open hole coupon, shell elements were utilized in order to make the analysis more efficient.
The results of the proposed progressive failure model were compared with experimental test results published in the open literature [4]. The good correlation between numerical and experimental results confirms the validity of the modelling approach. Future modelling efforts will try to further improve the prediction capability of progressive failure analysis and to utilize the methodology for the simulation of various loading conditions.

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Putting Stiffness where it's needed: Optimizing the Mechanical Response of Multi-Material Structures

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Modern manufacturing processes like multi-material additive manufacturing or, to a lesser degree, compound casting, allow almost arbitrary distribution of different materials, or, for that matter, different levels of local density, over a component's volume. The difficulty lies in determining the optimum spatial material distribution. Multi-Phase Topology Optimization (MPTO) is one approach towards this end. This method relies on iterative, linear-elastic FEM simulations which provide element- as well as part-level data on elastic strain energy. Information of this kind is used to redistribute multiple predefined material fractions, which are characterized by different values of Young's modulus, according to their relative properties in order to minimize the total strain energy under a given design load. Solving such a minimization problem is the central part of this work. Achieving this aim means that a configuration has been identified which provides maximum stiffness under the conditions of the assumed load case. This said, the present study compares different material redistribution and optimization techniques based on genetic algorithms and simulated annealing and compares them in terms of their optimization results, applicability, relative performance and scalability. Specifically, unconstrained (randomized) model-free approaches using Monte Carlo methods are contrasted to others incorporating physically or technically justified constraints limiting the configuration space during the re-association of materials properties to the individual finite elements. Typically, such minimization problems deliver a set of solutions. In doing so, iterative minimization algorithms tend to settle into local, non-optimum minimum states. Evolutionary algorithms as well as simulated annealing employ partial randomization for the generation of new configurations, a key methodology to explore a much larger volume fraction of the full search space than accessed by classical gradient-based algorithms. A major difference between these two methods is that in contrast to simulated annealing, genetic algorithms construct new material configurations from previous solutions via operations such as crossover and mutation. The cost functions used by both approaches depend on FEM simulation, a computationally intensive task. To minimize the required number of cost function calculations and thus FEM simulation runs, approximative caching as well as configuration pre-analysis and selection using constraint models are introduced. The methodology is initially validated based on a simulated three point bending test. The cuboid sample is composed of matching amounts of three different materials. Evaluation of the optimization algorithms is based on the improvement in stiffness achieved and the number or iterations required.

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Cr free chemical stripping of anodic layers formed on aluminium alloys used in aerospace

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The use of Cr(VI) will be banned by 2024 by regulations such as REACH. This affect both surface treatment for coating metallic parts and repair and maintenance process. The solutions currently in use for oxide layers are acid based containing Cr(VI) and NaOH as Cr free alternative. The stripping of oxide layers needs to be done with Cr free solutions and for the moment there are no market available solutions to perform this task, assuring at the same time same performance for the coating after re-treatment process.
Pre-treatment of aluminium substrates (2024 and 7075) was done with an alkaline cleaner followed by acid etching. In order to produce the oxide layer the Al substrates were anodized using a Cr free process (SAA) and a Cr(VI) process (CAA).
Stripping of the Al oxide layers was performed using state of the art and commercially available solutions for other applications, that were not yet tested as stripping solutions. Surface morphology of anodized aluminium alloys was investigated by mean of scanning electron microscopy (SEM with EDX) before and after the stripping process. Cross-section investigations of the samples after stripping process were performed using focused ion beam (FIB) in order to quantify the oxide layer removal and its uniformity. Stripping solution temperature and stripping time were tailor to investigate their effect on oxide layer removal. For short stripping time (few minutes), oxide layer is not or just partially removed from the surface. For long stripping time (e.g. 1 hour - solution dependent) a total removal of the anodic layer is achieved, and the aluminium surface is damaged. Samples weight loss as a function of the stripping time was evaluated. Raman spectroscopy was used for detection of Cr on the samples surface after stripping step. Comparison of the commercially available solution with the classical Cr(VI) based solutions regarding their performance on uniform removal of oxide layers without damaging the Al substrates was done.

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Fatigue behaviour of a spring: a case study

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Due to time dependent damage, as in the cases of corrosion, creep, fatigue or combinations thereof, the prediction of the durability of a component or structure is crucial in many engineering applications. In particular, fatigue damage occurs in materials subjected to cyclic loads and eventually leads to rupture. Fatigue is therefore a key consideration in the design of structures as aircraft, metallic bridges, ships, or elements of machines as the spring analyzed in this case study.

In this communication a real case study is presented and discussed. A procedure assisted by the finite element method was used to study a U spring made of steel with 650 MPa ultimate tensile strength. For a given geometry of the component, the question was to predict the maximum permissible displacement per cycle whilst ensuring a service life of at least 260 kcycles.

The spring behaviour was modelled using the finite elements software SolidWorks®, leading to the numerical calculation of the spring stiffness, i.e. ratio force / displacement. As an approximation a linear model was used in the finite elements analysis, which was also compared with an analytical treatment based on Castigliano's theorem.

Using a given safety factor, a high cycle fatigue (HCF) fatigue analysis was performed to evaluate the maximum displacement per cycle compatible with the intended service life of 260 kcycles. The spring is either loaded by an imposed displacement, or it is load free. Therefore, the load ratio R (defined as the ratio minimum load / maximum load per cycle), is null in the present real case. An algorithm based on finite fatigue life prediction techniques, the Basquin and Goodman diagrams, and the relationship between ultimate tensile strength and fatigue limit was used and will be briefly presented and discussed. Although the calculation was performed for steady cyclic loading with constant load range and R ratio, the analyses are easily extended to variable amplitude loading. Also, the stress analysis helped to highlight the need for some minor geometry changes.

The outcome of the study was the evaluation of the maximum permissible displacement per cycle, as required in the real life case addressed.

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Multiaxial cyclic deformation and life-prediction models for super-elastic NiTi shape memory alloys

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NiTi shape memory alloys (SMAs) have extensive potential applications in aeronautics and astronautics fields owing to their superelasticity and shape memory properties. The components and structures made by SMAs usually endure complex repeat loadings in applications, leading to cyclic deformation and fatigue failure are key issues that should be taken into consideration. Meanwhile, the unique deformation behaviors of SMAs usually result in relatively great deviations in the predictions of fatigue failure by using the classical fatigue models, especially for the multiaxial loadings. Thus, in this paper, two new models which can give predictions on the residual strains during the non-proportional cyclic loadings and their fatigue lives are proposed. The results show that the predicted residual strains fit well with the experimental ones, and the fatigue lives are all in the twice error bands.

Bioinspired Cementitious-Polymer Composite for Increased Energy Absorption

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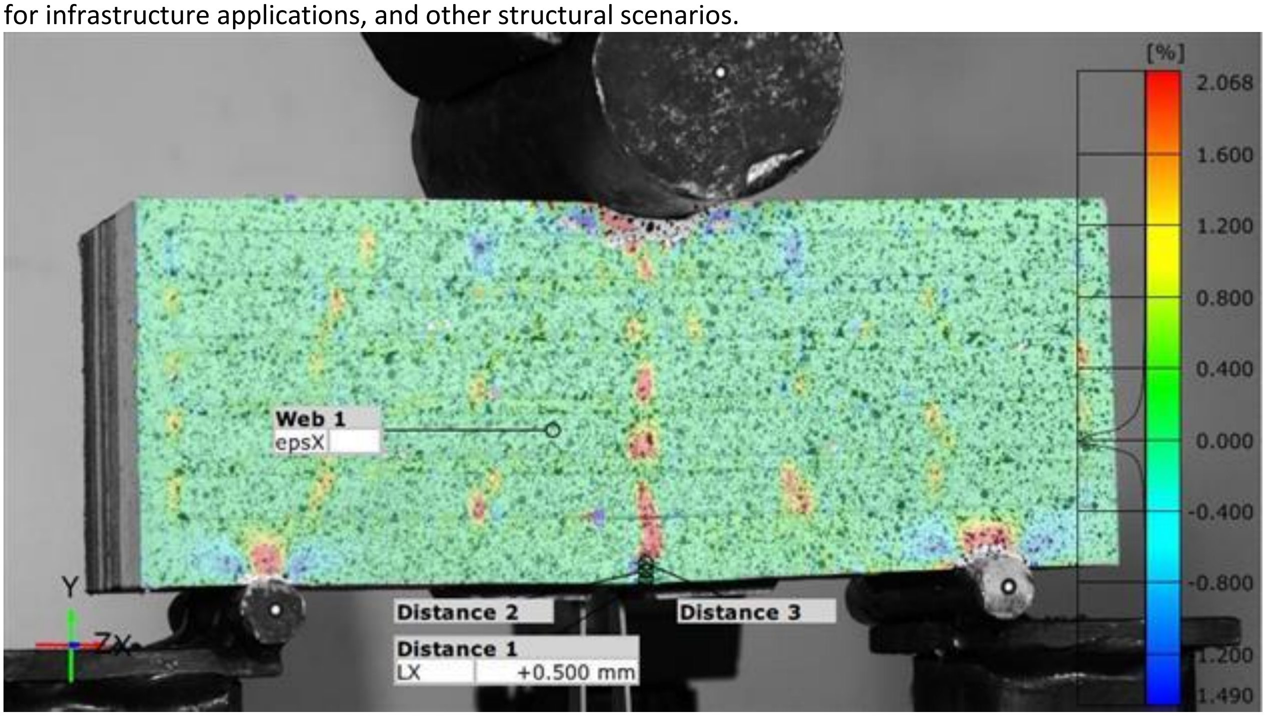
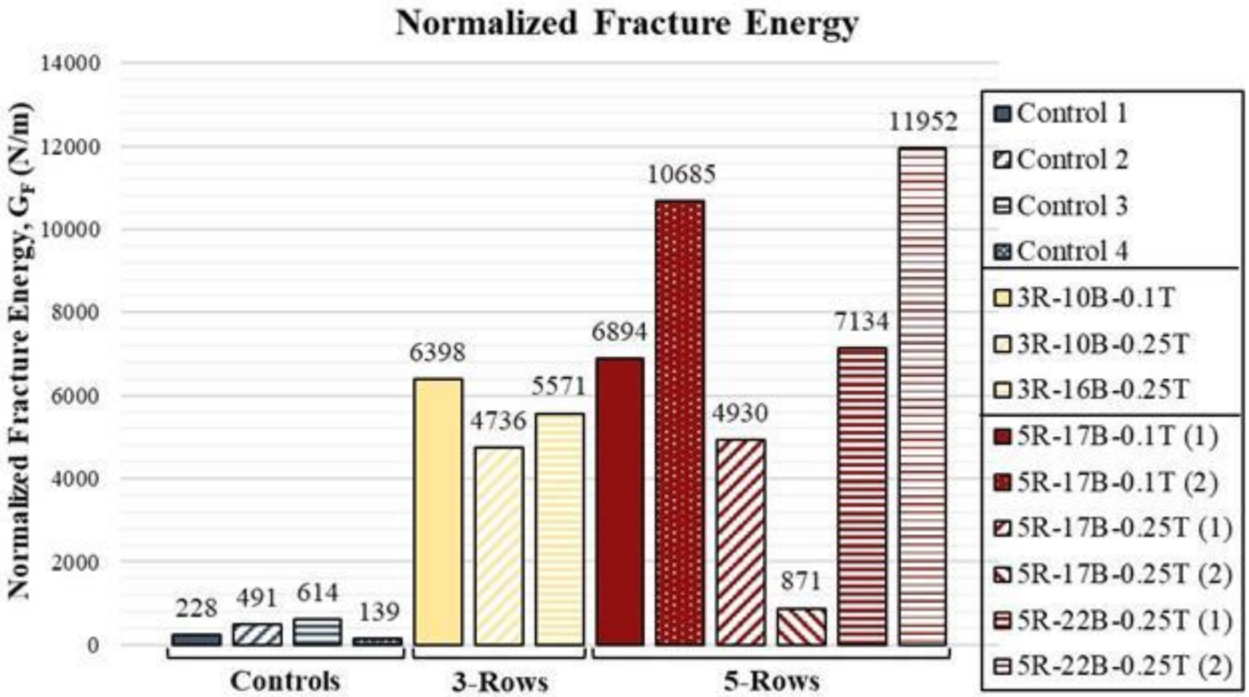
Preliminary results are presented on the energy absorbing characteristics of an innovative bioinspired cementitious-polymer architecture for ballistic impact resistance. Nacre, an organic-inorganic composite found in mollusk shells, provides natural protection against predatory penetrating impacts. The proposed bioinspired architecture consists of an open cell, platelet-shaped 3D-printed thermoplastic lattice filled with high-performance cementitious paste. This bioinspired architecture, designed to mimic the hierarchical "brick-and-mortar" arrangement of brittle aragonite platelets interpenetrating a soft organic matrix found in nacreous organisms, promises substantial enhancements in fracture energy compared against the bulk cementitious material alone. Initial laboratory-scale investigations were performed using notched beam samples constructed with the proposed bioinspired architecture and subjected to static three-point bending. Stereo-digital image correlation was used to track localized strains and Hillerborg's method was used to estimate the total fracture energy according to the crack mouth opening displacement. Data will be presented on the effects of the polymer lattice geometry (e.g., size of cementitious platelets, degree of platelet overlap, and thickness of the polymer between the cementitious platelets).

The results presented herein will be beneficial to an audience interested in protective design, materials science, and structural engineering in that a novel view of ballistic impact resistance is formulated by taking inspiration from nature. The data will demonstrate how an innovative bioinspired architecture can inform structural engineering across multiple length scales, presented here at the laboratory scale but future work will be discussed at a larger scale. While discussed here with an application to energy absorbing characteristics, future applications can consider blast resistance in panels or beams, improved fatigue life for infrastructure applications, and other structural scenarios.



A cementitious-polymer composite beam under 3-point bending. The image is overlaid with the localized strains computed from digital image correlation.



Normalized fracture energy from various replicate tests of cementitious-polymer composite beams relative to a control.

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Impedance spectroscopy as a tool for monitoring the properties in cementitious nancomposite materials with advanced functionalities

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The research of new materials in the construction industry is focusing on the development of a new generation of smart materials. Materials that would provide properties that will meet the high standards of modern buildings. Part of this research is focused on the use nanomaterials with high conductivity such as carbon nanotubes (CNTs) as additives in cementitious composite matrices, towards cement-based nanoreinforced composite materials for multifunctional purposes. The physico-mechanical properties of cement-based composite materials depend on a variety of factors such as the water-to-cement ratio, the amount of the nanofiller, admixture procedure etc. All these factors affect the evolution of the hydration process which is a process of major importance in the manufacturing of nanoreinforced cement-based composites. The stages of the hydration process can be effectively monitored by the non-destructive technique of Electrochemical Impedance Spectroscopy (EIS). Another crucial step in the manufacturing of nanoreinforced cement-based composites with multifunctional properties is the control of the components that provide the conductive behavior, the CNTs in the current study. EIS can also play a vital role in this case for the online monitoring of the dispersion of CNTs in the selected solution medium providing information for the formation of a conductive path which can then be integrated in the cement matrix.
In this research Impedance Spectroscopy was used to monitoring the changes in the dispersion of CNTs in deionized water. The dispersions contain different concentrations of CNTs by cement weight. Every 30min of the sonication an EIS measurement was performed to detect the formation of a conductive path. The results of the magnitude of |Z| as a function of frequency showed a dramatical change which may be regarded as an indication of the formation of a conductive path. Impedance Spectroscopy was also used to monitoring the hydration process of cement nanocomposites. It is particularly interesting that the values of |Z| are lower in relation to the cement reference as the concentration of the CNTs in the composite increases. The changes of the magnitude of |Z| as the hydration process progresses demonstrate the existence of a conductive network from the CNTs.

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Development and validation of a cohesive zone-based numerical methodology for delamination prediction in laminated composite structures

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The use of fibre-reinforced materials is increasingly growing in a wide range of applications, where the inherent advantages of composites are required for the development of lightweight structures that should exhibit high stiffness, increased strength and fatigue resistance characteristics. Despite their important advantages compared to conventional metallic materials, laminated composites present specific limitations which should be overcome to enable their extensive acceptance throughout different engineering sectors. The most significant among the restrictive characteristics of composite laminates is related to their reduced resistance to out-of-plane loads, which often results to separation along the interface of neighbouring plies. This failure phenomenon, which is widely known as delamination, may appear under different manufacturing and loading conditions. It significantly affects the stiffness of the laminate and could be a risk for the load-bearing capacity of a structural component.
Delamination may be considered as a crack that propagates through the matrix of a laminate. Three separate fracture modes are usually utilized to describe the complex phenomena that arise at the region of the crack tip, namely Mode-I, Mode-II and Mode-III. The interlaminar fracture toughness that corresponds to each of the fracture modes is crucial for delamination prediction. The primary experimental approaches used for fracture toughness evaluation are the Double-Cantilever Beam test (DCB), the End-Notched Flexure test and the Edge Crack Torsion test.
Several approaches for numerical prediction of delamination are based on a Fracture Mechanics foundation. Among the different numerical models that have been proposed for delamination prediction, the Cohesive Zone Model has been extensively applied due to the accuracy and efficiency it presents. However, definition of all parameters that are relevant to delamination initiation and propagation is an intricate task that requires extensive investigation, in order to establish a reliable numerical prediction. In the present work, a strategy based on finite element analysis is developed for the simulation of laminated composites, with emphasis on interlaminar damage prediction. Three different modelling techniques are used for simulation of a laminate's layers, namely solid element, shell element and a joint solid/shell element modelling approach. The delamination initiation and propagation interface is simulated using two distinct methods: one refers to the use of 3D-solid cohesive elements for modelling of the resin-rich matrix interface, while the other approaches the simulation of the crack propagation area through the application of a suitable contact interface with cohesive zone modelling characteristics. The prediction capabilities of the developed methodology are validated through comparison of numerical results to corresponding experimental data of a Mode-I DCB experimental campaign. The accuracy and computational efficiency of the different modelling methods is thoroughly investigated and evaluated, with emphasis on the future application of the developed methodology to medium and large-scale structures.

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Certification challenge for self-responsive materials in aeronautics

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Innovation and continuous development of cutting-edge materials find robust interest of companies for using avantgarde technologies. Material research is widening toward mainly two directions: the improvement of the existing functionalities and the development of new functionalities of the materials. However, widespread applicability of materials with new functionalities and their marketing requires also efforts towards the creation and implementation of technical standards and measurement techniques. Standardization is an important stage in the development of any new material and it is based on the consensus of stakeholders including end users, businesses, standards organizations and governments.
The main function of standards is to define the qualities and technical properties of a material to ensure consistency across different manufacturers and industries. It is important to assure that a product is genuine, safe and will perform in the way it is expected. For new materials standardization will also enable easier communication between producers and consumers.
In this context, the current paper shows the activities performed within MASTRO Project – H2020, focusing on the possible strategies to reach the standardization of innovative materials in aeronautic field. In MASTRO Project self-healing, de-icing, self-sensing and self-curing materials, obtained using nanocomposite technologies, have been widely studied and tested to understand their usability in a significant environment. The purpose of the standardization activity in MASTRO project is to explore the possibility of transferring the results of research into one or more standards. The first step is to understand the research results which have not necessarily a need to be transposed into standards, and those that potentially will provide valuable support to new or existing standards through, for example, the validation of test methods or product and /or process.
The second part of this activity was the identification of needs and opportunities for standardization in the eventuality partners have developed specific procedure or protocol to overcome particular issues, which were not reported in literature. Generally, in this process the applicability of the possible standard to other bodies (research groups both academic and from industries) was considered. The use of some innovative functionalities developed in MASTRO project, such as those related to self-healing materials, has not been yet regulated with any of the available standards. For these materials, standardization need and opportunities have been identified in order to enable their widespread use. The preparation of a New Work Item Proposal on this kind of functionalities (with all relevant documentation that can help for the procedure) is in progress.
Figure 1 shows the followed approach and the applied strategy to rationalize data regarding available standard, standard needs and opportunities of the developed materials for the evaluation of possible Standardization Processes. The used algorithm for the rationalization of the information is based on the readiness level of the technology and on the relevance to improve the safety of the material.

Strategy for standardization of Innovative Materials in MASTRO Project

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Patient specific implants and 3-D printing in Orthopaedics

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Introduction
Three-dimensional printing technology has revolutionized orthopedic clinical practice. Applications of 3D technology include preoperative planning, surgical simulation and patient-specific instrumentation (PSI). Customized 3D printed implants have been used mainly in reconstruction surgery, in orthopedic oncology after tumor resection and limb salvage surgery and in complex trauma cases.

Materials-Methods
In our Department 3D printed custom made implants have been used in 11 patients for limb salvage surgery with bone sarcomas (9 patients), for internal stabilization after curettage of a benign bone tumor (1 patients) and in one difficult trauma case with osseous void (1 patient).
Two patients (a 16-year-old male and a 46-year-old female) with Ewing's sarcoma of the calcaneus were treated with foot salvage. After en bloc resection of the calcaneous custom 3D made endoprostheses were inserted.
A 30-year-old woman with a Ewing's sarcoma of the talus underwent total talectomy and replacement of the entire talus with a custom made 3-dimensional printed talar prosthesis. Total scapulectomy and shoulder reconstruction using a 3D scapular prosthesis and constrained reverse shoulder arthroplasty have been used in 6 patients with bone sarcomas of the scapula after Malawer type III and IV shoulder girdle resections.
A 3D printed calcaneus implant have been used in a patient with extensive bone loss of the calcaneous, due to a complex open type IIIB fracture.
Finally, a male 26 years old with monostotic fibrous dysplasia of the proximal radius with progressive radial cortex expansion and thinning was treated with curettage, bone graft substitute and stabilization with a 3D-printed proximal radial plate.

Results
The postoperative course was uneventful for the patients with Ewing's sarcoma of the calcaneous. At the last follow-up 2.5 years after treatment, there was no local recurrence or distant metastasis in either patient. Plain radiographs showed perfect fit of the endoprosthesis and no evidence of loosening.
The patient with Ewing's sarcoma of the talus, at the latest follow-up, 3.5 years after surgery, had no pain and could walk unsupported barefoot. Radiographic evaluation showed no loosening of the prosthesis.
For the 6 patients with scapula tumors, the mean follow-up was 37 months. The functional and oncologic outcomes were satisfactory. No intraoperative complications were noted. At the latest follow-up, all patients had a stable and painless shoulder. The mean International Society of Limb Salvage score was 24 points (80%).
For the patient with the open type IIIB calcaneous fracture, plain radiographs of the foot at 1 year follow-up showed the implant in place. The patient had mild restrictions of his daily activities due to mild heel pain.
Finally forearm radiographs at 18 months follow-up of the patient with the fibrous dysplasia of the radius showed graft incorporation and the 3D-printed plate in place without signs of loosening. The patient was pain-free, had full range of motion in the elbow, and no restrictions to his daily activities.

Conclusions

3-D printed implants are associated with satisfactory functional results and may successfully address reconstruction challenges of limb salvage after tumor resection and in complex trauma cases.

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Design and characterization of lightweight green composites obtained from natural resources for high-performance use in transport structures

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The use of lightweight composite structures is supposed to have several predictable impacts on the design of transport vehicles, mainly by providing safer, faster and cheaper transportation. Their main aim concerns the preservation or expansion of a product’s functionality ensuring an overall weight saving. Significant weight reductions with improved performance will mean less fuel consumption and CO2 emissions. To achieve that, foam, less dense or composite materials are being used. Therefore, the main targets for future development must be the use of hybrid composites. The traditional material employed are characterized by high environmental impact due to the fact that such materials are derived from fossil fuel, they have harsh processing conditions and limited recyclability. To overcome these drawbacks, the research is now focusing on the investigation of alternative sustainable materials derived from natural resources. A possible route lies either in the reduction of not renewable materials or in the potential substitution of synthethic fibers with natural ones obtained from natural resources. The lightweight, low cost natural fibers offer the possibility of replacing a large portion of the synthetic fibers in several transport structures. Natural fibers such as kenaf, hemp, flax, jute, and sisal are providing automobile and aircraft part reinforcement due to the reductions in weight, cost and CO2, less reliance on fossil sources and recyclability. In the framework of the sustainability, a more eco-friendly approach was proposed to design a novel, sustainable and green multi-layered composite with improved performances for transport structures through the application of layer-by-layer (LBL) assembly. The proposed flexible methodology is based on alternate deposition of a positively charged and negatively charged layers, enabling to improve flame retardancy and water repellency properties of green hemp-based multi-layered materials through LBL assembly based on clay layers hydrophobicized by stearic acid. The designed methodology highlights the possibility of designing layered composite materials with improved physical properties for high-performance use in transport structures, exploiting the synergy between an inorganic and an organic compound through the formation of an hybrid system.

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Map of local mechanical properties of anticorrosive graphene-based coatings

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An exciting challenge to face in the field of paints and protective coating is the design of materials characterized by high chemical and mechanical resistance able to avoid microscopic failure in the coating that can pave the way to oxygen, water and other pollutants, thus favoring corrosion reactions. In this context, the interest by researchers and industrialists around the world towards graphene as a material of the future for corrosion resistance is gaining momentum. In recent times, there has been much discussion about this material and its potential as an additive to paints and varnishes for the formulation of barrier effect coatings with exceptional anticorrosive properties. The structure of graphene nanoplatelets (GNPs) offers exceptional electrical and impermeability properties, low-density characteristics and a large surface area that guarantees perfect adhesion to different materials. Recently, the effectiveness of graphene nanoplatelets (GNPs), dispersed in low quantity in a waterborne epoxy resin, in enhancing the coating anticorrosive properties and strongly contrasting its photooxidative degradation has been demonstrated [1-2]. It is well known that epoxy-based coatings are vulnerable to ultraviolet (UV) damage and their durability can be greatly decreased in outdoor environments. In this work, we aim to focus on the exceptional ability of GNPs incorporated in the epoxy films, at different weight percentages, in increasing the photooxidative resistance of polymeric films, thus consequently determining a strong decrease of the mechanical damages caused by UV irradiation. The effects of UV light on the morphology and mechanical properties of the solidified nanofilled epoxy films are investigated by Atomic Force Microscopy (AFM), in the acquisition mode “HarmoniX”. This work highlights the possibility of extending traditional AFM imaging with a technique, which is sensitive to the punctual changing in the mechanical properties of the surface film, providing information on the heterogeneity of multiphase polymeric systems. The polyharmonic response varies with modifying local mechanical properties. It is worth noting that, by coupling the AFM phase maps with the AFM modulus maps, morphologies and distribution of crystalline aggregates (for both unfilled and GNP filled samples) can be simply identified.
In this work, in order to supply pertinent information on the local changes caused by the photooxidative degradation, a comparison of the material properties on located regions, before and after UV irradiation, is shown. In particular, AFM microscopy, in the acquisition mode “HarmoniX”, has allowed studying both qualitative and quantitative nanometric-resolved maps of the mechanical properties, highlighting that the incorporation of low percentages, between 0.1 and 1.0 wt%, of graphene nanoplatelets (GNPs) in the polymeric film causes a significant increase in the mechanical stability of the irradiated films. The advantageous effect increases progressively as the GNP percentage increases.

Acknowledgements
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Topography induced de-adhesion of a viscoelastic patch off a wrinkling bilayer

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Dynamic topography, such as the reversible transition of flat to wrinkled surfaces, is widely observed in natural systems which provides it as a potential mechanism to prevent biofouling. The applicability of this mechanism in designing bio-inspired surfaces requires an understanding of different mechanical factors affecting the detachment process of biofoulants from a wrinkled surface. The viscoelastic nature of biofoulants adds more complexity to the situation as it gives rise to a complex coupling between material dissipations, delamination, and geometry. Here, we present a model system to better understand the controlling parameters of this topography-induced de-adhesion mechanism. A trilayer system is considered in which the biofoulant is modeled as a thin viscoelastic patch that is attached to an elastic bilayer. The elastic bilayer is composed of a thin, stiff layer adhered to a softer substrate to allow the generation of a controlled wrinkling pattern upon being subjected to compression. Specifically, as the setup is compressed, a wrinkle pattern with well-defined wavelength and amplitude is developed. The wrinkle amplitude increases with compression and when it reaches a critical value, the delamination between the patch and the bilayer interface is triggered. Finite element and analytical models are employed to study the influences of various parameters including the relaxation characteristics, surface energy, and the excitation rate on the detachment onset. Such understanding is critical for aiding the designs of surfaces with efficient self-cleaning capabilities.

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Remodeling of collagen fibers in bowel tissues induced by anastomotic geometry

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Anastomotic geometries are common in many surgical interventions of the gastrointestinal tract. However, it remains unclear how these highly non-linear and non-native geometries affect the mechanics and functionalities of the soft tissues. Thus, in this study, finite element modeling is used to simulate the realistic opening of such an anastomosis subjected to internal pressure. The submucosa layer of the bowel wall is modeled using the widely known model developed for soft tissue, the Ogden-Gasser-Holzapfel model, with two cross-ply collagen fiber families perfectly aligned along the ±30° axis with respect to the longitudinal direction [1]. The model is further integrated with the remodeling capacity of collagen fibers due to the stress states in the tissue [2]. Simulations show that stress-focusing locations (e-cone and d-cone) are generated as shown in Figure 1. Furthermore, near the focal d-cone points, the tissues can experience a stress state that resembles a biaxial stress state which leads to the remodeling of the collagen fibers in these areas. Specifically, Figure 1 also demonstrates that collagen fibers in the far-field stress focusing d-cones exhibit a more random distribution. The fiber dispersion parameter κ approaches 1/3 in these areas, indicating an isotropic fiber architecture. κ ~ 0 away from these focal points, signifying a more aligned fiber architecture. This result is further verified through histological image analysis of collagen fiber dispersions in the submucosa dissected from anastomotic geometry. Such understanding of how bowel tissue responds to surgical anastomosis is important to the development of new surgical practices to minimize leakage and improve patient outcomes.

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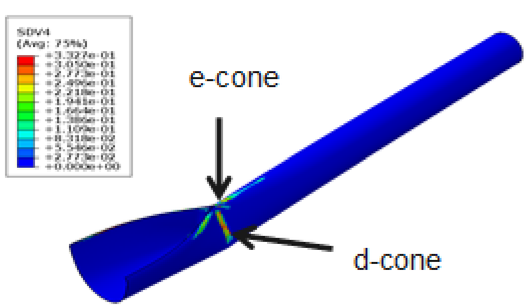

Stress focusing leads to remodeling of collagen fibers. Near the focal points, collagen becomes randomly distributed, while away from the focal points, they preserve the original more aligned architecture.

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Development of a Machine Learning Approach to Estimate In Vivo Properties of the Aorta and Better Understand Aortic Shape Variation

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Introduction: The mechanism by which aortic diseases occur is unclear but is strongly influenced by the aorta's geometry and anisotropic fiber-reinforced composition. The development of aortic diseases is often accompanied with major shape changes. Furthermore, nonpathological aortas have also been found to exhibit shape changes over short periods of time. The evolution of aortic shape can be better understood using finite element analysis (FEA), in which dynamic changes in aortic geometry can be modeled as a function of outward pressure. The aortic wall's anisotropic material can be modeled using the Ogden-Gasser-Holzapfel (OGH) constitutive model, as a bulk substrate innervated by two families of collagen fibers. However, a central challenge in using OGH to model aortic shape changes is that a realistic parameter set remains largely unknown. We intend to develop a non-invasive approach to extract the in vivo material properties of the aorta. Machine learning techniques have often been used to replace the need for FEA in making predictions on aortic shape variations, but has not been used to aide FEA modeling. In order to address the gap in knowledge, we develop a machine learning approach to discover the parameter set, and thus material properties, that best model aortic shape changes in FEA.

Methods: We developed our methodology by testing if we can model shape changes of nonpathological aortas over an acute time point between two computed tomography angiography (CTA) scans of a patient. First, we chose to vary 5 parameters. We varied fiber angle from 0 to 90 degrees, fiber stiffness from 0.01 mPa to 9.99 mPa, fiber nonlinearity from 0.001 to 0.099, fiber dispersion from 0.0 to 0.3, bulk substrate stiffness from 0.01 mPa to 0.98 mPa. We uniformly sampled 5 values for each parameter for a total of 2750 FEA simulations, keeping bulk substrate stiffness less than fiber stiffness. For each simulated model, we quantified geometry by using a reduction of per-vertex curvature values to a two-dimensional histogram of two curvature indices. Using a random forest regressor, we trained the curvature measurements on the parameter space to build a prediction model. We then used our machine learning model to predict the properties of the aortic wall that would best follow the patient aorta's true shape variation via FEA simulation. Finally, we tested the accuracy of our model by simulating the first scan using the chosen material properties and investigating whether the geometry of the simulation aligns with the true patient geometry in the second scan.

Results: We found that the prediction had a mean absolute error of 4.98º for fiber angle, 0.62 mPa for fiber stiffness, 0.03 for fiber nonlinearity, 0.02 for fiber dispersion, and 0.00 mPa for bulk substrate stiffness.

Conclusion: Our study develops a plausible framework for characterizing and modeling aortic shape variation. We plan to apply our methodology to a large set of patients to gain a better understanding of mechanical properties of the aortic wall. Furthermore, we seek to apply our methods to patients with aortic dissections to better understand dissection evolution.

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Crack propagation simulation in adhesively bonded composite joints with a complex crack initiation.

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The simulation of crack propagation in adhesive joints and adjacent parts, in order to design and develop fatigue resistant adhesive joints, is still a challenge today. Thus, many approaches are being developed for different applications. Cohesive zone elements are already implemented into commercial software but often extended through user defined subroutines. This work builds upon a user-defined material based on a crack growth model, which describes the cohesive stress and damage in the joint. The model is implemented in ABAQUS via a user-defined subroutine. It uses a load enveloping damage model together with a mixed mode Paris' law to capture the influence of the mixed-mode ratio on crack growth and allows the simulation of fatigue crack growth. It shows good results compared to the specimen it was compared to. However, the crack growth is limited to a flat plane and the crack cannot leave this single plane of elements. Despite using cohesive zone elements an initial crack is needed.
In this Study the limitation of the model on a single plane is lifted by extending the algorithms behind the model from 2D to a full 3D. In Order to validate the model a simulative validation approach is used. The simulation results of the same physical problem simulated in different previously not possible ways are compared against each other. Further, a comparison of the results with intentionally deformed meshes is used to validate the changes done to the user defined material model. These changes allow not only for a free orientation of the model in space but also widens the range of application of the model.
The model was further extended to allow for multiple crack fronts running in the same simulation, to allow a fatigue analysis of complex damages. One example of such a damage would be an impact damage with delamination's in multiple layers. The aim of these changes is to transfer the good simulation results achieved with this single plane model to complex damage scenarios of more actual facts. These scenarios require the crack being able to follow a part curvature or different kind of initial damages to be analyzed in possible multiple delamination's.

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Organic dyes as corrosion inhibitors of commercial AA1050 aluminum alloy in sodium chloride environment

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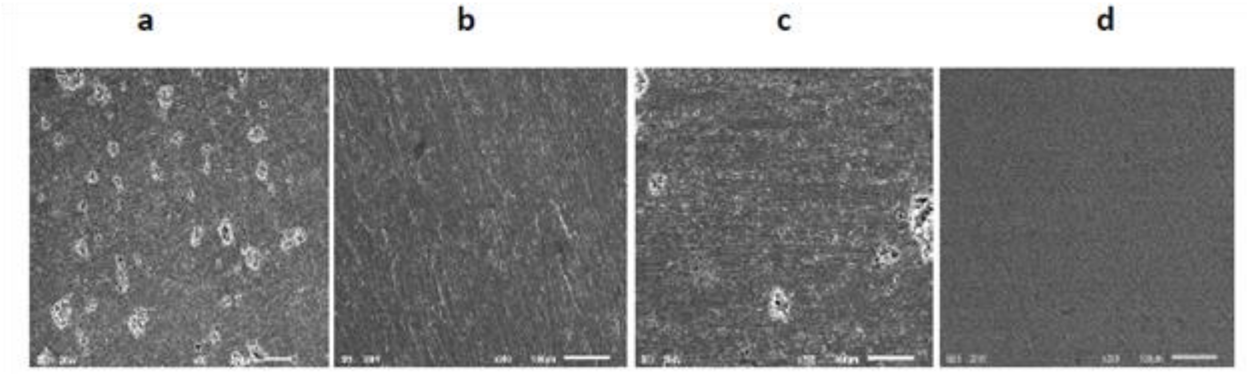
The use of aluminum alloys is of continuous interest in numerous applications because they are lightweight structural materials with suitable mechanical properties.
Aluminum structures, ships and equipment used in the aggressive marine environment suffer from many different types of destructive corrosion attack. This is a continuous and constant problem, often difficult to eliminate completely, since it depends on various factors, such as the composition and the properties of the alloy, the aluminum surface morphology, as well as the local environment, such as the changes in pH and temperature values and the composition of the corrosive solution.
The corrosion control of aluminum is of great technical, economical, aesthetical and environmental importance and the use of inhibitors is one of the promising solutions for protecting aluminum and its alloys against corrosion. Recently, the research about green corrosion inhibitors which are environmentally friendly, do not contain heavy metals or other toxic compounds has gained a large interest. Although extensive investigation about organic and green inhibitors has been reported, papers on the comparison between synthetic and natural organic dyes are still scarce.
This study is an effort to investigate the role of a natural organic dye, Crocin, against the corrosion of a commercial aluminum alloy AA1050, in an aggressive chloride ions environment of NaCl 0,01M, in comparison with a synthetic dye, Alphazurine A. Crocin is a natural carotenoid chemical compound that exists in the crocus flower and primarily responsible for the color of saffron. Alphazurine A is a thriphenylmethane synthetic dye which has already shown a protective anticorrosive action.
The test specimens were cut into 50mmX50mmX3mm and mechanically polished with emery papers of 600, 800, 1000 and 1200 grades. Then the coupons were degreased using acetone, rinsed with plenty of deionized water, dried in air and stored in desiccators prior to use.
In order to study the corrosion behavior of the AA1050 specimens in the NaCl 0,01M solution at room temperature, their electrochemical behavior was investigated in the absence and presence of the two organic dyes, using DC Corrosion techniques and Electrochemical Impedance Spectroscopy (EIS). The effect of the organic dyes as corrosion inhibitors was also evaluated by mass loss measurements. Study and characterization of the morphology of the surface of the specimens, before and after the corrosion measurements, was performed using Scanning Electron Microscopy (SEM), equipped with Energy Dispersive Spectroscopy (EDS).
The results obtained showed that the examined dyes have a protective action against corrosion of aluminum surface in the corrosive environment. This is attributed to their chemical structure and size, as well as the position of their polar groups, which contribute to the chemisorption or adsorption process of the dyes on the aluminum surface forming protective layers. The differentiation between the inhibition efficiency of the examined dyes could probably explained by their individual molecular size and stereochemistry. Furthermore, the increase in Crocin concentration showed an improvement of its protective inhibition efficiency.



SEM images of the surface of AA1050 aluminum alloy specimens after electrochemical corrosion techniques in NaCl 0,01M solution a) without inhibitors, b) AlphazurineA 1,25mM c) Crocin 0,025mM, d) Crocin 1,25mM.

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On the applicability of cyclic and fatigue parameters estimation methods to high strength steels

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Due to very favourable combination of properties, high strength steels are of great importance for numerous industrial applications where lightweight designs are of interest, such as automotive/mobility industry. Material modelling and simulation are an integral part of fast and integrated product development in these areas, so that detailed knowledge of materials' cyclic stress-strain and fatigue behavior and corresponding properties/parameters, as early in the product design process as possible, becomes ever more important. Consequently, various existing methods for estimation of cyclic/fatigue parameters from monotonic properties are used, and new ones are developed. With rare exceptions such as method of variable slopes and modified uniform material law where high strength steels and sheet steels are treated separately, most estimation methods have been developed and evaluated using data on wide range of metallic materials or on rather general groups such as unalloyed, low-alloy and high-alloy steels. As previous evaluation of estimation methods performed on a representative HSLA steel has shown, this may result in significant results averaging and estimation errors. In this work, several methods for estimation of cyclic and fatigue parameters have been analyzed and evaluated with regard to their applicability to high strength steels. Using error criterion i.e. fraction of data points falling within a predefined scatter bands, performance of individual methods has been evaluated in low-cycle and high-cycle fatigue regime separately. Comparison is provided based on estimation results obtained for more general groups of steels (all steels, unalloyed, low-alloy, high-alloy steels). Notable differences could be observed and are reported regarding the applicability of analyzed methods for low- and high-cycle fatigue regimes and for selected subgroup of high strength steels.

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Failure analysis of metallic components due to improper materials and fabrication method

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It is important to understand the origins of the in-use failure of metallic compounds to avoid their reoccurrence. In most cases, the causes of failures are complex and linked with external factors that were not known at the time the system was designed or that have arisen in the course of use. However, in some cases the causes are much simpler: failures are caused by the improper use of a material or the use of assembly processes without expertise. The analysis methods can then be simple and precise, and they allow to quickly find the origin of the failure and to propose solutions: visual examination, optical microscopy, X-ray fluorescence analysis, macro and microhardness.
During this presentation, we describe two cases of failure and the results of our examinations to explain their causes. The selected cases are (1) a rotating machine shaft and (2) two angles welded on a hopper. The first case of failure is due to the use of an improper grade of stainless steel. The second one is due to the absence of preparation before welding and the use of a non adapted welding technique to make the weld beads to weld a carbon steel grade with an austenitic stainless steel weld bead.

Figure 1. The broken rotating machine shaft.

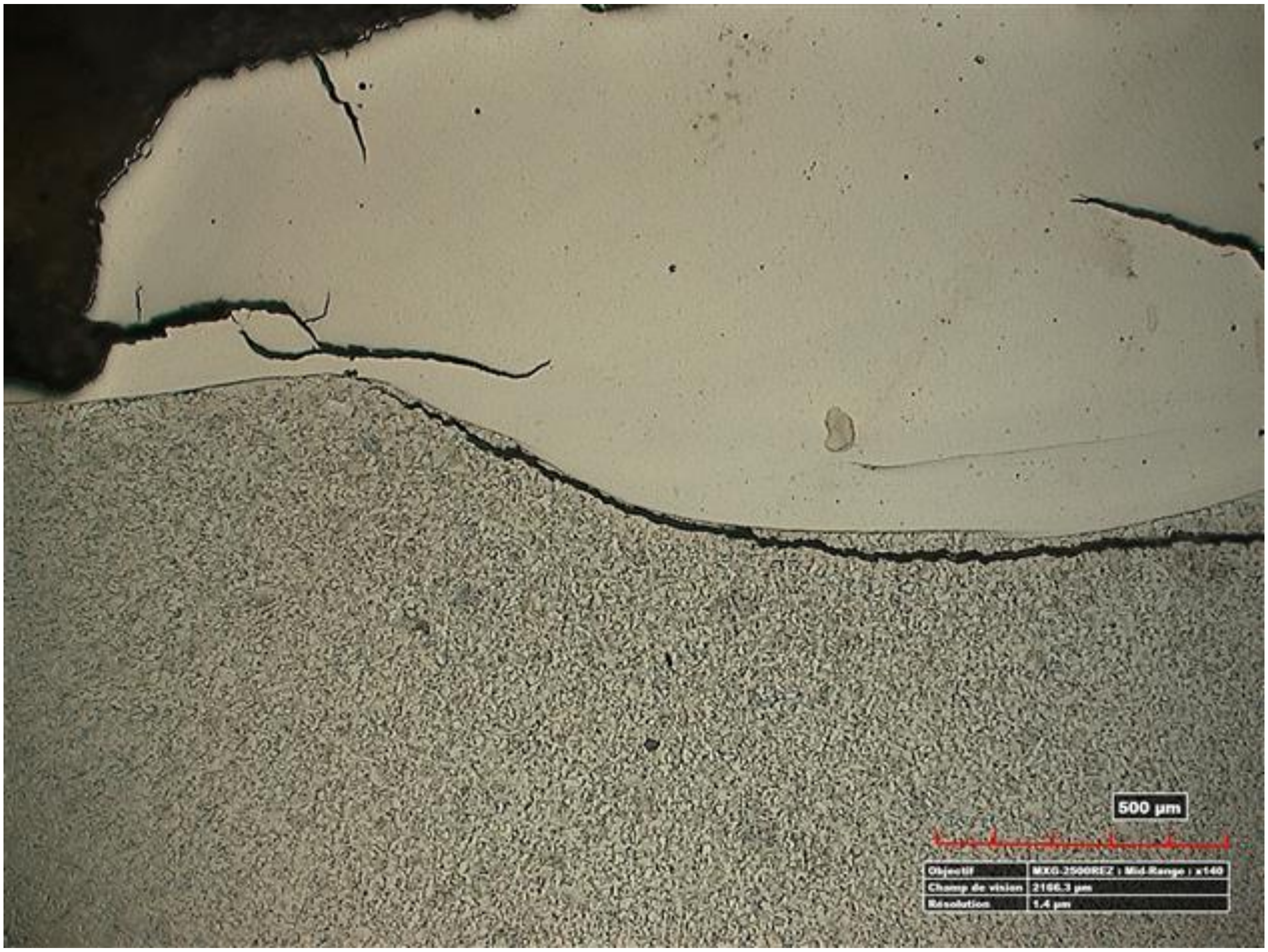

Figure 2. The broken weld (Nital etching).

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Non-destructive Inspection of Composite Aileron during Fatigue Test

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A certification test of a new composite aileron of a new turbofan-powered military trainer and light combat aircraft was performed. Compared to the previous model, the aircraft has significant changes, such as a new engine, wing design with integrated fuel tank, and more modern avionics. Furthermore, several parts of this metal airframe aircraft were made of carbon fibre-reinforced composite.
One of the composite parts was the aileron which was made by carbon fibre winding technology and not by traditional moulded skin bonded to the ribs. The uniqueness of the production of this aileron was in the process of applying robot-assisted filament laying in the automated production of aileron structures.
The fatigue test is one of the most important steps in the long and demanding way to obtain airworthiness certification of every new aircraft structure. The arrangement of the realized fatigue test is shown in Fig. 1.

Basic NDT methods used for the inspection of the aileron were visual testing (VT), eddy current testing (ET) and ultrasonic testing (UT). Both conventional and phased array UT techniques were used.
An inspection of the inside and outside surface of the aileron was performed by visual testing. The method is focused on detection and evaluation of the part surface condition directly by eyes or special equipment (videoscope).
The eddy current method was used to inspect the metal parts of the aileron, such as end ribs.
Two types of damage such as artificial defects were created in the aileron structure. Artificial defects were made to simulate manufacturing and operational defects. The operational defects were made after 30 000 simulated flight hours of fatigue test using an impactor. The range of energy used for impacting was from 20 J to 50 J. In total, 85% of manufacturing artificial defects and 100% of operational artificial defects were found and each artificial defect was monitored during the test due to its propagation using NDT methods, especially UT.
The result of NDT inspections showed that artificial defects were not propagated, and the no-growth concept of the aileron was confirmed.

The prototype of the aileron was subjected to a fatigue test to obtain airworthiness certification. The aim of the article is to show the process of the fatigue test and NDT inspection during the test.
It was found that in this type of carbon fibre-reinforced composite structure, the artificial defects were not propagated by the loading which was proven by the NDT inspection of inserts and impact damage. The aileron structure was appeared to be extremely resistant to damage as it withstood up to 50 J impact energies.

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Fig. 1: NDT inspection during fatigue test of the aileron

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Propagation of the destruction stage of the ash tank structure during operation

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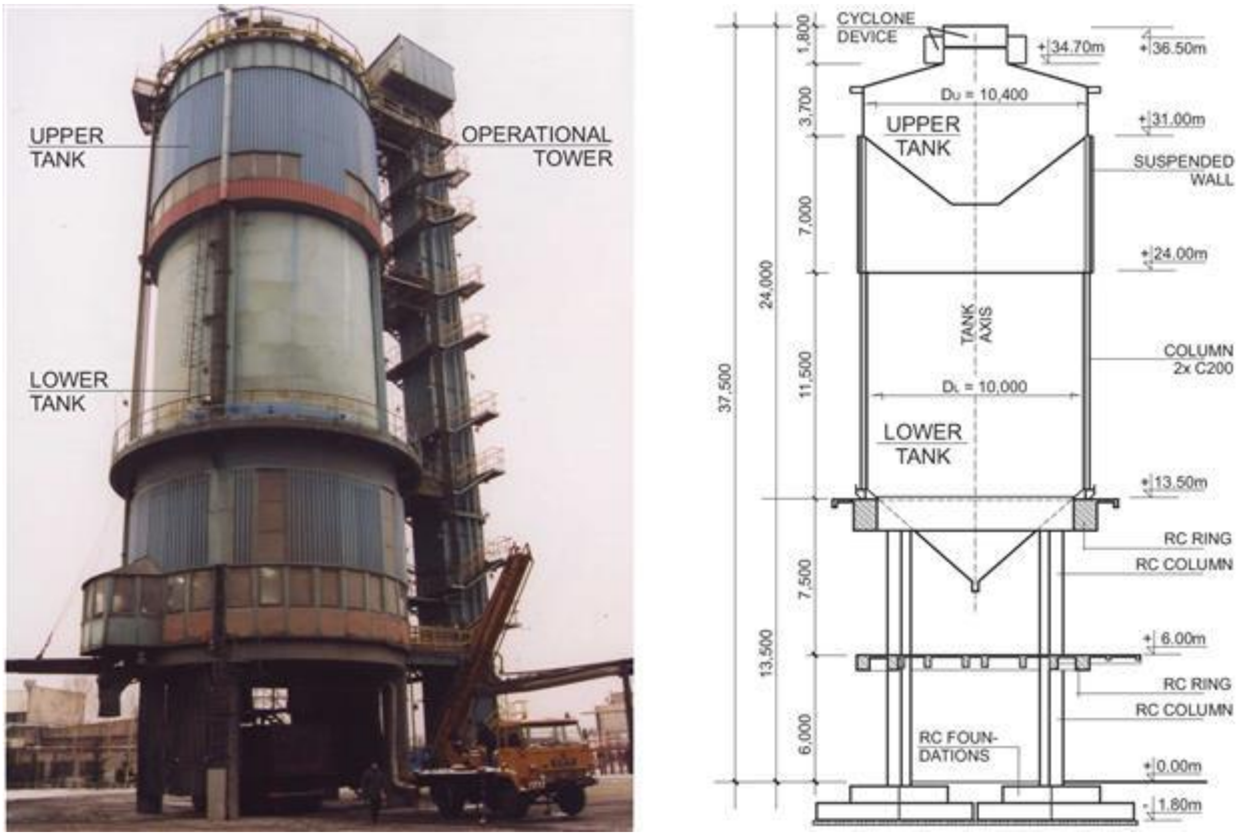
The article assesses the consequences of the lack of proper maintenance of engineering structures in industrial facilities, which may result in a construction disaster. The indicated thesis is illustrated by an example of the destruction state analysis of a steel ash tank with a total height of 36.5 m. As a result of completed research and analyses, a universal concept of strengthening works and guidelines for the proper operation of the facility were formulated. The tank, located on a two-storey reinforced concrete support structure, was used without periodic inspections. During more than twenty years of continuous operation, both steel and reinforced concrete construction elements have been gradually degraded. In view of the defects, as a result of visual tests, the object underwent comprehensive diagnostics. The steel elements of the tank structure were subjected to corrosion and local mechanical damage. Other defects were a consequence of improper execution of RC elements. An additional reason for the increase in concrete carbonation processes and steel corrosion was the lack of proper maintenance of the facility functioning in an aggressive environment. The additional tensile stresses resulted in cracks in RC elements due to progressive corrosion processes and insufficient concrete strength. Mechanical damage resulted from the impact of trucks moving in the tank unloading zone. Damage to the elements of the support structure resulted in the need for immediate execution of strengthening works, which had to be carried out during the ongoing operation of the object. Identification of defects, immediate implementation of diagnostic tests, and then strengthening of the facility allowed to avoid disaster.
Conducting ongoing monitoring of the condition of the structure, regular periodic inspections, consistent implementation of recommendations for the repair, strengthening or reconstruction of damaged elements form the basis for the safe operation of engineering structures.



Construction parameters of the ash tank

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Phase-Field Modeling of Fracture in Cr-Al_2O_3 Metal–Ceramic Composites with Experimental Verification

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The metal-ceramic composites are advanced structural materials which have wide range of industrial applications in, for instance, aerospace, automotive, and energy sectors. The metal-ceramic composites are being often used in harsh environments characterized by severe thermomechanical loading and chemical aggression. Under such conditions, fracture is one of the main failure modes which needs to be well understood.

Both experimental and numerical works are available in the literature regarding the fracture behavior of different metal-ceramic composites. For instance, the fracture mechanisms in the Cu-Al_2O_3, Al-Al_2O_3, and Al-SiC composites are studied in [1] using three-point bending tests. Finite element modeling is used, for instance in [1-3], to study the fracture mechanisms taking place at the vicinity of the crack tip in metal-ceramic composites with consideration of the real microstructure. However, these finite element models belong to the discrete approaches which have the drawback of huge computational costs.

In order to overcome the computational limitation of the discrete approaches, a homogenized phase-field model is used in this work to simulate the fracture in the chromium-alumina metal-ceramic particulate composites fabricated by powder metallurgy, and to predict their fracture toughness. Composites with different reinforcement volume fractions and the matrix material grain sizes are considered. To reduce the computational tasks, the composites are modeled as homogeneous isotropic materials whose elastic properties are calculated by the rule of mixture. A novel approach is proposed to determine the phase-field length scale parameter by measuring the process zone length at the vicinity of the crack tip through the microscale observations of the fracture surfaces. It is found that the reinforcement volume fraction does not considerably change the fracture length scale. However, the composites with bigger chromium grains have a wider process zone.

A staggered finite element solution scheme based on the model presented in [4] is used to solve the phase-field equations. In order to validate the numerical results, fracture experiments are conducted on the single-edge V-notched beams under four-point bending. The predicted values of fracture toughness by the homogenized phase-field model are in excellent agreement with those obtained from the experiments. It can thus be concluded that a physically meaningful phase-field length scale parameter can be obtained from direct measurements at the vicinity of the crack tip.

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Numerical Modeling of the Low Cycle Fatigue: Effect of Manufacturing Imperfections Caused by Machining Process

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The majority of mechanical components, in the nuclear power plant industries, are designed to withstand severe cyclic loading conditions. In fact, the low cycle fatigue leads to extensive plastic deformation in the material that, in the absence of security guidance, may cause chaos. Moreover, imperfections due to the machining process are one of the most limiting features of the service life for these components. In the present work, using finite element analysis, a methodology was proposed to assess the low cycle fatigue life of tridimensional cylindrical parts made of 316 austenitic stainless steel, at ambient temperature, and subjected to nominal strain amplitudes ranging from ± 0.5 to ± 1.2% for different surface roughness. Two different multiaxial strain-life criteria were used, namely Brown-Miller and maximum shear strain. Comparison between the numerically predicted fatigue lifetimes and those obtained experimentally revealed that the aforementioned multiaxial strain life criteria could successfully estimate the fatigue life of 316 austenitic stainless steel grade under uniaxial loading conditions. Additionally, based on the finite element results, it was found that the fatigue life decreases as the value of surface roughness average increases, which indicated the strong effect of the surface regularities on the low cycle fatigue. Hence, the proposed methodology was found capable of quantifying the effect of surface roughness on the life of this particular steel in the low cycle fatigue regime.

Keywords— surface roughness, 316 stainless steel, low cycle fatigue, multiaxial strain-life criteria, finite element analysis, Fe-Safe.

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Heat Shielded Unmanned Aerial Vehicle (UAV)

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Flying has always been a fascination which aviation has brought to fruition. However, beyond recreation, aviation has had a prominent role in building economies and modern civilizations. The industry's expanded services across the logistics sector have been supporting societies in coping with the boom in electronic shopping, mass-scale supply of goods and access to remote destinations. These facilities have been especially helpful in recent times when remote access and social distancing have been brought onto focus due to the global pandemic. In addition to conventional aircraft, the air-transport industry has received contribution from a thriving category of small-scaled aerial vehicles called 'Unmanned Aerial Vehicles (UAVs)', more commonly known as 'Drones'. Available in a variety of shape, size, and function, they can be piloted remotely or allowed to operate autonomously. They are generally categorized as Single/Multi-Rotor, Fixed-Wing or hybrid forms of aircraft and utilized for an extensive range of applications which include aerial surveillance and transportation of goods. Their flexibility in flight paths, operational readiness and prospects of a cleaner environmental footprint as compared to conventional aircraft and automotive have drawn considerable interest from leading institutions, industries, and governments. Following the same trend, this research will be aimed at investigating the challenges of operating UAVs in high-temperature environments such as those of the Middle East, specifically the Sultanate of Oman to aid in the development of UAV operations in those regions. The study will involve literature research on UAV and thermal protection technology to investigate possible concepts and finally produce an initial design of a UAV structure which incorporates heat-shielding features. Graphical representation of the design may be produced using basic graphic design software or Computer-Aided Design software such as Fusion 360 and AutoCAD while utilizing Microsoft Word or Latex as software tools for documentation purposes.

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An Integrated Application of Sensors, Physical Failure Modeling and Data Analytics to Enable Optimal Maintenance Strategies

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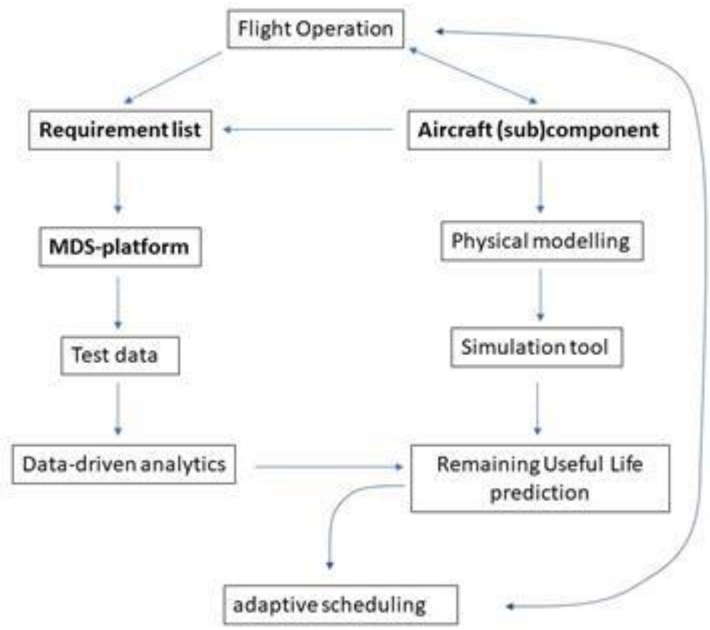
In recent years availability, serviceability, and sustainability have been of high interest for the aviation sector. Although the Corona-pandemic seriously affected the airline industry, growth is most likely returning within the coming decade. To accelerate recovery, airlines should increase efficiency (minimize a.o. downtime, operation disruptions) and reduce costs.When we focus on the Maintenance, Repair and Overhaul (MRO) operations, a total of $69 billion was spend in the year 2018, which represents around 9% of an airline's annual operational cost. Moreover, the aircraft MRO tasks are often characterized by unpredictable process times and material requirements. At the same time, contemporary demands for sustainability are increasingly affecting the aviation sector in a variety of fields including maintenance.
Current aerospace maintenance operators use a preventive (stage 1) approach where a scheduled program is followed based on flight hours and/or cycles combined with a reactive approach, in case of unforeseen failures. The employed strategy contributes to increased flight safety however with an inevitable suboptimal utilization ofmaterial and labor. In the case of propulsion systems, where amultiple number of sensors is installed compared to other parts of the airframe, a condition-based maintenance strategy (stage 2) is typically in use. In that case, the actual condition of the component is considered based on real-time sensor data and using threshold conditions to determine when there is a need for maintenance. A next step (stage 3), is the predictive maintenance approach where patterns are obtained from the analyzed data sets, using analytical models and machine learning, to determine when failure occurs. The latter approach is capable of detecting failures, before condition-based maintenance is able to. An even more advanced approach (stage 4), is prescriptive maintenance. Using advanced physical modeling and data-driven techniques that identify the underlying physical phenomena, it is possible to find the root cause of the occurring failure and realizing long term effects, minimizing maintenance and maximizing the life-cycle of the object under consideration.
Our research is focused on the application of maintenance strategies where it becomes possible to optimize MRO operations. The objective is to implement adaptive scheduling on the basis of real-time monitoring of the actual status of systems/components. Based on an elaborate requirement list, containing attributes related to the aircraft system, critical components and the operator, aMaintenance-Data-Sensing (MDS) platform can be assembled. Multiple sensors can be connected to the platform for tests on benchmark aircraft components and subcomponents. Physical failure modeling of the (sub)component is merged with sensor data from the MDS-platform, on which data-driven analytics is applied. Finally, the modelled data is combined with the measured data to determine the Remaining Useful Life (RUL) of the (sub)component and a connection ismade to optimize flight operation scheduling.
The higher staged maintenance techniques, condition based, predictive and prescriptive maintenance, offer the possibility to reduce downtime, having less disruptions in scheduled flight and minimizing the ecological footprint, as is observed with earlier applications within the propulsion maintenance sector.



Project process steps toward adaptive scheduling based on maintenance requirements

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Non Destructive Testing for contaminated surface inspection before bonding

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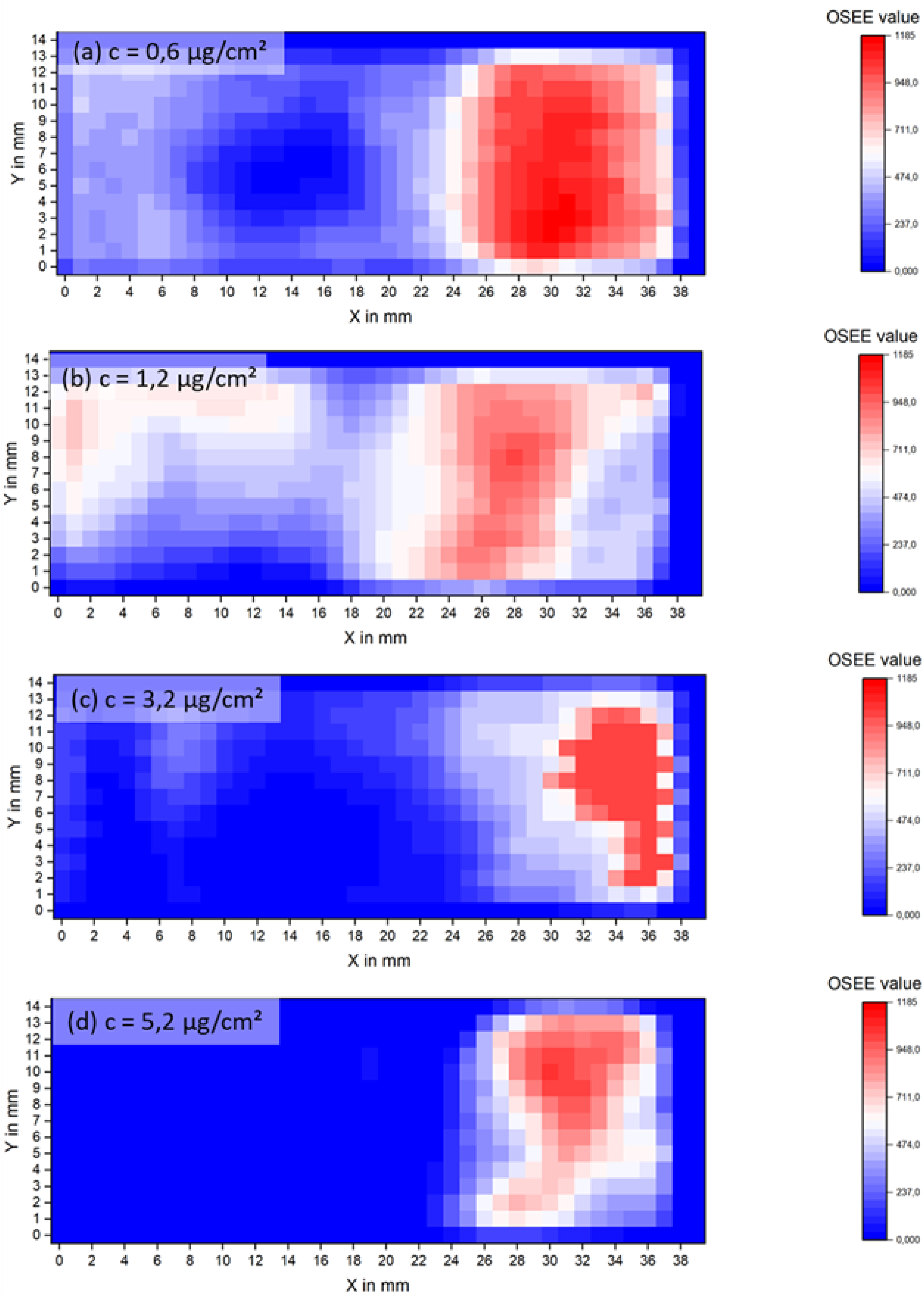
Structural bonding is a promising way to lighten structures such as launch vehicles or aeronautic engines. However, adhesion performance suffers from surface contamination coming from production environment, such as silicon or fingerprints. The inspection of the cleanliness of a surface is then essential in order to ensure adhesion performance. In the past years, several NDT techniques assessed surface contamination before bonding with a restricted spectrum of applications.

In this study, contaminated samples of different substrates were prepared in order to assess detection capability of two non destructive testing techniques. Aluminum and CFRP samples were contaminated by spraying at concentration levels as low as µg.cm-2, for which a loss in bonded assembly mechanical performance has been established. Samples were contaminated with different categories of contaminating agents representative of those encountered in production facilities, such as silicon based released agent, cutting fluid and artificial handsweat simulating fingerprints.

Optical Stimulated Electron Emission (OSEE) was investigated on different aluminum alloys, presenting different surface finish. A significant decrease of OSEE signal enables to detect the contaminants assessed. Spatial detection of contaminated zones was possible for concentration levels less than 1 µg.cm-2 (Figure 1). Laser Induced Breakdown Spectroscopy (LIBS) with UV laser source was applied on peel-ply and smooth CFRP finish surface. For each contaminant, a specific element allowed both detection and contaminant identification, for both surface finish. Moreover, this technique showed a sensitivity allowing to detect contaminant elements for the lowest concentration levels assessed, such as a dependency of the signal levels with concentration.


(a) c = 0,6 µg/cm²
(b) c = 1,2 µg/cm²
(c) c = 3,2 µg/cm²
(d) c = 5,2 µg/cm²
OSEE value
1185
948,0
711,0
474,0
237,0
0,000
Y in mm
X in mm

Heatmaps of OSEE signals on aluminum surface contaminated with cutting fluid (left side of the surface) at (a) 0.6 µg.cm-2, (b) 1,2 µg.cm-2, (c) 3,2 µg.cm-2, (d) 5,2 µg.cm-

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A novel infrared thermography approach for automated rapid detection of damage in aeronautical composites.

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The current need for innovative nondestructive techniques enabling quick and effective defect identification on aircraft fuselage and wing skin parts is currently prioritized by the scientific and industrial community in order to reduce aircraft maintenance costs and effectiveness. Pulsed Phase-Informed Lock-in Thermography, a new low-cost thermographic strategy based on the synergy of two separate active infrared thermography techniques, is described in this paper for the rapid and quantitative assessment of superficial and subsurface damage in aircraft-grade composite materials. The two-step approach is based on a fast, qualitative assessment of defect position and identification of the optimal material-intrinsic frequency using Pulsed Phase Thermography, followed by lock-in thermography for quantification of the damage's dilatational characteristics. A state-of-the-art ultra-compact infrared thermography module was conceived, produced, and tested on aircraft-grade composite specimens with impact damages induced at variable energy levels and on a full-scale aircraft fuselage skin composite panel as part of a fully-automated autonomous nondestructive testing inspection solution for aircraft. The latter experiments were conducted in semi-automated mode with the infrared thermography module mounted on a prototype autonomous vortex robot platform. The time required for a full assessment of damage(s) within the sensor's field of view is on the order of 60 seconds, which, when combined with the methodology's high precision, unfolds unprecedented potential for reducing the duration and costs of tactical aircraft servicing, as well as improving performance and reducing accidents.

infrared thermography; damage assessment; aircraft composites; nondestructive evaluation; lock-in thermography

Behavior of Constitutive Models from Fatigue Test of Maraging 300 and 350 Steels

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The mechanical properties of steel alloys make its study of great importance for applications in the Defense, Aerospace and Nuclear sectors, which are of extremely relevant for the national progress. Maraging steels are ferrous alloys based on Ni-Co-Mo-Ti with low carbon content and belong to a special class of ultra high mechanical strength steels. This steel family belongs to a strategic group of materials and has multiple applications, including pressure vessels until sportive equipment. Thus, the knowledge of stress for number of cycles behavior performed at rotative fatigue test (RFT) are very interesting for processing, manufacturing and service from these high-performance alloys. In this work were performed RFT in solution treatment and aged conditions at 783K for 6 hours in maraging 300 and 350 steels. Therefore, an analysis by environmental test was performed by curves from the rotating beam fatigue experiments to allow the reproduction of the tests made in laboratory and the modeling of the tension by number of cycles curve. These study were performed microstructural analysis using microscopic and X-ray diffraction. Afterwards, several models were analyzed, including linear, logarithmic, exponential and Chandran for describe the behavior from these alloys. In this work the experimental values were fitted using an iterative regression method of R2, which allowed to obtain values close to the unit. The fitting by exponential and Chandran models provide more accurate predictions at fatigue life when compared with linear's, logarithmic's models like showed in Figure 1. Finally, the work concludes by presenting an analysis of the behavior of the coefficients under different class of metals studied and correlates the values obtained with the RFT (Figure 2) and fractographic analysis, demonstrating the models can be used with good accuracy to describe the mechanical behavior in fatigue life on maraging 300 and 350 steels.

keywords:
Maraging steel; aging; rotative fatigue test; fatigue life; modeling.

TABLE 1 – The experimental values were fitted using an iterative regression method of R^2

MODELS	STEEL 300	STEEL 350
Linear	0.51	0.39
Logaritmico	0.92	0.83
Exponencial	0.98	0.92
Chandran	0.96	0.96

FIGURE 1 – The experimental values were fitted using an interative regression method of R2

TABLE 2 – RFT for MA300 Steel.

MA 300 (SEO				
Corpo de Prova	Diâmetro Médio (mm)	Momento Fletor (N·mm)	Tensão (MPa)	Número de Ciclos
1	3.850	7908.94	1411.68	10,600
2	3.825	7457.00	1357.28	14,000
3	3.825	7457.00	1357.28	13,800
4	3.850	6779.09	1210.01	16,200
5	3.800	5649.24	1048.67	55,500
6	3.825	4519.39	822.59	78,700
7	3.825	4519.39	822.59	102,900
8	3.825	3389.54	616.95	831,300
9	3.825	3389.54	616.95	1,141,000
10	3.850	2259.70	403.34	10,030,600
11	3.850	2259.70	403.34	10,420,400

TABLE 3 – RFT for MA350 Steel

MA 350 (SEO,				
Corpo de Prova	Diâmetro Médio (mm)	Momento Fletor (N·mm)	Tensão (MPa)	Número de Ciclos
1	3.850	5649.24	1008.34	26,000
2	3.850	5649.24	1008.34	48,700
3	3.825	3389.54	616.95	174,600
4	3.850	3389.54	605.01	289,800
5	3.825	3389.54	616.95	203,500
6	3.850	2824.62	504.17	1,492,100
7	3.850	2824.62	504.17	1,051,900
8	3.850	2824.62	504.17	1,202,500
9	3.825	2259.70	411.30	10,912,100
10	3.850	2259.70	403.34	10,212,000
11	3.850	2259.70	403.34	10,147,800

For the construction of the curves, Equation 1 was used to determine the maximum applied stress, according to the geometry of the specimen and the moment applied during the test.

$$\sigma_{max} = (M \cdot y)/I \;\Rightarrow\; \sigma_{max} = (M \cdot d/2)/((\pi d^4)/64) \;\therefore\; \sigma_{max} = (32 \cdot M)/(\pi d^3), \qquad (1)$$

FIGURE 2 - Values obtained with the RFT for 300 and 350 ferrous alloys

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Study of modified CNTs dispersions with the use of Electrical Impedance Spectroscopy

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In order to produce cementitious nanocomposites, the nanomaterials are incorporated in the mixing water in the form of aqueous dispersions. The aim of the present work is to study aqueous dispersions of modified carbon nanotubes (CNTs) as the first step of the production of cementitious composites. More specifically, four sulfonated CNTs dispersions were produced at different concentrations. Ultrasonication energy with a probe sonicator is applied on all dispersions and their electrical properties are measured through the application of Electrical Impedance Spectroscopy (EIS) during ultrasonication. Based on the EIS results and the respective Equivalent Circuit Model (ECM), as well as on analytical methods, the acceptable range of concentration and ultrasonication energy was determined for the production of the aqueous dispersions. The experimental results showed that this can be achieved for concentration of about 0.15 wt% (or 0.10 wt% of cement) and ultrasonic energy of about 60 kJ, so that conductive networks are formed and at the same time the nanostructures are not damaged.

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Investigation on the interfacial properties the CNF/CNT sized carbon fibre reinforced composite using a push-out method via a nano-indentation technique

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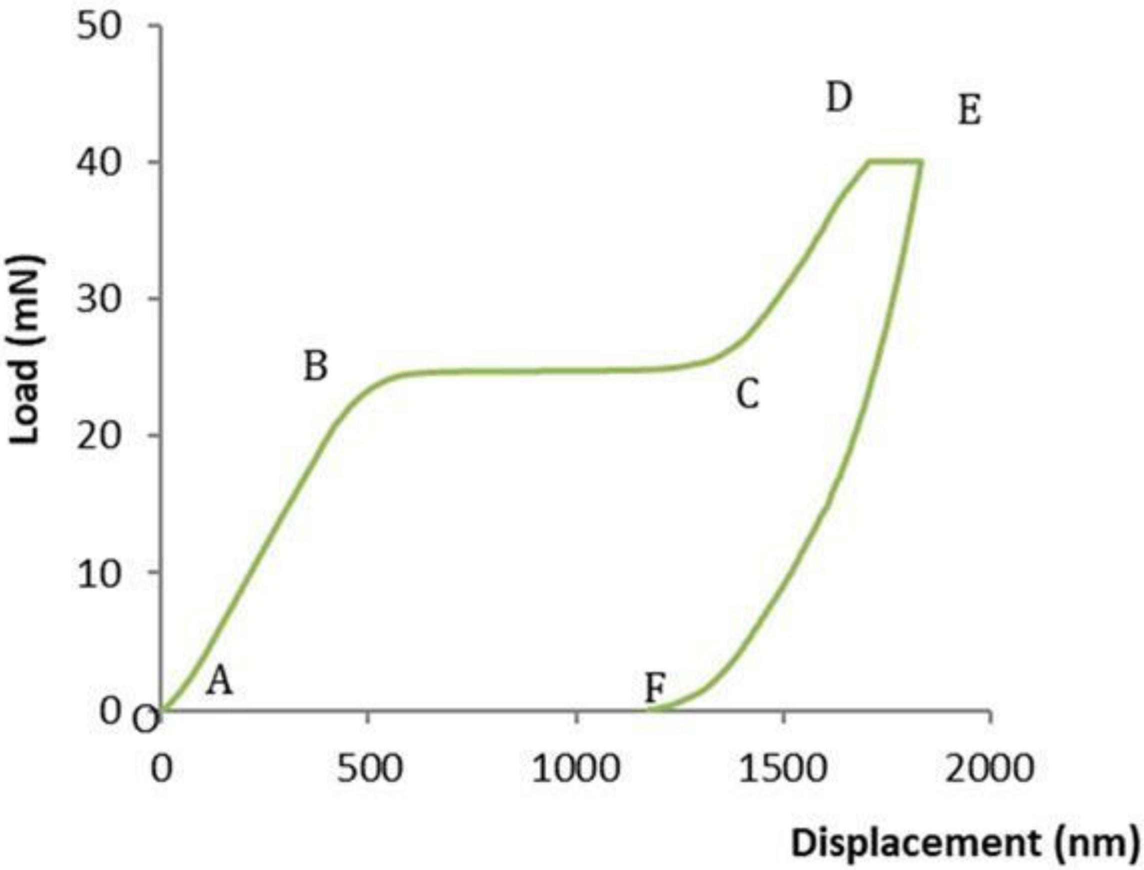
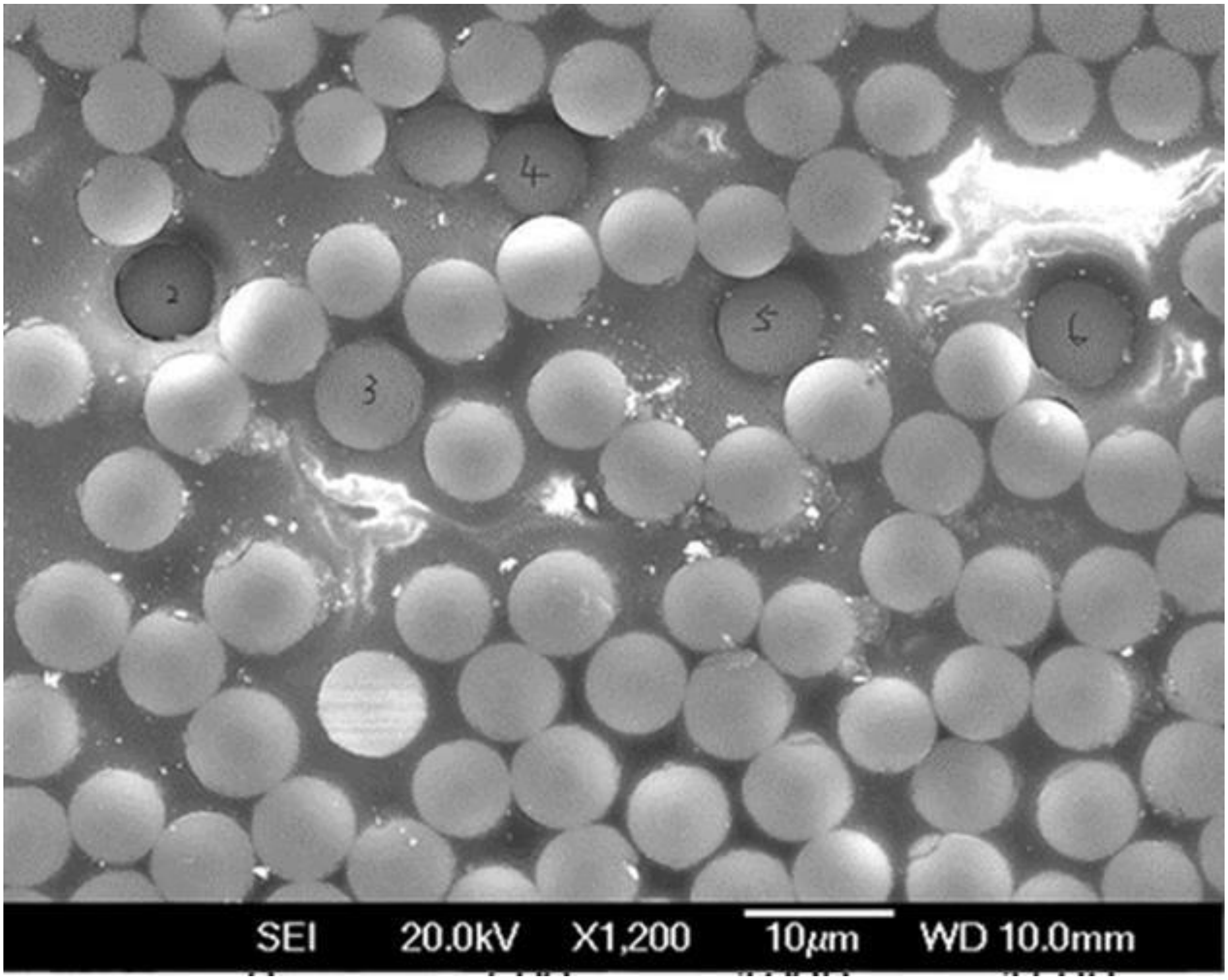
The interface properties of fibre and resin often influence significantly the performance of all types of composites, such as failure mode and fracture toughness. The carbon fibres surfaces are modified via surface treatment methods – sizing - in which a reinforcing carbon fibre is coated with a very thin layer of a complex formulation incuding carbon nanofibers and carbon nanotubes. This formulation aims at an easy processing of the fibre but also creating strong interfaces between the fibre and the matrix resin in the final composite.
A push-out method has been developed based on nanoindentation to assess the debonding mechanism of carbon fibres in an epoxy matrix and the viscoelastic response of carbon fibre. In the push-out test, the load was applied continuously on a single fibre using a specially designed cone-shaped diamond indenter and a counter plate was used to support the thin disc sample. As the load increased, cracks initiated and propagated along the interface, producing the non-linear section. A complete debonding of the fibre was marked by a constant load with increased displacement corresponded to a critical load. The average interfacial shear strength (IFSS) at the fibre/matrix interface can be calculated by the critical load, the sheet thickness and the fibre diameter.
The interfacial properties of sized carbon fibres by CNFs/CNTs reinforced composite were investigated using the instrumented nano-indentation machine. The mechanical properties such as indentation hardness, reduced modulus, indentation displacement and indentation creep of the composite were evaluated by means of the Oliver-Pharr method. The critical load of different composites was measured and the interfacial strength were calculated to compare the effect of different sizing, for example, varied amount of CNFs or CNTs tests. The after pushout characterisation by OM/SEM were carried out to ratify the results. It was found sizing with a small amount of evenly distributed nano-inculsion (CNFs/CNTs) on CFs can increase the interfacial shear strength and therefore enhance the strength of the composites.



load-displacement of a single fibre during push-out test.



SEM image of the carbon fibre after push-out test

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Acoustic emission monitoring of composite plates under bending – dimension effect

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The acoustic emission (AE) monitoring technique has shown its suitability to characterize the structural condition of engineering materials in laboratory and in-situ conditions. In structural composites, several breakthroughs have been accomplished regarding the fracture mode characterization based on the AE waveform parameters, as acquired by piezoelectric sensors on the surface of the material under test. However, the recorded signals, apart from the fracture source strongly depend on the size and shape of the specimens. Although the effect of the wave propagation path has been sufficiently analyzed, the effect of the dimension lateral to propagation or width of the component has not been highlighted. This is a missing link in the chain of interpretation of the results from small coupons to realistic members. This work studies the AE activity of glass textile reinforced cement (TRC) plates under bending in addition to wave propagation from artificial sources. It is shown that both the AE behavior and the wave propagation conditions vary greatly based on the width of the specimens, resulting in strong differences in the acquired signals even for the same excitation or fracture mechanism. The results suggest that great care should be taken in the interpretation of the fracture monitoring results as they are firmly connected to geometric factors.

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Design of the multipurpose test rig

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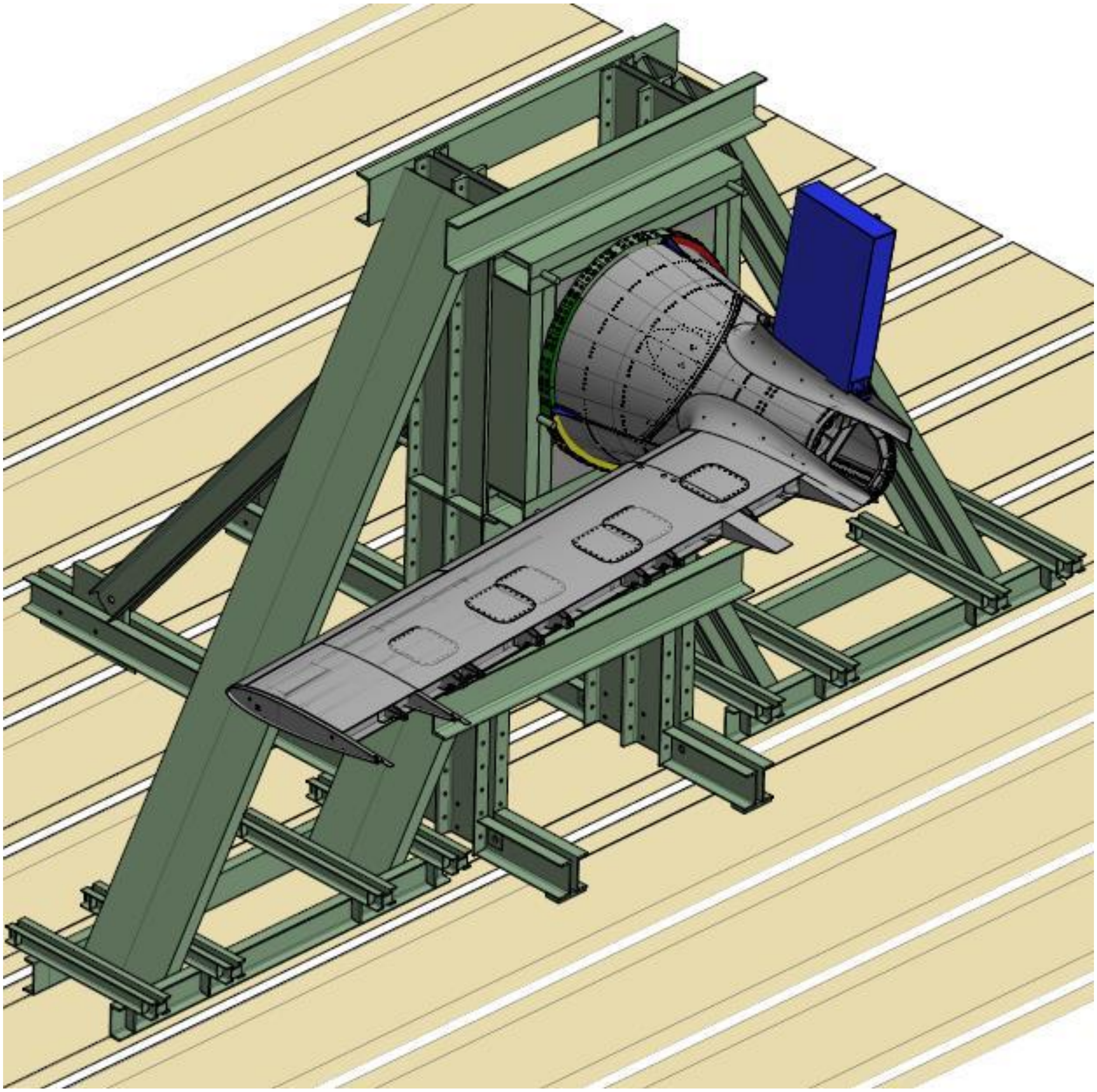
The paper discusses an innovative multipurpose test rig designed with the aim of full-scale rotorcraft fin verification. The developed test rig includes a load application mechanism able to apply loads representative for rotorcraft tail structure. Both conventional metallic components and innovative thermoplastic composites are used in the rotorcraft tail structure. The test rig is designed in a way that a variable stiffness of the fuselage to the fin joint can be achieved. Verification of the new tail test structure is supported by additional experiments and numerical analyses. Experimental work can be summarized into the building block diagram which is shown in Fig.1.

The multipurpose test rig is designed to meet several parameters - optimized attachment of the fuselage to ground support fixture, optimal loading of the fin and the dummy for I/F loading and sufficient accessibility of the test rig for measuring systems and NDT.

A segment of the fuselage with a specific dimension will be part of the VZLU ground support fixture. Special aluminium inner contour boards, outer contour boards and stringer interfaces of the fuselage part will be used for test rig assembly. A liquid shim will be added between the fuselage and the outer and inner contour boards and the contour boards will be screwed together. The rotation of the fuselage will be done so that the tail is horizontal to the ground which simplifies its loading.
Two possibilities of the loading systems are considered. The first is using textile pads on both sides of the tail surface, the second is using clamps with contour boards.
The aerodynamic load of the Ruddervator is provided either via separate hinges via dummy or Ruddervator. The loading of the Ruddervator (or hinges) is introduced in the neutral position, i.e. without turning of the load system.
The tail on the RH substitutes with a dummy for I/F loading. The dummy has an identical attachment to the fuselage as the left Tail. One loading actuator as the resultant force is considered for the load application of each load case.
The scheme of the test assembly is shown in Fig 2. The walkways will be built around the test rig to guarantee accessibility to the critical points of the structure. The design of the walkways must guarantee accessibility for all measurements perform during the test and for performing all necessary artificial damages (category 1 and 2).
Further work will be focused on the final design of the loading system with a whiffle-tree representing the pressure aerodynamic load on the Fin, the load from hinges (eventually Ruddervator) and the load from the Ruddervator control actuators.

Acknowledgement:
This paper is supported by European Union's Horizon 2020 research and innovation programme under the call H2020-CS2-CFP09-2018-02, grant agreement No 865123, project TAILTEST - Development of a multipurpose test rig and validation of an innovative rotorcraft vertical tail.

Building block diagram for testing and numerical simulation



The test rig (without actuators and the loading systems)

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Structural Integrity and Thermomechanical Response of Fe3O4/Carbon Nanotubes/Epoxy Resin Hybrid Nanocomposites

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Polymer matrix nanocomposites with conductive and/or semiconductive nanoinclusions are mostly employed in electrical and magnetic applications. Increasing the conductive filler content results in a gradual alteration of composite's conductivity and at a critical reinforcing phase concentration an abrupt increase of a few orders of magnitude appears in conductivity. This critical concentration is also known as percolation threshold. The presence of semiconductive nanoparticles within the polymer strengthens the dielectric response of the insulating matrix, while the magnetic inclusions induce magnetic properties to the composites. Dispersing nanoparticles in a polymer matrix can be considered as a distribution of nanocapacitors, where energy can be stored and retrieved. The simultaneous presence of semiconductive-magnetic and conductive nanofillers in a polymer matrix, results in a hybrid multifunctional system, where dielectric, electrical and magnetic properties are adjustable by controlling the type and the amount of the fillers [1,2]. A significant drawback for the applications of these hybrid systems can be their mechanical performance under both static and dynamic loading.

In the present study, a set of hybrid nanocomposites consisted of an epoxy resin as matrix and magnetite (Fe3O4) nanoparticles, multiwall carbon nanotubes (MWCNTs) as reinforcing phases was fabricated and studied, with filler content as a parameter. Systems' morphology was assessed via Scanning Electron Microscopy (SEM). Their thermomechanical characterization was conducted via Dynamic Mechanical Analysis (DMA) and their structural integrity via static tensile tests. Thermal properties were assessed via Differential Scanning Calorimetry (DSC) and Thermogravimetric Analysis (TGA). SEM images revealed fine nanodispersions in all cases, with limited and small clusters in the high filler content specimens. The presence of MWCNTs appears to be beneficial to both electrical behaviour and mechanical properties of the nanocomposites. On the contrary, the increase of the magnetite nanoparticles content, besides the effect of reinforcing the dielectric and magnetic performance, has a detrimental influence on the mechanical response of the systems. Glass to rubber transition temperature, as determined via the DMA tests, seems not to vary significantly with the reinforcing phases' content.

Optimum multifunctional performance, considering in tandem the thermal, electrical, magnetic and mechanical responses is derived by compromising positive and negative influences of fillers, upon every type of properties and accounting the requirements of a specific application.

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Acknowledgments

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Epoxy Based Composites for Electromagnetic Applications: Probing their Mechanical Properties

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Metal micro- or nanoparticles are embedded in polymer matrices aiming either to enhance electrical conductivity or to influence the dielectric response. The electrical heterogeneity of the constituents gives rise to dielectric permittivity, especially in the low frequency range and at high temperatures. In addition, metallic particles are highly conductive and thus increase the composites' conductivity. At a critical concentration of filler content, referred as percolation threshold, an increase of conductivity for several orders of magnitude occurs [1,2]. Dielectric properties can also be tailored by including metal oxide particles, which in general are of semiconductive nature. Distributed particles can act as a network of capacitors where energy can be stored and retrieved, defining thus a device behaviour of the composite in the micro- or nanoscale level. Further, incorporating magnetic inclusions, such as iron oxide or ferrites, magnetic properties are induced to the composites. The applications of these types of composites include, although not limited, electromagnetic interference shielding, integrated decoupling capacitors, self-current regulators, interlayer capacitors, conductive adhesives, drains for electrostatic charges, portable energy storing devices, micro-electro-mechanical systems and information storage materials [1-5].

In all these cases, besides the electrical and magnetic properties, composites should exhibit sustainable behaviour in order to carry the applied mechanical and thermal loads at service. The particulate form of the reinforcing phase and the adhesion between particles and matrix might act as detrimental factors upon the composites' performance. Poor mechanical and thermal behaviour could lead to early failure, cancelling any electrical and magnetic benefits of the employed inclusions.

In this study, series of composites consisted of an epoxy resin as matrix and silver, copper or copper oxide particles, as reinforcing phase were fabricated and studied, varying the filler content. The morphology of the prepared systems was investigated via Scanning Electron Microscopy (SEM). Thermal properties were examined via Differential Scanning Calorimetry (DSC) and thermomechanical characterization was conducted via Dynamic Mechanical Analysis (DMA). The structural integrity of all systems was studied via static tensile tests. Obtained results are discussed by means of the type and content of the employed filler, temperature and exerted mechanical load.

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Estimation of fatigue life for clinched joints with the Local Strain Approach incorporating the impact of cold forming to cyclic material properties

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Joining by forming is a commonly applied technique in the automotive industry to assemble parts of thin metal sheets to meet the demands of lightweight design. Joining of dissimilar materials, cost efficiency and greater fatigue life in the high cycle fatigue compared to spot welds are the major advantage of mechanically clinched joints. The joining operation induces changes in material behavior due to cold forming, that can be observed in increased hardness compared to the base material. Within the scope of ongoing research, the applicability of the Local Strain Approach to assess the fatigue life and crack initiation location of clinched joints from aluminium wrought alloy sheets considering the affect of changes to cyclic material properties is studied.
Complex geometrical features of a clinched joint on a small scale and lacking of nondestructive methods to track local stresses and strains require a combined approach utilizing numerical and experimental techniques. Material characterisation for the aluminum wrought alloy EN AW 6060T66 is accomplished by common uniaxial tension tests to determine a flow curve for the process simulation. An extrapolation approach is utilized to acquiere the stresses at higher degrees of forming. Hardness measurements are performed to assess changes in material properties. Cyclic properties to estimate fatigue life are obtained by strain controlled constant amplitude tests on speciments of base material.
Commercial finite element software LS-Dyna® is used to perform the process simulation in 2D, followed by mapping to 3D with constant amplitude loading to investigate local stresses and strains within the contact region. The Local Strain Approach with damage parameter PSWT [1] is applied to estimate the fatigue lives of several clinched joint variants under constant amplitude loading. Estimation of cyclic properties from hardness measurement, specifically derived from data of different aluminium alloys [2], is incorporated. Fatigue life estimations obtained from simulation results are compared to those from experiments.
The results obtained so far indicate that the Local Strain Approach is suitable for fatigue life estimations of clinched joints under constant amplitude loading.

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A holistic End-of-Life (EoL) Index for the quantitative impact assessment of CFRP waste recycling techniques

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By the year 2050, approximately 500k tones of accumulated CFRP waste from the aviation industry, will reach their EoL cycle [1]. In contrast to other classes of engineering materials for which a solid recycling industry has been established, a commercially viable recycling method for CFRP remains still a challenge. Landfill and incineration still constitute the most popular methods for disposing CFRP waste, although both methods cannot be classified as recycling since they do not involve recovery of materials. In that context, alternative recycling methods are being developed during the last two decades [2].

Commercial viability of CFRP recycling is associated with the quality and value of the retrieved fibers. However, due to degradation of the fiber mechanical properties, to achieve for a composite material containing recycled carbon fibers (rCF), comparable mechanical properties to those of a composite involving virgin carbon fibers, a higher rCF volume fraction would be required. To assess the environmental and financial impact of waste treatment processes and methods, either life cycle assessment (LCA) or life cycle cost (LCC) models involving fiber recovery, have been developed and applied (e.g. [3]). Nevertheless, a holistic concept or tool allowing quantifying the overall impact of CFRP waste treatment processes, by accounting for their economic and environmental assessment combined with the reusability potential of the retrieved fibers, does not currently exist. To this end, an EoL Index is introduced to serve as a decision support tool for choosing the optimal recycling process among a number of alternative recycling processes. For the choice of the optimal recycling process, the aspects of quality of the recycled fibers as well as cost and environmental impact of the recycling methods under consideration are accounted for. Quality is interpreted as the reusability potential of the recycled fibers and the importance weights of the above aspects are determined by the engineer as initial input for implementing the Index, through a multi criteria decision analysis (MCDA). When reusability of the recycled fibers is prioritized over the environmental and cost performance, the ranking among the different recycling methods considered, presents a clear advantage of Microwave Pyrolysis and Solvolysis with Supercritical Water over Fluidized Bed Process and Conventional Pyrolysis.

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An overview on nanoparticle reinforced lightweight metal composites

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In view of global warming, the reduction of greenhouse emissions has become a central topic for the transportation sector. In this context, the development of light metals is attracting attention for structural applications. Nanoparticle reinforced metal composites are a promising solution due to potentially excellent mechanical properties and low density. However, experimental results fall short of the theoretical predictions. The reinforcing mechanisms acting in nanoparticle composites are also not yet well understood.

The well understood strengthening mechanisms for metal composites are load transfer, Orowan strengthening, grain refinement and thermal mismatch as summarised in our previous work [1]. However, those mechanisms were formulated for micrometre-sized particles and therefore have certain limitations when applied to nano-reinforcements.

- Load transfer: requires good interfacial bonding between nanoparticle and metal matrix, which is said to be poor according to some research.

- Orowan strengthening: It is not clear whether dislocation motion in the context of nanoparticles requires the formation of Orowan loops, or whether the strain caused by shearing of the metal around nanoparticles can be accommodated by deformation or failure of the nanoparticle-matrix interface leading to a quasi-cutting mechanism.

- Grain refinement: There is no clear evidence of nanoparticles acting as nuclei due to their nano-scaled dimension.

- Thermal mismatch: It is unclear to which extent the analysis of Arsenault [2] developed for micron sized particles can be applied to the scale and geometry of nanoparticles.

In this paper, we looked into using different nanoparticles including carbon nanotubes, graphene and SiC with different geometry in lightweight metal matrix. Both, experimental and theoretical results were compared to gain a better understanding on the influence of difference nanoparticles. We also discussed possible reinforcing mechanisms regarding nanoparticles based on both micro-scale observation and simulation.

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Designing a knowledge management system for Naval Materials Failure Analysis

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Preliminary results of an HFRI funded project with the acronym NAVMAT are presented in the current paper. NAVMAT attempts an interdisciplinary approach by integrating Materials Engineering and Informatics under a platform of Knowledge Management. Failure analysis expands into forensics engineering for it aims not only to identify individual and symptomatic reasons of failure but to assess and understand repetitive failure patterns, which could be related to underlying material faults, design mistakes or maintenance omissions. NAVMAT approach, utilizes a focused common-cause failure methodology for the naval and marine environment, to begin with. It will support decision making through appropriate Artificial Intelligence and Natural Language Processing methods.

The presented work describes the design of a knowledge based system dedicated to effective recording, efficient indexing, easy and accurate retrieval of information, history of maintenance and secure operation concerning failure incidents of marine materials, components and systems in a fleet organisation. Based on materials failure ontology, utilising artificial intelligence algorithms and modern approaches in data handling, NAVMAT aims at the optimisation of naval materials failure management and the support of decision making in Maintenance and Repair Operations (MRO), materials supplies and staff training.

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Quantitative evaluation of knee and shoulder dysfunction using Inertial sensor technology

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Introduction
Human motion tracking based on Inertial Measurement Units (IMUs) offers several advantages for the kinematic evaluation of the human body. The analysis is fast, reliable and can be carried out in various locations and not only in the laboratory environment. The IMU's include a 3-axis accelerometer, a gyroscope, and a magnetometer providing real time data of human motion. We have used a Motion Capture System for motion analysis and clinical research primarily focused on the shoulder and the knee joint.
Materials-Methods
We used the Shadow Motion Capture System to quantify the instability of the knee after an acute injury of ACL (Group A) and to quantitively evaluate the scapular kinematics in athletes with a partial articular surface rotator cuff tear (Group B). In both groups the contralateral side was used as a control.
In Group A, the inertial sensor was placed on the the flat medial surface of the upper third of tibia and the second on the lateral surface of the lower third of the thigh using elastic straps to maintain their position. The sample rate was 100 Hz with 0.5° static accuracy and 2° dynamic accuracy. Overall, five repetitions were performed in each knee for every test. The rotational displacement of the tibia in degrees in three axes and the global anterior translation in mm were recorded. In Group B, scapular kinematics was evaluated using IMUs positioned in the upper limb, the scapula and the sternum. The patients were asked to perform shoulder abduction and forward flexion in the scapular axis and the displacement and rotational data of the movement were recorded using the dedicated software. Statistical analysis was performed using SPSS v.24 implementing the one-way ANOVA and paired X2 statistical tests.
Results: In Group A, the mean rotational displacement in the normal knee for the pivot shift and the Lachman-Noulis test was 26.46±4.5° and 7.73±0.86° respectively, while in the injured knee it was 29.67±3.34° and 10.03±0.61° respectively ($p<0.05$). For the Lachman–Noulis test the mean anterior translation was 14.4±2.9 mm and 6.7±1.2 mm (study group) and for the anterior drawer test 8.2±1.6 mm vs 5.4 ±1.23 mm (control group) ($p<0.05$). In Group B, the scapular translation in abduction was higher in the affected shoulder along the laterally directed x axis (23.54 ±7.1 mm vs 19.58 ±6.9 mm) and the anteroposteriorly directed z axis (13.97 ± 2.97mm vs 7.17 ±4.73mm), The same finding was noticed in forward flexion for the z axis (14.03±2.53 mm vs 9.41±5.92 mm). The rotation, in rads, was significantly higher in the anteroposteriorly directed z axis (0.50±0.23 vs 0.37±0.052). All differences were statistically significant.
Conclusions: The use of inertial sensors in the injured and the normal knee and shoulder joints provide quantitative information regarding the translational as well as the rotational element of the knee instability in real time as well as information about the abnormal scapular kinematics.

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Simulation of the mechanical behavior of Self-healing Composite materials

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In recent years, the high performance and design flexibility of the composite materials has led to their rapid spread in the field of Aeronautics and Space, Automotive, Marine etc. At the same time, the growing technological demands require for advanced material properties with superior properties or even an extended lifespan[1]. In this context and inspired from the healing mechanisms of living beings, many studies have been focused on the evolution of multifunctional composite materials, which mimic nature by incorporating self-healing microcapsules in the matrix of the material aiming to heal, either stop possible microcracks occurred in the matrix[2]. This new class of materials is called self-healing materials. A self-healing material that has attracted much attention is the self-healing material with embedded encapsulated healing agents into polymer matrix containing dispersed catalysts. When a crack occurs, the crack ruptures the embedded microcapsules, releasing the healing agent into the crack plane. Then, the healing agent contacts the catalyst, which is dispersed into the matrix, triggering polymerization and hence healing the crack faces by filling them with the released agent[3], as seen in figure 1.
In the present work, a multi-scale model was developed, the mesh of which can be seen in figure 2, both in the reference material with voids and in the composite fabric, in order to simulate the effect of microcapsules on the mechanical behavior of the polymer matrix. Furthermore, the effect of the microcapsule diameter as well as the effect of the microcapsule's concentration on the mechanical behavior of the composite have been studied. For the simulation of the self-healing composite, the Digimat software as well as the ANSYS software have been used.

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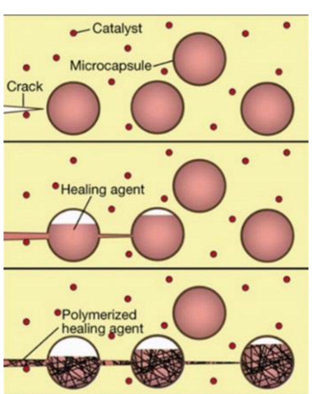
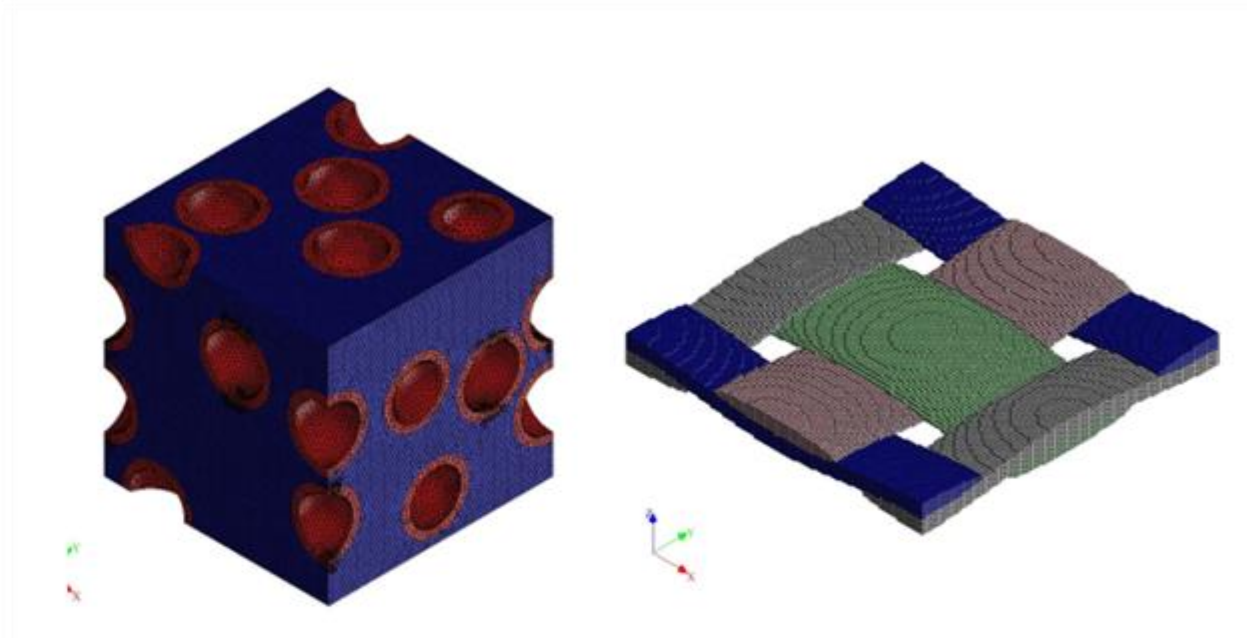


The self healing mechanism



On the left, mesh of the reference material with voids and on the right mesh of the composite fabric

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Temper embrittlement of 9%Ni low carbon steel and non-destructive inspection by magnetic Barkhausen noise

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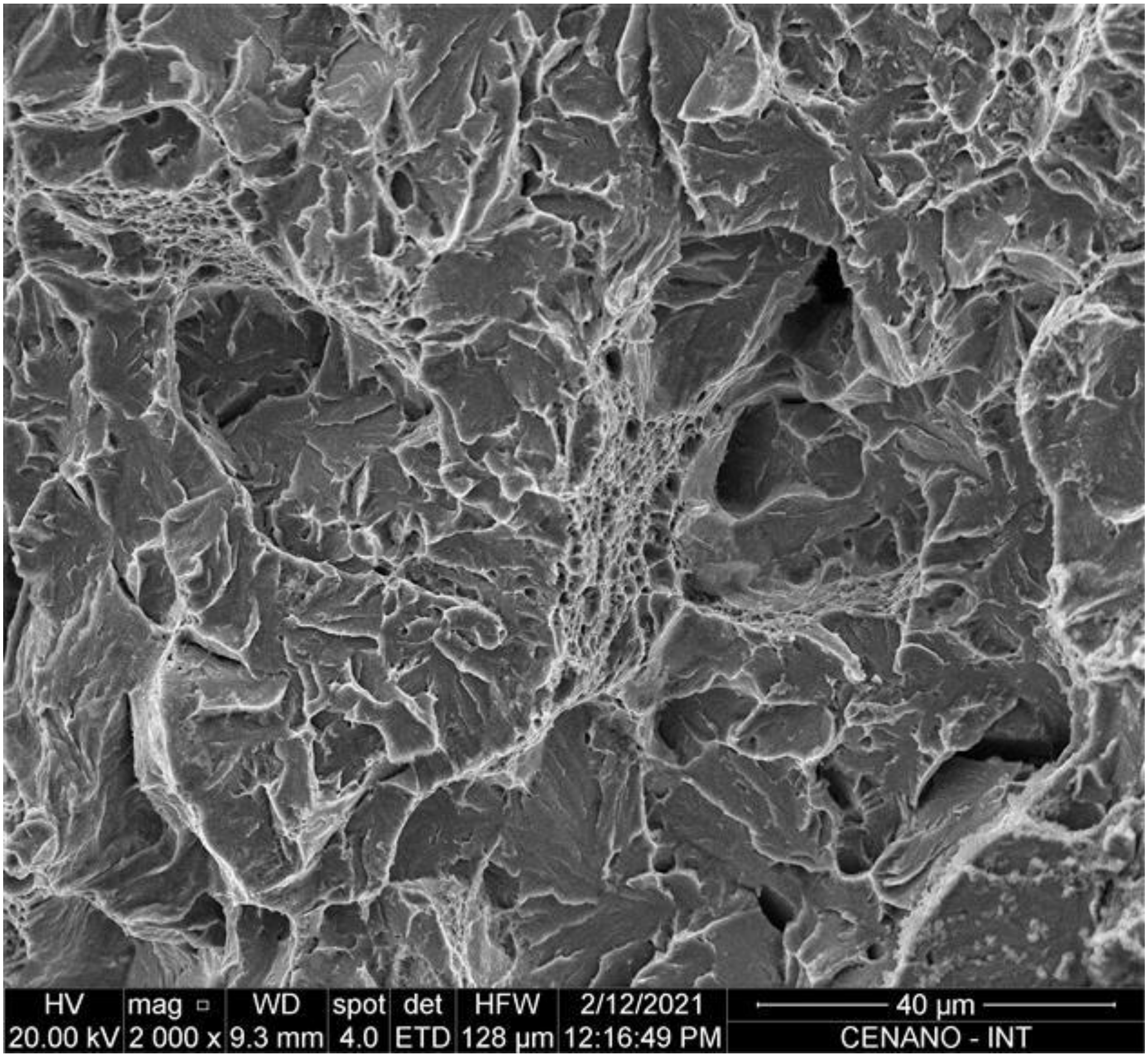
Temper embrittlement of 9%Ni low carbon steel and nondestructive inspection by magnetic Barkhausen noise

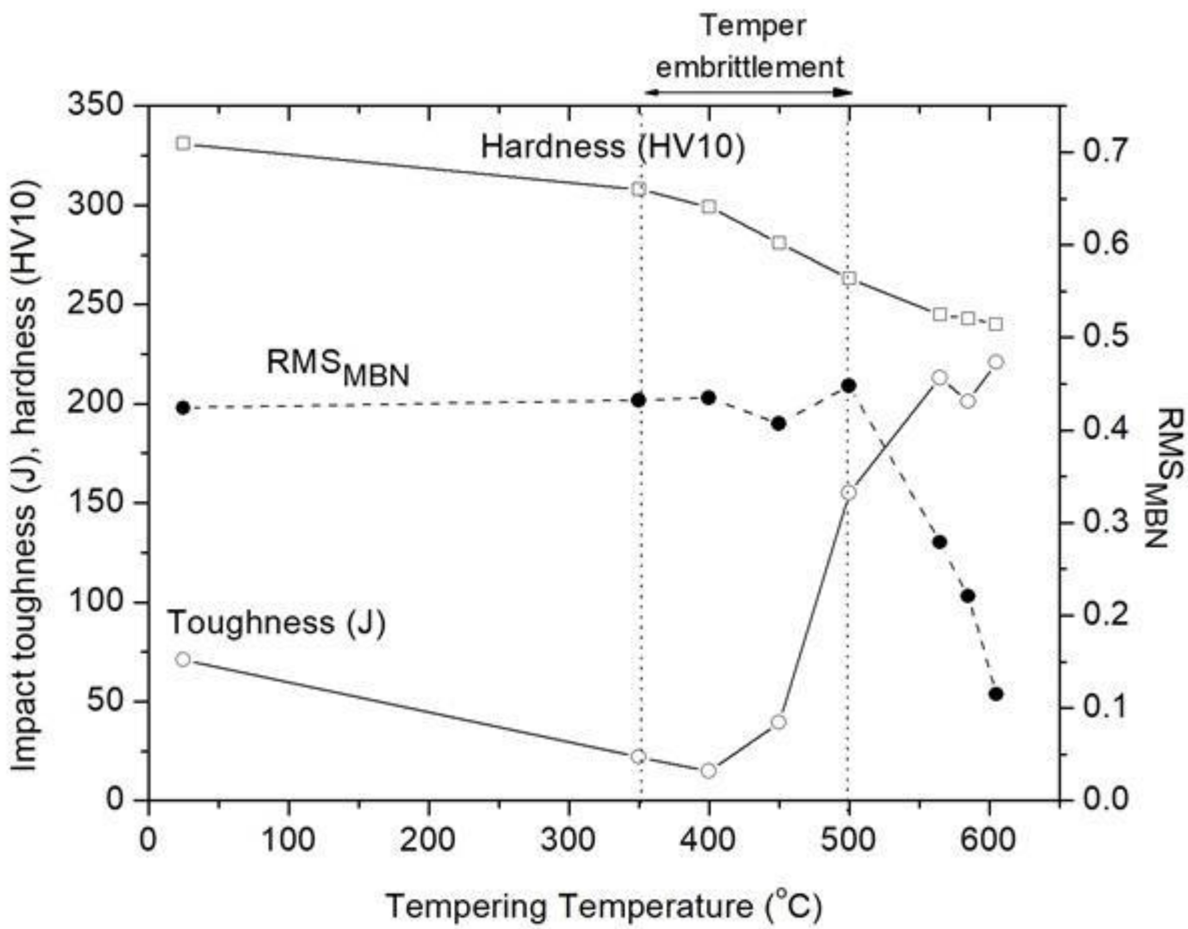
Sérgio Souto Maior Tavares, Fernanda Freitas Neves, Hugo Ribeiro da Igreja, Odivaldo Cambraia Alves, Leosdan Figueredo Noris, Juan Manuel Pardal

ABSTRACT

9% Ni low carbon steel is used in cryogenic services pure gas production and, recently, in oil and gas off-shore exploration. The final mechanical properties of this steel are adjusted by quenching and tempering heat treatments. However the un-correct tempering temperature selection may cause temper embrittlement of this material, which has his cryogenic toughness drastically decreased. Also, if the cooling rate from the tempering temperature is too low, temper embrittlement aslo occur. In this study, this phenomenon was investigated in specimens of 9% Ni low carbon steel quenched and tempered at different temperatures and cooling media after temper.
Specimens tempered at 350°C, 400°C and 450°C showed very low toughness in low temperature (-196ºC) Charpy tests due to temper embrittlement. Specimens slowly cooled from the tempering temperature (565ºC, 585ºC and 605ºC) also showed toughness reduction in comparison with specimens tempered at the same temperature and rapid cooled in water. The brittle fracture was characterized by intergranular cracks and cleavage (Fig.1). The Magnetic Barkhausen Noise (MBN) inspection was conducted to verify if this technique can be used to detect the temper embrittlement in 9Ni steels. The root mean square (RMS) of the MBN signal was calculated and it was found to be higher in specimens as quenched and in specimens tempered in the temper embrittlement range (350ºC - 500ºC) than in specimens which were correctly tempered (565 – 605ºC and water cooled). Figure 2 summarises the RMS-MBN, Charpy tests results and hardness of specimens tempered and water quenched. The RMS-MBN cannot be related to the hardness of 9Ni steel, but can be a powerful technique to detect microstructures with low toughness in 9Ni-low carbon steels. Comparing specimens tempered in the 565 – 605ºC range slowly cooled with those water cooled, the RMS-MBN was higher in the former group which presented the lower toughness. The RMS-MBN is sensible to carbides precipitation and to austenite formation in the tempering treatment, and the results will be related to these phase transformations.



Fractography of the specimen quenched and tempered at 585ºC with furnace cooling.



Variation of hardness, impact Charpy and RMS (MBN) with tempering temperature for specimens water quenched after tempering.

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A computational study of mechanical performance of bioresorbable polymer composite stents

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Stents are the preferred means of restoring and maintaining patency of narrowed blood vessels affected by coronary artery disease (CAD). Coronary stents are conventionally made of metal alloys. Nowadays, bioresorbable stents (BRS) offer enormous potential as they meet specific medical requirements, such as degradability. In addition to medical and biological behaviour, requirements regarding their mechanical properties should also be met. They must have sufficient radial strength to support the vessel and be flexible for deployment. Biodegradable stent material has much lower mechanical properties than metallic stents, therefore stent geometry and material properties must be considered simultaneously when evaluating stent performance. However, there are still many challenges, such as understanding and evaluating the mechanical properties of polymeric stents. Recently, a new concept has been proposed regarding the feasibility of polymer composite stents for treatment of cardiovascular disease using a 3D printing process based on Fused Deposition Modelling (FDM). By combining different polymer materials, a good solution for BRS could be provided.

The research presented in our paper focuses on the finite element simulation of mechanical performance of PLA/PCL composite stents. Numerical analysis is a useful tool that, after careful verification and validation, can replace expensive and time-consuming experiments and provide experts with additional knowledge. Three different stent geometries are selected and a comparative study is performed regarding their mechanical performance using finite element analysis (FEA). Their comparative effect on radial strength, flexibility and radial stiffness is investigated using the simulated results. The stent deformation and stress/strain distribution were analysed. The results show the attractiveness of using polymer composite stents to meet the mechanical requirements. The computational solution to evaluate the mechanical strength of the stent can also be used as a guideline for the design of polymer composite stents.

Keywords: coronary stent; finite element analysis; bioresorbable polymer; composite

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Embedded Structural Health Monitoring through Surface Acoustic Wave Inspection Deployed on Capillaries Integrated in Additively Manufactured Components

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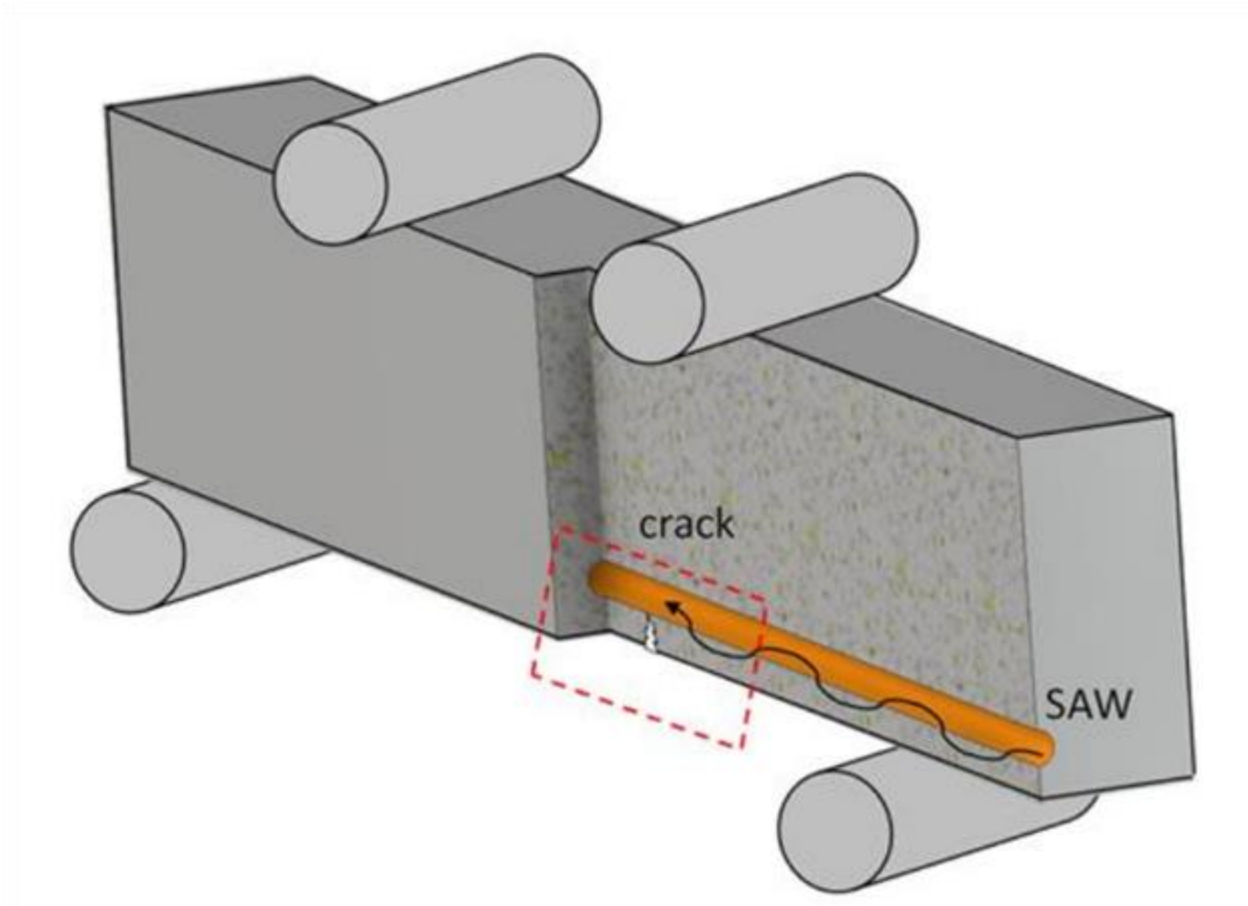
Surface Acoustic Wave (SAW) inspection is a well-known non-destructive-testing technique that receives considerable attention to become implemented as a Structural Health Monitoring system. As these SAW's typically travel on free surfaces of solid bodies, they are often exposed to environmentally conditions such as oil and grease ingress, accidental damage causing surface scratches, mechanical contacts, and others. All of these conditions may vary over time and impact the SAW propagation properties, making it difficult to implement this SAW inspection principle as a continuous, online, Structural Health Monitoring system.

A novel approach to overcome beforementioned difficulties would be to deploy SAW inspection on the inner surface of a capillary channel integrated in a solid metallic component produced by means of metal additive manufacturing. Whilst avoiding external influences on the propagation of the SAW's, such capillary would furthermore act as a waveguide for the SAW's inside the solid metallic component. SAW attenuation will therefore be reduced and specific areas of interest, e.g. fatigue hot-spots, can receive focused attention by redirecting the capillary.

The current work will present initial proof-of-concept studies of this novel SHM principle. SAW's will be excited on the capillary surface and their propagation and attenuation properties on straight and bent capillaries will be studied. Also the interaction with mechanical damages will be investigated.



Graphical representation of Surface Acoustic Wave Inspection deployed on an inner surface of a capillary in a solid body, manufactured by additive manufacturing.

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Characterization of surface integrity of shot-peened leaf springs by micro- and nano-indentation

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Lightweight steels with demanding requirements for durability and safety are applied in high performance automotive leaf springs. Various surface treatments have been developed toward this goal, i.e. shot-peening (SP) and stress-shot-peening (SSP: combination of pre-stressing and shot peening), inducing compressive residual stresses with a view to fatigue life enhancement.

The microstructure of a material strongly influences strength, toughness, ductility, hardness, corrosion resistance, high/low temperature behavior or wear resistance. In case of SSP leaf springs, there is a significant degree of distortion in the microstructure of surface and sub-surface compared to the core, reaching in some cases a 300 µm deep zone from the heat-treated surface. This effect can be captured both by Vickers micro-hardness measurements and nanoindentation. The latter combined with a FEM-based algorithm enables the determination of different material's stress-strain curves over the affected zone, capturing internal stress changes.

The aim of the present work is to fully analyze the material properties of a shot peened steel at various depths from the surface. A combination of microstructural analysis, microhardness and nanoindentation explains the behavior of the treated material, offering input for more realistic FEM-based simulation and insights on the material performance.

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Disclaimer:
The paper contains the authors' work and technical results. The Commission does not carry any responsibility for any use that may be made.

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Record Terahertz shielding behavior of lightweight CVD graphene nanolaminates

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Owing to its extraordinary material properties, graphene has attracted considerable interest for the development of light-weight, high strength composite materials with several multi-functionalities; actually, this two-dimensional lattice of sp2-bonded carbon exhibits remarkably high electrical conductivity, mechanical and thermal properties [1]. So far, only graphene in a form of small flakes (e.g. nanosheets of graphene oxide or of reduced graphene oxide and graphene nanoplatelets) has been adopted for the production of polymer composites for large scale applications. Unfortunately, in such discontinuous composites it is difficult to fully exploit the extraordinary properties of graphene; in fact, their actual mechanical performance is still below the expectations due to the small lateral size of the flakes that results in poor transfer of stresses from the polymer matrix. Other limitations are due the difficulties with dispersion and poor control of flake orientation and thickness, which require higher filler content for decent electrical and thermal conductivities. The use of large-size monolayer graphene growth via Chemical Vapour Deposition (CVD) can overcome these drawbacks by offering (i) large lateral size of the continuous reinforcement and thus efficient stress transfer, and (ii) uniform and controllable dispersion of the filler in the polymer matrix. In this way, the sequential alternation of the layers consisting of matrix and filler in the nanolaminates can produce highly performant materials with interesting combination of physical properties.

Herein we report on the development of centimetre-size CVD graphene-polymer nanolaminates that have the potential to outperform the current overall state-of-the-art graphene-based composite materials in both mechanical and electrical properties per graphene content, and that show impressively high absolute EMI shielding effectiveness in a full frequency decade approximately centred at 1 THz. We adopted a new approach based on the combination of ultra-thin polymer casting, "lift off-float on" process and wet deposition, and we have produced freestanding nanolaminates with layer numbers ranging from 10 to 100 and volume fractions of 0.04 to 0.5%. Moreover, supported nanolaminates with higher graphene content (1 vol%) have been produced revealing the impressive potential of this class of material. In fact, these nanolaminates present a significant enhancement of Young modulus, with an estimated effective modulus of 846 GPa for CVD graphene, combined with in-plane electrical conductivity as high as 250 S/cm, and an absolute EMI shielding effectiveness (~ up to 3�105) which is amongst the highest reported for synthetic, non-metallic materials produced so far.

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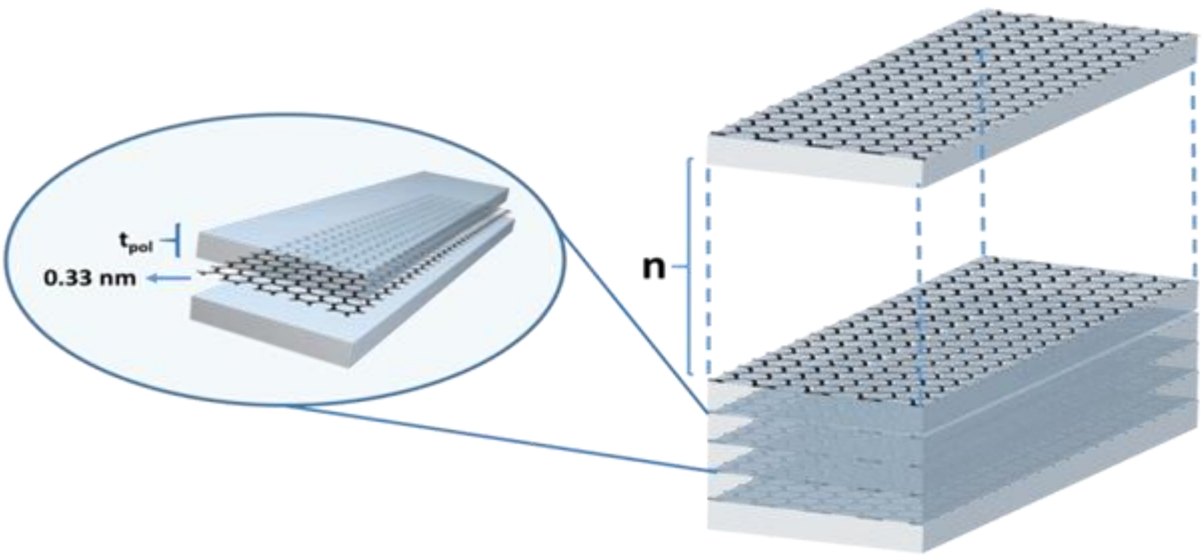
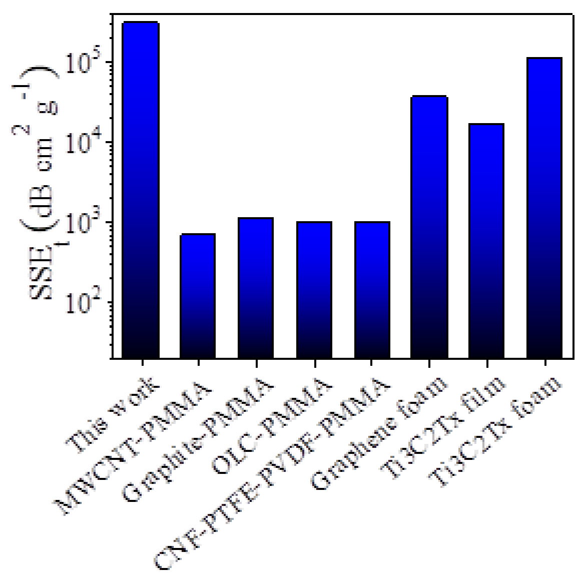


(n=number of plies Polymer/Gr)

Schematic illustration of structure of the Gr/polymer polymer nanolaminates.



Comparison of absolute shielding effectiveness values between Gr/PMMA nanolaminates and SOTA shielding materials in the THz range.

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Diffusion phenomena at the interface zone of A1050/Ni201 explosively welded clads leading to disintegration of the weld

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The limitation of high manufacturing cost and related unit price of a given structural material is in many cases effectively compensated by designing engineering structures using layered materials obtained by explosive welding. There is a strong correlation of the conditions of the explosion welding process with the microstructure and phase composition as well as selected properties of the weld in the state immediately after joining, which in turn very significantly affects the phase composition and integrity of the weld after heat treatment. Welds obtained using three detonation velocities were selected for this study: 2000, 2400 and 2800 m/s. The A1050/Ni201 welds have been characterized at the micro and nano scale by electron microscopy techniques with special emphasis on the interface zone. The investigations of the microstructure of the welds were carried out after the explosive welding process and annealing to observe the evolution of the microstructure of the interface the changes of the chemical composition resulting from the activated diffusion processes and the kinetics of the growth of the intermetallic phases in the joined area.
Immediately after the explosive welding process irrespectively of the mutual location of the colliding plates, the presence of a continuous melted layer in the form of asymmetric waves has been observed. The reaction zone morphology development was significantly dependent on the process dynamics. When low detonation velocities were used, the formation of an almost flat boundary between A1050 and Ni201 alloys was revealed. In contrast, an increase in velocity resulted in the formation of massive, relatively short and densely distributed waves. On the basis of the investigations carried out, it was shown that in the case of extreme conditions of pressure and locally higher temperature prevailing in the case of the highest detonation rate, in addition to the Al_3Ni, Al_3Ni_2 and AlNi phases also present in the other welds, a metastable monoclinic Al_9Ni_2 phase was identified inside the remelting zones. The study of the evolution of the interface microstructure of the heat-treated welds allowed to determine the kinetics and growth mechanisms of the intermetallic phases from the Al-Ni system. The analysis of the obtained results unambiguously indicated a strong correlation between the changes of the microstructure and the weld quality on the conditions of the joining process of A1050 and Ni201 alloys. After short annealing times, Al_3Ni and Al_3Ni_2 phases were present in all welds, while their amount varied with respect to the explosive welding conditions. In addition, for the welds obtained at the lowest detonation velocity, a complete disappearance of the Al_3Ni phase was observed after longer annealing times and only the Al_3Ni_2 phase was present in the reaction zone. Significantly, for this plating, cracking was observed due to the formation of high porosity at the Al_3Ni_2/Al interface. This in turn was due to the Kirkendall phenomenon intensified by the mechanism of growth of the intermetallic phase along the grain boundaries acting as fast diffusion pathways.

Acknowledgments:
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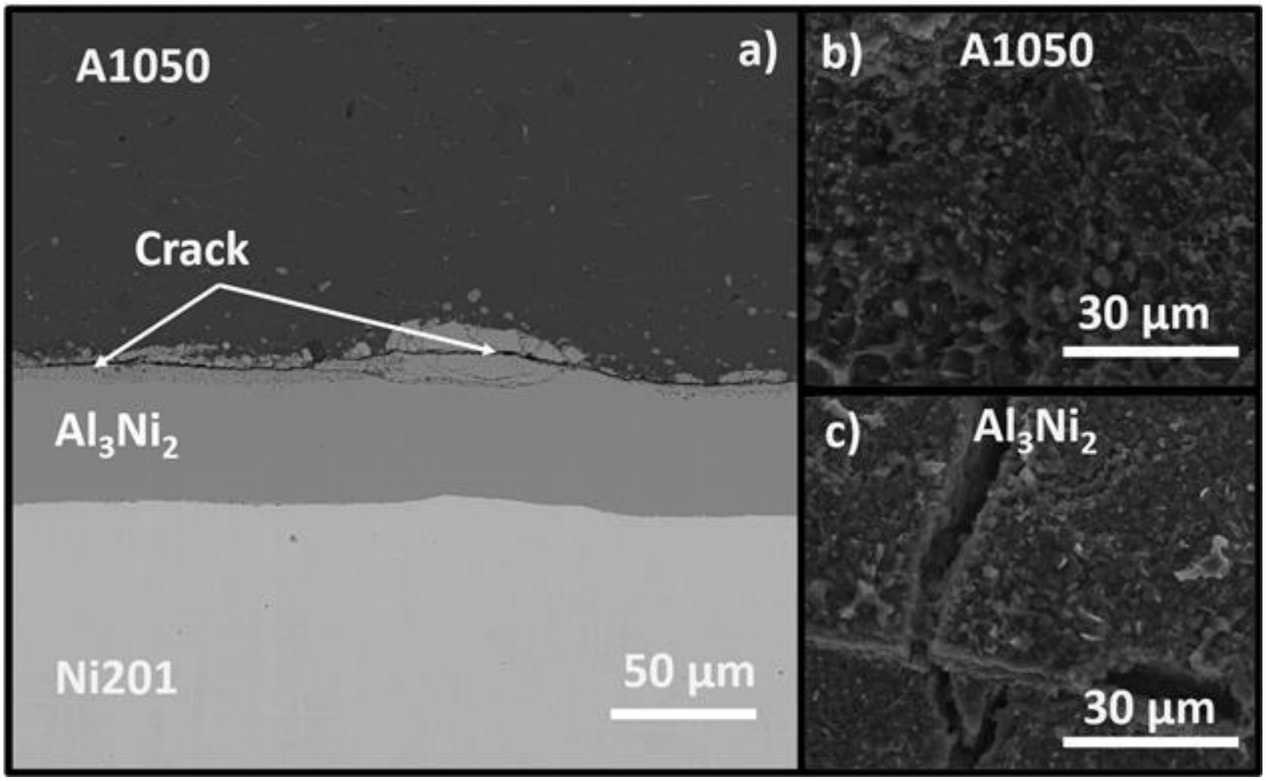

Fig. 1 Interface zone microstructure of explosively welded A1050/Ni201 clad after long term annealing at 500 °C: overall view showing crack propagation with the surfaces' fractures after disintegration.

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Design of a bonnet of a sport vehicle realized with an innovative recyclable Polymeric Matrix Composite and Virtual characterization of the related structural sandwiches reinforce.

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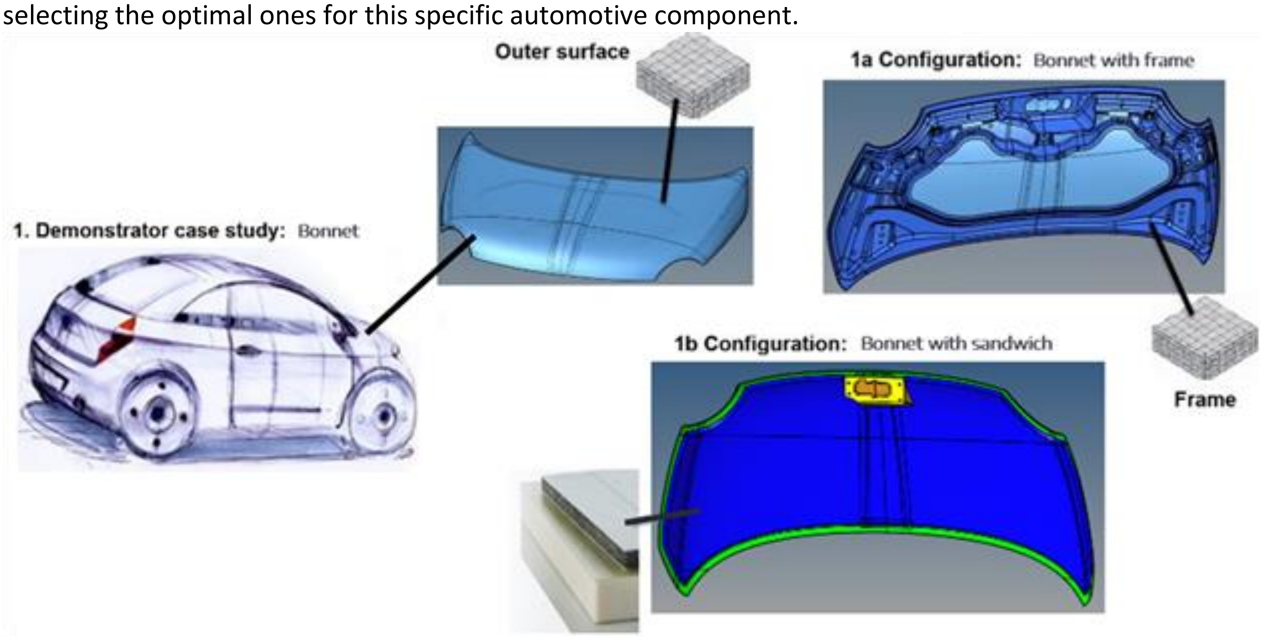
This article presents the activities design of an automotive component to be produced using a cradle-to-cradle recyclable Polymeric Matrix Composite based on cleavable-epoxies matrix and Basalt-Derived Mineral Fibers (BDMF). The material innovations are being studied within project C2CC (www.c2cc-project.eu), aimed at satisfying latest EU directives regarding end-of-life reuse and C-footprint reduction. The main targets are the weight reduction, obtained employing raw materials with lower footprint (in C2CC project it is obtained by the adoption of a biomass derived epoxy) the cleavable hardener (which avoids the need of a pyrolysis step to recover and recycle the fibre) and finally the cradle-to-cradle recyclable mineral fiber, that is a fibre that (differently from carbon fibre) can be remelted to long fibre with no decrease in mechanical specifications. The main project demonstrator is the front bonnet of segment A vehicle: the selected case study is the FIAT 500 Abarth. One potential approach to reach the component expected performances is using the semifinished composite materials (prepregs) produced by the project to manufacture the final structural sandwich. From the modelling and simulation point of view, this work carries out a multiscale approach starting from the basic constituents of skin and core and ending with the model at the mesoscale of the specimens of the sandwich. Considering the innovations proposed in C2CC project imply the development and characterization of innovative semi finished materials (prepregs) in a pilot line, some mechanical inputs for FE modeling needed to be derived experimentally, applying international standards (e.g. ASTM D3039, ASTM D6641, ASTM D3518). The here presented modeling activity has been conducted considering the possible recyclable sandwich cores, and the comparison aims at selecting the optimal ones for this specific automotive component.



C2CC project - Main Demonstrator - bonnet of the FIAT 500 Abarth

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Production and applications of superlubric graphene coatings

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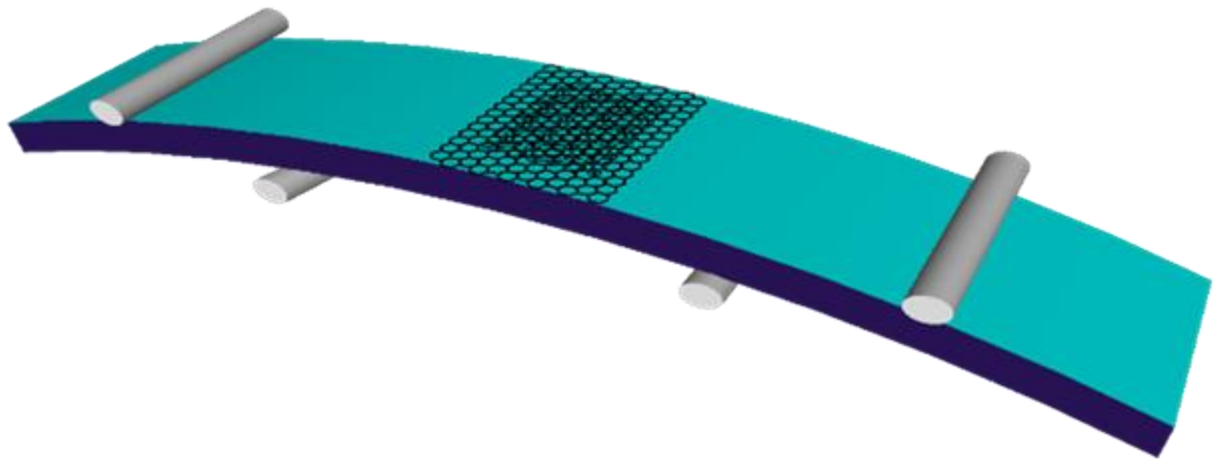
When two solid surfaces in contact are subjected to relative motion, friction appears converting an amount of kinetic energy to thermal energy, but can also cause serious wear problems such as mechanical degradation or damage of the moving components. On the other hand, superlubricity is the state of matter of ultra-low or vanishing friction, where these issues are significantly suppressed. However, there is not a strict definition from a quantitative perspective. To put that roughly in numbers, the friction co-efficient needs to be less than 0.01 for superlubricity to be claimed. Superlubricity arises when two crystalline surfaces are in an incommensurate stacking state and slide with respect to each other under dry conditions. Graphite is a well-known solid lubricant material, a property that originates from the weak interlayer coupling between individual graphene layers with van der Waals bonds. Other graphitic materials such as mono and few-layer graphene and its derivatives have also been examined extensively for their use as lubricant coatings. A major bottleneck is that for graphitic samples with lateral dimensions in the micron and macro-scale, the large contact areas contain many commensurate stacking domains which in turn result in mechanical interlocking and breakdown of superlubricity. Recently, the concept of strain engineering has gained traction in the field and studies report that macro-scale superlubricity can be achieved by the use of strained graphene layers. It was shown that by applying increasingly mechanical tensile strain in a step-wise manner to a two-layer graphene, a transition from commensurate to incommensurate stacking can be realized. The tensile strain creates a lattice mismatch between the two layers which practically slide relative to each other after a certain threshold of tension. Monitoring the shearing mechanism with Raman spectroscopy and the use of continuum theory it is estimated that the interlayer shear strength (ISS) is in the range of ~0.05-0.15 MPa. This ISS range is associated with superlubric behaviour. The phenomenon is robust as it is observed in relatively small samples produced by mechanical exfoliation of a few microns, as well as in large CVD samples in the mm scale.
The understanding of the interlayer shearing mechanism and its effect on friction reduction on the graphene-graphene system can lead to better exploitation of graphene as a lubricant material in a number of state-of-the-art applications. These include dry lubrication into mechanical drive components such as micro/nano-electromechanical systems (MEMS/NEMS), electrical switches, aerospace and wind energy applications. Reducing friction and mechanical energy loss at interfaces of components, in can minimize wear damage and significantly increase the lifetime of these applications.



Schematic of the experimental setup is shown with two single-layer graphenes stacked in an incommensurate state.

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Effect of Impact Modifiers on Strength and Fracture Toughness of CFRPs

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Carbon fiber-reinforced composites are widely used in industries, such as aerospace and automotive. The widespread use of these materials is due to their very good mechanical properties, high modulus of elasticity and low density. The fact that the fibers are not chemically bonded to the epoxy matrix makes these composite materials sensitive to crack propagation and in combination with their fragility, exhibit weak impact resistance. This phenomenon affects the mechanical performance of materials [1].
The role of the core-shell rubbers (CSR) into the fiber-matrix composite, is to absorb an energy amount during mechanical stresses and thus extend CFRPs' service life and strength [2]. The impact resistance of composites with embedded CSRs is improved through their ability to absorb vibrations and terminate propagation of cracks [3]. The aim of this work is to study the effect of core-shell rubbers on mechanical properties of CFRPs and exploit simulation tools to further expand this investigation.
For the preparation of composites, two types of resins were used, a three-component Araldite resin (resin-hardener-accelerator system in proportions of 100-90-0,5 by weight respectively), and MX 156, which contains 25 % core-shell elastomers and 75 % Araldite resin. Depending on the mechanical test, two types of carbon fiber fabrics (UD C415, G0926) are used with corresponding number of layers. The composites were prepared by vacuum infusion and cut to the appropriate dimensions by water-cutting. They were tested for mechanical performance, by bending, shearing, tensile, impact and fracture toughness tests, to compare the properties of CSR-containing composites and reference CFRPs. Fracture analysis of specimens was performed by scanning electron microscopy (SEM). Specifically, in the bending test the strength of the CSR specimens is reduced by 13,81 %, the elasticity modulus by 20,57 %, while the deformation of both samples is almost the same. In the tensile test, the strength with the presence of CSR, decreases by 12.5 %, the Young modulus also by 7.12 % and also in this case the maximum deformation is almost the same. In the impact test, compared to the specimens with the reference resin, those with CSRs, showed, as expected, 49.8 % increased strength. In the fracture toughness tests, the energy absorbed by the specimens with CSRs is about four times greater comparted to reference materials. Finally, shear strength is slightly lower in case of CSR reinforced materials, however their endurance through time is prolonged with higher max strain.

Acknowledgements
This work was supported by the EU H2020 Project "SMARTFAN" under Grant Agreement no 760779.

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Short-beam Test (ILSS) of CFRP with CSR

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Plasma Enhanced Chemical Vapor Deposition of SiOx-like thin films for corrosion protection of light metals

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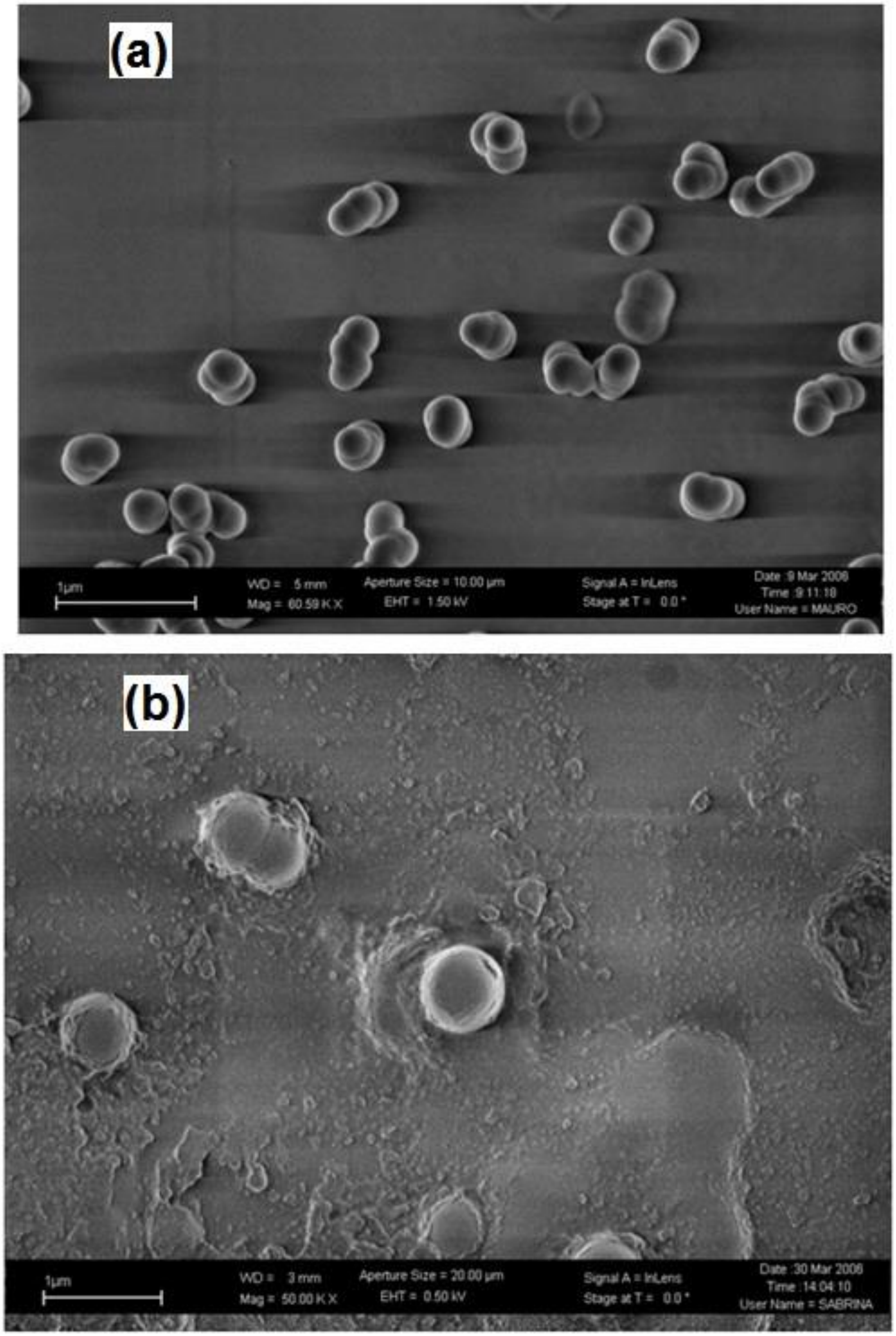
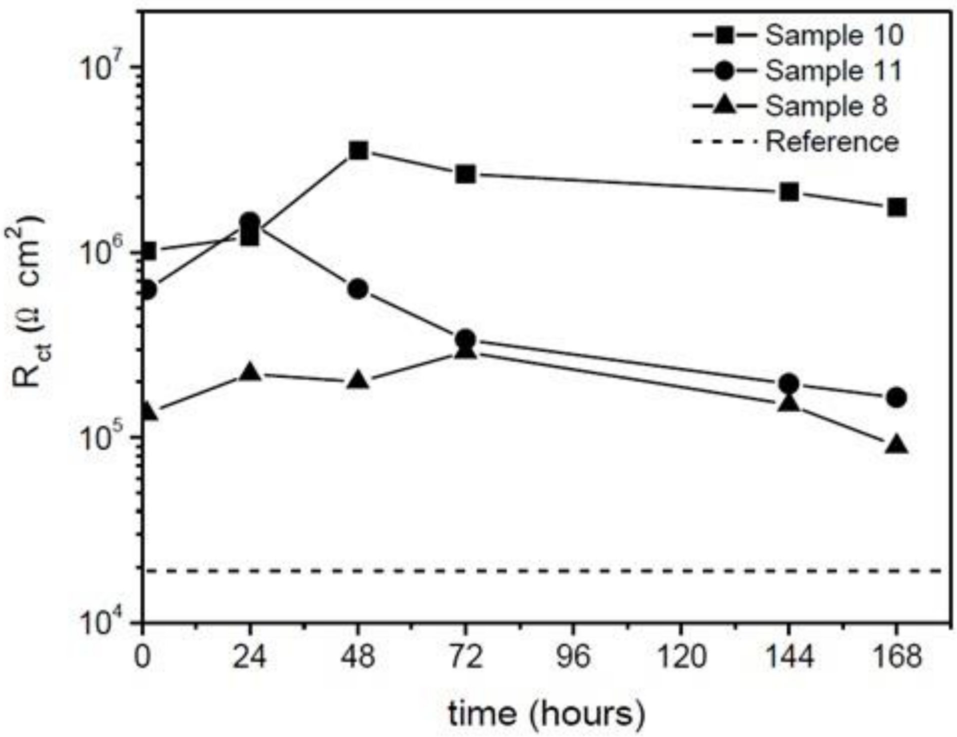
In this work we investigate the influence of 27.12 MHz Tetraethoxysilane (TEOS)/ O2 discharge power, of TEOS fraction in the gas mixture and of substrate pretreatment on the deposition of SiOx-like thin films on aluminum and magnesium substrates. The real power dissipated in the discharge, the fraction of TEOS in the mixture and the pre-treatment of the substrate with SF6/He and H2 discharges were examined in relation with the changes they produce in the gas phase properties, thin film morphology and corrosion protection performance. For the investigation of the changes on the gas phase properties several plasma diagnostics were applied. Namely, plasma electrical measurements were used for the calculation of the real power consumed in the discharge. In addition, mass spectrometric measurements were used for the measurement of the total consumption of TEOS and O_2 and the deposition rate was recorded in-situ by using Laser Reflectance Interferometry to relate the gas phase properties with the film growth. The SiOx films were characterized by means of Field Emission Scanning Electron Microscopy while their protective effectiveness against corrosive environments was assessed by Electrochemical Impedance Spectroscopy and further analyzed to investigate the most probable mechanisms of thin film failure. Films deposited after substrate pre-treatment exhibited the best adhesion with the substrate. The films prepared in high plasma power conditions and with a high fraction of TEOS in O_2 present characteristic surface nanostructure (figure 1) and show extremely good effectiveness in the protection of aluminum and magnesium samples from corrosion (figure 2).



FESEM images of SiOx films with SF6 pre-treatment (a) as deposited and (b) after 168 h immersion in 0.1M NaCl solution



Charge transfer resistance, Rct, as a function of immersion time in 0.1M NaCl solution for samples submitted to a SF6 (sample 10,11) and H2 (sample 8) plasma pre-treatment

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The effect of ball milling on the Mo-Cu alloys reinforced with Al2O3 particles

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Currently Mo-Cu alloys are applied in many environments due to their beneficial thermal properties and high temperature strength. In order to improve applicability of the alloy, its strength and hardness values should be preserved at high temperatures. In this research Mo-Cu alloys were reinforced with alumina (α-Al2O3) particles to produce a novel metal matrix nano-composite (MMNC) in which the effect of the ceramic reinforcement on the microstructure, and on the mechanical properties was characterized. The manufacturing route consisted of ball milling/mixing of the constituents, cold-pressing with high pressure and hot pressing below the melting point of Cu (950°C). Investigations were done on both the powders and the hot-pressed bulk samples. The microstructure and composition of the samples were characterized by SEM and XRD. The mechanical properties were described by room temperature hardness and compressive strength tests.

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Production and Characterization of dual scale Ti produced by powder metallurgy

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Novel, dual scale Ti were prepared by press and sinter technique using a different ratio of micron- and nano scaled powder. The results show, that due to the mixing the two type of powders, the hard and fine milled particles are coated to the surface of the relatively soft and coarse-grained sponge-like particles. The different milled content powders were pressed at room temperature with 1.6 GPa pressure to a cylindrical shape. Sintering was conducted in the temperature range 800–950°C for 60 min in argon atmosphere. The fabricated samples were characterised in term of density, hardness and compression test. The results are confirmed that outstanding mechanical properties can be achieved using this type of material and manufacturing method.

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Damage and failure evaluation of diamond wire for multi-wire sawing of hard stone blocks through modeling and numerical simulation

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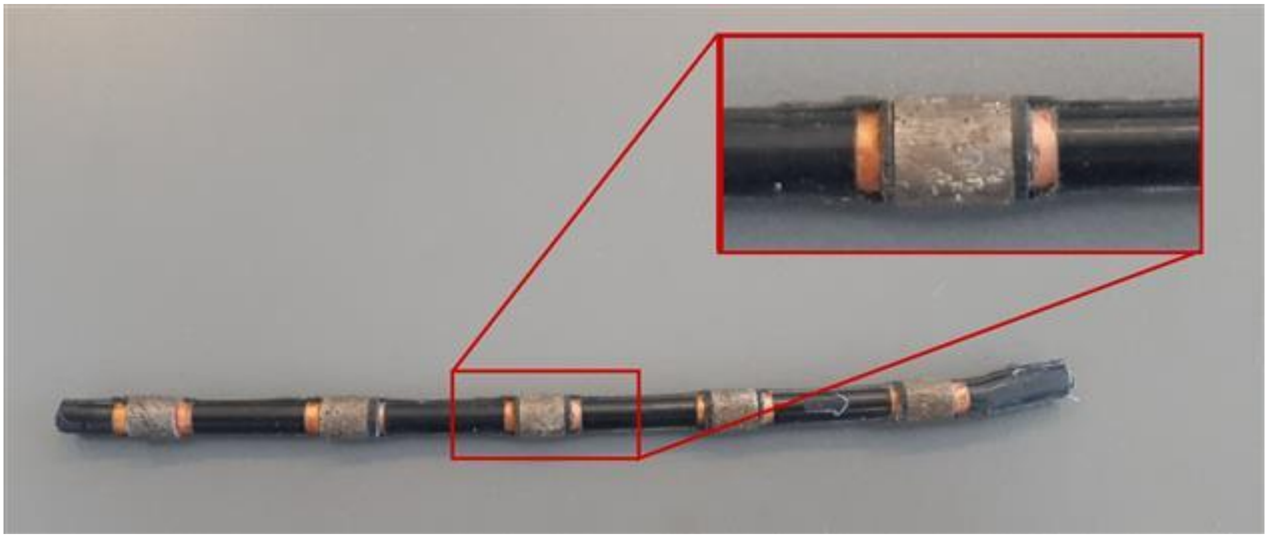
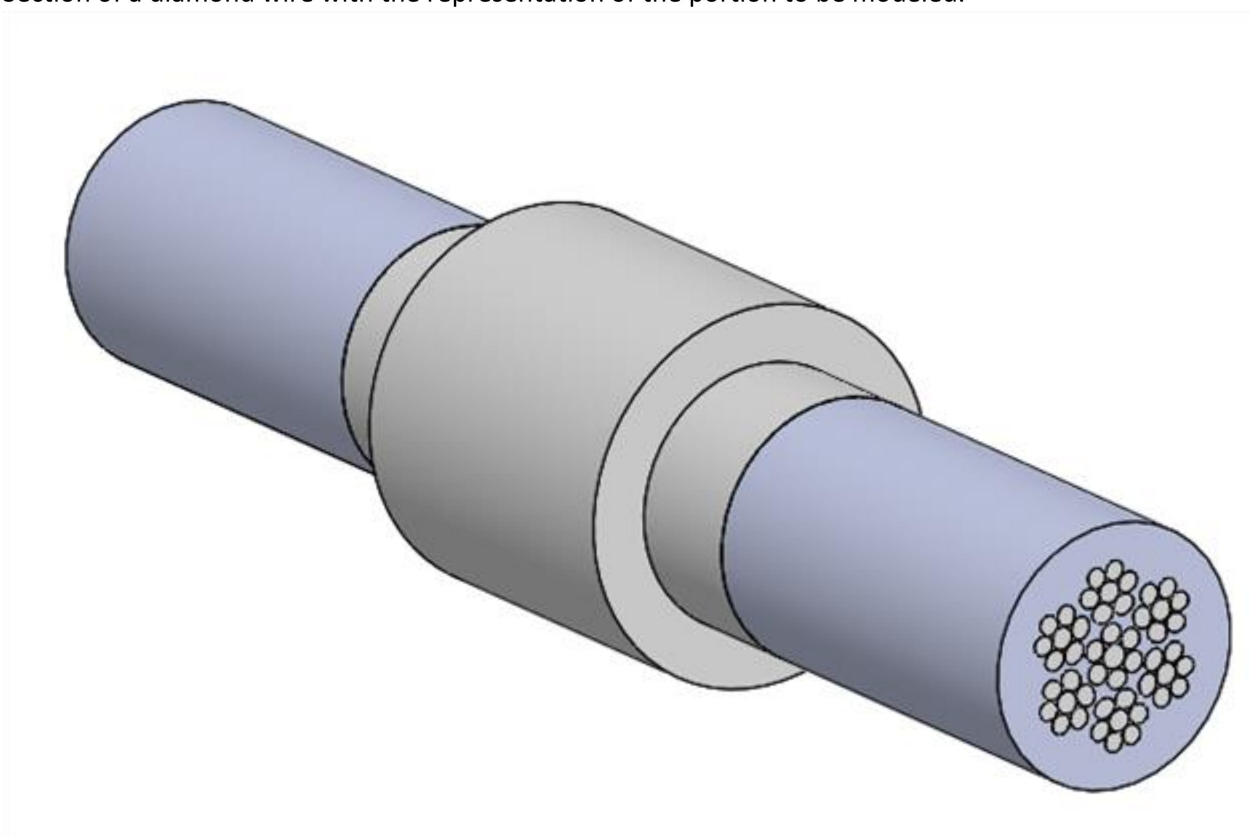
Diamond wires are high-speed, efficient and cost-effective stone cutting tools used both in quarries, to obtain large stone blocks, and in block-processing plants, to shape ornamental stones. The wires are generally composed of a steel cable with evenly spaced diamond beads locked in place by a polymer or rubber coating (Figure 1). The continuous development of the resistance to wear of the diamond beads allowed the use of this tool in the processing of granite and other hard stones, which in addition, imposes a higher resistance requirement on the steel wire and the overall strength of the diamond wire for longer service life. Given that the competitivity of a certain diamond wire is mainly dependent on its cutting efficiency and service life, a numerical model of the diamond wire was developed in Abaqus FEA to study the damage and failure of the steel wire during the cutting operation (Figure 2). The model is intended to support the development of this component, to increase its life expectancy up to 600 hours.

This work started with the development of a detailed 3D model of a 7x7 steel cable, followed by numerical simulation that was compared to experimental tensile test results. After validation of the cable model, the diamond wire model was developed. For this, the coating material, thermoplastic polyurethane (TPU), was characterized experimentally in tensile and compression tests. The data acquired was implemented in the Abaqus FEA software to characterize the hyperelastic behavior of this material.

The numerical results of the model presented an error smaller than 6% relative to the experimental tensile test results of the diamond wire. Therefore, the model provides a valid representation of the component, and it has practical significance for the evaluation and further development of the diamond wire. Afterward, different simulations were performed to analyze the tension distribution on the steel cable during the cutting operation. With these simulations, it was possible to observe the influence of the cutting parameters applied to the diamond wire. It was found that the pre-torsion applied to the cable during manufacturing has a great influence on the load distribution between the core and the strands of the steel wire. It was also observed a stress concentration on the diamond bead ends, mainly on the first fillet of the bead thread, that may cause damage on the TPU coating and lead to failure of the diamond wire. Finally, the model allows the variation of geometrical and material characteristics of the diamond wire and the evaluation of its influence on the tension distribution and overall performance of the wire. Based on this, appropriate solutions can then be designed and implemented in the diamond wire to improve its service life.



Section of a diamond wire with the representation of the portion to be modeled.



Diamond wire 3D model composed by the 7x7 steel cable, TPU coating and one diamond bead.

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Development of recyclable Fiber Metal Laminates (FMLs), their mechanical characterization and FE modelling, aiming at application to structural aeronautic components

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This ongoing study concerns the optimisation of a fibre-reinforced composite material plybook and application to an aeronautical component. The presented material solution are recyclable FMLs (Fiber Metal Laminates) which aim at unlocking possible recycling of production scraps and end-of Life components in the specific case of fire-resistant structural materials. The recyclable PMCs (Polymeric Matrix Composites) developed up-to now in ENEA had to be improved to satisfy the high-demanding fire characteristics requirements in aeronautics, in particular in the case being considered in project FireMat (www.firemat.it) that is a turbine-bonnet production. Structural fire-retardant PMC were improved by introducing aluminum layers inside the lamination, which act as oxygen barriers. Material characteristics studies were performed to optimize the composite plybook, taking the expected working condition and the component design into consideration. FMLs were obtained starting from a fire-retardant biobased resin, which was associated with aeronautical grade BDMF (Basalt Derived Mineral Fibers) fabric and processed in the form of a prepreg and then coupled with aluminum foils (which can be from secondary source, being used primarily for their non-structural contribution to final properties). The project objective is combining weight reduction and fire resistance, maximizing the use C2C recyclable, secondary and biomass derived raw materials. Combining multiple innovations to achieve a single product requires a careful analysis and prediction of expected performance, aided by reliable virtual modeling. FE modelling results, supported by mechanical characterization of the single layers and inter-layer adhesive strength of the ply stack, and the potential benefits of a composite sandwich structure (including aluminum honey comb) were evaluated. The mechanical properties of the materials, inputs for FE modeling, were obtained experimentally, applying international standards (e.g. ASTM D3039, ASTM D6641, ASTM D3518, ASTM D1876).

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Investigation of Thermophysical and Thermomechanical Properties of Highly Porous SiC for Solar Receivers in CSP Plants

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This paper aims to present the outcomes of the thermophysical and thermomechanical characterizations conducted on porous SiC materials employed for solar receivers in CSP plants. The use of CSP plants is currently hindered by weaknesses of the receiver materials like limited working lifetime, insufficient mechanical strength and low resistance to thermal gradients. First generation solar receivers need to be replaced by innovative ones, whose materials must be characterized by higher mechanical toughness and higher thermal conductivity, so that they can withstand extreme thermal cycling conditions at maximum material temperatures of at least 800°C working continuously for over 20 years. This research investigated the thermal and thermomechanical properties of highly porous SiC, one of the materials that can meet the requirements of high oxidation resistance and adequate thermomechanical performances. The first part of the paper deals with thermophysical characterization, which was conducted with the Light Flash Technique (LFA). Firstly, thermal diffusivity was determined directly; next, specific heat and thermal conductivity between room temperature and 1000°C were assessed indirectly. The results of the experimentation were post-elaborated to identify the mathematical model that best fitted the experimental data. Three different mathematical models available in literature and provided in improved versions in the software of the LFA were compared: the Improved Cape and Lehman Model (Standard Model), the Cowan Model and the model based on the findings of McMaster and others (Penetration Model). The Improved Cape and Lehman Model proved to be the most suitable for our analysis, since it allowed modelling experimental data to assess thermal diffusivity values with high accuracy.

The second part of the paper goes on by examining the results mechanical characterizations in order to evaluate different ceramics durability and reliability in expected working conditions in CSP. In this case, performing service-condition tests is virtually impossible (they would last too much), so predictions of service life can only be achieved by performing accelerated thermal cycling, which allow to identify focus prevailing degradation of materials and its kinetics over time. The following international standards for advanced ceramics were applied: EN 843-1, EN 843-2 and ASTM C 1499. Regardless to the standard, it is very important to include in the report the number of standard samples which broke during machining. Furthermore, it is necessary to enquire the source of failures by fractographic analysis, performed using SEM, to ensure main degradation mechanism is the same (which cannot be taken for granted) and data comparison is significant. Where possible, heating and cooling rate will be better expressed in term of thermal gradient along the thickness of the sample (K/mm) aiming at focusing threshold values not to overcome. Mass effect (that is sample thickness in the range 2-5mm) will also be investigated. Expected solar receivers are expected to be produce by extrusion, with a sample thickness of 3mm.

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Characterisations in expected working environments of recyclable fire resistant materials

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This ongoing study concerns the development of multimaterial solution for fire-resistant structural materials for transports and thermal insulation in constructions field: the presented solutions aim at maximising use of secondary, recyclable and bio-mass derived raw materials, paying attention their combination is done without interfering with an easy end-of-life separation, recycling and reuse.
Recyclability in the case of fire-resistant and thermal insulating materials, combined with satisfying durability and low cost requirements, are well known open issues. Fire-resistant biomass derived resins were associated with Basalt Derived Mineral Fibres (BDMF) in the form of prepregs, which were studied as semi finished material for fire-resistant thermal insulating facades and for structural components for transports applications. Fire-resistance of multimaterial is obtained associating these prepregs with thin (3-4 mm) gres tiles (in the first case) and aluminum layers (in the second case, taking to Fibre Metal Laminates), which act as oxygen barriers. Mechanical inputs for FE modeling are being measured experimentally, applying international standards: in the case of FMLs, tensile tests (ASTM D3039) were repeated after ageing in saline mist. In the case of thermal insulating material, the most relevant test is the freeze/thaw ageing (performed according to the ETAG 04 standard, which is defined by very strict parameters in terms of temperatures and cycles), followed by weight measure and visual inspection of sample conditions.
The thermophysical characterization of the developed solutions allowed identifying the thermal behaviour under steady state and transient conditions. In particular, the thermal conductivity of prepregs was determined at an average by means of a heat flow meter taking into account different thicknesses of the material, in order to optimize the thermal performance of the multilayer solutions as a whole. The thermal characteristics of the prepregs associated with gres tiles and BDMF felts were also determined by means of the heat flow meter apparatus, to assess their performance and adequacy in the framework of the ventilated facades. Prepregs associated with aluminum layers were characterized by means of the Light Flash Method (LFA) in the temperature range between 25°C and 500°C. The analysis allowed estimating not only the thermal conductivity of the materials but also their thermal diffusivity, which describes how quickly the material reacts to a change in temperature, thus playing a crucial role in the development of fire-resistant structural materials for transports.
The fire assessment was implemented by testing heat release and mass loss rate (cone calorimeter method), in compliance with the EN 13501-1 and ISO 5660 standard. For each material, both tests were carried out with the flame ignition system (electric arc) activated and deactivated (non-combustibility test, EN ISO 1182).

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Small size 3D printed hydraulic components with integrated fluid sensing capabilities: A proof of concept

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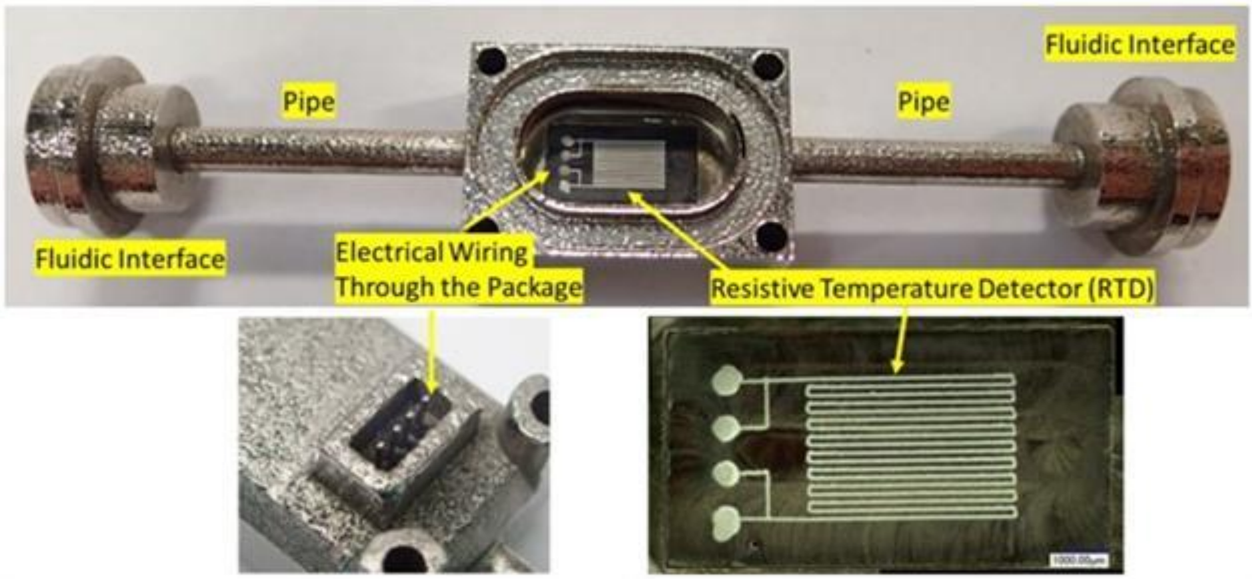
Additive Manufacturing (AM), commonly known as 3D printing, is nowadays introducing impressive transformation in the field of manufacturing techniques. AM is a key factor which is opening new horizons and possibilities, in terms of design freedom, complex geometry, and large to micro scale on demand production. In particular, printing of electronics provides fabrication of smart devices by integrating electronics, such as sensors and actuators in almost any structure. In this work, a combination of AM methods has been applied to develop revolutionary components with integrated sensing capabilities, to measure fundamental fluids properties of circulating fluids.

This work is part of the project SWaP (Smart Wall Pipes and ducts), a collaboration between CERN and CSEM. SWaP has received funding from the ATTRACT project funded by the EC under Grant Agreement 777222. The inspiration of SWaP was derived from the limitations and difficulties of directly measuring fluid properties in a hydraulic circuit of a cooling system with existing methods. The breakthrough character and aim of the project is the combination of advanced manufacturing methods; Selective Laser Melting (SLM) and AerosolJet Printing (AJP), to create a new generation of smart fluidic elements for cooling systems and to meet the high requirements in the field of thermal management systems.

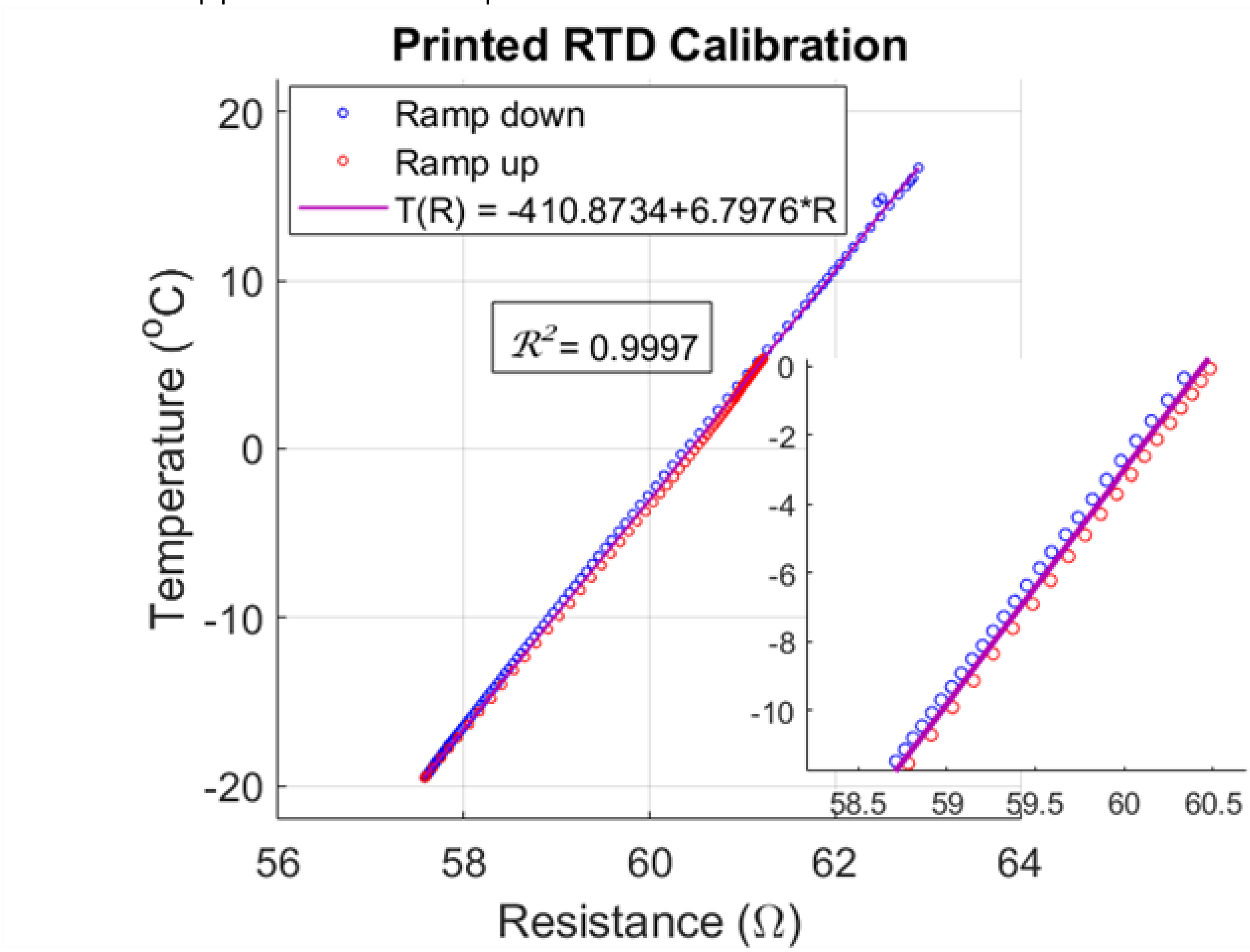
The prototype (Fig.1) is a pipe with fluidic interfaces and embedded temperature sensors in the inner wall of the pipe. Fabrication of the pipe, the electrical wires, electrical connectors, and fluidic interfaces utilizes SLM. A layer of UV curable epoxy is casted around the electrical wires to hold the wires in position as well as to create an electrical insulation layer. Silver-based nanoparticle ink is deposited in aerosol form to the cured insulation layer by means of AJP, to form the temperature sensor; a Resistance Temperature Detector (RTD). After the deposition, the RTD is thermally sintered to enhance material and electrical properties.

A set of tests performed in order to validate SWaP's developed technology and to compare to that of the current fluid temperature sensing methods. The prototype was connected to a test setup with a circulating coolant, where fluid temperature is adjusted by a chiller's control panel, while mass flow and pressure of the fluid by a flowmeter. First, the tightness of the pipe was ensured by leak tests with helium and carbon dioxide (CO_2). Tests performed in a closed vacuum chamber, where temperature and resistance measurements recorded by reference PT100 sensors and the printed RTD, respectively to obtain the calibration line (Fig.2).

The obtained results have been quite significant in that the pipe has been successfully produced by SLM with hydraulic and electrical connectors as well as embedded RTDs by AJP. The smart fluidic element has been successfully tested in hydraulic circuits for cooling system applications where leak-free integration in a piping system with circulating fluids has been achieved. Temperature measurements from the embedded sensors have been successfully recorded and the results were comparable to that of commercial RTDs. The printed RTDs have shown linear response, positive resistance-temperature relationship, low hysteresis and reproducibility.



AM constructed pipe from SLM with AJP patterned RTD embedded



Calibration line with the corresponding Positive Temperature Coefficients (PTCs) of the printed RTD presents a linear behavior with low hysteresis

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Crack detection in concrete bridges using Deep Convolutional Neural Networks

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Cracks are largely considered in the condition assessment of reinforced concrete bridges given their potential to induce other serious defects (e.g. concrete spalling and rebar corrosion) and to lead to an eventual loss of structural safety of the bridge.
The common crack detection methods are laborious, subjective and error-prone requiring the intervention of experts to detect cracks in bridge images acquired during an on-site bridge inspection. Hence, automating the crack detection process has gained significant interest among researchers to overcome challenges related to conventional bridge inspection practices.
Recently, Deep Convolutional Neural Networks have outperformed traditional image processing techniques (e.g. spatial domain edge detectors) in the crack detection task and helped to address limitations related to the complexity of concrete surface conditions. However, in order to achieve high detection accuracy, these networks require massive and comprehensive datasets that cover the diverse representations of cracks encountered in deteriorating concrete bridges.

We propose in this work to train two state-of-the art Deep Convolutional Neural Networks, from the computer vision literature, on three annotated image datasets of cracked and non-cracked images of concrete bridges: two public datasets released by the scientific community and a dataset constructed by the authors based on images of Moroccan concrete bridges. The three datasets contain images with challenging surface conditions (e.g. stains, strong light, and surface roughness) and cover concrete cracks in bridges with different sizes and patterns. The models used by the authors are trained in Transfer Learning mode with the pre-trained parameters using the ImageNet dataset.

The authors conducted multiple experiments on the datasets and results show the significant potential of leveraging knowledge transferred from different datasets to improve the performance of the trained models for crack detection in concrete bridges.

Keywords: Concrete bridge, crack detection, dataset, deep convolutional neural network, transfer learning

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Enhancement of damping response in polymers and composites by the addition of graphene nanoplatelets

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The damping characteristics of advanced lightweight composites are of paramount importance for a variety of applications particularly those employing composite parts or components operating under dynamic external loading. Graphene has been shown to possess high stiffness and strength and is widely esteemed as an ideal additive for enhancing the mechanical properties of polymeric, ceramic and even metallic composite matrices. However, it has been postulated that if such behaviour can be combined with increased fracture toughness and damping characteristics then a whole new class of multifunctional composites could emerge.
In this work, the effect of GNPs addition on the damping characteristics of both neat polymer and CFRPs is studied, based on a tailor-made experimental setup. Given the fact that a component should operate at a specific frequency band to maintain its damping capacity, the work is focused on studying/exploiting the capability of GNP inclusions to tune (and not necessarily maximize) the energy absorption properties of modified composite materials and polymers for structural applications. In this frame, a complete experimental investigation of the damping response under free oscillation is performed. The type of GNP materials studied herein were selected (see experimental section) for potential use in several lightweight applications (aeronautics, automotive etc.). The mechanical damping trials were followed by DMA testing in order to demonstrate the effect of graphene on the energy absorption characteristics of the materials, under significantly different loading conditions (forced oscillation), and not for direct comparison. Specific surface calculations were also made to provide evidence of the mechanisms at nano level that govern the damping behaviour.
The results presented here indicate that the addition of GNPs into both the neat polymer and the CFRP, affects significantly the damping behaviour. In particular, for the CFRP a significant increase of damping capacity is observed for low concentrations in the range of 0.15-1 wt. %, whereas for higher concentrations the corresponding enhancement does not follow a clear trend. Plausible explanation for this behaviour is presented herein.

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Investigation of Penetrator Defect Formation during High Frequency Induction Welding in Pipeline steels

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The aim of this study is to investigate the formation of oxide defects known as penetrators during high frequency induction welding process of high strength low alloy pipeline steels. Penetrators formed during the welding process can be detrimental for the impact properties of the weld seam. For this purpose, six different pipeline steel samples (X60, X65) with different chemical compositions, were investigated. In order to characterize the oxide defect and correlate their formation with the chemical composition of the steel, optical microscopy and scanning electron microscopy paired with energy dispersive spectroscopy were employed. In addition, thermodynamic calculations were performed in order to examine whether the chemical composition of pipeline steels is prone to oxide formation. The results showed that oxides with pancake type morphology were found alongside the fusion zone of the samples. They mainly consisted of manganese and silicon. The Mn/Si ratio showed that the higher ratio is less susceptible to oxide formation.

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Examination of Fracture Mechanisms in two Al – Ti – V – Cr – (Si) High Entropy Alloys

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This work focuses on the examination of two High Entropy Alloys (HEAs), the AlTiVCr and AlTiVCr–Si7.2, which have been observed to fail in a brittle manner directly after casting. Understanding the failure mechanics is a prerequisite for an alternative enhanced alloy design in order to prevent early failure without loading application. The specimens were produced using the Vacuum Arc Melting methodology in a protective argon atmosphere. The material was re–melted five times in combination with electromagnetic stirring in order to achieve a fully homogenized microstructure. Based on our findings, the failure occurred in the first 10 minutes after casting during slow cooling. Similarly, the same took place during thermal treatment after the third re–melting. The specimens were first prepared for optical (OM) and scanning electron microscopy (SEM) analysis. Then, after etching with Hydro Florine (HF) they were examined in the SEM. The material consists of a coarse dendritic microstructure as well as a retained BCC phase, which is the AlTiVCr phase. In the AlTiVCr – Si7.2 alloy a uniformly dispersed, angular intermetallic compound, namely the Ti5Si3, was identified, which increases the failure resistance of the material. Based on these findings the alloy will be redesigned.

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Fatigue life evaluation of functional elements

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Functional elements like press studs are mechanical joining elements inserted into sheet metal structures and provided with a threaded support. [1]

These components serve the function of a weld stud, with the advantage that no heat distortion occurs. Further advantages are the avoidance of weld spatter, a better surface finish and the higher flexibility and better automatability of the mechanical joining process. Press studs are mainly used as non-load-carrying attachments. For the sheet metal section, this joined connection represents a failure location with a high stress concentration under cyclic loading in the carrier sheet. Fatigue tests of press stud connections under constant amplitude loading revealed interesting fatigue properties. For example, preloading by tightening has positive effects on the fatigue life of the joints.

There are actually no guidelines available which provide fatigue live calculation concepts for these functional elements. As the requirements for the fatigue strength of mechanical joints have recently increased, a first approach for a calculation concept for press studs is presented here. In order to make mechanical joints comparable to welded joints, an approach for a structural stress concept according to [2] was investigated. This approach has to include the forming history and the contact state of the press stud joint to the fatigue life calculation. Numerical investigations showed that, despite the complicated contact state and the forming history, an assumption as a linear composite contact is justified in order to identify a structural stress for the fatigue strength calculation.

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Microstructural Characterization of AlCrTiV – Si High Entropy Alloy for advanced applications

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This work deals with the microstructural characterization of two equiatomic high-entropy, low-density alloys (HEA), the AlCrTiV and AlCrTiV-Si7.2. These alloys can serve as potential candidates for advanced applications where high strength and enhanced ductility is demanded. For ensuring high ductility the alloys must contain as minimum as possible hard precipitates. As the strength increase is based on both solid solution and precipitation hardening, the laboratory made alloys were investigated in as-cast and heat-treated conditions. For the heat treatment a high soaking temperature of 1200℃ for 8 hours was selected to ensure microstructure homogenization. Micrographic observations of the AlCrTiV and AlCrTiV-Si7.2 samples in the as-cast condition indicated the presence of a dendritic microstructure. Furthermore, chemical micro-analysis showed segregation in the matrix in both samples. This is a critical result as this segregation will lead to heavy precipitation at interdendritic regions, it may sensitize these regions and in the worst-case scenario may cause cleavage fracture in the micro scale, which can trigger brittle fracture during cooling even without the application of deformation. However, the selected heat treatment eliminated the segregation phenomena forcing the alloying elements to be uniformly distributed in the matrix. At the center of the heat-treated AlCrTiV-Si7.2 sample the fragmentation and spheroidization of the intermetallic phase Ti5Si3 was observed. For the same sample, at the mold-sample's interface, the particles Ti5Si3 were shown to dissolve and form aggregates. Both alloys exhibited high hardness values with small differences between the as-cast and heat-treated conditions, which indicates that the AlCrTiV–Si7.2 high entropy alloy presents high yield strength and may operate at high temperatures without deterioration of the mechanical properties nor unexpected failure.

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Correlation of dominant texture components located near the fracture with the tensile directions

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Aluminum sheets are subjected to deep drawing in order to form complicated shapes, for packaging applications. Failures and high amount of rejected material, are frequently observed during this process and are attributed to the sheet anisotropy. The latter is essentially correlated with the texture obtained throughout the thermomechanical process. Most samples for these applications are annealed after the final cold roll pass and not used at full-hard condition. Subsequently, contemplation of the texture components is crucial for the decision regarding the appropriate production path that is to be utilized for the manufacture of products from those materials. Therefore, understanding of the texture components present at the most susceptible to fracture areas can give fruitful information towards the failure analysis investigation. This is because texture components exhibit different response towards mechanical testing and different preferred orientations of growth. The scope of the present study is the observation of the texture components, which prevail near the fracture surfaces of tensile specimens at 0o, 45o and 90o towards the rolling direction and the correlation of these components with the measured r values.
Annealing treatment of AA3104 sheet samples was conducted after 87% and 94% cold rolling reduction. The annealing conditions (time, temperature) were selected in order to simulate the industrial annealing process. Tensile testing, hardness and electrical conductivity measurements were conducted in order to examine the microstructural response towards anisotropy. After thermal treatment, the samples were cut parallel to the rolling direction and observed by optical microscopy (in as polished and etched condition). EBSD (electron backscatter diffraction) measurements were conducted to selected temperatures and directions and highlighted the correlation among the texture components and the tensile directions.

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Plasma enhanced chemical vapor deposition of hydrophobic, hydrophilic and amphiphilic coatings

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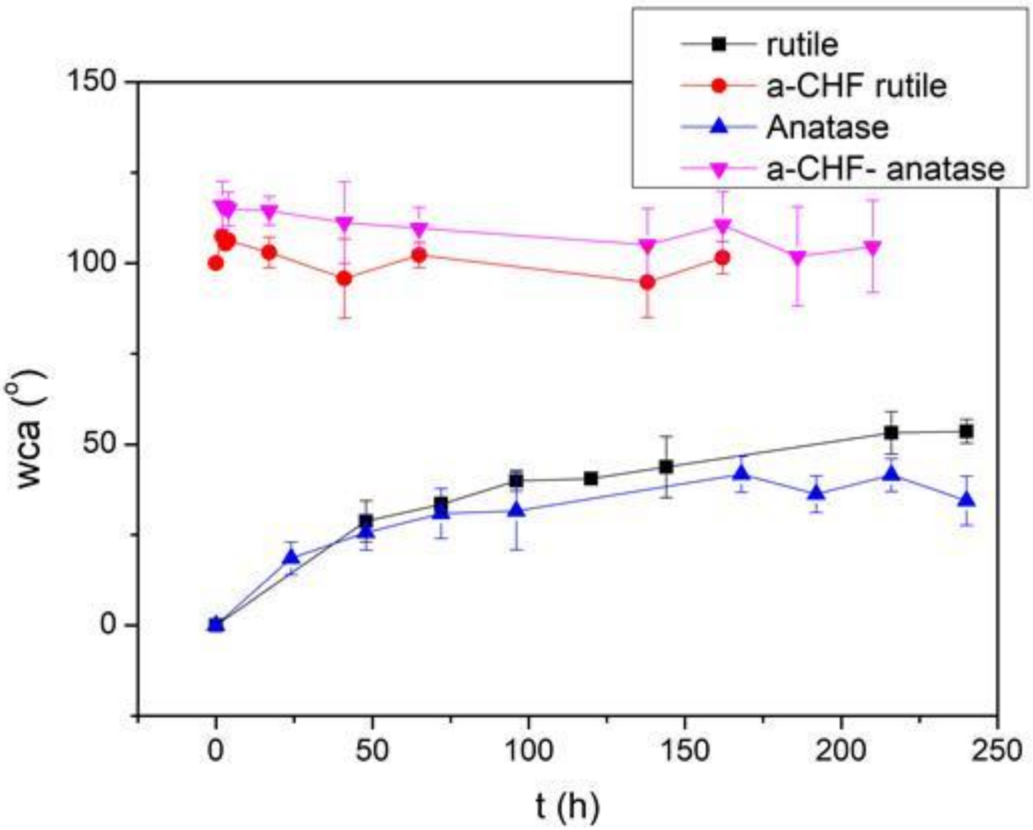
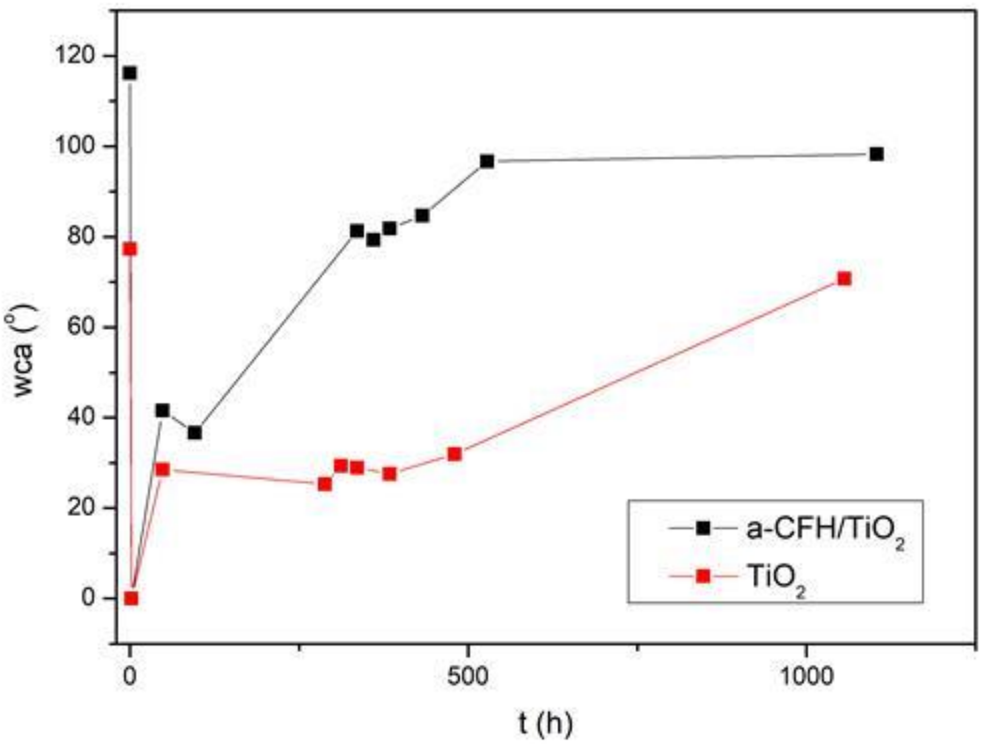
During the last decades there has been a great research interest focusing on the control of the wetting state of surfaces, towards the fabrication of thin films possessing different wetting properties. Stable hydrophobic or hydrophilic coatings have been proposed as candidates for self-cleaning, biomimetic and drug release applications while smart materials which switch their wettability in the presence of UV irradiation have been proposed for microfluidic devices, sensors etc. As long as the wettability of a surface, and thus its use, is affected by its chemical composition and its morphological features different strategies can be adopted involving plasma deposition or/and etching. In this work plasma enhanced chemical vapor deposition of hydrophobic, hydrophilic and amphiphilic coatings is demonstrated.
The work focuses on the deposition of hydrophobic fluorocarbon coatings, hydrophilic, hydrophobic and amphiphilic TiO_2 coatings and the combination of TiO_2- fluorocarbon coatings deposited in series using two different plasma deposition techniques. Namely the depositions of fluorocarbon coatings were carried out in a capacitively coupled plasma reactor using C_2F_6 – H_2 mixtures as precursor while the TiO_2 depositions were carried out in a magnetron sputtering reactor using Ar- O_2 mixtures. The effect of processes parameters on the materials physicochemical processes and thus on their wettability is discussed. Materials deposited through C_2F_6 – H_2 discharges are hydrophobic . On the other hand, the wettability of the TiO_2 coatings strongly depends on the deposition parameters, which affect the crystal phases and their specific morphology, and the storage conditions. When fluorocarbon coatings were deposited on TiO_2 surfaces, the samples were hydrophobic and stable regardless the initial properties of the TiO_2 coatings as illustrated in Figure 1. It is worth noticing that the presence of the fluorocarbon coating did not suppress the UV- induced wettability conversion of the TiO_2 coatings (Figure 2) but it decreased the recovery time.



Wetting angles as a function of time of titania coatings and titania surfaces coated with amorphous fluorocarbon coatings (a-CHF) as a function of storage time in dark



Wetting angles of pure titania coating and titania coated with amorphous fluorocarbon film (a-CHF) after their exposure in UV irradiation

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Plasma processing of metal surfaces: approaches for enhanced corrosion protection

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[1]University Of Bari Aldo Moro, [2]CNR-NANOTEC

In this contribution, we will review the different strategies to the deposition of protective coatings for different metals and alloys, based on the results obtained in our laboratory over the last 15 years. In particular, it will be shown that plasma deposited inorganic and dense coatings can be not enough to ensure optimum protection to metal degradation. Designing a correct plasma pre-treatment of the metal surface can enhance the coating performance. The feed gas choice for this treatment is important for some metal alloys as Mg and Ag based ones, and can be done using simple chemical considerations. Additionally, some more parameters are discussed for optimization of metal protection: pulsed plasma deposition and hydrophobization of the top layer, demonstrating that process based on pulsed plasma can lead to more stable and corrosion resistant coatings, and similar results can be obtained by the addition of a top hydrophobic layer.
Furthermore, we will address the deposition of organosilicon multilayers as high-performance metal protection coatings. The alternated deposition of silicon oxide and organosilicon layers, developed as ultra-barrier films against the transmission of vapors and gases through plastic substrates, has been demonstrated to be also an effective tool for the deposition of highly corrosion protective coatings on low-carbon steel substrate. Plasma Enhanced Chemical Vapor Deposition (PECVD) reveals to be convenient for the deposition of multilayered stacks since it allows the deposition of the organosilicon and silicon oxide layers in the same process chamber and using the same precursor, tetraethoxysilane. The multilayer approach leads to 600-nm-thick coatings with high corrosion resistance (RCT of 1.1*107 Ωcm2), while a layer of SiOx has the same protective effectiveness only for thickness greater than 1 µm. Finally, the use of modulated discharges for the multilayer deposition exhibits an improved resistance to corrosion by two orders of magnitude with respect to continuous mode.

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Thermodynamic and kinetic study of intercritical annealing of DP 1000 Steel

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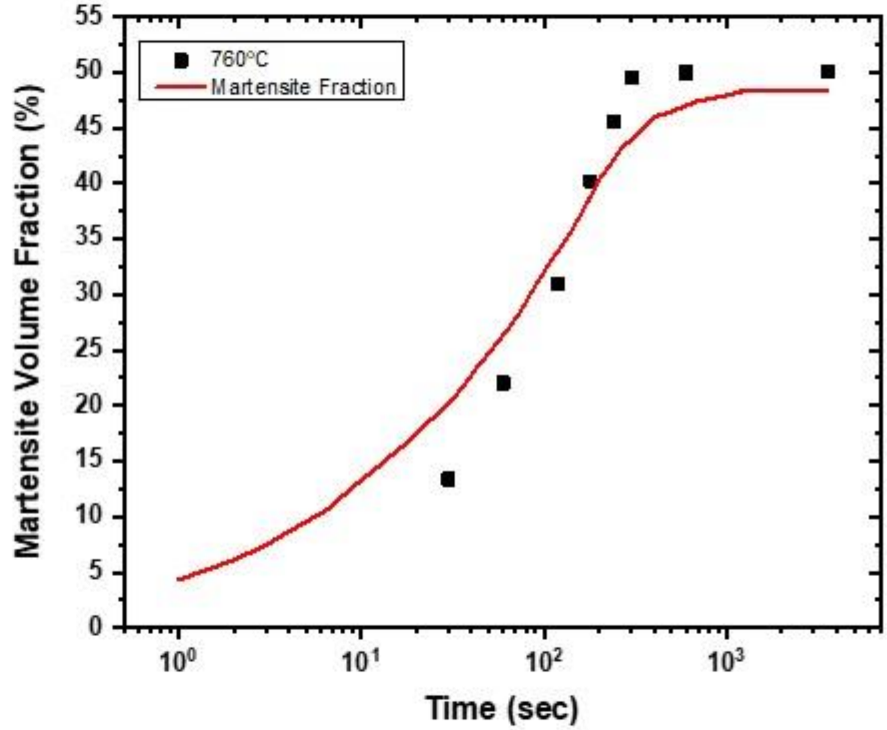
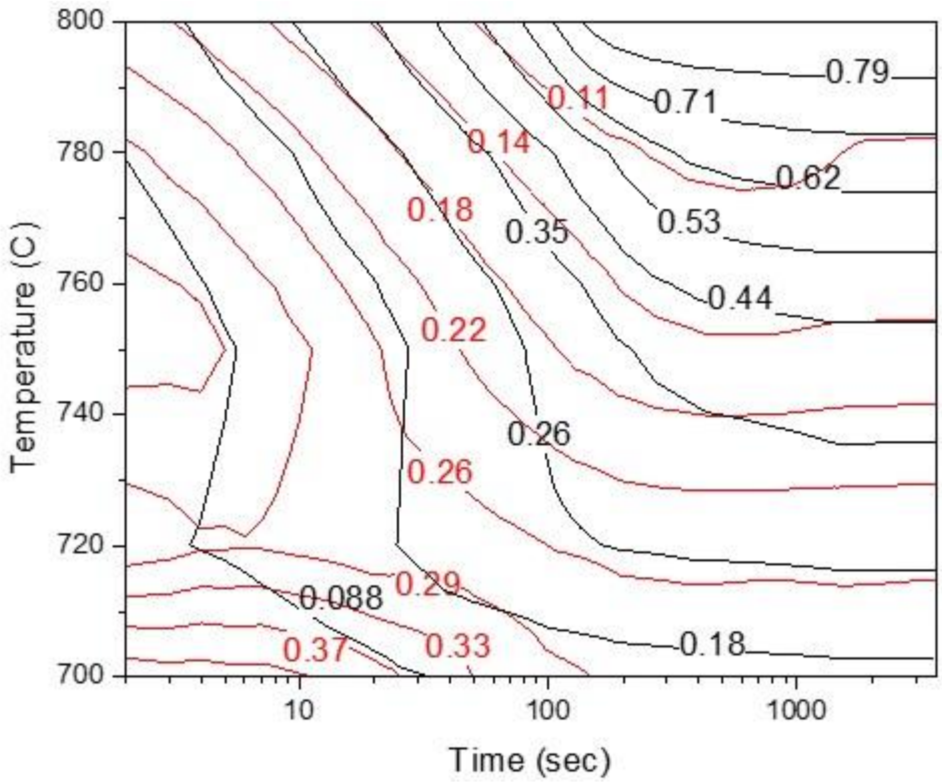
During the last few decades, the automotive industry's main objective has been the development of materials with the best combination of cost and safety. This involves the use of materials that are characterized by high mechanical properties - both high durability and high plasticity capacity and can also be easily manufactured to keep costs low. The combination of these needs has led automakers to use high-strength steels (AHSS - Advanced High Strength Steels). The most common material in this industry is DP - Dual Phase. This class of steels includes DP1000 steels, whose microstructure consists of ferrite and martensite in varying percentages, thus achieving the desired mechanical properties.

The purpose of the present study was the development and implementation of a model, combining a thermodynamic and kinetics computational framework, in order to determine the most desirable processing path for the production of Dual-phase steels with advanced mechanical properties. In order to validate the developed model, results from experiments of intercritical annealing and quenching for DP1000 steel were performed (Figure 1). Two different models were applied. The use of ThermoCalc software resulted in the phase diagram and the initial compositions of the participating phases, which were then introduced into the DICTRA software to simulate the intercritical annealing process. Thus, the results for the austenite volume fraction and the concentration profiles of the alloying elements were obtained. The volume fraction of martensite and retained austenite, as well as the element's concentration in martensite, were calculated as a function of heat treatment time and temperature. In order to perform this simulation, the appropriate code was used in MATLAB software, incorporating the Barbier and Koistinen-Marburger models. Finally, processing maps were developed in terms of Intercritical annealing temperature and time (Figure 2). These maps make it possible to select the most appropriate heat treatment conditions, in order to achieve the required microstructure (phase fractions) and strength (martensite carbon content).



Kinetics of austenite formation for intercritical heat treatments at 760°C. Symbols represent the experimental results, while the continuous red line the kinetic calculations with DICTRA software.



Mapping of martensite volume fraction (black lines) and carbon content in martensite (red lines) with respect to IA time and IA temperature for 3600 sec.

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In-situ examinations of nano- and microscale fatigue and fracture in device-relevant materials

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We have utilized in-situ nanomechanical test instruments to examine nano- and microscale fatigue and/or fracture in copper and silicon, two materials found in a vast array of electronic devices.

Thin metal films, such as copper interconnects, are typically nanocrystalline. Nanocrystalline metals exhibit high strength (hardness) but their grain sizes are less stable under fatigue or increasing temperature. Fatigue-induced grain growth has been studied primarily by post-mortem means. While this can lead to a phenomenological understanding of stress concentrators, it does not provide direct evidence of the mechanism. Here, room-temperature tension – tension fatigue tests (R ~0.5) were performed in-situ in a transmission electron microscope (TEM) using a nano-resolution transducer to quantitatively determine stress during each cycle [1]. Controllable oscillatory loads were applied over a frequency range of 1Hz to 200Hz enabling accumulations approaching 10^6 cycles within one hour. The high spatial resolution of the TEM allowed for quantitative measurement of fatigue crack growth rates, here measured in the picometer/cycle range. This stage I fatigue crack growth was at stress levels well below the tensile yield stress and near the minimum conditions for fatigue crack growth. Evidence of plasticity and grain growth accompanied growth of nanoscale cracks.

Silicon has important temperature-dependent fracture properties as it undergoes a transition from brittle crack growth to a more ductile behavior. Here, we employed a novel test geometry comprised of clamped three-point bend specimens of silicon combined with a high-performance heating element used over the range of room temperature to 600degC [2]. This allowed small-scale in-situ fracture tests in a scanning electron microscope (SEM) at temperatures up to and beyond the bulk brittle to ductile temperature transition. We also examined dislocations at the crack tip via post-mortem TEM.

In-situ nanomechanical test instruments for electron microscopes have advanced considerably since the two studies highlighted here. An overview on the state-of-the-art in such instruments will be provided.

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Fatigue strength evaluation of a 13%Cr supermartensitic stainless steel by the thermographic method

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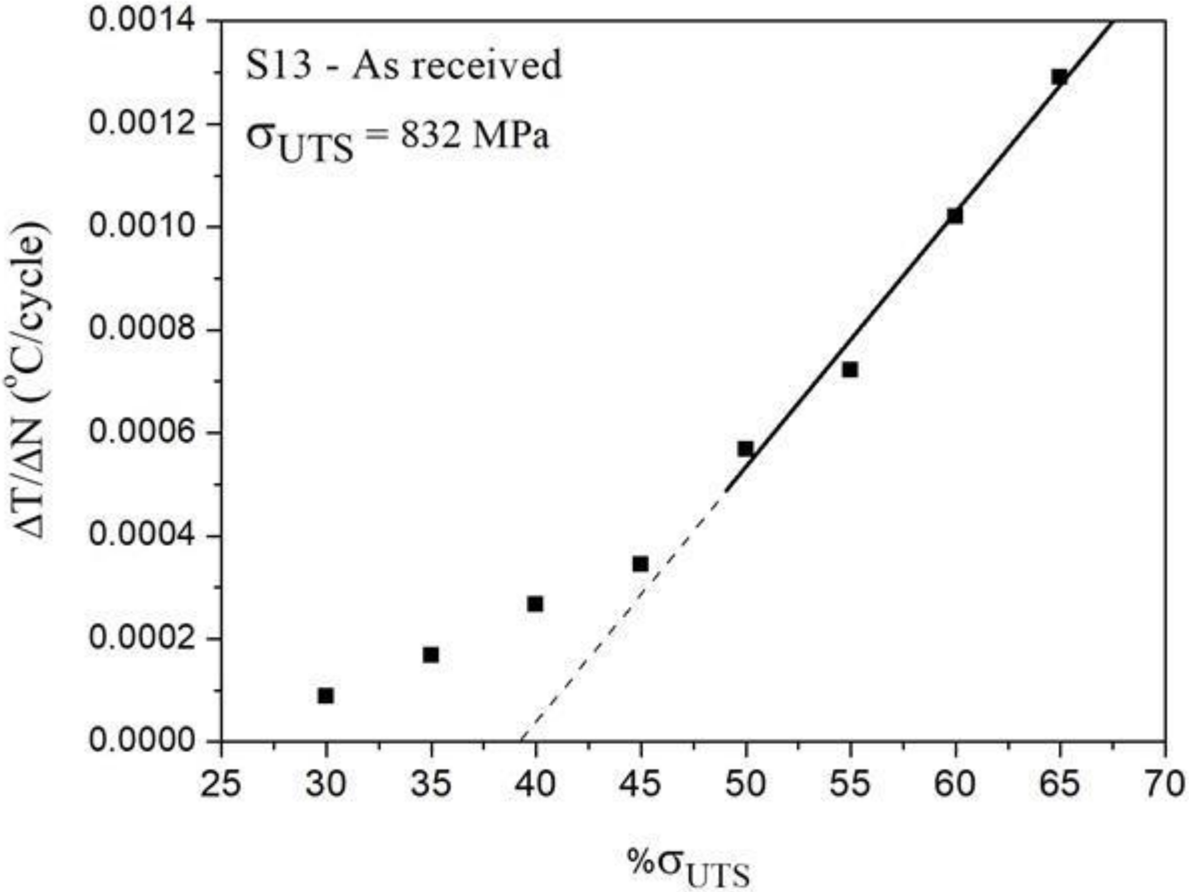
The fatigue limits of a 13Cr super-martensitic stainless steel from a hot rolled seamless tube were determined for several heat treatments, including the as received (AR) condition, quenched (Q), quenched and tempered at 620ºC (QT-620) and quenched and double tempered (QT-DT). These heat treatmens were applied to produce different microstructures and different tensile mechanical properties. The microstructures were characterized by microscopy and X-ray diffraction, and the tensile properties were obtained from the engineering curves and true stress-true strain curves. The fatigue strength was accessed through the utilization of the thermographic technique. The experimental apparatus consisted of a rotatory fatigue machine and a thermographic camera. This technique uses a small number of specimens if compared to the traditional Wohler Method. Also, the thermographic technique does not have to test the specimens up to final failure, turning this approach more than ten times faster than the Wohler method. Fig. 1 exemplifies the thermographic method. Each point on the graph is plotted as follows: the specimen is loaded with a bending moment that generates bending stresses in the specimen of a % of the ultimate tensile stress (σUTS) of the material. Each test is runned until it reaches between 9000 and 10,000 cycles. At the end of these cycles, which was recorded with the thermographic camera, the temperature variation in the smallest diameter part of the specimen is verified, generating the ΔT value. The division of delta ΔT by the number of cycles (N) imposed on the specimen with bending stresses in a percentage of σUTS of the material forms a point on the graph. Each specimen has been tested eight times, so there are eight points per specimen. The line is passed through the last points (with the highest % σUTS) that showed a visible change of angle in relation to the initial points. In Figure 1, the four last points were used, resulting in a fatigue limit equal 37.5% of σUTS. The preliminary results show that fatigue limits measured were between 37.5% and 44.0% of the ultimate strength and the as received condition gave the lower fatigue limit (312 MPa). The results aid to decide the best heat treatment condition for applications where dynamic loadings are expected.



ΔT/ΔN x %σUTS graph for determination of fatigue limit by the thermographic method in the as received material.

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Corrosion-induced hydrogen trapping and the effect of ageing treatment in Aluminum alloy 2024

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Corrosion represents a major concern for the structural integrity of aging aircraft structures. The damage tolerance of advanced aluminum alloys is influenced by the corrosion mechanism, followed by absorption and trapping of hydrogen in the microstructure. Previous work has shown evidence of corrosion-induced hydrogen embrittlement in alloy 2024 and the association of hydrogen traps with specific microstructural components. Different microstructures were produced in alloy 2024 by varying the heat treatment of the artificial aging conditions. Underaged, peak and overaged conditions were achieved by exposure to 150°C, 160°C, 170°C and 210°C.
The present work contributes to the microstructural characteristics, mechanical properties and the hydrogen trapping mechanism. Optical microscopy and high resolution transmission electron microscopy were used for the microstructural investigation. After the corresponding heat treatment procedure, the specimens were exposed to an exfoliation corrosion solution (EXCO) and hydrogen uptake was measured with thermal desorption spectroscopy (TDS). Finally, the hydrogen trapping state spectrum versus aging time was recorded providing further insight of the distinct trapping states in the interior of the material.

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Experimental investigation on flexural properties of FDM-processed Pet-G specimen using response surface methodology

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Fused deposition modelling (FDM) is one of the leading additive manufacturing technologies for producing plastic parts by a layer-by-layer technique with reference to digital 3D model. In order to study and enhance the mechanical properties of parts fabricated with FDM methods the proper selection and optimization of processes input parameters is considered of major importance. The present work reports on the effect of five independent parameters, namely, layer height, deposition angle, infill density, printing speed and temperature on the flexural strength of PET-G fabricated specimens. According to the low and high levels determined for the independent parameters, following Taguchi's fractional factorial design, 27 runs were conducted to obtain the results for flexural strength. Statistical analysis was performed on the experimental results and robust regression models were generated to predict the response of flexural strength and utilize them as objective functions for implementing intelligent algorithms for process optimization.

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Tensile and fatigue behaviour of Plasma Sprayed Titania and Chromia Coatings

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This paper studies the effect of titania (TiO2) and chromia (Cr2O3) plasma sprayed coatings on the tensile and fatigue properties of steel substrate. Optical and electron microscopy was used for the assessment of the coatings microstructure. The titania and chromia plasma coatings were found to reduce the tensile strength of the both substrates. The elastic modulus and tensile strength (σTS) of coated specimens for both titania and chromia coatings decreased proportionally by increasing the thickness of the coating. Titania coatings exhibited lower elasticity modulus compared to that of chromia and downgraded less the mechanical properties of steel substrate.
The failure of the coated steel specimens initiated by cracking on the coating surface, transverse propagation of the cracks towards the coating - substrate interface and diversion along the interface leading to local delamination and breakage.
Fatigue test (number of strokes / time unit) showed that with increasing applied force the diameter of the craters created in both coatings increased. However, increasing the thickness of the coating increases the fatigue strength (reduction of the diameter of the craters).

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Evaluation of the effect of uncertainty in the strengths of composite materials on the efficiency of failure criteria using interval analysis

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The uncertainty in the strengths of UD composite lamina, which originates from manufacturing defects and experimental errors, reflects to failure analysis of composite materials, thus influencing the numerical design of composite structures. In this work, we present an interval-based approach for the computation of the uncertainties in the strengths of UD composite plies and the evaluation of the effects of theuncertainty on the efficiency of failure criteria. The strengths of the UD lamina have been derived using micromechanics equations, while the levels of uncertainty of the input properties of the fibers, the matrix and the composite content are arbitrarily assigned to be the input parameter plus or minus a percentage of it. Our aim is to compute the "tightest" lower and upper bounds for the range of the strengths. This problem is equivalent to finding the global minimum and maximum values. To this end, we propose an interval branch-and-bound algorithm for computing the verified enclosures on the exact range of the strengths, when the input parameters vary over the uncertainty intervals. The required inclusions are obtained via the use of interval arithmetic which constitutes a valuable tool for estimating and controlling the uncertainties automatically. Implementation was done in C++ on a Linux platform, while the bounds are computed with the prescribed accuracy 10-15. The proposed methodology has been applied to the AS4/3501-6 carbon-epoxy UD composite. Since the micromechanics equations are deterministic, for assessing their uncertainty, we have repeatedly running the analysis using different levels of uncertainty from ±0% to ±5% for the uncertain inputs. The corresponding distributions as well as summary statistics for each strength are reported. Having already computed the ranges of the strengths of the UD ply, we have used interval arithmetic operations to derive in a closed-form the damage prediction uncertainty for the Hashin-type failure criteria. Using the closed-form uncertainties of intervals and sets of stresses obtain by finite element analysis for a quasi-isotropic AS4/3501-6 composite laminate, we have quantified the uncertainty of damage prediction for each damage mode.

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Cement/ SWCNT thermoelectric nanocomposites for potential large-scale thermal energy harvesting

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This study reports on the utilization of SWCNTs as nanoadditives in a cementitious matrix, resulting into a new class of functional nanocomposites capable of converting thermal energy into electricity via the well-known thermoelectric (TE) effect (otherwise known as Seebeck effect). Thermal energy harvesting in buildings suggests a new strategy towards the reduction of human-activity's energy emissions. The use of conductive carbon nanomaterials in cementitious matrices has received an explosive interest over the past years. The resulting nanocomposites have shown amongst others enhanced mechanical properties, variable electrical conductivity (σ), piezoresistive strain sensor property, as well as thermoelectric functionality as recently reported [3]. The final properties of the cement/ CNT nanocomposites are highly dependent on the possible alignment and quality of CNT dispersion in the cementitious matrix driven i.e., by the cement /nanofiller interfacial interaction, method for dispersing the CNTs and mixing of the CNTs with the cement matrix. Relatively, the ultrasonication process followed to disperse CNTs is of great importance since inadequate ultrasonication energy and ultrasonication time will not be sufficient for the uniform dispersion of the nanomaterial, while a surplus of ultrasonication energy and time could result in a "shortening" effect of the CNT material inherent length.

In the study at hand, SWCNTs were introduced into cement matrix, while the Seebeck coefficient (S), electrical conductivity (σ), and power factor (PF) for different SWCNT contents were measured and calculated. Also, the influence of SWCNTs content on the thermoelectric properties of the cement/ nanocomposites at an age of 28 days were examined, exhibiting an n-type semiconductor behavior.

Acknowledgment: This research has been co-financed by the European Union and Greek national funds through the Operational Program Competitiveness, Entrepreneurship, and Innovation, under the call RESEARCH-CREATE-INNOVATE (HICOTEG-T1EDK-03482).

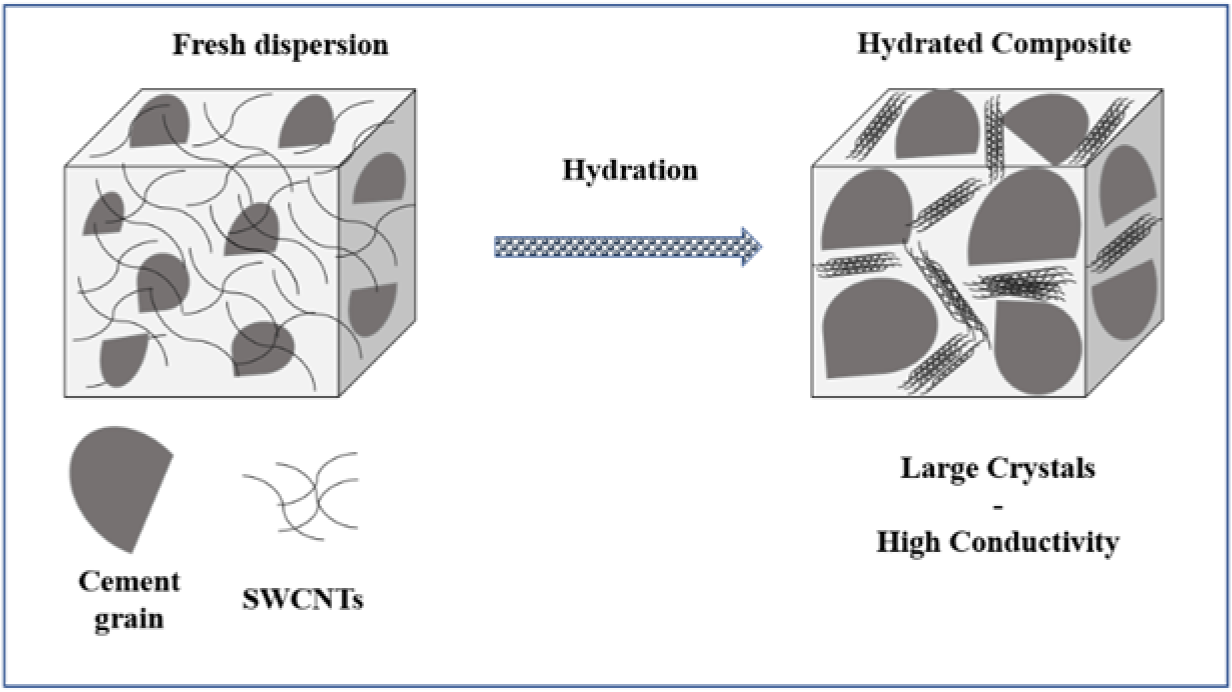

Fig.1 - SWCNTs network induced by a volume exclusion effect during the cement hardening’

Design and optimization of multilayer shielding device based on graphene

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Electromagnetic compatibility (EMC) problems become more important since the microwave spectrum becomes more and more crowded. New advanced materials with improved shielding efficiency (SE) are required for EM applications.

Recently, graphene was adopted as reinforcement for dielectric polymeric resins in order to obtain electrically conductive nanocomposites with good EMI SE while preserving flexibility, chemically inertness, ease of shaping and lightness of the host matrix [1], [2].

The impact of technological processes of carbon-based materials on their electromagnetic behavior is not entirely understood. In order to achieve an effective design of innovative e multifunctional devices, the onerous experimental characterization has to be complemented with suitable numerical models and/or theoretical studies able to predict the overall properties of the resulting materials.

In this contribution, the effects of uncertain (uncontrollable) and variable (controllable) physical parameters on the SE are considered for performance optimization purposes of a multilayer shield [3], [4]. In particular, commercial software (Comsol Multiphysics®, RF module, and MATLAB® RSTool) is used in order to derive an analytic expression of the shielding effectiveness of a device obtained by stacking a variable number of CVD graphene planes (GP) on poly-methyl methacrylate (PMMA).

Between the considered design parameter (i.e., the number of layers in the sandwich structures, the conductivity of the adopted carbonaceous film and the thickness of the dielectric spacer):

- The number of layers is the most relevant factor for the SE, whereas the thickness of the PMMA is the less one.
- A quadratic equation describing the SE for each considered number of layers is reported and will be used in order to optimize the design by considering the uncertainty on the conductivity of the adopted carbonaceous film and on the thickness of the dielectric spacer.
- Future works will attempt to evaluate the possibility of using various conductive carbon films as building blocks for passive EM devices, including EMI shielding layer, filters, polarizers, modulators, and collimators for microwave and THz radiation in order to assist the development of functional nanomaterials with improved and tailored properties.

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Electromechanichal performance variability of Capacitive Micromachined Ultrasonic Transducers (CMUTs) by FEM modeling

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Capacitive Micromachined Ultrasonic Transducers are acoustic transducers able to transmit and receive ultrasonic waves by performing an electromechanical conversion of energy. The inherent low acoustic impedance and the full-compatibility with CMOS technology have made these devices very attractive for the development of high-performing ultrasound transducers for medical imaging, and the first commercial probes have recently hit the market.

CMUTs are MEMS devices made by microfabricating small cavities in an elastic material, creating an array of suspended micromembranes. Several membranes compose an element; several elements compose the 1D or 2D array placed inside the imaging probe head [1].

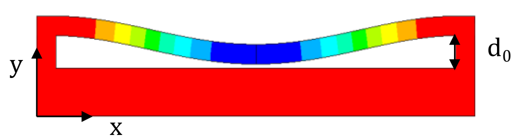

Fig. 1. Representation of the cross section of a CMUT cell, when a bias voltage is applied. The Silicon Nitride membrane is bending towards the substrate.

In the membranes and in the substrate below the cavities, metallic electrodes are placed to form the electrostatic cell. By applying a static voltage across the electrodes, the electrostatic force causes the bending of the membrane towards the substrate (see Fig. 1). Providing an alternate voltage signal makes the suspended membrane move by flexural vibration, generating an acoustic wave. Conversely, the biased membrane vibrates when an incoming acoustic wave impinges on the transducer's front face, generating an electric signal across the electrodes (see Fig. 2). During the ultrasound scanning the CMUT is in contact with the human body, which acts as an acoustic load, and is operated in pulse-echo mode near the cells mechanical resonance frequency.

The fabrication process of CMUT arrays involves the definition of the cavity inside the structural Silicon Nitride by the deposition of a sacrificial layer, and the deposition of the Aluminum electrodes and the passivation layers of Silicon Nitride [2]. Different phenomena determine the tolerance of the layers' thicknesses, which causes a variability of the electromechanical and acoustic behavior both among the transducer elements and among the different cells of the same element [3]. In particular, variations in the thickness of the layers causes unevenness of the resonance frequency of the different cells, which is even more significant when the cells are biased. Consequently, there are changes also in the membrane collapse voltage and membrane displacement, as well as in the cells static capacitance. All these inequalities lead to an uneven electromechanical behavior that determines an impairment of the overall transducer performance.

In the view of optimizing the fabrication process to improve repeatability and reduce the performance variability, it is important to identify the process-related parameters variation that is most effective on selected performance indicators. In this scenario, modeling the performance variation in response to the process-related factors variation can help driving the fabrication process optimization.

Fig. 2. Half the cross section of one cell from the considered CMUT device. The different layers are, from the top: the membrane (yellow), the additional membrane layer for the resonance frequency tuning (blue), the top electrode (light grey), the top passivation (green), the cavity (red), the bottom passivation (green), the bottom electrode (light grey), the substrate (light grey).

We propose a local sensitivity analysis of the electromechanical performance of a Reverse-Fabricated CMUT array for medical imaging based on Design of Experiments and Vertex Analysis. The sensitivity analysis is performed by simulating the device by means of a Finite Element Model. The model represents half the cross section of a circular CMUT cell, shown in Fig. 2 [4]. The process parameters considered as the factors causing the performance variability are the thicknesses of the layer underlying the front membrane (placed to tune the membrane resonance frequency), of the passivation layers (which separate the electrodes from the cavity) and of the sacrificial layer (hence, the thickness of the cavity) [5].

The selected output performance indicators are the electromechanical parameters of the CMUT, such as static capacitance, mechanical resonance frequency, biased resonance frequency, and collapse voltage.

Dex Scatter Plots and Main Effect Plots are used to assess the linearity of the dependence of the output parameters with respect to the input factors, and to compute the coefficients relating the performance variability to the factors tolerance, according to a linear regression model in the form of

$$\Delta y \approx \beta_1 \Delta x_1 + \beta_2 \Delta x_2 + \beta_3 \Delta x_3$$

where y is a performance indicator, x_1, x_2, and x_3 are the considered process-related factors, and β_1, β_2, and β_3, are the linear regression parameters.

The simulation results provide useful insight into the impact of uncertainty on the output performance.

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Design Criteria of Strain Sensors made of Self-Sensing Nanocomposites for Structural Applications

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Polymer composites reinforced with nano dimensional fillers (less than 100 nm), better known as nanocomposites, have attracted great interest in material science due to the interesting properties resulting from the sinergic interaction between the two or more components. Among the broad variety of polymer matrices suitable for embedding nanoparticles and to give rise to lightweight and high-strength materials, epoxy resins are the most promising candidates [1]-[2]. In particular, by using different nano-scale particles such as carbon nanostructures, nanocomposites and multifunctional smart materials with stimuli-responsive properties can be obtained [3]. Both in the case of monodimensional (i.e. carbon nanotubes or nanofibers) and bidimensional (monolayer graphene based nanostructures) electrical conductive fillers, their tendency to easily form electrically conductive networks when embedded even at low concentrations lead to modify the electrical properties of the hosting resin, passing from an insulator to conductive behaviour. The obtained nanocomposites are suitable for sensors and actuator applications, specially around the percolation threshold region (Fig. 1) [4]-[6]. Based on the experimentally detectable correlation between reversible mechanical deformation and electrical resistance of such kind of nanocomposites, several results have been reached showing these nanomaterials suitable for use as strain (or stress) nano-scale sensors [7]-[9].

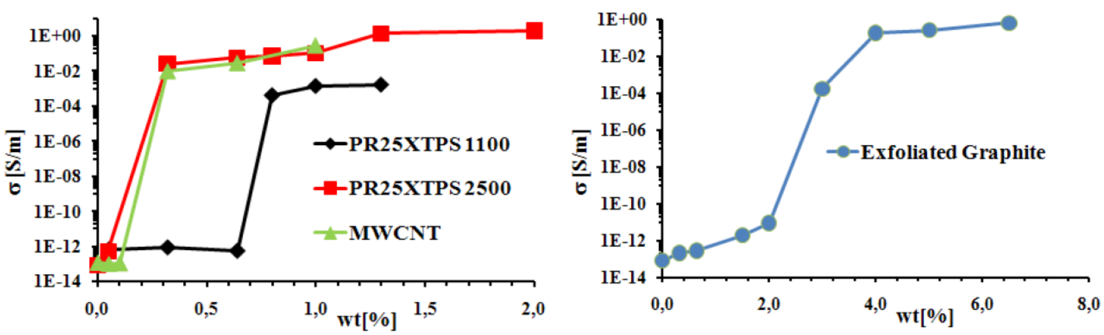

Figure 1 Different detected percolation threshold for monodimensional (rigth) and bidimensional (left) carbon fillers [10]

Moreover, filled polymers can be designed to have specific and tailored multifunctionality thus offering many advantages in comparison to conventional materials based on electro-active polymers or piezoelectric ceramics which present different limitations due to their fragility, non-negligible weight and high voltage or current required for their proper use. Therefore, the adoption of such approach based on nanocomposites leads to the availability of a new generation of sensor with customized features, design flexibilities and employable even in very harsh environments. These features result particularly attractive in industrial sector, such us the aeronautic or automotive or building onces, where the stress/strain sensors could be exploited for online structural health monitoring (SHM).

Neverthelss, the choice between the most suitable matrix and filler is not an easy and fully defined task.

In this contribute the effect of different matrix and of different fillers (monodimensional/bidimensional, geometric and chemical-physical characteristics) on the relationship between mechanical and electrical responces exploitable for strain-sensing application will be described. It will show that different specific solutions could exist and the choice between them depends on the specific application. As an example, two different epoxy precursors, the tetrafunctional tetraglycidyl methylene dianiline (TGMDA) and the bifunctional bisphenol A diglycidyl ether (DGEBA) will be considered (Fig. 2).

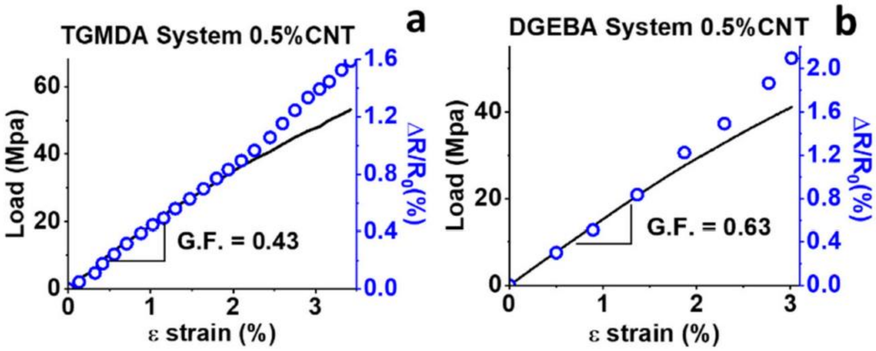

Figure 2 Mechanical response (Load – ⍰, left vertical axis) and resistance change ratio (⍰R/R_0, right vertical axis) observed in tensile stress as a function of the axial strain (⍰) of: (a) TGMDA system with 0.5%wt of monodimensional filler; (b) DGEBA system with 0.5% of monodimensional filler.

The different functionality of the precursor strongly affects the crosslinking density and, as a direct consequence, the electrical and mechanical behavior. The properties exhibited by the two different formulations can be taken into account in order to make the most appropriate choice with respect to the sensing performance. For practical applications, the choice of one formulation rather than another can be performed on the basis of costs, sensitivity, processing conditions, and most of all, mechanical requirements and in-service conditions of the final product.

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A design tool for the tuning of carbon-based nanocomposites material properties

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Nanocomposite materials exhibit tunable properties that can be exploited to develop high-performing functionalized innovative materials. It was observed that by combining carbon nanotubes (TNCNT) and graphene nanoplatelets (IGNP) in a hosting polymer matrix, it is possible to obtain 3D-printable filaments (Figure 1) with tunable properties, such as thermal conductivity σ_T and electrical conductivity σ_E [1].

Based on a database of thermally and electrically characterized samples (parameter space in Figure 2) made of carbon nanofillers-enriched PLA (Polylactic acid) [2-4], we developed a design tool for the computation of the percentage of both Multi-Walled CNTs and GNPs fillers required to achieve a fixed σ_T and $\sigma_{E.}$

Figure 3 – 3D-printable filament

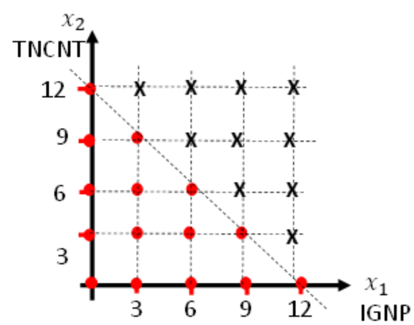

Figure 4 – Parameter space and adopted factors

The proposed design optimization tool relies on the representation of the nanocomposite's thermal and electrical conductivity dependence on the fillers' concentration according to a second-order polynomial model with interactions:

$$y = \beta_0 + \beta_1 x_1 + \beta_2 x_2 + \beta_{12} xy + \beta_{11} x_1^2 + \beta_{22} x_2^2$$

where y is the quantity to compute (performance) and x_1, x_2 are the percentages of fillers (Figure 3).

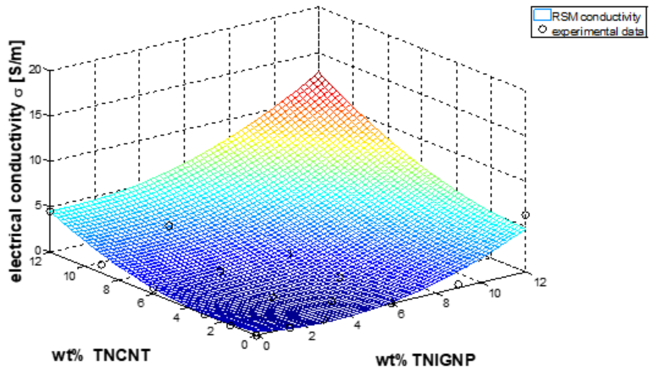

Figure 5 – Reconstructed performance function *y* (i.e. electrical conductivity, colour map) as a function of the condidered factors (percentages of fillers) together with the experimental data (black circles).

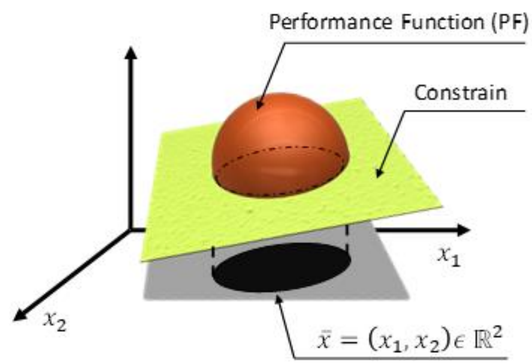

Figure 6 – Bi-dimensional ROA (black hole) for a generic PF (orange sferical shell) in presence of an assigned constrain (green plane)

The regression coefficients β_i are computed by applying the Response Surface Methodology to a discrete set of measurements, performed on samples selected according to a Design of Experiments-based approach (Figure 2). By fixing the desired value of the performance, and by applying to the input factors the constraints related to the physical feasibility (e.g. maximum weight percentage of carbon fillers allowing the filament extrusion), the Region of Acceptability (ROA) of the factors is determined.

The proposed method provides a tool for the engineering of carbon-based nanocomposites for possible application in 3-D printed sensors, actuators or electrodes design for biomedical systems, EM shielding packaging for electronic components protection, coatings for thermal dissipation, and several others.

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