The Second International Symposium on Risk Analysis and Safety of Complex Structures and Components
IRAS 2023

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IRAS23

BOOK OF ABSTRACTS

Proceedings of the *Second International Symposium on Risk analysis and Safety of Complex Structures and Components*

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DIVK

ESIS
European Structural Integrity Society

Title

PROCEEDINGS OF THE SECOND INTERNATIONAL SYMPOSIUM ON RISK ANALYSIS AND SAFETY OF COMPLEX STRUCTURES AND COMPONENTS - IRAS 2023

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Preface

Dear Colleagues, Dear Friends,

With great pleasure that we welcome you to our beautiful city of Belgrade (Serbia) for the second edition of the International Symposium on Risk Analysis and Safety of Complex Structures and Components (IRAS 2023). But first, a couple of words about the Technical Committee in charge of the conference.

The tasks and objectives of the Technical Committee are the following: - consolidation of the European scientific community to solve scientific and technical safety problems; - development of perspective research directions, computational and experimental methods and technologies in the area of safety of engineering systems; - cooperative researches, held by specialists an scientists from various countries on behalf of reducing the rate of accident risks while operating dangerous objects and systems; - development of modelling the incident theory of large technical systems; - development of mechanical and mathematical models and risk-analysis technologies; - development of reliability and probabilistic approaches for the fatigue and fracture characterization of materials (metals, polymers, composites among others) and structures (metallic, composite, joints, etc); - elaboration of standards using methods of probabilistic risk-analysis of technical systems according to fracture mechanics criteria; - elaboration of standards using reliability and probabilistic models for the large structures and components according to local criteria; - elaboration of standards using risk models of complex hierarchical technical systems; - unification of approaches to safety analysis of large technical systems; - unification of analysis methods of information on technical condition of large technical systems; - creation of unified methods and the harmonization of national regulatory documents in the area of technical systems safety; - elaboration of special study courses, problem books and test books on fracture mechanics, fatigue, reliability theory, and risk-analysis of technical systems.

The Second International Symposium on Risk Analysis and Safety of Complex Structures and Components (IRAS 20233) is organised by ESIS TC12 (with support from local institutions, such as the Faculty of Mechanical Engineering and its Innovation Center). It will take place in the Faculty of Mechanical Engineering of the University of Belgrade, in the City of Belgrade, the capital of Serbia, from 2-4 April 2023.

This conference is intended as a forum for discussion about recent advances in the aforementioned topics, including maintenance, safety, risk analysis, probabilistic assessment, life-cycle performance, fatigue, fracture, damage mechanics, numerical simulations of a wide range of infrastructures, such as engineering technical systems, transportation systems and their applications in various fields, such as civil, mechanical, aerospace, traffic and chemical engineering, as well as to a wide variety of structures and equipment, including but not limited to bridges, buildings, dams, railways, pipelines, wind towers, offshore platforms, naval vessels, nuclear and hydropower plants…

The Organizing Committee of the IRAS 2023 conference sincerely thanks all contributing authors for playing a significant role in the overall success of this event, with their exciting presentations. The members of the International Scientific Committee are also fully acknowledged for their support of the IRAS 2023 event. Special thanks to the Thematic Sessions Organizers and Plenary Speakers for their dedication and knowledge and energy brought to this event. The Organizing Committee would also like to express their gratitude to the sponsors for their time and support without which the conference would be impossible to organize. Finally, chairmen sincerely thank the tireless efforts of Organizing Committee members, as well as students and other Faculty of Mechanical Engineering Innovation Center of Faculty of Mechanical Engineering staff.

The second edition of the IRAS 2023 event, organized between 2nd and 4th of April, 2023 at the Faculty of Mechanical Engineering of the University of Belgrade, Serbia, gathered around 80 participants from all over the worlds, with more than 20 nationalities demonstrating the vitality of this new event, both in person and on-line. This book gathers the abstracts of the works presented in the conference, including keynote lectures and regular presentations alike. In general, the abstracts were organized into chapters, according to the five main topics of the thematic sessions foreseen in the programme of the conference, in accordance with the general topics covered by the TC12.

The editors of the Proceedings of the Second International Symposium on Risk Analysis and Safety of Complex Structures and Components (Book of Abstracts),

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- **Chao Gao**, Norwegian University of Science and Technology of Trondheim, Norway
  Bioinspired strategy to break trade-off between strength and toughness

- **Abílio M.P. de Jesus**, Faculty of Engineering of the University of Porto, Portugal
  Exploring the Local Fatigue Approaches to Improve the Structural Integrity of Metallic Structures and Mechanical Components

- **Liviu Marsavina**, University Politehnica Timisoara, Romania
  The size and notch effect on additive manufactured polymers

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  Size-Effect in Fracture Mechanics Testing by Using the Weibull Jc Cumulative Distribution Function

- **Nenad Gubeljak**, University of Maribor, Faculty of Mechanical Engineering, Slovenia
  Fatigue lifetime of a howitzer cannon

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  The use of hydrogen as an additive to improve the characteristics of low-calorific value gaseous fuels

Bioinspired strategy to break trade-off between strength and toughness

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Abstract

Breaking trade-off between strength and toughness is always challenging in material science. Traditional approaches—e.g., chemical-based and micromechanics-based—are difficult to attain strength and toughness simultaneously. However, Nature offers tremendous examples that have potential to break this trade-off. For example, many biological armors are architectured materials with building blocks across multiple length scales. In these natural architectured materials and their bioinspired composites, undulated soft interfacial layers enable efficient load transmission between the hard phases, resulting in enhanced mechanical properties—especially stiffness, strength, and toughness. This strategy has been exploited by many biological examples—e.g., turtle carapaces, boxfish armor, and woodpecker beaks. In these animals examples, the soft undulated sutural articulations show relatively small amplitude. However, much larger amplitude of sutural articulations has been found in the seedcoat of plant species—e.g., Portulaca spp. and Panicum spp. The seedcoats play an important role to protect the seed from external damage and environmental pressure, and they have been reported to exihibit complex morphology—periodic arrays of tile-like building blocks that articulate with each other through wavy interfaces. Traditionally, these unique morphology of seedcoats have been employed as a diagnostic role for species identification purposes. However, little attention has been paid to understand the mechanical performence of these interesting yet complex morphologies.

In this study, a combination of bioinspired design and finite element (FE) simulations toghether with the mechanical testing on the 3D printed multimaterial structural analogues has been exploited to understand the fundamental mechanisms.

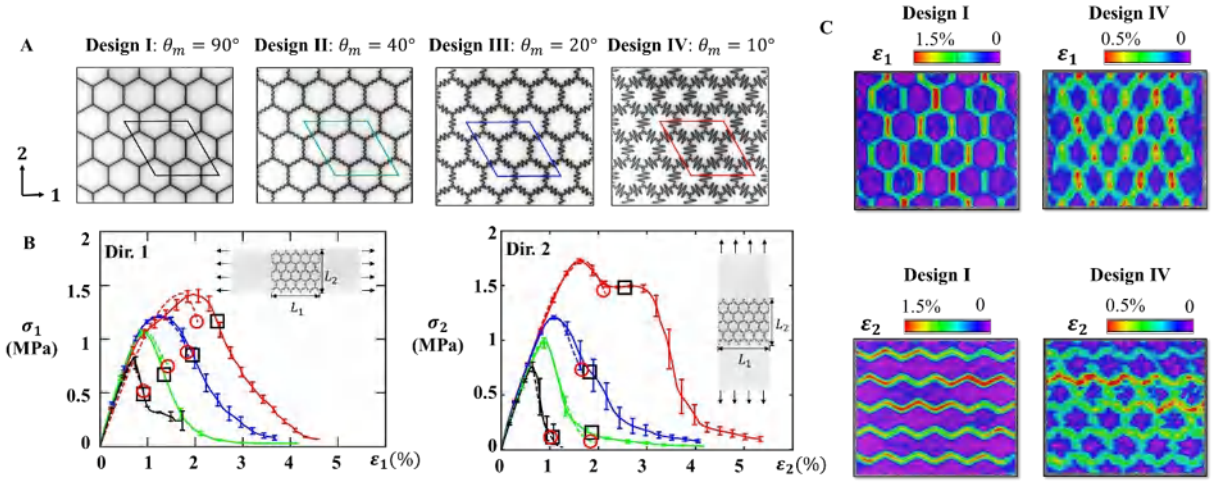

Figure 1 Mechanical responses of suture tessellation cases in loading directions 1 and 2. (A) Representative volume elements and 3D printed samples. (B) Stress-strain curves of the four cases in loading directions 1 and 2. (C) Strain contour obtained by digital image correlation at the global strain 0.2% under loading direction 1 and 2.

Experimental and FE results have demonstrated that the waviness of the sutural tessellation plays a more important role in governing mechanical response than the volume fraction of hard phase. When the sutural tessellations become wavier, an applied load can be more effectively transferred to the hard phase, thereby enhancing overall strength and toughness simultaneously. Furthermore, a comprehensive parametric study on

the stiffness ratio between the hard and soft phase has shown that the stiffness ratio can amplify the influence of the waviness on the mechanical properties of tiled composites.

The design principles learning from seedcoats show a promising approach to enhance the mechanical performance of tiled composites by rationally designing wavy interfaces. This new strategy offer great potential to develop new functionally graded composites for protection, energy absorption, and dissipation.

Keywords: strength and toughness trade-off; bioinspired design; Finite Element simulations; multimaterial structures; sutural tessellation

Exploring the local fatigue approaches to improve the structural integrity of metallic structures and mechanical components

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Abstract

Structural integrity is the forefront of the concerns of the structural engineers of new structures as well as of the infrastructure owners and maintenance engineers. There are several physical degradation phenomena, but fatigue degradation still appears as one of the main phenomena affecting the structural integrity and reliability of those structures, when subjected to variable amplitude stress histograms. Fatigue still is one of the main causes of unexpected failures being responsible for significant economic losses. The existence of fatigue design rules is mandatory to cope with the new structural design needs. Safe, accurate and sustainable design rules are required to cover the vast diversity of structural and mechanical systems and the loading conditions they are subjected to. The world evolution is claiming for the coverage of more extreme loading conditions by design codes aside with the need of more efficient material usage and the need of retrofitting and extension of the life of existing infrastructures. In addition, fatigue models applied in structures are based more and more on local approaches instead of the classical nominal/global approaches, which raises concerns about material characterization and laboratory/real structures transfer issues.

This work presents some of the author research group experience in the field of fatigue modelling of a number of structural and mechanical systems (see Fig. 1), most of them focused on the fatigue resistance modelling. This experience has been proposed to improve the current available approaches, exploring local fatigue modelling approaches and covering existing gaps in the design codes. The first topic will be the ultra-low-cycle fatigue (ULCF) behaviour of pipeline steels and components. This extreme fatigue regime is important for the cases where extreme cyclic loadings are applied to pipelines, such as in the case of seismic actions. This research was preformed within the ULCF EU project and resulted in new local fatigue model and valuable full-scale fatigue data, which was used to validate the model. A multi-axial fatigue criterion was proposed for ULCF, which accounts for the stress tri-axiality and Lode angle histories.

A second research case brought to this presentation is the case of riveted and welded railway bridges. In this research, multiscale approaches have been developed to compute the local fatigue parameters based on modal superposition. This technique is proposed to compute the local stress intensity histories or local stress and strains histories for a number of different trains and accounting for their dynamic effects in an efficient way by combining modal local quantities (ex. modal stress intensity factors). Linear behaviour is assumed, which is valid for welded construction. For riveted bridges, locally non-linearity may be present due to contact between rivets and plates and therefore the technique will lose some efficiency but still applicable to the local boundary conditions of sub models. The local fatigue models are then applied to case studies, showing its efficiency. Also, for welded bridge joints, the application of the static equivalent structural stresses and the master curve concept is demonstrated and applied.

Finally, the case of rack structures is referred in this work. Rack structures produced by thin cold formed rolled profiles are being more and more subjected to cyclic loads due to the non-stop economy and there is a strong demand for material usage reduction (thickness reduction) to increase the European industry competitiveness. Thus, fatigue has raised as a main concern of designers, which do not find answers in current EU design rules that were developed for thick hot rolled sections. Within the FASTCOLD EU project new design rules for cold-formed profiles were developed, an overview being presented in this research. Local approaches to fatigue were proposed. Besides, cold roll forming simulation was performed to generate residual stress profiles. Also, full-scale fatigue data was generated to allow the validation of new details categories for rack structures.

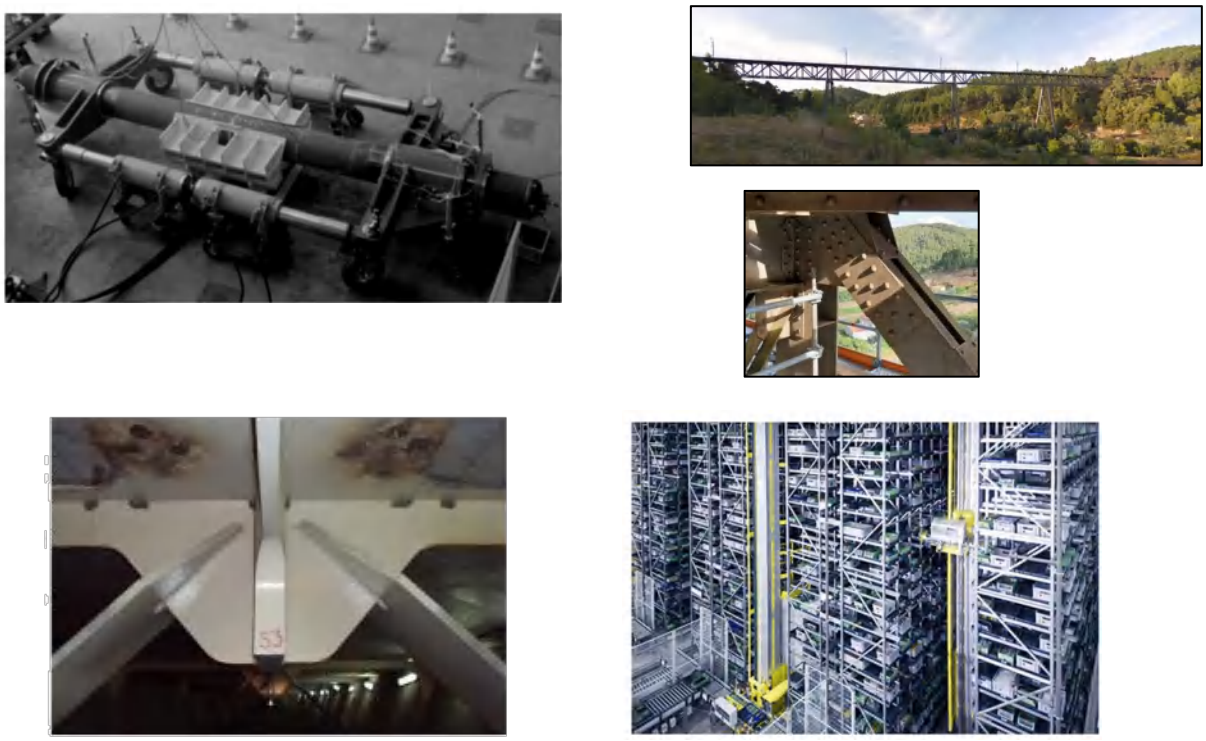

Fig. 1. Structural systems under research by UPORTO: piping (top left); riveted bridges (top right); welded bridges (bottom left) and rack structures (bottom right).

Acknowledgements

All funding institutions are acknowledged namely European Commission through the ULCF, FASTCOLD, IN2TRACK2 and INTOTRACK3 projects, and Portuguese Science Foundation (FCT). Also, PhD and MSc students are acknowledged.

Keywords: local fatigue approach; Ultra-Low Cycle fatigue (ULCF); railway bridges; rack structures; cold rolling; residual stress

The size and notch effect on additive manufactured polymers

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Abstract

The size and notch effect are very important in assessing the structural integrity of additive manufactured components, especially for larger ones with complex geometries. This paper presents the size and notch effect on additive manufactured PETG materials. Semi-circular bending (SCB) specimens were considered with cracks and rounded notches, having different specimen sizes. The mean of fracture load was compared for the considered geometries. An increase of fracture load with specimen size and with increasing notch radius was observed.

Introduction

The additive manufacturing techniques developed quickly in the last decades. The Fused Deposition Modeling (FDM) is one of the most used method for additive manufacturing due to simplicity, cost effective and the good mechanical properties obtained. In consequence, now the tendency is to produce larger components with complex geometries. On this regard, the size and notch effects are very important for designing large 3D printed structures. The presence of notches creates a stress concentration effect, which can lead to crack initiation and decreasing the load carrying capacity of the structures.

The Semi-circular bending (SCB) specimens were successfully used for mixed mode investigations of brittle and quasi-brittle materials like rocks, polymers, ceramics, and so on and were adopted for this study.

This paper presents the results of the notch effect investigation on PETG polymers obtained through Fused Deposition Modeling using a PRUSA 3D printer. The SCB specimens were considered with crack and rounded notches with radius ρ = 0.8 mm and 2.2 mm. Four specimen sizes were considered with radius R = 10, 20, 30 and 40 mm all having the same thickness of 6 mm. The ratio between crack/notch length a and specimen radius R was considered a/R=0.5. Static three point bending load, Fig. 1 was applied to SCB specimens at room temperature with a loading speed of 2 mm/min in a Zwick Proline Z005 universal testing machine. Five specimens for each geometry were tested.

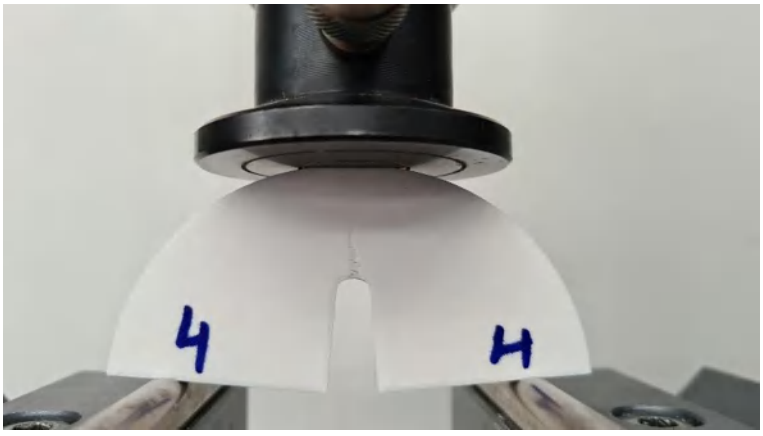

Fig. 1. Three point bending test of PETG SCB specimen with radius 40 mm and notch radius 2.2 mm

Results

The mean value of the fracture load resulted from the testing program are shown in Fig. 2. It could be observed that the fracture load increases with increasing the specimen size with 130% for cracked specimens, 155% for specimens with rounded notches of 0.8 mm, respectively 180% for specimens with rounded notches

of 2.2 mm. These maximum differences were obtained comparing the specimens with radius R = 10 mm with those with R = 40 mm. Comparing the fracture load of cracked specimens with the round notches with 0.8 radius it could be observed that the fracture load increases with around 24%, respectively with around 45% for rounded notches with ρ = 2.2 mm radius.

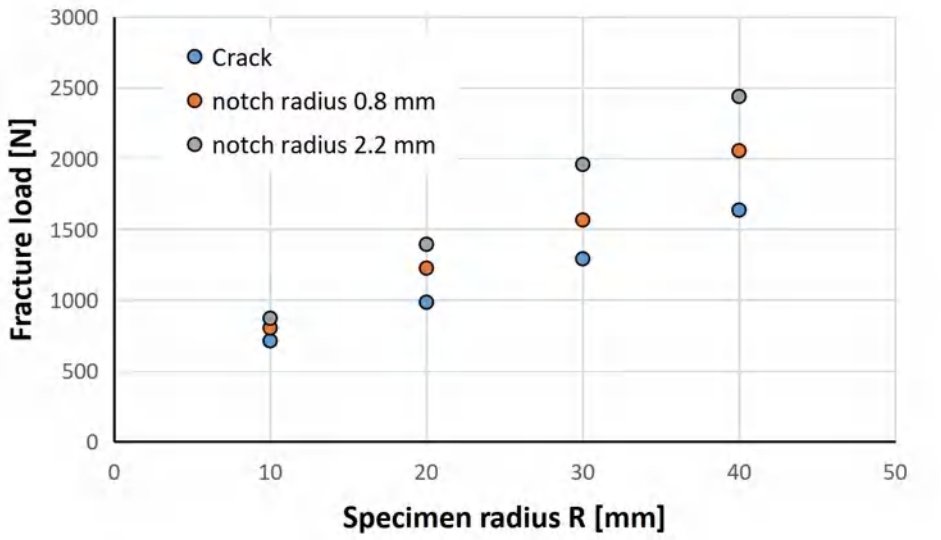

Fig. 2. The notch effect results for PETG material.

Conclusions

The experimental program on three point bending tests of SCB specimens with different sizes show a strong size and notch effect for the PETG material 3D printed using FDM technology. On one hand the fracture load increases with the size of the specimens, on the other hand the presence of rounded notches produce an increase of the fracture load comparing with the case of a crack.

The Theory of Critical Distance will be employed to predict the fracture load of PETG notched specimens.

Acknowledgements

The project leading to these results has received funding from the European Union's Horizon 2020 research and innovation program (H2020-WIDESPREAD-2018, SIRAMM) under grant agreement No. 857124.

Keywords: additive manufactured polymers; fused deposition modeling; semi-circular bending; Theory of Critical Distance

Size effect assessment in fracture mechanics testing using the Weibull J_c Cumulative Distribution Function

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Abstract

The size-effect aspect of the DTB (ductile-to-brittle) transition in ferritic steels has been a ubiquitous research challenge for the last 50 years. In this article, the investigation of the size effect is focused on the Weibull cumulative distribution function (CDF) of the critical value of the J-integral (J_c). A new scaling algorithm has been developed [1, 2] to tackle the effect of the CT specimen size on the Jc CDF. Two CT-size experimental data sets in the DTB transition temperature region provide the necessary inputs (e.g., the reactor steel 20MnMoNi55 corresponding to testing of CT 1T and CT 2T specimens at - 60 °C). Due to the specific form of the two-parameter Weibull CDF, $F(J_c \mid \beta, \eta)$, the procedure is applied according to a novel two-step-scaling (2SS) scheme [1] (Fig. 1). First, the Jc scaling along the abscissa (defined by the scaling parameter κ) is performed to ensure the overlap of the CDFs at $F(J_c = \eta) = 1–1/e \approx 0.632$ for the two input CT specimen widths W (or thicknesses B), which implies the constancy condition $\eta_* = \eta \cdot W\kappa$ = const. (or $\eta_{B*} = \eta \cdot B\kappa$ = const. if the Weibull CDF is defined in terms of B) (Fig. 1b). Second, the F-scaling along the ordinate (defined by the scaling parameter ξ) is performed to ensure the equality of the CDF slopes (and, consequently, the probability density function maxima) in the scaled $F \cdot W^{\xi}$–$J_c \cdot W^{\kappa}$ space (alternatively, $F \cdot B^{\xi}$–$J_c \cdot B^{\kappa}$) (Fig. 1c). The pair of scaling parameters (κ, ξ) is at the core of the 2SS procedure. The objective is to obtain the Jc CDF that encapsulates the CT specimen size.

The proposed 2SS scheme (illustrated in Fig. 1) is applied to two CT experimental datasets [1]. Application of the procedure results in a pair of scaling parameters (κ, ξ) = (0.42, -0.14) that drives the scaling and defines the size-insensitive Weibull parameters (η_* = 1850. and S_* = 0.00024) in the scaled $F \cdot W^{\xi}$–$J_c \cdot W^{\kappa}$ space (Fig. 1) [1]. The Weibull J_c CDF can eventually be written in the following form

$$F(J_c \mid W) = 1 - \exp\left\{-\left(\frac{J_c \cdot W^{\kappa}}{\eta_*}\right)^{\beta(W)}\right\} = 1 - \exp\left\{-\left(\frac{J_c \cdot W^{0.42}}{1850}\right)^{\beta(W)}\right\} \tag{1}$$

The size-sensitive Weibull shape parameter $\beta(W)$ is uniquely defined by the shape function

$$\Xi(\beta) = \beta\left(1 - \frac{1}{\beta}\right)^{1-1/\beta} \exp\left[-\left(1 - \frac{1}{\beta}\right)\right] = S_* \cdot \eta_* \cdot W^{-\xi} \quad \Leftrightarrow \quad \beta(W) \tag{2}$$

once the scaling parameters are determined (see Fig. 1d for illustration and reference [1] for details).

Finally, due to the geometric similarity of the CT specimen, $B \propto W$, the Weibull J_c CDF (1) can be also defined in terms of the thickness

$$F(J_c \mid B) = 1 - \exp\left\{-\left(\frac{J_c \cdot B^{\kappa}}{\eta_{B*}}\right)^{\beta(B)}\right\} \tag{3}$$

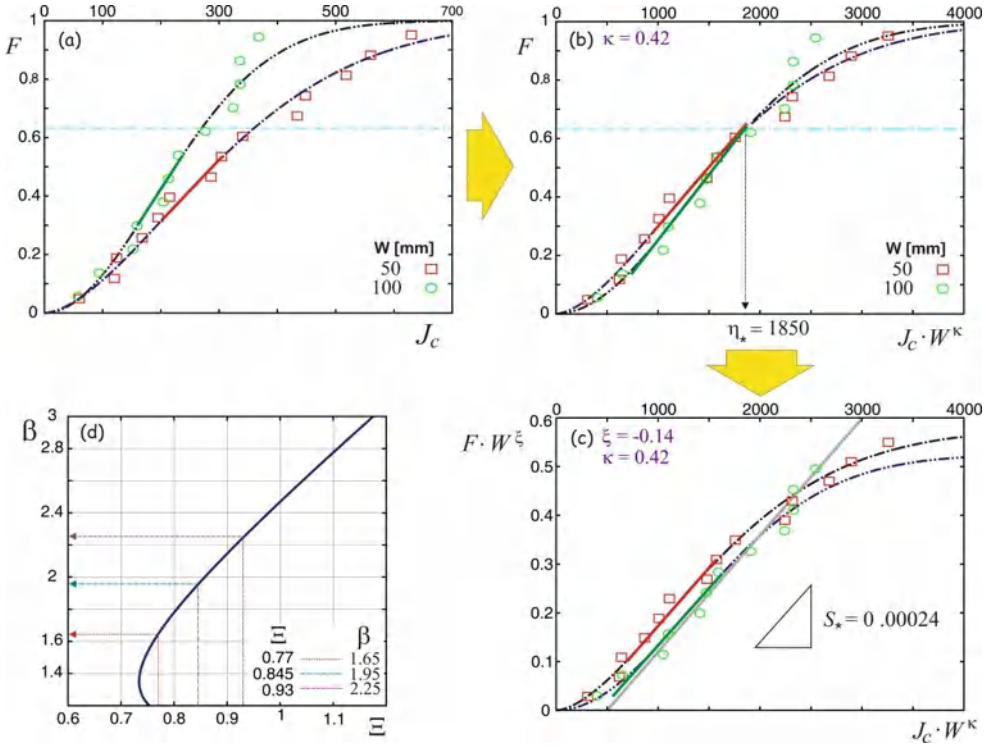

Fig. 1. The 2SS procedure applied for two experimental data sets (CT50, CT100) of 20MnMoNi55 steel at -60 °C

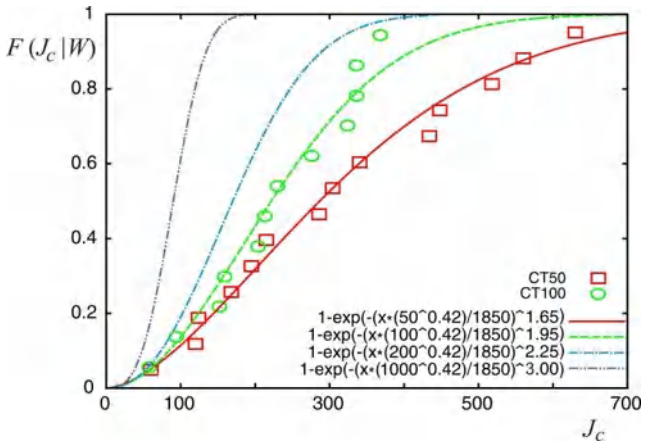

Fig. 2. Illustration of the results of the proposed 2SS procedure as given by Eq. (1).

Keywords: size effect; Weibull distribution; scaling; fracture toughness; ductile-to-brittle transition.

Fatigue lifetime of a Howitzer cannon

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Abstract

This work analyses the integrity and fatigue life of a barrel made with an KATO1 alloy (35NiCrMoV12-5) with two different heat treatments. For this, a fracture mechanics approach is applied based on the concepts of fatigue resistance curve. In order to carry out the analysis, the different necessary variables were experimentally measured or theoretically estimated: micro-structural size, static strength, fracture toughness, fatigue threshold for long crack, short crack range, fatigue crack propagation properties and fatigue limit. The fatigue limit of the two analysed materials was estimated experimentally by using the thermographic method. The approach has shown that it is possible to quantify the influence of the different variables involved in the definition of the fatigue resistance and life of the barrel, or its safe operating conditions.

Although the differences found between both materials are not very important, the analysis shows that the barrel made with material B could operate at a somehow higher pressure or that it could shoot a greater number of projectiles at the same pressure.

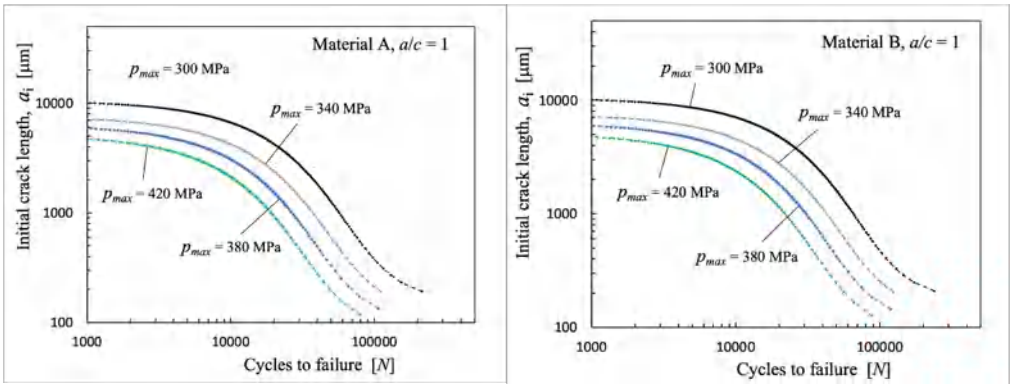

Fig. 1. Comparison of fatigue behaviour for both materials

This work analyses the integrity and fatigue life of a barrel made with an KATO1 alloy (35NiCrMoV12-5) with two different heat treatments. For this, a fracture mechanics approach is applied based on the concepts of fatigue resistance curve, ΔK_{th} vs a. In order to carry out the analysis, the different necessary variables were measured experimentally or theoretically estimated: micro-structural size, static strength, fracture toughness, fatigue threshold for long crack, short crack range, fatigue crack propagation properties and fatigue limit. The fatigue limit of the two analysed materials was estimated by using the thermographic method.

The approach has shown that it is possible to quantify the influence of the different variables involved in the definition of the fatigue life of the barrel, or of the safe operating conditions. A safe domain of use of the cannon barrel and the fatigue life for an unsafe condition could be estimated. Besides, a maximum allowable defect size can be defined for a safe service.

The analysis has generated indications of what to improve in the material used to increase the fatigue resistance of the barrel. One of the important parameters to improve would be the fatigue threshold for long crack growth, which would directly increase the critical crack length for a given maximum pressure. Or the maximum pressure in the barrel during the shot could be increased, that means choosing different parameters when shooting that could increase the range of the projectiles without reducing the lifetime of the barrel. The

choice of material with a higher threshold value for crack propagation can therefore greatly affect the lifetime of the barrel. From the above analysis, we can conclude that a cannon barrel made of material B for the same lifetime, which in our case means the number of projectiles, could operate at a higher pressure. Higher allowable pressure in the barrel means choosing different parameters when shooting, and this could increase the range of the projectiles without reducing the lifetime. Greater certainty in the predictions could be obtained by adequately measuring the parameters identified as important and decisive for the estimations.

Keywords: Howitzer; cannon barrel; lifetime; thermographic testing; fatigue limit

Structural health monitoring by Embedded System for Remote Strain Gauge Measurement

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Abstract

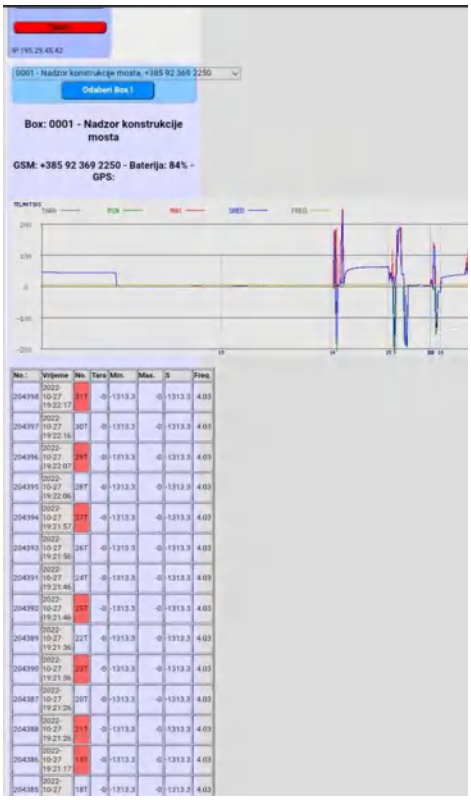
Structural Health Monitoring sets out to determine the health of a structure by reading a network of sensors that are permanently attached to structure and monitored over time [1]. It is particularly useful for remotely monitoring large stationary infrastructure systems, such as bridges and dams, but it is demanding to use it for onsite monitoring of aircraft, spacecraft, ships, offshore structures, and pipelines. To be able to detect and quantify the presence of damage in structure we can use active and passive sensors. Passive sensors only register the value of some physical quantities, but without interaction with the structure (f.i. AE transducers, resistance strain gages, fiber optics strain gages, filament crack gages, etc.). Due to the fact that loading conditions are changing over the time, it is not enough to measure the strain only once or periodically, it should be measured continuously to enable active monitoring and decision making on time.

In this paper our own original and patented IoT solution for remote continuous strain measurement will be presented on concrete engineering structure [2]. The measuring system Telmatiks presented in Fig. 1 has been calibrated and then tested in static and dynamic load conditions to prove its usability and accuracy. After the initial testing, system has been upgraded and connected with IoT device what makes it possible to monitor remote constructions 24 hours per day with any device equipped by web browser and internet connection (smartphone/computer).

Fig. 1. Telmatiks system for the remote measurement

Web interface for collecting of the measured data is presented on the Fig. 2. The measured data could be exported and afterwards imported in some other software, if necessary. The system can store all data locally at the point of measurement, which can be accessed later in the event of an internet outage. Also, there is a possibility to communicate with the device via SMS messages for some urgent actions, for example if the observed value is coming close to critical point.

An example of the measurement carried out on the bridge by this system is presented on the Fig. 2 together with the real stress-time diagram taken during the crossing of the freight train over the bridge.



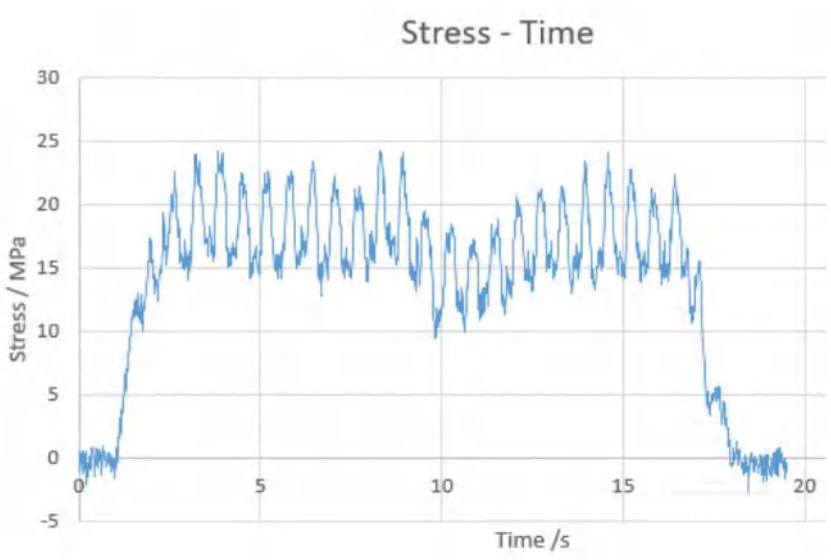


Fig. 2. Recorded values by monitoring in a real time

Keywords: remote strain gauge measurement; structural health monitoring; passive sensors; Internet of Things

The use of hydrogen as an additive to improve the characteristics of low-calorific value gaseous fuels

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Abstract

The quite certain introduction of hydrogen and mixtures of hydrogen and low calorific value gases (biogas and landfill gas) for the energy needs of modern society reveals a number of open questions related to the problems of applying these fuels in future commercial gas devices and systems. Hydrogen is the first and lightest chemical element. At standard conditions of pressure and temperature, hydrogen is a colorless, odorless, and tasteless diatomic gas. It is non-toxic and significantly lighter than air. The ease with which it ignites is the greatest danger in production, use and storage. It differs from other gases in that, when expanding from high pressures, it heats up, not cools down. Water is the most abundant natural resource in the world. Converting water into usable energy has always been man's dream. With the help of new technologies, hydrogen and oxygen gases can be generated from water. Currently, hydrogen is mostly produced from natural gas. The key way to obtain hydrogen is electrolysis, and in this way "green" hydrogen is obtained. Hydrogen is a highly explosive gas and creates one of the highest flame temperatures. It is a very reactive element, with one valence electron. The character of the energy balance of hydrogen chemical reactions is exothermic in nature, which means that energy is released. Oxidation, that is, the burning of two hydrogen molecules, creates a water molecule, which makes hydrogen the most environmentally friendly fuel. Due to its high reactivity, hydrogen can be added to other, low-calorie fuel gases, with a higher percentage of inert components in their composition, in order to improve the efficiency of the combustion process of such fuels. This fact can be very interesting and useful, considering the current situation on the natural gas market. Namely, we are aware of the current increase in the price and demand of natural gas in the world. On the other hand, there are deposits of low-calorie natural gas in Serbia, the potential of which could be used more efficiently precisely thanks to hydrogen, that is, the use of hydrogen in the form of a gaseous additive in a mixture with domestic low-calorie natural gas.

This principle is also applicable to other low-calorie gaseous fuels (biogas, landfill gas, blast furnace gas). In the case of the production of renewable energy sources, the impact of adding hydrogen to biogas with a lower percentage of fuel components (CH4), such as obtained from bovine excrement, is particularly interesting. This type of hydrogen use could have a significant impact on the use of existing energy potentials related to both primary and secondary gaseous fuels in our country. Currently, fuel cells are the only commercialized devices for using hydrogen. In the case of using hydrogen by the combustion method, there are already commercialized gas turbines of high power, while in the case of devices of lower power, manufacturers are still in the research and development phase. Serbia is given the opportunity to be in the process of developing technology for the application of hydrogen in the energy sector. One of the ways to achieve the above goals is to develop fuel flexible, low emission, low-cost burner, purposely designed and optimized, in order to be fueled by renewable gases - biogas, landfill gases, and their blends with hydrogen. Biogases are usually utilized in specialized engines to generate power in the form of electricity and heat (CHP), at industrial levels and larger thermal loads, over 50 KW, at given minimum methane content in biogas. The presence of hydrogen in fuel can be tolerated by up to 20%, according to engine manufacturers, although there are some doubts about the proper type of engines and fuel feeding systems. Serbia is about to reach about 100 MW biogas-installed CHP plants which is the highest among the neighboring countries. On the other hand, biogas is less often utilized in households, farming, and similar, mostly in less developed countries, using high emission, low efficient burners, and no hydrogen is expected to blend with biogas. There is no low emission burner with multi-fuel capabilities that can be fueled by biogas, landfill gas, and their blends with hydrogen. A free flow burner performance is governed by a number of factors, including fuel type,

air coefficient, fuel concentration distribution in fuel/air mixture, velocity field, residence time, turbulence intensity and scale, fuel/air preheating temperature, and pressure drop. The pollutant emissions of NOx and CO are controlled in complex ways. While higher flame temperatures are favorable for NOx production, they have an adverse effect on CO production, and vice versa, when flame temperatures are lower. The flame temperature is mainly controlled by the air coefficient. On the other hand, combustor efficiency depends on air coefficient. The flow field and air coefficient are the main factors regarding flame stability. The increase of thermal power and flow mean velocity, and increase of air coefficient make favorable conditions for flame blowout. The decrease of the two factors, including the role of a boundary layer, can induce flame flash-back. Both situations, flame blowout, and flash-back are highly unacceptable situations that must be avoided. Besides, flames of low calorific value fuels, such as biogas and landfill gas, are inherently unstable, and favorable for flame blowout, while hydrogen flames, due to their high laminar flame velocity, are prone to flame flash-back. The reverse flow, swirling flow field, and increased turbulence intensity improve flame stability and increase flame residence time. The above-stated, interrelated influential make design and performance optimization of burners a demanding task. The porous medium combustion technique is based on flame stabilization in a porous ceramic matrix. The advantages of the technique are wide thermal power modulation capabilities, low pollutant emissions, good flame stability, high specific thermal power by volume, wide combustion stability limits, and radiant heat transfer characteristics. The combustion takes place in the solid matrix. The flame stability is supported by the excellent heat transfer characteristics of thermal radiation, heat conduction in a solid matrix, and convective heat exchange between solid and gas. The drawbacks include high-pressure drop, heat transfer mostly by thermal radiation which requires adequate heat exchangers for burner utilization, low combustion dynamics, increased thermal stresses, followed by possible cracks and deterioration of ceramic matrix elements, non-homogeneous flow field, and sensitivity to higher flame temperatures due to maximal temperature that ceramic material can withstand. The lower life span of ceramics, and the need for more often maintenance of a burner.

Keywords: hydrogen; low-calorific value gaseous fuels; fuel cells; combustion; biogas and landfill gas; burner with multi-fuel capabilities; free flow burner; low emission, flame blowout; flame flash-back; heat transfer

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Towards new fundamentals for structural integrity of large-scale pressure systems

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Abstract

It is an age-old human experience that every system is finite and its lifetime –the time during which it can be safely used– is also finite. The very existence of a finite service lifetime and its determination requires particular care in the case of systems with a large size and subject to high loads. Such large-scale and highly complex systems are usually custom-designed, custom-built systems with a Design Life (DL) of several decades –i.e., even multiple generations of people–. Such systems are usually safety-critical systems, meaning that if some unforeseen accidental events were to occur, the impact on human life and the natural environment could very easily become catastrophic. The history of technology shows examples of accidents that have resulted in human casualties, and serious environmental and material damage. The conclusions that can be drawn from accident investigations are that catastrophic accidents have always been caused by an unfavourable combination of factors, the main ones being human error, hostile conditions and unexpected events that have resulted in a sudden and significant overloading of a structure or parts of it.

One of the greatest challenges of the power industry is the efficient and environmentally friendly production of electricity in a way that also preserves the stability of the global electricity grid. Electricity generation technology is more efficient the more intensive are the non-equilibrium processes underlying the energy generation technology. Technologies proven to be efficient for power generation need specific thermodynamic parameters and require the technology to be strictly separated from the natural environment and to ensure that this separation is perfectly preserved under all conditions. In this case, the technology can be considered safe. As the unit performances in the power industry are high and the thermodynamic parameters (p, T) of energy generation technologies are increasingly high, the geometric dimensions of the Pressure Systems (PSs) to serve the needs of the technologies are large. These systems are called Large-Scale Pressure Systems (LSPSs). Since the operation of any technology with high unit performance and high thermodynamic parameters is associated with risks, the design, and Structural Integrity of LSPSs is focused on guaranteeing that the safety risk of a system is reduced to the minimum achievable.

In the power industry, Nuclear Power Plants (NPPs) are of particular importance for the stability of the electricity grid. Their safety is ensured by consistent application of the principle of defence in depth. PSs in the reactor cooling systems of Pressurized Water Reactors (PWRs) are a key part of both the operational and the safety system. Therefore, the LSPSs are dimensioned and checked with particular care during design phase by means of design safety calculations. According to the modern safety design concept, a system is considered safe if it is damage tolerant and accident tolerant. By definition, a designed system is damage tolerant at a given load level if, for crack-like failures postulated in it –according to the safety specifications–, there is no risk of fast crack propagation induced catastrophic failure. The system is called accident tolerant if, according to strength calculations for processes considered as accident events of the technology system, the LSPS remains safe throughout these events. Obviously, the LSPS under consideration is damage tolerant and accident tolerant if both criteria are fulfilled at the same time. Material properties used in the Design Safety Calculations (DSCs) are taken based on valid safety standards and relevant international good practice. The service life determined by the DSCs is called the Design Life (DL). The safety assessments of an implemented LSPS are called Structural Integrity Calculations (SICs). The methodology for SICs, in the spirit of current international good practice, is essentially the same as for DSCs, but material property data used in the calculations are derived from experiments of the unit specific surveillance programs. Since the properties of structural materials of manufactured systems are significantly better than that assumed in standards, the Technically Allowable Lifetime (TAL) of an LSPS determined by the SICs is also longer than its DL. The majority of PWR units currently in operation were designed in the decades around 1970-80, typically with an

expected lifetime of 30-40 operation years. During the last two decades, the service lifetime of many units has been extended to 50-60 operation years. The main reason allowing such an extension was that surveillance programmes for these systems provided sufficient information to extend the operating time. The methodology of SICs to determine the TAL was practically identical to the methodology of DSCs, which bear imprints of hundred-year-old ideas encoded within them.

A hot topic today is the extension of the service lifetime of PWR units to 60-80 years of operation, in the Long-Term Operation (LTO) range. LTO is a major challenge, as there is much less directly usable experimental information available today than for the previous projects. This also raises the need to reconsider the whole methodology of SICs in the light of recent results in basic sciences. The effectiveness of SICs depends heavily on the predictive capabilities of the computational tools built around the core theory of relevant phenomena. Although the application of experimental methods (e.g., destructive, and non-destructive material testing methods) and recent advances in information technology (data acquisition systems, high performance computing) have greatly improved the accuracy of SICs for LSPSs, the predictive power of the standards-based analysis methodology has not improved significantly. In addition, their ability to predict the LTO behaviour of LSPSs is severely limited by the strong dependence of the methodology on empirical models describing the behaviour of structural materials during ageing.

Currently, research is being conducted in the Centre for Energy Research with the aim, to develop a new, generalized methodology for future SICs of LSPSs with integrated ageing computations. According to our results, the reliability of the computational methodology should be based on more general –philosophically and scientifically deeper– principles than those found in the standards-based methodologies [1]. The starting point is modern, non-equilibrium thermodynamics, supplemented with transformations derived from the system's finiteness, the corresponding stability constraints, and the resulting conditions on the changes of all these. The theoretical framework is a tightly coupled, non-equilibrium model, which can consider the simultaneous existence of thermal and mechanical interactions and their impacts on ageing in inhomogeneous solids. Governing relations for thermomechanical fracture are derived in the form of a generalized J-integral [2]. Since the model is based on very general principles and assumptions, the framework seems to be an adequate tool serving to derive complex, thermodynamically consistent, application-oriented damage and fracture models for a wider class of structural materials. Recent results show that a phenomenological model of material ageing may be constructed to describe the behaviour of structural materials becoming increasingly brittle as they age [3]. The significance of this approach is that it may pave the way for a more systematic modelling of material ageing in future, fracture/damage-mechanics based computations. The presentation outlines the basic considerations of the ageing model.

Keywords: structural integrity; large-scale pressure systems; non-equilibrium thermodynamics

A review of Artificial Intelligence (AI) methods for Non-Destructive Testing and evaluation of materials and structures

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Abstract

A large number of industrial equipment all over the world are degrading due to age-related mechanisms, such as corrosion, erosion and fatigue. The degradation is usually assessed with respect to change in a physical parameter; for instance, in structures it can be measured in terms of reduction in stiffness or strength of material. The degradation of components and structures can be a serious concern because if it is not detected and controlled, it may cause failures and catastrophic events. Therefore, structural inspection and monitoring is vital to assess the condition of the components and ensure safe operating conditions.

Non-destructive testing (NDT) is a modern technology that is used in a variety of industries to detect and evaluate flaws in materials, components, or structures without damaging or destroying them. The science of NDT is concerned with all aspects of uniformity, quality and serviceability of materials and structures to ensure they are in good condition and functioning properly. NDT experiments are conducted in a manner that does not affect the future usefulness of the test components. These experiments produce huge amount of data in different formats, such as acoustic signals, ultrasound images or optical measurements, that can valuable if analysed and interpreted appropriately. During the past several years, various NDT methods and procedures based on different principles, with their individual merits and limitations, have been proposed for the inspection of engineering components and structures. Automating the NDT experiments is one of the important strategic objectives of high-value industries such as aerospace, transport systems, renewable energy, automobile and manufacturing machinery. Automated computer-based NDT technologies can improve the accuracy, precision and speed of inspection operations while reducing fault diagnosis time and associated labour costs compared to manual data collection and analysis.

Artificial intelligence (AI) is an emerging technology that has attracted increasing attention in the NDT field for the purpose of automatic acquisition and interpretation of large volumes of inspection information. AI is a branch of computer science that deals with the simulation of human intelligence processes by machines, especially computer systems. These processes include learning (the acquisition of information and rules for using the information), reasoning (using rules to reach approximate or definite conclusions) and self-correction. The use of AI can offer significant efficiency and comprehensive advantages in the NDT domain, such as increased consistency, faster data interpretation, and automatic reporting of results to clients. In recent years, several AI techniques including expert system, fuzzy logic, genetic algorithm, neural networks, machine learning and deep learning have been applied for semantic segmentation of NDT signals or images to localize and recognize defects without the need of human intervention. Some bespoke software tools have also been developed to automatically interpret the NDT results. For instance, DNV GL has developed an image detection and classification tool, called NDT.ai, for detecting weld imperfections (e.g., porosity, slag, and cracks) from the radiography testing images. AutoWDA (Automatic Welding Defect Assessment) is another software written in lab using Microsoft Visual C++6 to detect and assess the welding defects of gas pipelines from the radiographic films.

The main aim of this paper is to review the state-of-the-art of AI techniques and tools and their applications in the automated analysis of the data yielded by NDT experiments for defect detection and characterization in materials and structures. We explore various types of data being collected from NDT techniques, including deflection data, static displacement and rotation, ground penetrating radar data, etc. and then provide a brief overview of the AI techniques that can be used to extract damage-sensitive features. A classification of the literature which have reported the deployment of AI techniques in the automatic acquisition and interpretation of NDT data from various sources is proposed. The engineering structural

components range from oil and gas installations and wind turbine structures to composite aircrafts, road bridges, and railway transport rolling stocks. This paper also provides insight on how to overcome the typical challenges related to implementing AI in NDT-based inspection and monitoring of critical assets for further research directions.

Keywords: artificial intelligence (AI); non-destructive testing (NDT); material inspection; structural integrity; machine learning (ML); degradation

Fatigue crack growth rate of a low carbon microalloyed steel for elevated temperature application

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Abstract

The operating temperature influence on the fatigue crack growth parameter, was analyzed by testing the chromium-molybdenum steel for elevated temperatures application of the new generation additionally alloyed with vanadium. The paper presents a comparison of the fatigue threshold value ΔK_{th} and the fatigue crack growth rate da/dN of the specimens cutting from pipe made of virgin steel, tested at room (RT) and operating (HT) temperature of 540 °C. The influence of the notch and crack initiation location, as well as the test temperature values, have a decisive effect on the fatigue threshold values ΔK_{th} of the investigated steel.

The macroscopic and microscopic specimens' fracture surfaces are also shown. Obtained results of fatigue crack growth parameter, correspond to the SEM micrographs of fractured surfaces.

Keywords: steam pipeline; crack growth rate; fatigue threshold

Advanced experimental validity of phase field fracture modeling using Digital Images Correlation technique

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Abstract

In this study, a normalized and modified eccentric edge notched tensile specimens (M-EENTS) extracted from a 2mm thin sheet made of a 2024Al alloy, these specimens were then tested under a tensile load, experiments were assisted with the Digital Images Correlation technique using the open-source DIC-code Ncorr. A finite element model was built to simulate the experiments and the phase field fracture method was used to model fracture in this case, this technique recently developed in fracture mechanics domain is now well implemented in many FE analysis codes. An elastic Phase Field Fracture model was used in FE-analysis. Results were extracted from both experiments and finite element models, the Digital Images Correlation technique gives access to more data, displacement field, strain field, crack tip opening displacement and Force-displacement curves are easily accessible. A special interest is given to fracture pattern (crack paths) which was shown in both experiments and FE-analysis by plotting discontinuities in the displacement field, the FE-analysis gives an additional information about fracture pattern via the plots of the phase-filed parameter. A discussion was then conducted aiming to show the power and capability of Phase-field fracture method to simulate fracture in metallic structures.

Keywords: cracks; Finite Element Analysis; Phase Field Fracture; Digital Images Correlation; Ncorr

Cavitation resistance of welded joints of AlMg4.5Mn alloy

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Abstract

Cavitation resistance of welded joints of the three-component aluminum alloy AlMg4.5Mn was examined in this paper. Tests were performed on samples of welded joints as well as on samples of the base material. Welding was performed by TIG and MIG procedures in a protective atmosphere of pure argon. After the welding, metallographic tests were performed. The ultrasonic cavitation test method with a stationary sample was used to test the resistance to cavitation according standard ASTM G32 [1]. During the test, the change in mass of the samples was monitored in order to determine the cavitation rate. The least squares method was applied, where the slope of the straight line determines the cavitation rate (Fig.1).

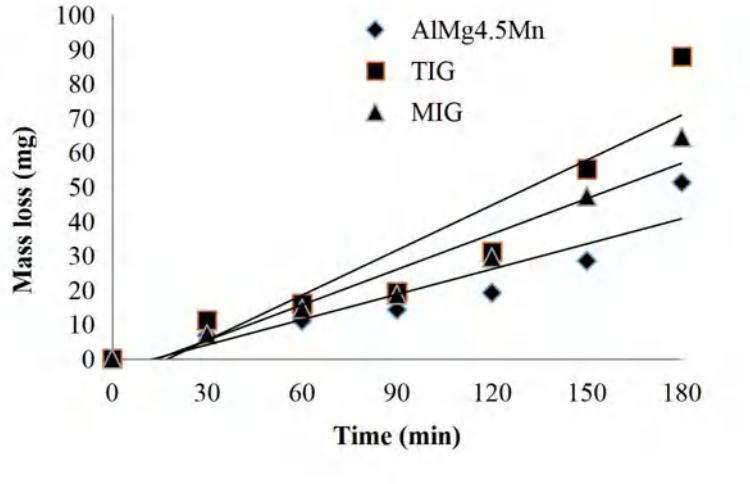

Fig. 1. Cavitation rates of tested samples

The base material of the AlMg4.5Mn alloy has the highest resistance to the effect of cavitation (the lowest total mass loss and the lowest cavitation rate). The welded joint obtained by the MIG process has a higher resistance to the effect of cavitation compared to the sample obtained by the TIG process. This behavior is a consequence of the smaller porosity and finer microstructure of the sample obtained by the MIG process (Fig. 1). The morphology of damage to the surface of samples exposed to the effect of cavitation during testing was monitored using scanning microscopy. It was shown that ductile fracture mechanism was identified for all studied samples together with the presence of small fatigue like craters.

Acknowledgements

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Keywords: cavitation resistance; welded joints; AlMg4.5Mn alloy; TIG and MIG welding process

Experimental Determination of J_{IC} for a HSLA Steel Welded Joint

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Abstract

Most serious weldment failures have catastrophic consequences in terms of damage to other equipment, loss of production, and risks to worker health and safety. For the above reasons, there is a tendency to find the line between safety and disaster, and this requires a guarantee of the integrity of the welded structure even if a crack is present.

The structural and mechanical heterogeneity of a welded joint affects its resistance to cracking in both the elastic and plastic regions. Therefore, it is important to define the test method and the position of the fatigue crack. The behavior of an elasto-plastic material, during stable crack growth can be described by the J-Δa diagram. As the crack propagates, a point on the curve is defined, which represents the critical value of the J-integral. The aim of this experiment is to determine JIC value and the procedure is reflected in the determination of the R curve, i.e. the J–Δa curve, which consists of the value of the J integral for uniform crack increments Δa. In this paper, two SEN(B) specimens with the fatigue crack in the parent material (PM) and weld metal (WM) were tested according to standard ASTM E1820 at room temperature (RT) as well as three specimens with the fatigue crack in the weld metal (WM) at RT, -20 0C, -30 0C.

Keywords: J-integral; J-R curve; HSLA steel; welded joints

Modeling of 6061-T651 aluminum alloy stress−strain diagram by methods of machine learning

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Abstract

Machine learning is an area that has developed from artificial intelligence (AI). One of the reasons for its widespread was the growing degree of automation; in particular, the amount of accumulated data is being increased. Therefore, machine learning methods are used to study input data and building a model by continuously evaluating, optimizing and setting parameters. In particular, due to the ability to interpret nonlinear relationships between input and output data, they can solve the problems of fracture mechanics with great accuracy. It is advisable to use them for modeling stress-strain diagram of aluminum alloy 6061-T651 at different temperatures.

The aim of the study is to predict the stress-strain diagram of 6061-T651 aluminum alloy at 6 different temperatures (20, 100, 150, 200, 250, 300ºC) using machine learning methods, in particular, the method of k-nearest neighbors and random forests, and to compare the obtained results.

The algorithm of k–nearest neighbors method compares the known elements with new ones. Its basic idea is that the new object to be predicted belongs to the class that is most common among k–nearest neighbors of training set. The distance between k-nearest neighbors is usually regarded as Euclidean. In this study, the number of nearest neighbors was equal to 10.

Random forest is an ensemble algorithm that uses the concepts of bagging and random subspaces, and the basic algorithms are decision tree. In the regression problem, their answers are averaged. In particular, this method of machine learning is less dependent on retraining. Also, the number of trees was 1000.

The stress−strain diagrams of aluminum alloy 6061-T651 at 6 various temperatures (20, 100, 150, 200, 250, 300ºC) were predicted according to the experimental data using methods of supervised machine learning. In the learning process, the data set was divided into two unequal parts, i.e., of which 80% were randomly selected for the training sample, and 20% were left for the test sample in order to assess the quality of the prediction.

The obtained results are in good agreement with the experimental one. In general, the best model for predicting the stress- strain diagram of 6061-T651 aluminum alloy at 6 temperatures (20, 100, 150, 200, 250, 300ºC) was built by k–nearest neighbors method. The prediction accuracy of k–nearest neighbors method was 90.4% in the test set, whereas the accuracy of random forests was 81.3%.

Keywords: Machine Learning; *k*-nearest neighbor training set; aluminum alloy 6061-T651; stress-strain diagram

Methods of Jump-like creep modeling of AMg6 alluminum alloy

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Abstract

Deformation of AMg6 alloy by tension under conditions of soft mode of loading is accompanied by jump-like deformation, which is registered graphically in the form of "steps" on the stress-strain curve. Jump-like deformation also occurs under creep conditions after reaching a certain stress level on the stress- strain curve.

There was studied the stress-strain curve of AMg6 alloy under quasi-static tension under soft loading conditions, which revealed the changes in the material microstructure, and there were proposed the models establishing a connection between them. The same studies were also concerned with the processes of creep and dynamic creep of AMg6 alloy. The microstructure analysis showed that after the creep tests in the AMg6 alloy there were the destroyed dispersoids, as well as the solid ones. It was assumed that the process of jump-like creep, like jump-like tensile strain, is caused by the dispersoids cracking in the material. The technique for predicting the initiation of jump-like creep depending on the proportion of destroyed inclusions was proposed.

ANSYS software package was used to predict the jump-like creep, in which finite element (FE) modeling was employed. The creep strain and dynamic creep of AMg6 alloy were calculated by FE method. In dynamic creep, the high-frequency loading component causes higher stresses on the inclusions, compared to creep, which increases the number of destroyed inclusions. The fracture of inclusions causes redistribution of stresses and strains in the model and intensifies creep under cyclic loading, compared to static loading. The accumulated strain under dynamic creep is greater than under static creep under the same level of maximum load. The maximum error between the results obtained by FE modeling and experimental data does not exceed 12%.

Considering the large amount of experimental data, machine learning methods were also used for this modeling, in particular, the method of neural networks. The input parameters for model were the creep stress parameters corresponding to the full plastic strain and the jump creep value. The increment parameter Δp was chosen as the initial parameter to assess the prediction quality. It was found that the resulting models can make predictions for the data that were not in the training set. The jump-like creep predicted by the method of neural networks is in good agreement with the experimental data. It was established that the accuracy of neural network prediction was 96.2%.

Keywords: Jump-like creep; AMg6 alloy; Finite Element Method; Machine Learning

Inspection of damage and risk analysis of connecting vessels in a coal drying facility in exploitation

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Abstract

Drying of raw coal (lignite) in Nova Sušara facility in Vreoci is performed in accordance with the Fleissner procedure, in dry saturated water steam atmosphere. Each autoclave in this facility is connected to a pipeline via connecting vessels. Due to severe working conditions and an unsuitable design of coal drying structure, failures and leakage of aforementioned connected vessels have occurred on several occasions. Main cause of failure was a combination of corrosion and erosion of wall surfaces of the connecting vessels. Due to difficulties with replacement of these vessels caused by the structure itself, it was decided to assess the risks of failure in order to determine whether these connecting vessels can be repaired. Risk analysis was performed using the Failure Modes and Effects Analysis (FMEA) method, in combination with the risk matrix approach.

Selected exploitation period which was analysed for all vessels was 5 years, since there is a lot of data about the maintenance that was performed during this period, including the results of material testing performed by an accredited laboratory. Based on all the issues which were detected by testing, risk probabilities (with corresponding levels of severity) of various defects were calculated, and potential expected repair costs were determined. These probabilities were then used as input for the risk matrix, which indicated the most critical types of defects, both in terms of probability of occurring and the severity of their occurrence.

It was concluded that through-thickness cracks were the most dangerous defect in this case. Furthermore, high probabilities of most defects that were considered implied that the connecting vessels will become unreliable and unfit for continued exploitation in the near future. Suggested means of preventing failures include a more thorough periodic maintenance and control of these vessels, until it is possible to fully replace them with new equipment.

Keywords: connecting vessels; damage repair; risk analysis; Failure Modes and Effects Analysis (FMEA); risk matrix

The effect of crack tip vs. notch on Charpy toughness value of duplex steel S32750

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Abstract

This paper describes this analysis of variable impact load on structural integrity and life of structures made of duplex steel S32750 (according to UNS standards) or W.Nr. 1.4410 (according to EN standards). This type of material is mainly used in highly demanding structural elements in chemical and oil industry, and has recently found application in aerospace engineering, especially in hydraulic installations. This analysis is based on the results obtained by experimental testing, with particular focus on influence of crack-like defects on parent material behaviour under exploitation conditions, including variable and impact load. It was performed for the purpose of assessing the integrity and remaining life of structures, as well as in order to determine how such structures can be revitalised, thus increasing their work life.

Acknowledgement

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Keywords: Charpy toughness; duplex steel S32750; crack-like defects; impact load

Experimental strain measurements on ring tensile specimens made of S235JRH steel pipe

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Abstract

In For various pipe manufacturing processes, information on the pipe's circumferential strain and stress state is needed (e.g. in the oil industry, the process of manufacturing seamless pipes with a conical shaft). This study's objective is to create a method for analyzing the strain and stress behavior of a pipe ring tensile specimen (PRTS) in the hoop direction. The potential for the creation of a PRTS is indicated by the absence of official standardized testing procedures. The use of the digital image correlation approach to test plastic PRTS is discussed in the paper. A steel instrument with two D blocks that has been particularly constructed is used to test PRTS. Over two D-shaped mandrels that are fixed to a tensile tool and a tensile testing machine, a 3D-printed PRTS is inserted. Three-dimensional Digital image correlation (3D DIC) method was used to record the strain evolution in the gage length of the specimens. All of the specimens are 3D scanned to verify the geometry of the cross-section of the PRTS following fracture. Five single PRTS were examined for the study. The results demonstrate that the DIC system, 3D printer, and scanner approach are efficient tools for characterizing the mechanical properties of pipes by mapping complete strain fields in steel PRTS.

Keywords: steel PRTS; S235JRH material; tensile testing tool; tensile test; Digital Image Correlation Method; strain; stress; thermal imaging camera 3D scanning

System for monitoring deformation processes in high-rise metal structure

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Abstract

Currently there is a trend in the design and construction of complex large-scale engineering and building structures to arrange the automated systems for monitoring their deformation state. The aims of this work are:

- present the stages of development and creation of an automated system for monitoring deformation processes in high-rise metal structure;
- present an analysis of the results of using the developed monitoring system obtained over several years of its operation.

The automated system is created for monitoring deformation processes in the metal structures of the overhead building of the skip shaft. A 64m high metal structure ensures the lifting of salt ore from the mine and its transfer to the factory for further processing. It rests partly on the ground and partly on the concrete head of the skip shaft. The deformation state of the structure is determined by the loads associated with the operation of the process equipment, external factors (wind, seasonal and daily temperature fluctuations), and interaction between the structure and foundation. Metal elements are exposed to corrosion caused by presence of salt dust in the air.

Possible deformation response of the structure to the whole variety of external factors were numerically simulated. Analysis of the numerical results determined the structure and parameters of the monitoring system. Information about the current state of the structure is generated using several blocks of primary sensors distributed over the key points of the object. The first block is the vibration control block, which analyzes the vibrational response of the structure to various technological operations. The second block is a system of strain gauges combined with temperature sensors that record deformation and temperature at structural key points. The third one is a hydrostatic leveling system installed on the lower tier of the structure. The fourth is a unit for measuring the angles of deviation of the structure from the vertical in two mutually perpendicular vertical planes. The presence of several independent units for recording deformation parameters makes it possible to collect sufficiently complete information, as well as to mutually control the readings of various measuring units. The control site of the monitoring system receives information about the history and current state of the main deformation characteristics of the structure, and gives visual comparison of the current data with the maximum allowable values is made.

The obtained monitoring results demonstrate the dependence of the deformation parameters of the structure on the evolution of technological modes of operation and on the ambient temperature.

Keywords: high-rise metal structures; deformation monitoring; numerical simulation; vibration control block; strain gauges; hydrostatic leveling system

Solutions and procedures for repairing a damaged vertical cylindrical tank – depositor

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Abstract

This research paper describes and evaluates the options for repairing and rehabilitating a damaged vertical cylindrical tank (depositor). The vertical cylindrical tank is part of a wastewater treatment plant located in the vicinity of a metallurgical plant for the production of ferrosilicon Jugohrom Alzar LTD, and its components, shell, and floor are severely damaged as a result of the tank's long-term exploitation and improper maintenance. The tank is used in a wastewater treatment plant station to reduce and neutralize the carcinogen hexavalent chromium (Cr VI) into Cr-III. Two repair techniques are analyzed and investigated. The first is to repair the damage by restoring the required projected thickness of the sheet metal walls through repair welding. The other method is to apply liquid metals to the damaged areas to achieve the required projected thickness of the materials of the individual components. Mechanical tests are required regardless of which of the two repair methods is used. In order to obtain a more realistic picture of the influence of the weld, respectively of the liquid metal, samples were made according to the tensile test standard, ISO 6892-1, on which damages similar to those found on the tank were made. The obtained experimental results, along with the discussions for future research possibilities, contribute to upgrading and enhancing current knowledge in the direction of finding the most appropriate way to repair the damage that occurs in vertical cylindrical tanks as a result of their long-term exploitation.

Keywords: vertical cylindrical tank; damage; welding; advanced materials

The influence of plasma transferred arc welding parameters on the obtained microstructure of the 316L coating

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Abstract

This paper describes the technology of surfacing a coating of high-alloyed austenitic steel 316L, on the base material made of steel S235JR. The coatings were applied by the plasma transferred arc welding process. The 5 samples were made using different welding current while the other welding parameters were constant. The metallographic analysis of the obtained samples were used to establish a correlation between the microstructural constituents and the used welding current used in the process of their surfacing. According that it was possible to determine the optimal parameters of coating surfacing. The filler material was in the form of the powder, and its characterization was performed by scanning electron microscopy, and the characterization of the obtained coatings by optical microscopy.

Keywords: S235JR; 316L; plasma transferred arc welding; surfacing

Experiments for the quantification of the initial stress state in UIC parabolic leaf springs

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Abstract

Leaf springs have been used for several decades in suspension systems, for example, in the suspension of good transportation vehicles. Distinct geometries of leaf springs may be found in different vehicles, however, in the freight railway sector, this element has been standardized by the International Union of Railways, UIC. Parabolic leaf springs are been preferred instead of conventional geometries due to their good intrinsic features that provide better vehicle drivability and greater safety.

UIC parabolic leaf springs are made of chromium-vanadium alloyed steel. These springs are quenched and tempered, giving them high mechanical strength and hence a higher fatigue strength. In spite of the quenching and tempering processes provide to their high strength, the structural integrity of leaf springs has a fundamental role in vehicle safety, becoming the fatigue, one of the concerning phenomena in the mechanical design phase. One way to increase fatigue resistance is by introducing an initial compressive stress state on the free-surface and sub-surface regions. One of the efficient and widely used in the leaf spring industry is stress shot peening. In addition to the residual stress by shot peening, the leaf spring assembling process may induce an additional stress state to the previous one.

The initial stress state analysis of parabolic leaf springs consisted of the analysis of residual stress by stress shot peening using the X-ray diffraction method, whereas the initial stress state by assembling was analysed by stress relief evolution using the electrical extensometry.

The obtained results by the X-ray diffraction method revealed on the one hand that the compressive residual stress by stress peening in UIC parabolic leaf springs may achieve 80 % of the yield strength of the material (see Figure 1 – Left). On the other hand, the stress state measured by strain gauges exhibited a value of 15 % with respect to the yield strength of the material (see Figure 1 – Right).

Considering the conventional fatigue limit of 51CrV4 steel, the combined effect with the assembling stress, and the residual stress state induced by shot peening, the fatigue limit increases to 1.7 in relation to the conventional value. In fact, this increase has been verified in other works.

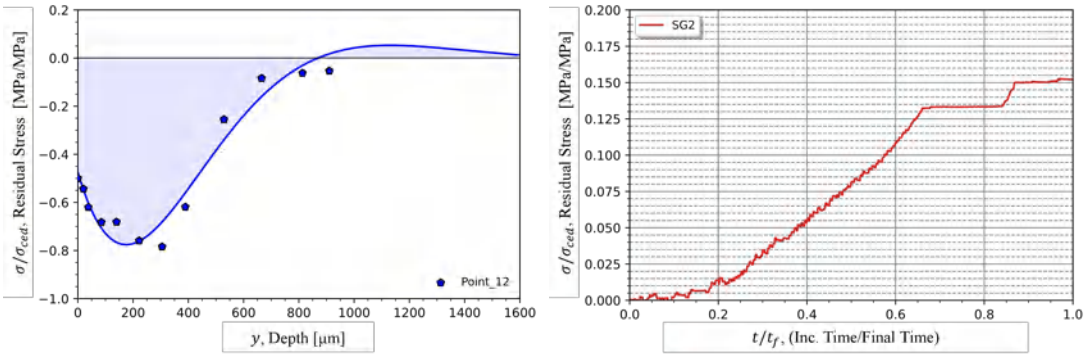

Fig. 1. Left - Residual stress distribution along thickness by stress shot peening using X-ray diffraction method. Right - Representation of the gathered data from the stress relief method by assembling to determine the initial bending stress on the free surface

Acknowledgements

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Keywords: residual stress; assembling stresses; stress shot peening; parabolic leaf springs; railway

Numerical and experimental determination of stress and strain state in connection elements

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Abstract

The research is based on structural elements of the connecting lug type and stress and deformation state was determined as the contact area size between the axle and the connecting lug was changing (gap). Numerical analysis was conducted by applying the finite element method in a "KOMIPS“ software package. Experiments were performed at the Laboratory for stress and deformation measurements, Faculty of Mechanical Engineering, Belgrade University, using "GOM“ equipment and "ARAMIS" software application. This paper demonstrates how it is possible to anticipate the results by applying FEM. A short review of current research in the field of structural elements is given within the framework of the paper.

Keywords: connecting lug; Finite Element Method; experiment; stress; deformation

Frequency effect in fatigue behaviour of a structural steel and a spring steel

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Abstract

In the last decades, the ultrasonic fatigue testing became a topic of interest due to the need of characterizing the fatigue behaviour of engineering components and structures in the very high cycle region, since some of them achieve 109 number of cycles during their service lives. Moreover, the high frequency of testing reduces the cost and duration of fatigue tests from months and even years to a few hours. However, this technology of testing brings some difficulties such as the overheating during the fatigue test or the frequency effect, which is already addressed in the literature for different materials. Thus, some authors have been proposing approaches and models to correct the frequency effect observed in ultrasonic fatigue data.

Therefore, the main goal of this work is to describe and analyse the frequency effect in the fatigue behaviour of two different steel alloys: S690 steel, a structural steel with application in offshore industry, and 51CrV4 steel, a leaf spring steel used in railways carriages. Thus, two different experimental campaigns were performed for each steel alloy at 150Hz and 20kHz frequency of testing. For the lower frequency, the experimental campaign was conducted in a Rumul Testronic 150 kN, which is a resonance testing machine, while the second campaign was performed in a Shimadzu USF-2000 ultrasonic machine, in order to achieve 20kHz frequency of testing.

For both steel alloys, a considerable difference between the experimental data obtained from each experimental campaign was observed, which leads to distinct S-N curves. Besides, it is noticeable that this difference increases with the number of cycles, while for 105 number of cycles the experimental data obtained at different frequencies of testing is overlapped. Thus, the influence of high frequency of testing which characterizes the ultrasonic fatigue testing is verified for S690 steel and 51CrV4 steel. In conclusion, in order to correctly evaluate the fatigue behaviour of this materials, the experimental data obtained at high frequency of testing should be corrected to include the frequency effect.

Acknowledgements

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Keywords: very high cycle fatigue; steel; frequency

Metallographic characterisation of the heat affected zone in welded joints with multiple defects

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Abstract

This paper is based on extensive research about the influence of multiple different welded joint defects on the intergity of welded structures. In this particular case, the focus was on the heat affected zone and its different subregions - up to this point, it was observed as a whole, with homogeneous mechanical properties along its cross-section. Due to the need to describe its behaviour in more detail, it was concluded that metallographic characterisation of the heat affected zone is necessary. Metallographic tests have provided a detailed insight into the microstructures with the heat affected zone, which be difficult to predict in this case, due to specific conditions, i.e., a welding technology which was adopted with the purpose of deliberately causing a number of defects in the welded joint. This would result in a more realistic distribution of mechanical properties along the heat affected zone, which in turn would provide more accurate input data for numerical simulations, since the use of finite element method will be the next step in this research.

Keywords: multiple welding defects; metallography; structural integrity; heat affected zone

Safety factor of the bolted flange joints

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Abstract

This paper investigates the load capacity of bolted flanged joints, which are a common type of mechanical joints used in machinery. Bolted joints offer several advantages, including easy maintenance and disassembly, sealing, reduction of vibrations and noise, and protection against pollution and moisture. However, they are also the weakest element in most structures, and their degradation can reduce the safety and reliability of the machine system. Using an analytical research method, the load capacity of two types shear-loaded bolted joints, fitted and clamped, was compared by varying the nominal thread diameter of the bolts, the number of bolts in a group joint, and the pitch diameter on which the bolts are mounted for torque transmission. The function that enables the reduction of the difference in load capacity between fitted and clamped bolted joints by varying their number and pitch diameter is derived in this paper. The research shows that with certain combinations of geometric characteristics and tightening conditions of clamped joints, the load capacity of clamped bolted joints can be improved. This study aims to provide the constructor with relevant practical data to make an appropriate choice of bolted joint type (fitted or clamped) by combining various influence parameters of group shear-loaded joint, and, at the same time, achieve the same desired load capacity or, in the case of different load capacities, to know the exact ratio of their safety factors.

Keywords: bolted joint; shear-loaded bolted joint; fitted bolts; clamped bolts; bolt safety factor

New life for historical steel bridges in Transylvania region

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Abstract

Sustainable development is a fundamental goal of the European Union and seeks to meet the needs of the present, without compromising the future. The rehabilitation of historic steel constructions and old steel bridges in service, is part of the maintenance and conservation of existing heritage, thus considering a sustainable development concept, while constituting an act of culture.

In present time, in Romania there are a relatively small number of steel bridges older than 100 years, especially in Transylvania region; they can be considered "witnesses of the past". Two important aspects are highlighted: consolidation costs are lower than for a new structure and the retrofitted bridge can receive a new, modern functional role that fits functionally into the landscape. The paper is presenting a study case for an existing steel bridge build in the beginning of twentieth century (around year 1925). There is presented an assessment method considering the structural integrity, by means of fracture mechanics and a solution for consolidation.

Keywords: historical steel bridges; structural integrity; fracture mechanics

Review of failure analysis of coupling systems on freight trains

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Abstract

This paper presents a review of screw coupling and draw gear failure analysis on freight trains in Europe and other countries where screw coupling systems are still in use. Analyses of failures show different characteristics and applications of root cause analyses and can group them into several categories that repeat on considered railways. A variety of failure types indicates that more than one factor causes breaks in the coupling system, and they didn't always equally present. Most studies of failure investigate fatigue of screw coupling and draw gear elements because of initial crack or corrosion. Some fractured elements haven't had signs of fatigue so other causes must be considered in the analysis, like overload, impact, inadequate material, or certain deficiencies in heat treatments of fractured elements. Investigations were performed via a series of experimental tests and numerical analyses using the finite element method.

Acknowledgement

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Keywords: railway; coupling system; screw coupling; failure; draw gear

Experimental investigation of the fatigue crack growth behaviour in SLM additively manufactured 17-4 PH stainless steel specimens

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Abstract

Selective laser melting (SLM) and in general the additive technologies potentially offer to designers and technologists numerous advantages such as the reduction of the lead-time of new product and the possibility of producing any kind of complex shape. The performance of components made by means additive manufacturing under cycle loading is influenced by crack orientation, porosities, residual stresses, heat treatments, corrosion environments etc. In particular crack orientation can influence the fatigue crack propagation. In this paper fatigue crack propagation behaviour of 17-4 PH stainless steel made by SLM under different crack orientation are presented. The tests were carried out using standard 6 mm thick compact specimens C(T) tested at R= 0.05 and with frequency 5 Hz. The main objective was to study the effect of the crack orientation on da/dN-ΔK curves and on the fatigue failure mechanisms.

Keywords: crack propagation; 17-4 PH; crack orientation

Modification of VCCT method with implementation of GTN model for the determination of J integral

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Abstract

The method for determining the long-term safe operation of nuclear power plants is based on a systematic ageing management procedure. A crucial part of this procedure is the demonstration of the integrity of the nuclear power plant structures. Therefore, identification, precise description and in-service monitoring and assessment of the relevant degradation processes in the structural materials of the concerned equipment are essential for assessing safe operation and for evaluating the expected lifetime.

The degradation of materials in the nuclear power plant was detected in a very early stage, and monitoring programmes were made to monitor the changes with Charpy test pieces. However they are currently being exhausted and it is necessary to test miniaturised specimens made from the used ones. However the standards and regulations currently in use do not apply to the evaluation of miniaturised specimens. Therefore a research project was launched to develop a simulation procedure for the evaluation of cases not covered by the standards.

In this study, the determination of material properties of a selected VVER440 power plant material and the optimization of the Gurson-Tvergaard-Needleman (GTN) damage parameters using artificial neural networks (ANN) are presented. The defined damage parameters are applied to standard CT specimens from which the fracture toughness (geometry independent) material properties are estimated using finite element simulation software. In the determination of fracture toughness, crack propagation is based on the virtual crack closure technique (VCCT). The method was originally developed for the simulation of brittle fractures, where the fracture criterion is defined as the limit of the strain energy accumulated at the crack tip. The new aspect of the developed method is that the main properties of the GTN and VCCT techniques have been combined, which provides the possibility to calculate the J-integral in parallel with the crack propagation. This unique method can calculate the integral J with very high accuracy, which is well suited for non-standard cases, such as the transfer of material properties from small-scale parts to large-scale parts. Future work is planned to apply this method to the simulation of the brittle-ductile transition zone.

Keywords: Virtual Crack Closure Technique; Gurson-Tvergaard-Needleman; J-integral; Charpy specimen

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Finite Element Modeling and Response Sensitivity Analysis of steel column base connections with shape memory alloy bolts

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Abstract

In this paper, finite element models are first developed and validated with experimental results for two self-centering column base connection specimens. Next, a statistical sensitivity analysis of the cyclic response of self-centering column base connections equipped with shape memory alloy (SMA) bolts is performed. The influence of fifteen design factors on the cyclic response of column base connections is statistically assessed through a two-level fractional factorial design. The behavior of these column base connection models is assessed by considering four different limit states, including decompression, yield-like point, self-centering, and ultimate limit state. The sensitivity analysis results show that the column axial compressive force, SMA bolt diameter, and column web slenderness ratio are the most influential factors affecting at least four response parameters with percentage contributions higher than 80%. Negligible residual deformations are observed in the analysis results of the column base connection models, indicating the high self-centering capability of SMA-equipped column base connections. The equivalent viscous damping ratio is mostly sensitive to the column axial compressive force, SMA maximum transformation strain, and austenite start stress. It was shown that only 30% of the column base connections provide a minimum equivalent viscous damping ratio of 8%. Therefore, the results highlight the need for improving the energy dissipation capability of column base connections for seismic applications.

Keywords: column base; self-centering; shape memory alloy (SMA); sensitivity analysis; rocking; finite element analysis

For an effective disruptions management in rail transport: Case study tramway of Constantine, Algeria.

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Abstract

The sustainability and maintenance in a satisfactory functional state of rail transport are of paramount importance for the national economy of all countries. However, the slightest error or disruption can cause serious damage, or even turn into a major accident. Therefore, the maintenance of the installations, the means to avoid their failures and the prevention of risks are necessary. Thus, to sustain technological systems and improve their performance in order to be competitive, efficient and competitive, any organization must engage in a process of continuous improvement. This is one of the principles of quality management in companies. It is a strong and indispensable management act. It aims to optimize the overall performance of the company to drive lasting and permanent positive change. Therefore in this work, we are interested in studying how to identify the priority actions of management and control of maintenance in rail transport in order to avoid any disturbances.

This study falls within the classic framework of the a posteriori analysis of failures aimed at understanding the origins of disturbances that can lead to accidents by determining their causes and thus making possible preventive actions, or even avoiding all kinds of disturbances, the objective of this work. As a case study, we took the operation of the tramway in Constantine, Algeria

Keywords: rail transport; maintenance; disturbances; management; priority actions; Pareto and FMEA

Crack development from gear stress concentrators of the main reducer of the PS90A engine in transition HCF-VHCF regime

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Abstract

Based on fractographic studies, the regularities of the occurrence and development of fatigue cracks from the surface of the gears Z4 and Z5 are generalized. Gears Z4 and Z5 of the main reducer of the PS90A engine are conical gears of the central and angular drives respectively. Both conical gears Z4 and Z5 are identical with the number of teeth, the rotation speed of 14,000 rpm, due to position on the same shaft, and the transmitted load, but differ in the gearing parameters.

The scatter of lifetime for the gear Z4 during bench acceptance-tests and in-service was in the range of 6-7,285 hours (or 5·106-6·109 loading cycles). The cracks originate in the transition regime between High-Cycle – (HCF) and Very-High-Cycle Fatigue (VHCF). This conclusion is confirmed by the statistical data analysis and the discovered regularities of gears Z5 fracture.

The gear Z5 fracture occurred in the lifetime range of 133-14,000 hours (or 108-1010 loading cycles). For the gears of this type, cracks were generated from a carbide placed close to the surface or a non-metallic inclusion located at a distance from the surface. The life of fractured gears Z5 corresponded to the VHCF regime, i.e. with lifetime exceeding 14,000 hours (or 1.2·1010 cycles). The regularities of crack growth according to the formed beach-marks were analysed.

As a result of the performed fractographic analysis and generalization of the discovered regularities of crack generation, the correction in the gears stress level was recommended in order to ensure their in-service life for more than 10,000 hours (or 1010 loading cycles).

Based on the multi-regime fatigue fracture model, introduced earlier, the numerical simulation on crack initiation and growth in gears under the in-service loading conditions was performed. The results of lifetime prediction and spatial crack path shape are in good agreement with observed in service failures. The numerical simulations shows that loading conditions considering a high frequency loads due to gear rotation are sifficient to initiate a fatigue crack. Therefore, based on performed calculation it can be stated that crack originates in the transition regime between HCF and VHCF.

The work was supported by RSF, grant N19-19-00705.

Keywords: High-Cycle Fatigue; Very-High-Cycle Fatigue, PS90A engine; fractographic analysis

Crack growth causes in supporting structures of hydraulic units

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Abstract

The runner is the main element of a hydraulic unit. It largely determines the efficiency and reliability of the HPP as a whole. Modernization of hydraulic units often does not affect the entire unit but is limited only to replacing the runner with a new one with a higher efficiency. Many components and parts of the hydraulic unit remain unchanged throughout the entire life cycle since it is assumed that they do not significantly affect the lifetime, structural integrity, durability and reliability of the equipment. However, when replacing the runner with a new one, it is not always possible to fully get the expected benefits from the modernized equipment due to the occurrence of intensive cracking in the elements of supporting structures of the hydraulic unit (spider and rotor frame of generator, guide and support bearing housings and etc.).

Comprehensive inspections of the supporting structures of several hydraulic units made it possible to establish the main causes of cracking in the supporting structures of the hydraulic unit after long-term operation, as well as to identify the characteristic zones most susceptible to cracking. The inspections included the analysis of equipment operation modes and the results of previous tests, non-destructive testing of the base metal and zones of welded joints, computational studies of the strength and durability of structures using mathematical 3D modeling methods.

The main practical result is the conclusion about the inevitability of crack formation in some welded zones of the supporting structures of the hydraulic unit, even if all operating conditions are met and the repairs are of high quality. This is due to the following factors:

- high local concentration of stresses in individual welds of supporting structures under the operational loads due to geometric features and uneven distribution of external forces;
- uneven distribution of stresses in similar elements, including for cyclically symmetrical structures; such unevenness causes additional loads on the elements not taken into account under the design stage;
- damage to the material of structures, accumulated over a long period of operation, reduces the mechanical and fatigue characteristics of the material, although it cannot be detected by traditional methods of non-destructive testing; this damage contributes to the appearance of cracks.

Hydroelectric units designed for more than 30-40 years usually did not take into account the factors listed above. As a result, today we observe intensive cracking in supporting structures on a number of units. This reduces the efficiency of the modernization and limits the lifetime of the hydraulic unit as a whole due to the reduction of overhaul periods and the expansion of restoration repairs. The results of the conducted study help to develop effective measures to reduce the intensity of cracking.

Keywords: crack growth; hydraulic unit; stress concentration; mathematical 3D modelling

Effect of floater geometry on the dynamic parameters of a spar-type floating offshore wind turbine

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Abstract

In recent years, the research and development of floating offshore wind turbines (FOWT) have accelerated to harvest energy more effectively by aiming for higher and more stable wind speeds. As the sites develop further offshore and into deeper water, the hydrodynamics parameter of the floater becomes increasingly important due to its significant impact on the wind turbine's performance. In this regard, the present papers discuss the phenomenon of response dynamics that changes in floater geometry affect the hydrodynamic performance of FOWT by utilizing the potential flow theory in BEM solver via the open-source software NEMOH. The OC3-Hywind spar-type floating platform was selected, and the geometric was varied to adapt to the depth of the site. Initially, the hydrodynamic analysis was conducted using a reference model, and the results were compared with the reference data. After being verified, the method will be used the hydrodynamic model for the varied geometry. The frequency domain approach was applied to compare the motion characteristics of FOWT.

Keywords: Floating offshore wind turbine; Spar-type; Boundary Element Method; Potential flow theory

Characterization of the applied materials on floating offshore wind turbine members: A review on the current state

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Abstract

Demand for further development clean harvesting energy in recent decades increases rapidly due to environment degradation after abundant use of fossil-based fuel. Marine sectors emerge as one of viable solution of clean energy as sustainable and renewable energy, which wind resource is a prevalent choice to be harvested. There are higher wind speeds offshore than on land, so that offshore farms are required to generate more electricity per amount of capacity installed. Offshore wind farms are also less possible of accidents than those on land, as this type has less impact on people and the landscape. Based on this advantage, harvesting instrument to produce wind-based energy, e.g., wind turbine is a critical subject which worth to be studied, especially in terms of its applied materials on each structural members. Therefore, this work is directed to characterize possible materials for applications on the wind turbine member, i.e., rotor blade. The scope is extended to metallic-based materials, such as aluminum, steel, etc., and advanced composite and polymer.

Keywords: marine-based energy; wind turbine; rotor blade; metallic material; advances composite and polymer

Influence of ventilation system effectiveness on the safety of hydrogen storage and transportation applications

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Abstract

More accessible, efficient and sustainable, fuels are needed in order to reduce environmental footprint of energy production. One of such promising fuels is green hydrogen produced by renewable energy sources. Storage and transportation of hydrogen is the most challenging in terms of explosion risk and safety. The primary hazard associated with any form of hydrogen is inadvertently producing a flammable or detonable mixture, leading to a fire or detonation. Safety will be improved when the designers and operational personnel are aware of the specific hazards associated with the handling and use of hydrogen.

In this paper influence of ventilation system effectiveness is evaluated by several different ventilation strategies that are considered in order to increase effectiveness and availability of ventilation with the aim to obtain high dilution for non-hazardous zone or to reduce Zone 2 area within storage room and transportation corridors. Several leakage cross section areas are taken into consideration from 0.025 mm^2 at flanges with compressed fiber and spiral wound gasket, 0.25 mm^2 at ring type joint connections up to 1 mm^2 at small bore connections. Hydrogen storage pressures were varied from typical spherical tank at 50 barg to vertical tube storage at 100 barg. In this case the release rate of gas from a container or pipeline is with choked gas velocity - sonic releases case. Dimensionless discharge coefficient (Cd) that accounts for the turbulence and viscosity is typically from 0.50 to 0.75. Safety factor was varied from 0.5 to 1, due to uncertainty related to LFL because of possibility of existence of hydrogen background concentrations. Grade of release is estimated as a secondary leakage due to a seal rupture.

Grade of hydrogen release and classification of explosive gas atmospheres is done in accordance with international standard IEC 60079-10-1:2015.

The results have shown that in the case of gas discharge at pressure of 100 barg from an opening with a diameter of 1 mm^2, it is not possible to achieve high dilution scenario and avoid the Zone 2 area. In the case of a pressure of 100 barg and an opening diameter of 0.25 mm^2, the air velocity in the vicinity of source due to the operation of the ventilation system should be at least 6 m/s, which can be achieved by the proper selection of the ventilation system in a closed space. In all other cases considered in the paper, the required ventilation air speeds are lower, so conventional ventilation systems (such as mechanical supply and extraction ventilation or local extraction ventilation) can be applied in order to prevent hydrogen explosive atmospheres.

Keywords: hydrogen storage; green hydrogen; explosion risk; ventilation systems

From component failure to hydraulic engineering complex systems safety

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Abstract

Objectives of the study: Water engineering professionals mostly agree that preventing accidents in complex hydraulic engineering systems have to be an integral part of the system management and decision support process, instead of being a separate, formal, annex to the technical analysis. The traditional approach, which usually ends up with finding a component failure and/or human error as a root cause of accidents, cannot give relevant results, since the other causes are left out (flaws during planning and design, organization and management flaws, etc.). Taking into account that hydraulic engineering systems are organized and very complex systems, which operate under various aspects of uncertainty, it is recommended to shift focus from preventing (only) component failures towards elimination and control of all hazards and possible adverse outcomes, in other words, to build system safety. Recent events related to the operations of Hydro-Power Plant (HPP) Pirot (Serbia) which caused adverse effects, both for human lives and environment, will be used to illustrate the approach.

Employed methods: Paper deals with the application of the STAMP (System-Theoretic Accident Model and Processes) and STPA (System-Theoretic Process Analysis) which are based on systems theory, control theory and cognitive engineering (Leveson, 2004).

Most significant results: Although based on the limited access to information, there were some interesting findings on the flaws in HPP Pirot operations. Some of the identified accident causes are:

- Annual production plan reached already in April (2018) which is implementation issue;
- Compensation basins not used by HPP - designed and constructed but not used;
- Unusually low levels in Zavojsko Lake were within design limits, which is design flaw;
- HPP Pirot operates as designed, there are no component failures - reliable in terms of energy production but unsafe, etc.

Safety constraints have to be re-examined after complaints and fatalities. Design parameters, relevant to the design phase, have to be updated on the basis of as-built/present conditions.

Keywords: water engineering; complex hydraulic systems; System-Theoretic Accident Model and Processes (STAMP); accident prevention

Repairing of cracks on tooth gear ring of a bucket-wheel excavator

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Abstract

Bucker-wheel excavators are continuously working machines used for removal of waste and useful materials in open-pit mines, mainly used for mining of lignite. The purpose of a tooth gear ring is to rotate the excavator using two reducers. Due to this, the structural integrity of such elements is of great importance for the safe and reliable operation of the bucket-wheel excavator as a whole. In order to ensure its proper function, non-destructive testing methods (namely magnetic particles testing) was performed after casting of gears. NDT revealed the presence of cracks with varying lengths (10-110 mm), which were located in the gear teeth, its main body and the openings used for connections between segments.

For this reason, it was necessary to adopt a repair welding technology which would eliminate the cracks. Since the tooth gear ring was made of GS-40MnCrSi3V low-alloyed cast steel, electrode 42 4 B 42 H5 (designation according to EN 499E) was selected as filler material, due to its exceptional mechanical properties, suitability for welding of low-carbon low-alloyed steels and low hydrogen content. Manual arc welding was the procedure used in this case.

Since these repairs were all performed on the surface of the tooth gear ring segments, final NDT included only magnetic particle and penetrant testing, both of which had shown that the repair technology was successfully applied, i.e. not new defects were detected in the repaired gear ring elements.

Keywords: tooth gear ring; repair welding; bucket-wheel excavator; GS-40MnCrSi3V steel

Information system development for increased production process sustainability planning

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Abstract

Extensive inconsistent use of natural resources by the people – especially in industrial production – and negative influence the global environment results from it, experienced our society in looking for sustainable acting. United Nations Agenda for Sustainable Development is the most comprehensive scheme of goals for the doing the acting of the civilization to slow down unsustainable goings-on and finally to stop environmentally unfriendly lifestyle. From the whole UN sustainable goals scheme are two of them directly related to the industry – consumption and production patterns (goal 12), and combat climate change and its impact (goal 13).

Authors deals with the application of information system developed at the Technical University of Kosice to the analysis of basic legal and professional approaches to sustainable production methods evaluation and with application to advanced technologies process planning in the article. Used sustainability and operating reliability evaluation methodology was created in cooperation with a multidisciplinary international team for optimal synergically processing of manufacturing design proposals. The methodology is based on the ISO 14040 standard and Professor Ashby simplification. The information system can be used for various sizes of manufacturing companies and it offers the possibility of an effective comparison of the economic and environmental impacts of the proposed production processes. The evaluation of the information system in production process design for a few selected real parts is presented by comparison of the operating reliability, financial and ecological impact of the selected processes with the focus on advanced and emerging technologies.

The results of the study is overview of the impact of changes in process planning input factors on the outputs – process energy consumptions, carbon dioxide generation, financial relationships on batch size and production volume. The complex comparison of the all process plans achieved results can be performed without corrections (arithmetic average of relative values) or utilizing weight coefficients emphasizing the priority of some characteristics. Both approaches are very appropriate to rational strategic decision making. This approach can be very suitable support for innovation of the production process, or preparation of various production strategies (e.g. maximum productivity, lowest cost, elimination of bottlenecks, etc.) in advance and use it in case of need.

Keywords: information system; sustainability; operating reliability; advanced technologies; emerging technologies

Properties of aluminum-steel plates explosively welded using Amonex explosive

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Abstract

Besides their application in munitions and armaments, explosives have a significant role in industrial applications, such as cladding or welding of metal plates. In the process of explosion welding, the energy of explosive detonation is used to achieve a metallurgical bond between two metal components, which are metallurgically compatible, but also those that are non-weldable by conventional methods. For this purpose, most often explosives of low values of detonation velocity are used, in order to avoid severe damage to the processed metal plates.

The aim of this study was to investigate the possibility to use the industrial explosive Amonex, which belongs to a group of low-to-middle detonation velocity explosives, for welding of metallic materials. It consists of ammonium nitrate and TNT as energetic components and other inert ingredients and has a powdery consistency, easily applicable in a desirable layer over the metal plates to be welded. Within this research, Amonex was applied to weld plates of aluminium Al 2024 and steel Č0345. Besides the initial data on the used metal plates, the main properties of the used explosives are also given, since based on these properties the needed quantity of explosive was estimated. The procedure of welding was carried out in the configuration of parallel plates, and afterward the welded joint was examined. Ultrasonic method and chemical penetrants were used as non-destructive techniques, and then the samples were cut from the welded plate using water-jet, in order to perform microscopic analyses on the cross-section and to determine the indentation hardness in the area of the joint. It was observed that a good-quality welded joint was obtained, and that the selected explosive may find further application in this area.

Keywords: explosion welding; steel; aluminium; non-destrustive testing; indentation hardness

Methodology for pressure equipment risk assessment based on fracture mechanics and influence of human and organizational factors

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Abstract

During the last couple of decades, there was a definitive increase in the need for process safety control due to working conditions and systems becoming more complex, up to a point where the existing methodologies could no longer provide satisfying results. Hence, the topic of this paper involves the development of an original methodology for risk assessment of pressure equipment, based on fravcture mechanics and the influence of human and organizational factors. This methodology resulted from the systemization of existing knowledge in the filed of process safety, innovations and integration of existing tools and models for risk assessment, as well as from improvements in working with pressure equipment in general and combining of above approaches with fracture mechanics, which allowed the solving of main issues that existed in these fields. This was achieved by establishing and verifying new methodologies and models, with particular focus on simplicity and adaptability to practical application, along with solving of problems related to the lack of systematic and practical approach to assessing of the influence of human and organizational factors on risk. In order to verify the newly proposed methodology, a case study was conducted in Serbia, related to Bajina Bašta hydropower plant, which confirmed the accuracy and simplicity of the methodology in question. It was shown that the application of this methodology enabled a systematic approach to quantitative risk assessment for pressure equipment in any and all companies which work with such equipment, regardless of their size or field of work. Thus, it was concluded that the proposed methodology has offered valuable insights, both to the scientific and public communities, through its improvement of process safety.

Keywords: risk; human factor; organizational factor; fracture mechanics

The concept of risk, fire and explosion from the perspective of forensic engineering

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Abstract

Risk assessments of the occurrence of accidents as unwanted events, in which fires and explosions may occur, among other things, are of interest to the professional and scientific community from the aspect of risk management and ensuring safety in a general sense. Risk represents the degree of probability that a certain event will occur, knowing the substances and conditions that can lead to event occurrence, leads to the determination of the elements needed for risk assessment. Forensic engineering methods are crucial for identifying the causes and consequences of fires and explosions and providing findings and opinions according to standards and legal norms. Theoretical and practical considerations confirm that, without the application of forensic engineering methods, the elements necessary for making risk assessment, cannot be obtained. Risk assessment is the basis for developing of fire and explosion protection systems, as cases of unwanted events, and that is subject of discussion in this paper. In addition, risk assessments correlated with the forensic engineering approach contribute to the development of recommendations, transferring it in guidelines, and its implementation directed to improvements of the security system for protection persons, facilities and other material assets.

Keywords: forensic engineering; risk assessment; fire and explosion protection systems

Integrated technical security systems in critical infrastructure facilities

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Abstract

In addition to the human factor, which is dominant and key in the security system of critical infrastructure facilities, which by their basic function are institutions with a high security risk, maintaining the required level of security is impossible to achieve without the technical component of the security system. In the modern and changed security context, critical infrastructure facilities face numerous security challenges, risks and threats, which require treatment and an integrated response in synergy between the physical and technical components of the security system. The research is based on the fact that objects of critical infrastructure are specific from the aspect of the security system, because they are institutions, which are subjects of importance for the functioning of the state and society, where there is a constant risk of security incidents. In the paper, by applying the method of content analysis and modeling, it can be concluded that the security problem of objects that are part of critical infrastructure is multi-layered, and its protection must have such a concept, which would be implemented through the integration of various security-technical systems. The degree and method of integration depend on the technical and security characteristics of the system and the type of space and object on which they are applied. Procedural security and technological procedures carried out in the protected area play a significant role in the integration. Taking into account the character of the facilities of these institutions, the positions of individual components of electronic protection should be visible and their presence deters from attempts to realize some form of security threat.

Keywords: critical; risk; security; infrastructure; entities; technical

Supporting structural life cycle analysis and non-destructive testing (NDT) with numerical methods

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Abstract

The life cycle analysis of a structure has many components, which can be complemented by state-of-the-art techniques, such as numerical, analytical and semi-analytical software. For such an analysis, it is important to know the life cycle of a chemical plant, followed by various analytical calculations to determine the allowable defects. It is also important to know the critical damage locations of the structure, for example welds and other locations, which can be determined empirically and by finite element modelling from the resulting stress fields. In addition, to assess the current condition of the structure, various material tests should be carried out, such as hardness testing or non-destructive testing techniques. It is important to know which testing technique is suitable for detecting the failure sizes determined by fracture mechanics for a given critical location (e.g. a weld). For this purpose, it is recommended to perform modelling using the non-destructive testing modelling software CIVA, which also provides the possibility to generate probability of detection (POD) curves. To determine these curves with sufficient accuracy, all the characteristics of the test method need to be known, which are given as input parameters in the software. After the appropriate ultrasonic settings, POD curves are already possible to be generated, for which it is necessary to know the variable parameters of the test, which can be determined from the test technique as well as from the information provided by the ultrasonic experts. These simulations help to select the most suitable test method for the task and to adjust the test parameters of the already selected method, such as the design and selection of the test probe suitable for the test, thus helping to optimize the settings and the entire design phase.

This article presents an industrial case study where the above mentioned modelling methodology was successfully applied, where a crack in a weld was detected and evaluated as it was described above.

Keywords: non-destructive testing; numerical methods; fracture mechanics; probability of detection curves

Reliability and probabilistic approach

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Progressive collapse analysis of inland waterway cargo vessel

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Abstract

Global structural response of ship hulls is generally assessed using elastic limit criteria defined by the technical standards. However, scenarios in which the ship is experiencing extreme and once in lifetime loads are investigated in recent years, as they are modelling events with potentially catastrophic outcome, i.e., loss of the complete ship and environmental disaster. Such scenarios can include excessive bending moments due to failed escape from dangerous storms, grounding, collisions, allisions, etc. Therefore, ultimate strength or hull capacity to withstand the extreme loadings is emerging as one of the most significant requirements for ship hull girder strength evaluation. Technical standards for large sea-going bulk carriers and oil tankers already have ultimate strength calculation incorporated within their rules. Ultimate strength of other cargo ships is also addressed in maritime regulations. However, there are no corresponding regulations for inland cargo vessels at all. Moreover, according to authors' knowledge, no studies or case study calculations on ultimate strength of inland vessels are presented in literature so far. This could be disturbing since, in recent years, numerous hull girder ultimate strength failures are recorded on Danube, especially due to vessel overloading or grounding. Furthermore, Danube inland cargo vessels tend to display reduced height and draught due to presence of bridges and low water levels, respectively. This produces high length to height ratio of the vessel making the hull prone to longitudinal bending issues. Nonetheless, the life service of Danube vessels is generally up to 50-60 years. Age-related degradation speeds up the effect of hull collapse. Therefore, the aim of this paper is to transfer the practice of ultimate strength calculations from sea-going ships to inland waterway vessels and provide the benchmark calculation. Ultimate strength is calculated here in a case study of typical inland waterway self-propelled tanker vessel operating on one of the most important waterway transport corridors in EU, connecting Danube and Rhine. Vessel main particulars are: 110.10 (length over all), 11.40 m (breadth), 5.30 m (height), 3.2 m (draught). Ultimate strength is calculated using progressive collapse analysis approach based on incremental- iterative sequences. The structure of the mid-section is divided into the segments for which the stress-strain relationship is derived accounting for both compression and tension in elastic and nonlinear region. The hull is then subjected to incrementally increased curvature for which the corresponding bending moment is calculated. As curvature increases, the segments of the hull section begin to fail; firstly, the ones mostly distanced from the neutral axis. Furthermore, the ultimate bending moment is plotted against the curvature. When the bending moment slope becomes negative implying that the hull girder reached its capacity after which it is expected to collapse, such is regarded as the ultimate value. The progressive collapse obtained ultimate bending moment is also compared to the results acquired from more simplified approaches such as Paik – Mansour presumed method and more traditional, first yield and first collapse approach. Results showed that ultimate bending moment values obtained from different models could be comparable, while the first yield approach vastly overestimated the structure's capacity.

Keywords: progressive collapse; ultimate strength; inland vessels; ultimate bending moment; hull girder

Assessment of the remaining life construction in exploitation

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Abstract

The paper provides an assessment of the integrity and remaining life of the structure, i.e. an assessment of the remaining life of the pressure vessel from the aspect of exploation conditions.

The obtained results and analysis of the results should give a practical contribution to the assessment of the influence ofexploation conditions on the behavior of the base material, components of the welded joint and the pressure vessel, intended for a work on higher temperatures, all with the aim of assessing the integrity and remaining life of the structure, as well as revitalization and extension service life of process equipment made of steel for working at higher temperatures.

Keywords: welded joint; service life; number of cycles; critical crack length

The loading and slenderness ratio effect on the failure probability of underground mine pillars: Case study

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Abstract

After digging a mining structure in a rock mass, a redistribution of stresses occurs around this mining structure. During this redistribution, the rocks tend towards a new equilibrium state and undergo certain deformations, which can become dangerous during the mine exploitation, or even turn into a major accident. Therefore, the study of stability in fractured rock masses, as well as the modelling of mining structures, requires a detailed description of the behavioral models and their mechanical properties. These mechanical properties are influenced by the scale effects, or even depend on the volume considered. The objective of this article is to study the influence of the effect of the shape and the load applied in order to approve the evaluation of the characteristic values of the mechanical properties of the excavated rock masses. Even to pinpoint the probability of a rupture in a perspective sizing of works and management of risks associated with the exploitation of mining resources (mines, quarries, drilling, etc.). The evaluation of the characteristic resistance of a pillar will be the main object of our research work. As a case study, we have taken the case of the Chaabet El Hamra underground mine in the city of Setif, Algeria.

Keywords: stability; excavation; probability of failure; rock mass; shape effect and mine

The structural limit of tubulars in wellbores subjected to Tension-Collapse Loads

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Abstract

In producing oil & gas wellbores, reservoir depletion induces compaction in the reservoir and tension in the overburden above the caprock. In most well architectures, the production casing is a thick-walled cylinder. In the section above the caprock, its bore is in hydraulic communication with the depleting reservoir. Therefore, the production casing experiences both collapse differential pressure and geomechanically induced tensile strains, simultaneously.

In geothermal and steam injection wells, the shallow thin-walled casings get compressively plasticized during the heating (or steam injection) phase. When the wellbore cools to the undisturbed geothermal temperature, the compressively plasticized casings unload and develop axial tension. Because the internal pressure in the casing reduces during cooldown, the casing is subjected to tension & collapse differential pressures simultaneously.

The magnitudes of the tensile strain and allowable differential pressures on the casings in both these situations exceed elastic limits by a significant amount, enough to rule out the possibility of working stress design. Also, the guidelines stipulated by API (American Petroleum Institute) are of limited use in this scenario. Though collapse of hollow cylinders has been studied extensively, the design and analysis of the casings in the loading conditions described above is performed with FEA and/or physical testing.

In this context, our paper presents a method to determine the structural limits of pipes in tension-collapse conditions in wellbores. For thick-walled cylinders that experience external pressure and axial tension or strain, we begin with the equilibrium equations. When loads exceed incipient yield, we assume that the plasticized zones obey the Prandtl-Reuss equations. We solve the full problem by tracking the elastic-plastic boundaries in the cylinder and determine its structural limit state from the slope of the deflection versus load curve.

Since the collapse of thin-walled cylinders is sensitive to manufacturing imperfections, we modify the governing equations to include initial cylinder ovality. We invoke Rayleigh's criterion for an inextensional median surface during the deformation of the thin-walled cylinder. Finally, we piece together the thick and thin-wall solutions based on Timoshenko's interaction equation. Our method provides a realistic structural limit state that can be used in the load situations described before. We present the complete finite difference equations of the solution method that can be (and have been) implemented in an EXCEL/VBA program. We finally show that our method agrees with the results of classical plasticity theory.

Keywords: wellbores; Tension-Collapse Load; thin-walled casings; Finite Element Analysis

Characterization of SA500 material - determination of resistant curves material

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Abstract

Steel SA500 belongs to the group of steels with pro-ballistic protection. It is one of the newer generation of steels with ultra-high strength, high hardness and good ductility. It is used in the dedicated industry for the production of tanks and armoured vehicles. The characterization of the material also involves looking at its behaviour in the presence of a crack-type defect. Tests are given in the paper: tensile tests, impact (Charpy) test and KJIC.

The obtained results should indicate the assessment of the resistance from the existing faults of the crack type, which is achieved by applying the concept of fracture mechanics.

Keywords: SA500; tensile test; Charpy test; KJIC; resistant curve

Nonlinear analysis of an idealized I-beam member: An investigation of mesh size on the structural behaviors using finite element approach

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Abstract

Structural engineering deals with analysis and design of structures. The purposes of design structure were to ensure safety and serviceability under severe conditions. Structure is everywhere in built environment, such as building, bridges, tunnels, and transmission lines. When a structure subjected an external loading, it results in internal stresses. Structural analysis concerned with this result includes determining the magnitude of the reactions, internal forces and displacement. Computational results finite element analysis (FEA) of structural steel are displayed in a variety of mesh size element and material type. Finite element analysis (FEA) nonlinear was carried out using ANSYS. In this work, nonlinear analysis is applied to materials structural steel grade SS400; SS490; and SS540 with a cross section wide flange (W). Variations of the mesh size element are 8 mm; 6mm; and 4 mm. Finite element analysis (FEA) are done by applying the variable load pressure on section area of materials under fixed support condition. The stress-strain curve and yielding point are knowing for each variation. Von-Mises stress increased with the reduction of mesh size element. Von-Mises stress under any load conditions showed good results on structural steel grade SS540 with the same thickness.

Keywords: Finite Element Analysis; Newton-Raphson's formula; structural steel; mesh size; Von-Mises stress

Innovative method of determining deflections of wooden beams on the basis of “Moment-Curvature” diagram

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Abstract

Wooden elements are most often used as load-bearing bending elements in the form of beams. Different loads act on such elements. These elements are reliable and durable, subject to normal operating conditions. In order to ensure the normal operation of wooden beams, it is necessary to determine the limit values of the load-bearing capacity and the possible limit deflection of such elements. This will ensure the reliability of the structure. The purpose of the work is to develop a method for determining deflections of wooden beams based on moment-curvature diagrams, taking into account the nonlinearity of the deformation of wood as a material.

To determine the limit deflection of the beam, we will use the normative value of the current normative documents DBN and Eurocode 5, namely the ratio of the deflection to the span $f_{\lim} \approx \frac{l}{150}, \frac{l}{250}, \frac{l}{300}..$ Several options for the operation of wooden beams with different loading options were simulated: a beam on two supports with a concentrated load, a cantilever beam, a beam with a pure bending zone. On the basis of the "moment-curvature" diagram, there was developed a method for determining the deflections of wooden beams, taking into account the nonlinearity of the deformation of wood as a material. Calculation sequence: 1) find the external graph of moments that act along the length of the beam using the basic principles of material resistance depending on the maximum moments M_F , $M_{F_к}$, M_q , $M_{q_к}$; 2) determine the curvature of the element based on the "moment-curvature" diagram depending on the maximum moments M_F , $M_{F_к}$, M_q , $M_{q_к}$. According to the same principle, you can determine the curvature along the entire length of the beam and build its graph; 3) find the rotation of the beam. The first option is the method of finite elements, the second is the integration of the curvature change function along the length of the beam; 4) determine the deviation of the beam from the initial position in the same way.

To determine the deflection of bending elements, the initial conditions should be set, since for a beam with a symmetrical load, the initial data will be the positions of the neutral line or the initial angles of rotation. Then the determination of the deflection of the beam will include the determination of the angles of rotation of the sections of the beam, as well as the determination of the deflections in each section of this beam.

Keywords: “Moment-Curvature” diagram; wooden beams; limit deflection

Pitting and uniform corrosion effects on ultimate strength of a bulk carrier

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Abstract

Over the past decade, ultimate strength assessments of ships have emerged as an important tool in ship structural design process. They provide an evaluation of structural safety level with respect to hull girder collapse [1]. Traditionally, ship structural integrity is generally assessed using prescribed rule-based procedures and additionally, direct calculations. **The outcomes of these assessments are then compared to the rule-prescribed stress in order to prove the strength of the structure. Such stress, i.e., the criterion, is provided as a share of the yield stress which keeps the evaluation always within the elastic behaviour of the structure. The difference between the criterion and yield stress is considered to act as a safety margin. Moreover, these analyses use just service loadings, as well as scantlings obtained for new built ship. This approach can deliver a sense of safety of the structure.

On the other hand, extreme loadings (large bow waves, overloading events, grounding, etc.) can lead to the collapse of the hull girder, i.e., ultimate strength, and loss of the ship. These loadings are still not in widespread use during the design phase, although some classification societies introduced the procedures for the estimation of ultimate bending moment [2]. Coupled with ship's aging and corresponding degradation of structural elements (corrosion), the ultimate strength can be significantly diminished.

Therefore, in addition to being designed according to their as - built scantlings (upon delivery), ships can be also designed considering their ultimate strength. Moreover, ships can be evaluated with regards to desired age (longevity) of structure, which includes the evaluation of ultimate strength based on reduced scantlings.

Therefore, this paper delivers the ultimate strength calculation for a 180 m long bulk carrier using:

- as-built scantlings,
- scantlings diminished by uniform corrosion,
- scantlings diminished by pitting corrosion.

Ultimate strength is calculated using progressive-collapse analysis procedure given by IACS [2] while assessing each of the structural elements' failure modes (elastic-plastic in tension and buckling modes in compression). In the next step, aging effects due to uniform corrosion are modelled by reducing the thicknesses of the structural elements. In addition, random pitting corrosion is included in analysis taking into account pitting intensity degree (DOP) and corrosion intensity degree (DOC) of affected zones. The modelling procedure proposal for pitting corrosion that can be incorporated within progressive collapse analysis is given in [3]. For the purpose of this assessments, all structural members are assumed to experience corrosion. Ultimate bending moment-curvature diagram is shown in Fig. 1, while the reduction of ultimate strength depending on the corrosion wastage (as a consequence of either pitting or uniform corrosion) is presented in Fig. 2.

Uniform corrosion allowable limit for the ship's elements renewal is generally taken as not larger than 25%. Its existence reduces the ultimate strength of presented bulk carrier. Moreover, depending of the severity of the pitting corrosion incidence (DOP, DOC), pitting almost linearly degrades new built ship's ultimate bending moment to the significant amount. Results have showed that both uniform and pitting corrosion vastly affects the ultimate strength of the ship and cannot be neglected in structural assessments.

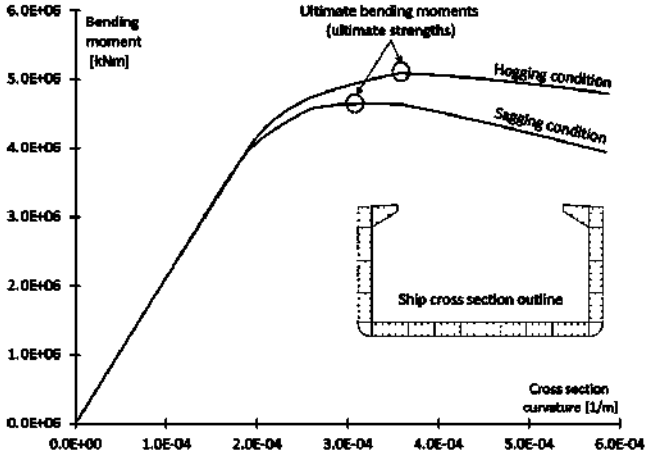

Fig. 1. Bending moment - cross section curvature diagram and ship cross section outline

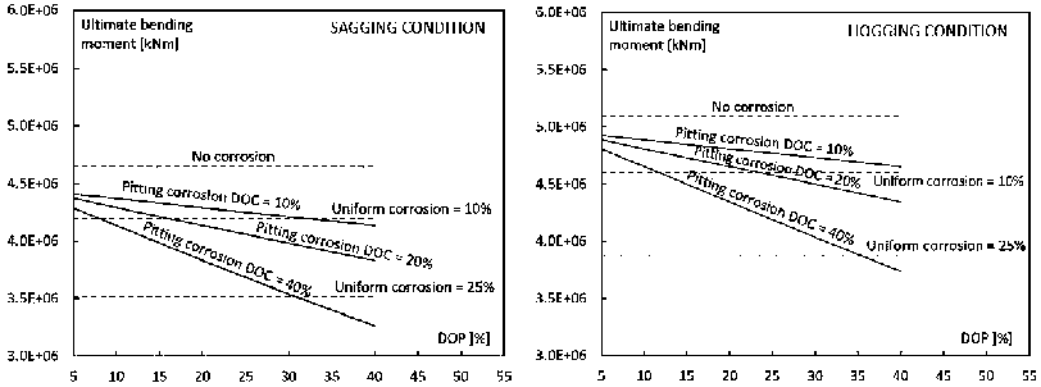

Fig. 2. Ultimate strength reductions due to uniform and pitting corrosion

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Keywords: ultimate strength; bulk carrier; progressive-collapse; ultimate bending moment; corrosion wastage; hull girder

Size effect assessment of KJ_c experimental data using the Two-Step-Scaling Method

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Abstract

The phenomenon of ductile-to-brittle (DTB) transition of ferritic steels, widely used in design of nuclear reactor pressure vessels, has been a pervasive semi-centennial research topic. Due to the extremely pronounced experimental data scatter, the statistical approach to characterization of this problem has become inevitable from the earliest analyses. In the present study, the data stemming from the Euro fracture toughness dataset for 22NiMoCr37 reactor steel are used with aim to explore utility of the recently proposed two-step-scaling method. Two widely different temperatures (- 154 ºC and -91 ºC; belonging to the lower shelf and the DTB transition regions of fracture toughness, respectively) are selected to demonstrate the applicability for extrapolation and interpolation of the fracture toughness CDF (cumulative distribution function) and the pertinent issues related to the method application. The fracture toughness measure used is the critical value of the stress intensity factor used in the master curve KJ_c [MPa√m]. The obtained predictions agree well with the experimental results and fall within the inherent scatter of the experimental data. The prediction of the fracture toughness CDF obtained by extrapolation using the novel two-step-scaling method is reasonably conservative as expected.

Keywords: size effect; Weibull distribution; fracture toughness; scaling method

Finite element and fracture mechanics analysis of a cracked oil-storage tank

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Abstract

Stress distribution, as obtained by the finite element method (FEM), and corresponding fracture mechanics parameters, have been used to assess integrity of a pressure vessel. Once the stress distribution is known, the most critical area can be analysed with assumed crack to estimate its critical length according to fracture mechanics parameters and basic laws. Toward this end, the Failure Assessment Diagram (FAD) is used to calculate the crack length corresponding to the limit curve. Once net stress and stress intensity factor are known, as well as their critical values, coordinates of a point corresponding to any crack length can be calculated and positioned in the FAD.

Keywords: Finite Element Method; Failure Assessment Diagram; stress distribution; oil-storage tank

Selection of safety level for marine structures

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Abstract

The selection of the safety level for design of marine structures being used in the oil and gas industry shall be made in view of the potential danger to personnel working on manned structures, the potential for huge negative effects on the environment in case of hydrocarbon spills and the large asset values involved. Unmanned structures could be designed for lower safety level, provided the environmental pollution be limited in case of failure. The design shall be in accordance with the International Standardization Organization's (ISO) 19900-series of standards for the Petroleum and natural gas industries.

For marine structures in the offshore wind engineering business and for marine structures in the aquaculture business, lower safety levels are specified by international standards. The set of design requirements provided by the International Electrotechnical Commission (IEC); IEC 61400 ensure that wind turbines are appropriately engineered against damage from hazards within the planned lifetime.

It should be noted, however, that wind farms will require transformer stations, which from time to time have to be manned. These substations have a considerable volume of toxic transformer oil for cooling and represent large investments. The safety level selected for the design of these substations will depend on the consequences of loss of the stations.

For the marine fish farms, it should be noted that aquaculture nets contain a huge number of fishes that will mix with wild fish and destroy the genes of the wild fish population in case of massive escape of fish from the nets. The fish population needs to be fed every day and personnel must be available to ensure the operation of the fish farm. The selection of safety level is crucial to protect the personnel involved and the environment. Presently, the ISO standard ISO 16488 related to Marine finfish farms — Open net cage applies.

This paper will discuss the relevant safety factors for marine structures in the offshore wind industry and the aquaculture business and will call for awareness related to personnel safety, environmental pollution, and the potential for loss of costly assets, A reminder that the "new industries" also must set sustainable goals should be in place.

Keywords: marine structures; ISO 199000 series standards; hydrocarbon spills; manned structures

On some applications of Sarhan–Zaindin modified Weibull distribution

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Abstract

The Weibull distribution has many applications in the Theory of Reliability. Various generalizations of the classical Weibull distribution and theirs applications have been investigated by several authors in the recent years. One of them is Modified Weibull distribution introduced by Sarhan and Zaindin in 2009, which contains as spacial cases the following distributions: exponential, Rayleigh, linear failure rate, and classical Weibull. The the cumulative distribution function of Modified Weibull distribution is $F(x) = 1 - e^{-\lambda x - \alpha x^{\beta}}$ when $x > 0$, and $F(x) = 0$, otherwise. For $\beta = 2$ we obtained linear failure rate distribution, for $\alpha = 0$ exponential distribution, for $\lambda = 0$ classical Weibull distribution and for $\beta = 2$and $\lambda = 0$Rayleigh distribution.

Let αi, β and λ_j be positive real numbers ($1 \leq i \leq N$, $1 \leq j \leq M$). In this talk (paper) we consider m elements in series system, such that its failures are independed events, and lifetime of ith element has Weibull $W(\alpha i, \beta)$ distribution. Futher if there exists M independed different types of accidents on this system such that j^{th} type of accidents has Poisson P (λ_j) distribution. We shall proved that lifetime of such system has Modified Weibull distribution MV ($\Sigma \lambda_i, \Sigma\alpha_{i,\beta}$) distribution, which implies that mathematical expectation of this lifetime is $\sum_{k=1}^{\infty} \frac{(-\Sigma\alpha_i)^k}{k!} \left[\frac{\Gamma(i\beta+2)}{\Sigma\lambda_j{}^{i\beta+2}} + \beta\Sigma\alpha_i \frac{\Gamma(1+(k+1)\beta}{1+(k+1)\beta}\right]$, where by Γ we denote gamma function.

Keywords: Sarhan-Zaindin modified Weibull distribution; Theory of Reliability; linear failure rate distribution

Reliability and optimization of the mechanical systems

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Abstract

The aim in this presentation is to explore the important relationship between optimum design of structures as it can now be stated in almost classical terms and reliability, or safety of structures. The discussion will focus on the kinds of structures for which reliability or failure probability can be reasonably analyzed, particularly in a redesign procedure. A review will be presented of those structural problems for which optimization in a reliability framework have been published. As the topic involves safety from a probabilistic viewpoint, some attention must be given to relevant questions of sensitivity, damage costs, limited empirical information and safety philosophy. Since some of these latter topics are considered in the literature, the main attention herein can be focused on the relationship between optimization and reliability. In view of the computational and philosophical questions raised by probability of failure analysis, and reliability based design, some attention should be given to the reasons for considering its use. This includes some of disadvantages of current deterministic approaches and some of the benefits to be realized by a probabilistic approach to safety and design. Most structural reliability analyses have been based on a static approach to loads and strength. However, a more general viewpoint cannot neglect such factors as stresses or fatigue strength, which may be stochastic or time dependent.

Acknowledgements

The results shown here are the result of research supported by the Ministry of Science, Technological Development and Innovation of the RS under Contract 451-03-47/2023-01/ 200105 dated 02/03/2023. year, also COST Action CA18203 - Optimal design for inspection (ODIN) and COST Action CA21155 - Advanced Composites under High Strain Rates loading: a route to certification-by-analysis (HISTRATE).

Keywords: structural optimization; reliability; structural modification

Probabilistic fatigue life modelling based on CMB and SWT criteria of a wind turbine wedge connection

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Abstract

Energy shortage and environmental degradation are two major crises facing human survival and social development. As reported in the BP Statistical Review of World Energy 2019, in the global structure of energy consumption today, renewable energy accounts for less than 20%. At present, fossil power, including coal, oil, and natural gas, is still dominant. However, they are after all non-renewable, and are gradually draining away with the long-term exploitation and utilization; in addition, a large amounts of greenhouse gases and certain harmful gases produce when they burn, which will cause the greenhouse effect as well as great pollution to the environment. Facing the pressing energy shortage, wind energy, as a vigorous section with bottomless reserve, is regarded as a promising solution. Through nearly a century and a half of efforts, the fundamental theories on wind turbine design have been well-discovered and accumulated. Today, the task of top priority is to develop wind turbines of higher power ratings for energy supply. Increasing capacity calls for better fatigue resistance of wind turbine elements under fluctuating loads [1]. As a result, C1 Wedge Connection [2], which can support higher service loads, was proposed. In the preliminary study, a probabilistic fatigue modelling based on CMB (Coffin-Manson-Basquin) and SWT (Smith-Watson-Morrow) criteria of the C1 Wedge Connection was suggested, which gives a favourable prediction on the fatigue behaviour of the surface polished holed thick steel plate with the help of the Smith–Watson–Topper (SWT) criterion when compared with the Coffin-Manson-Basquin (CMB) criterion [1].

The fatigue tests were performed in the Schenck® PCX 0001 equipment with a load capacity of ±600kN. Figure 1 is shown the scaled central holed thick plate that was tested, for being the most critical detail of the wedge connection (Figure 2). The central holed thick plate is made from StE460 high-strength steel. The preload on the bolt of each specimen is 80kN (measured by torque spanner), and the distributed force transferred to the upper hole edge of the studied object is 405kN (derived by FE simulation). After that, the two ends were directly clamped. The load stress ratio is 0.1, the loading wave is sinusoidal, and the load frequency was set as 5 and 12Hz respectively according to the load level. The specimens were tested until failure and their stiffness degradations were monitored during the tests. A “run out” conclusion will be drawn if a specimen doesn’t fail after at least 3,000,000 cycles (the loaded cycles are not fixed as there are holidays sometimes).In Table 1, the mechanical parameters of the material used in the C1 Wedge Connection are presented. The finite element modelling was done using the ANSYS® Mechanical 19.0 FE software. In this model, 2-order 20-node quadratic brick 3D elements Solid 186 were utilized, and the same mesh sensitivity analysis process was carried out (Figure 3). The material modelling was based on the Ramberg–Osgood model parameters given in Table 1. The stress–strain responses at the critical location were inputted into CMB and SWT models.

In Figure 4, for the failed specimens of machined holed thick steel plates where the surfaces were carefully polished, the SWT model led reasonable predictions of their fatigue lives, while the CMB model provides too optimistic prediction. In addition, using the local stress–strain approach is fine in this case as crack initiation is a local phenomenon compared to the dimension of the studied object.

Fig. 1. Scaled central holed thick plate (all dimensions are in mm).

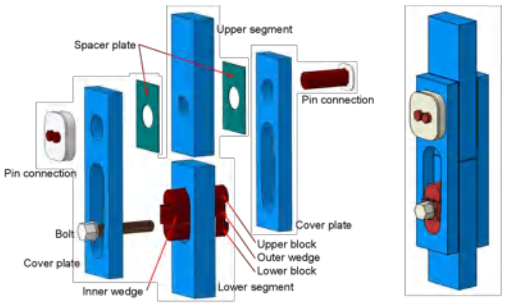


Fig. 2. CAD graphs of the C1 Wedge Connection: left in an explosive view, and right in an assembly view.

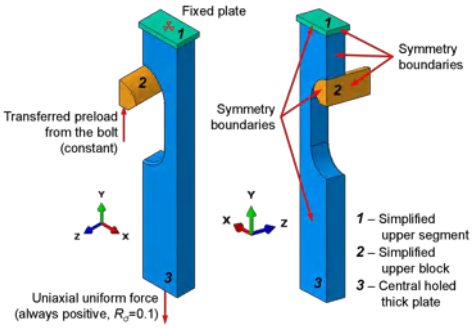
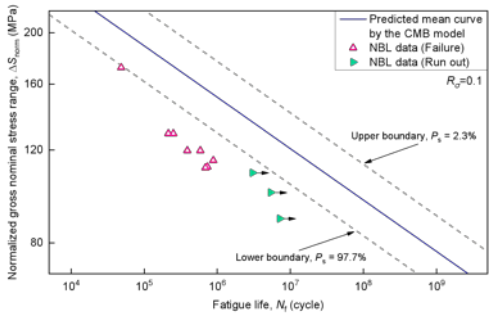


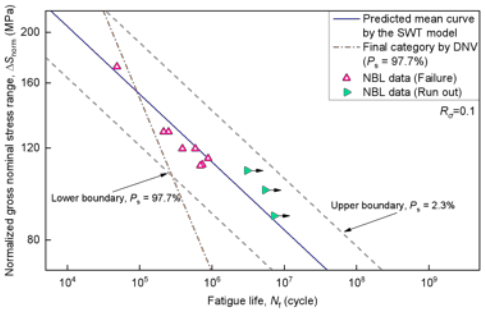
Fig 3. Boundary and load conditions in FE simulation.

Parameter	Symbol	Value	Unit
Elastic (Young's) modulus	E	208	GPa
Elastic Poisson's ratio	ν_e	0.29	/
0.2% offset cyclic yield stress	$\sigma_{0.2}$	434	MPa
Cyclic strength coefficient	K'	1181	MPa
Cyclic strain hardening exponent	n'	0.161	/
Axial fatigue strength coefficient	σ_f'	1124	MPa
Axial fatigue ductility coefficient	ε_f'	0.1925	/
Axial fatigue strength exponent	b	-0.094	/
Axial fatigue ductility exponent	c	-0.437	/

Table 1. Mechanical and fatigue properties of StE460 steel.



(a) CMB model-based



(b) SWT model-based

Fig. 4. Predicted P-S-N curves.

Acknowledgements

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Keywords: fatigue; life prediction; probabilistic; C1 Wedge Connection; wind turbine.

Environmental effect on structural integrity

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- I. Čamagić, M. Jovanović, S. Sedmak, P. Živković, M. Radojković - *Influence of temperature on crack initiation and crack growth resistance of welded joint constituents for steel SA-387 Gr. 91 welds subjected to cyclic loads*

Be careful! Our planet is in danger

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Abstract

Rethinking their model of governance and vision in order to build the foundations for a more sustainable, more positive, more just and more secure future is largely being laid by nations. As a result, the various dimensions of sustainable development and the means to achieve it become one of the most important priorities of the action programs of nations in their agenda and sustainable development is at the heart of reflections, in all areas. . In short, societies are in the process of reinventing themselves, or in any case, they are forced to do so in the face of the threats posed by the ecological crisis, the health crisis, climate change or even the transformations of civic and democratic aspirations. From now on, certain practices do not spread these inspirations and will have cascading and irreversible effects in the nature of things leading to serious consequences, even catastrophic for our planet, objectives of our work.

Keywords: belief; sustainable development; environment; ecosystem; ethical responsibility

A review on the hull structural steels for ships carrying liquefied gas: Materials performance subjected to low temperatures

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Abstract

A higher level of safety is needed in transporting and handling liquefied natural gas (LNG) fuel. At a cryogenic temperature that can reach -163°C, LNG is kept in specialized storage units like Type-C independent tanks. This cryogenic liquid might damage the ship's structure if a gas leak occurred accidentally. During long-term exposure to LNG flow, steel may become more brittle. An accidental load on the ship's structure may result in a structural collapse due to brittle fracture and cause a significant loss. As a mitigation measure against accidental LNG release on the LNG-fueled ship, higher strength, and cryogenic temperature-resistant steel must be used. This paper presents a discussion of high-strength steel for shipbuilding uses. It covers the background of the risk of the possible accidental LNG release on the ships carrying LNG, the performance of the high-strength steels impacted by a low temperature, and a material modeling of high-strength steels using coupled thermal-stress finite element analysis. The steel performance can be described through the experiment of tensile and Charpy impact tests at low temperatures. The parameters such as ultimate tensile strength, fracture strain, and ductile-to-brittle transition temperature (DBTT) will be addressed as material performance. The experiments and numerical finite element analysis procedures as well as the results of high-strength steel performance will be discussed.

Keywords: brittle fracture; DTBTT; Charpy V-notch test; Tensile test; Cryogenic temperature; Finite element analysis

Idealized critical marine structures under dynamic loading and fire state: A benchmark study using explicit-dynamic FE approach

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Abstract

Loadings on ships and offshore vessels and equipment are mostly classified as dynamic type, which are borne by the strength of the structure. Regarding structures of ships and offshore, their components generally involved with gas, oil and coal, such as for combustion engine power, and generally have complex electrical circuits to meet the operational needs of their crews. Thus, structural members of the offshore and ship have a high risk of catching fire in accidental events. The applied materials on these structures will experience a decrease in mechanical properties when experiencing temperature changes. The combination of the heavy loading borne by the structure and the decrease in the mechanical properties of the material can cause immense structural failure. This paper aims to highlight the strength of an idealized structural member from ship and offshore structures in the event of a fire accident, and extends the discussion to the areas that have not been reached by standard fire tests. Structural failure due to fire is a complex phenomenon is analyzed by ABAQUS finite element analysis which adopts the explicit-dynamics approach. Pioneer laboratory tests are pointed as benchmark references which are redesigned and calculated by numerical methods to obtain rapid estimation of the structural condition under dynamic loading and burning state.

Keywords: ship and offshore structures; fire analysis; laboratory test; Finite Element Analysis; Force-temperature behavior

Flood resilience

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Abstract

The location of a project is a crucial factor that must meet essential requirements. Siting criteria should take into account both anthropogenic and natural circumstances. Anthropogenic factors, such as accessibility to amenities or proximity to places of employment or education, can influence the project's success. Additionally, distinctions can be made between mobility via walking and accessibility via transportation. On the other hand, natural factors, such as the project's location in reference to the cardinal directions, wind or snow conditions, and land use conditions, can also impact the project's success. One particular natural factor that poses a significant risk to a project is flooding. Therefore, it is necessary to determine whether a project is situated in a flood risk area or not. Evaluating flood risk maps is an effective way of assessing flood risk, and it allows us to specify the risk factor and the likelihood of flooding. Flood risk is a critical element that must be considered in project location decisions. For instance, the building in question is located in the Kysucké Nové Mesto neighborhood, which is a zone with a minimal annual probability of flooding. To determine the risk zone, we consider the causes of flooding in the present and future, and a cadastral map is used to identify the precise location of the property. Next, we compare the flood risk and flood hazard maps, which depict the flood lines, to the cadastral map. The flood lines indicate the areas where floods are most likely to occur based on their intensity. Based on this evaluation, a property may be situated in a risk zone with a chance of occurrence of once every 5, 10, 100, or 1000 years, or in a zone with no defined risk. Generally, the most severe flooding occurs every five to ten years, and a higher probability indicates a lower risk of flooding. Therefore, careful consideration of the natural circumstances that can impact a project's location, such as flood risk, is crucial in making informed decisions that can ensure the project's success.

Acknowledgement

This work has been supported by Slovak Research and Development Agency under the Contract no. APVV-20-0281 and SK-SRB-21-0052 Innovative approaches to the assessment and management of drought risk due to climate change.

Keywords: flood risk; flood lines; climate change; cadastral map

Rain droplet model of atmospheric induced damage growth rate in mild steel

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Abstract

Degradation of structural materials under atmospheric conditions has serious impact on service life-time span of mechanical components. Localized attack of the agressive environment on the metal surface can serve as nucleation spots that considerably accelerate stress concentration and, eventually, lead to premature cracking. It is a wide topic of materials degradation, commonly described as Stress Corrosion Cracking (SCC). Reliable assessment of service life-time demands prediction of initiation and kinetics of SCC damage growth rate. While there is not yet detailed theoretical consensus about SCC operative mechanism(s), kinetics of crack propagation is governed by localized anodic dissolution on the metal surface and the strain rate at the crack tip. The aim of this paper is to propose comprehensive model of SCC damage growth rate under the rain droplet on mild steel plate.

Finite elements model was written in Python language, on Fenics solver for partial differential equations. Results of simulations were processed in Para View. All programs were run under Linux OS.

The model consists of two sub domains: rain droplet, small-scale electrolyte, where the Laplace equation is solved for potential distribution. Boundary values were set as Buttler Walmer equations for anodic and cathodic reactions. Once the potential distribution is solved, anodic current density is calculated from Ohm's law and the rate of anodic dissolution is calculated from Faraday's low. Initial conditions were set as shallow, 0.2 mm, preexisting surface damage of mild steel plate which is another sub domain of model. The plate is subjected to uniaxial tension. Following the paradigm of Fracture mechanics, Stress Intensity Factor (SIF) was calculated and strain rates at the crack tip were calculated from Hutchinson - Rice-Rosenberg (HRR) far field strain-distribution. Finally, the rate of damage growth rate is calculated as a superposition of anodic dissolution and Fracture mechanics straining.

Keywords: Rain Droplet Model; mild steel; atmospheric induced damage; Stress Corrosion Cracking (SCC)

Surface microcracks initiation and growth under thermal fatigue

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Abstract

The model for multiple cracks initiation and their subsequent growth under thermal fatigue was developed on the basis of the Monte Carlo method. There was considered a plate, which size was 5 by 5 mm, made of 25Cr1Mo1V steel. It was assumed that a new crack can initiate only in a certainly defined place (the nucleation core). There were placed 20 x 20 = 400 evenly distributed nuclei on the plate. Therefore, the distance between the nuclei was 0.25 mm in both the horizontal and vertical directions.

Damage was accumulated in each core under the cyclic thermal loading. The rate of accumulation of damage per load cycle was determined according to the experimentally obtained data. A crack with a length of 0.2 mm originated in the core if the degree of specific core damage exceeded the threshold. The inclination of the cracks at their initiation was chosen perpendicular to the direction of action of the principal stresses or randomly in the case of equal principal stresses.

The dual boundary element method was used to calculate the stress fields in the nuclei and to determine SIF. For efficient calculation of singular and hypersingular integrals of the problem, as well as taking into account the square-root singularity of the solution at the crack tips, special numerical quadratures, nonlinear polynomial mappings and special shape functions were used.

The procedure to model the nucleation and growth of thermal fatigue cracks was constructed as follows. At the first stage, the value of the maximum possible damage was assigned to each crack nucleus in a random manner according to a uniform distribution. It was assumed that the first crack initiated at a node with the smallest value of the damage threshold. The number of cycles before the initiation of this crack was also calculated.

The main cycle of the algorithm consisted of the following steps. The input parameters were the number of cycles performed in one iteration and the maximum possible distance between the crack tips. For the system of cracks in the body, the SIF range, the parameter of overall damage and the length of crack growth, which was calculated on the basis of the Paris formula, were calculated. If the crack length exceeded the threshold value, then during the subsequent execution of the main cycle, it no longer grew. In the second part of the main cycle the damage level to the nuclei of microcracks was calculated for the number of cycles estimated during growth. In each of the cores, for which damage exceeded threshold, a crack with a length of 0.2 mm was initiated. The surface of the crack was directed along the platform with the maximum principal stresses.

This model allows modeling the fatigue behavior of surfaces under cyclic thermal loading.

Keywords: surface microcracks; thermal fatigue; Monte Carlo method; hypersingular integral

Study of change of strength and deformation properties of wood under the action of active acid environment

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Abstract

In recent years there was increased the consumption of wood by various areas of world economy. Wood is used in civil engineering, ship building, machine building, bridge construction, wood processing, furniture, chemical industry, mining and many others. In most case wood is exposed to the action of active acid environment (aqueous, alkaline, acid). It is extremely important to study such effect on the mechanical properties of the deciduous and coniferous wood species experimentally and in the future to take it into account when designing parts, materials, products, elements, structures for their work in such environments.

The purpose of the work is to establish the effect of an active acidic environment on the strength and deformation parameters of birch and pine wood and to compare them with the parameters at standard humidity.

A method of experimental studies of solid birch and pine wood under the influence of an active acidic environment on compression along the fibers under short-term loading has been developed.

There were performed the experimental studies of solid birch and pine wood under the influence of various acidic environments (hydrochloric, lactic, acetic acids of various concentrations) with axial compression along the fibers and short-term loading. Complete stress-strain curves of wood at standard humidity and under the action of various acidic environments have been built.

Experimentally, it was established that the temporary ultimate strength of solid pine and birch wood decreases by 20-42% after 30 days of treatment with various acidic media, compared to specimens tested at a standard humidity of 12%.

It was found that the critical strains $u_{c,0,d,agr}$ of the studied wood species increased by 12-19%.

It was established that the residual strains $u_{fin,agr}$ of the studied wood species for 30 days of treatment with various types of aggressive acid media increased by 10-22% compared to the specimens tested at a standard moisture level of 12%.

Keywords: Acidic environment; birch and pine wood; critical strain

For a better governance of harmful events in companies: A case study

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Abstract

The assessment of occupational risks (EvRP) is a crucial step in the prevention process. It is the starting point to ensure the sustainability of any company, and even to avoid any kind of physical, material, or environmental damage. Thus, the identification, analysis, and classification of the risks allow for defining the most appropriate prevention actions, covering the technical, human, and organizational dimensions. This is an essential element for building a risk prevention and management policy in companies. It is, therefore, necessary to identify, for each activity in the different areas of the company, all the dangerous situations that may occur. To do this, we used the HIRA method, which aims to identify hazards and assess risks, and even plan work safely to prevent accidents. As a case study, we have chosen the steel complex of El-Hadjar, Algeria.

Keywords: Hira method; management; risks; company; evaluation; prevention and priority actions

Research on regularities of deformation behavior of building structures in the areas of technogenic impact caused by mining

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Abstract

Construction and operation of various structures on the territories of mineral extraction requires solving a large number of technically complex problems. This is due to the fact that the development of mineral deposits can cause significant deformation in the overlying ground massif and provoke catastrophic deformation processes in the objects that are located in this area. Such impact on construction structures is unique and is not envisaged by the construction project. The deformation field forming on the earth's surface is very heterogeneous, and the rates of deformation changes are also non-uniform. Their formation is influenced by the processes that are implemented in the depth of the soil mass during normal operation of underground facilities. It is also very important to consider the impact of emergency situations in mining. For example, it is possible to refer to them destruction of supports, flooding of workings, non-project development of damage of bearing layers. That is why provision of safe operation of facilities, located on such territory, is an important and urgent problem. The methods for estimation of the stress-strain state of the systems "building - foundation - soil ", which are given in the normative literature, establish some rules for design and operation. They allow taking into account the existing technogenic processes in the soil mass or require special structural reinforcement measures in case the controlled deformation characteristics of the building exceed the limit values. However, quite often it turns out that the existing building has been designed without taking these factors into account. And the changed state of the environment makes it necessary to evaluate the possibility of its operation on the basis of the deformation processes accumulated by now in the whole system. This work was motivated by the need to assess the operability of a large array of residential buildings and other construction sites located in the town of Berezniki, which is located on the territory of the Verkhnekamskoe potassium salt deposit. Over a long period of time certain sections of the city territory have experienced significant vertical displacements. As of 2022, the vertical displacement of some parts of the urban development was about 1.3 meters. In 2007-2018, several ground failures were registered in the urban development area. In the present research the estimation of permissible and limiting ground deformations for a wide variety of building structures is carried out on the basis of numerical simulation results. The values of linear ground deformations in the vicinity of buildings, at which the limit state is reached in the significant structural elements of the building, are taken as the parameters of the limit deformation of ground. The dependence of soil limit deformation characteristics in the vicinity of foundations of buildings on the conditions of contact of the foundation itself with the soil has been established. The results of computational experiments for different physical and mechanical properties of soils and contact parameters between the foundations of structures and soils at the base are presented. The models have been verified on the basis of a comparison of the nature and level of damage in the elements of structures based on the study of real residential buildings in Berezniki, Perm region. The results of measurements of deformations of the soil massif in the city of Berezniki for the period from 2007 to 2023 are used in this work.

Keywords: mining; technogenic impact; ground deformation; “building-foundation-soil” system

Dynamic response of a reinforced concrete structure to an impulse localized impact

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Abstract

The main approach to ensure safe operation of unique engineering and construction structures is the development and use of automated deformation monitoring systems. Such monitoring system should take into account all individual features of the structure and its operating conditions. One of the promising directions of development of monitoring systems is the transition to "active systems". These are systems in which there is an active device. It provides quasi-static or dynamic test action on the structure in a given mode. The basis of such devices can be, for example, electromechanical actuators, that is, ceramic piezoelectric elements. The purpose of this work is to establish the possibility of using ceramic piezoelectric actuators in monitoring systems. This is required in order to perform a localized pulse action on a reinforced concrete structure. The reinforced concrete structure is a four-story fragment of a monolithic concrete structure. Its length is 6.4 meters, width is 4.4 meters, height is 6.57 meters. At present this structure is mounted on an experimental stand for large-scale physical modeling of building structures (Institute of Continuous Media Mechanics, Russian Academy of Sciences). To achieve the goal, a cycle of numerical experiments was carried out. At the first stage and within the framework of theoretical provisions of electroelasticity, numerical analysis of interaction of the ceramic piezo-element with characteristic elements of the structure was carried out. Based on the results of this analysis, the possible parameters of the impulse force impact of the actuator on the structure were established. At the next stage, the determined impulse was used for numerical modeling of the problems about the dynamic elastic response of the reinforced concrete structure to the impulse localized action. Analysis of the results of numerical simulation of this stage allowed to form vibrograms of accelerations, as well as Fourier and Wavelet imagery of the response at various points of the structural elements for each pulse impact. The totality of the obtained numerical results determined two vibration portraits of the structure. One portrait was determined for a structure without a defect and the second was determined for a structure with a crack defect. The results of the comparison of these vibrational portraits are given in the paper. The totality of the obtained results allows us to draw the main conclusion. The usage of ceramic piezoelectric elements in active monitoring systems is an effective measure of registration of cracks in reinforced concrete slabs. It should be noted that in this case the linear scale of the crack is comparable with the characteristic scale of the slab fragment.

Keywords: impulse localized impact; automated deformation monitoring systems; ceramic piezoelectric elements

Transportation pipelines corrosion: The roles played by pressure, metallurgy, and geography

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Abstract

Corrosion has always been a major concern for oil and gas pipeline operators. Although, it has been recognized that internal operating pressure, metallurgy, and external working conditions all play different roles in pipeline degradation rates. However, there have been few case studies that have documented the various effects of operating pressure, metallurgy, and geography on observed pipeline corrosion. This case study is based on a magnetic flux leakage (MFL) inspection of a 24-inch oil-products transportation pipeline in Syria, where more than 376,000 metal loss features were discovered, 96% of which were internal and only 4% were external. We were able to recognize the influence of each operation variable on corrosion rate through a quantitative analysis of the inspection data, as well as a thorough review of the stable operating conditions, maintenance records, and oil-product properties. The inspection data revealed that the frequency of corrosion features increased among miles with high operating pressure, with 81% of the features detected where the mean operating pressure is 51 (Bar), and the remainder (19%) detected where the operating pressure varied between 41 (Bar) and 19 (Bar). Since the pipeline is constructed from multiple pipe grades, the frequency of identified metal loss features was significantly higher in the X48 pipes, with an average of 7,039 identifiers per km compared to the Gr B line pipe's average of 824/km. The elevation profile of the pipeline varied significantly along its 116 km length, ranging from 0 (m) to 554 (m) above sea level. In comparison to the higher sections with a height average of 326, the frequency of corrosion anomalies increased significantly in the low sections of the pipe with a mean height of 19 (m), where 81% of the features were detected (m)

Keywords: internal corrosion; transportation pipelines; oil products

Numerical simulation of fatigue crack growth in Ti-Al6-V4 hip implants under different exploitation conditions

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Abstract

One of the most important aspects of materials typically used in biomedical engineering is their resistance to various unfavourable exploitation conditions, which greatly impact their work life. In terms of extreme conditions, two major factors include fatigue and corrosion, and a combination of these can significantly decrease the expected life of various implants. The focus of this paper will be on hip implants made of Ti-Al6-4V titanium alloy, a material commonly used in such applications, due to its resistance to corrosion and biocompatibility. Research shown here was based on experimental testing of said alloy in order to determine its mechanical properties under different working environments, including normal, salty and wet conditions. These properties were then used as input data for Extended Finite Element method (XFEM) numerical simulations of fatigue crack growth in hip implants with various geometries. This was of particular interest since specimens which were kept in salty and wet environment had a slight degradation of yield stress and tensile strength, but an increase in plasticity.

Keywords: Ti-Al6-V4 alloy; hip implants; fatigue crack growth; corrosion; Extended Finite Element Method

Fracture modeling of a weld damaged by hydrogen embrittlement

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Abstract

This presentation is devoted to the measurement and modeling of degradation processes of welded structures due to hydrogen embrittlement. Currently, we encounter different approaches to hydrogen storage. On the one hand, there are already industrially used methods of storing compressed gas or liquefied gas in containers. At the same time, work is being done on methods based, for example, on the storage of hydrogen bound in the chemical structure of the compound or in the micro-porous structures of materials. When storing hydrogen in containers, we have progressed from steel containers to significantly more durable composite containers, however, the entire working set of hydrogen operation still contains many metal elements. Hydrogen diffuses very easily through metallic materials, which is due to the fact that its atoms are very small. This hydrogen accumulates in local pockets, which results in the creation of internal stress that leads to a local decrease in the strength of the material. We refer to this effect as hydrogen embrittlement. At present, we are able to distinguish different ways in which hydrogen (under specific conditions) affects the breaking of the material, therefore we speak, for example, about „cold cracking“, „hydrogen induced cracking“, „stress corrosion cracking“ etc. In this article three different approaches to modeling of hydrogen embrittlement are discussed. All this models were already presented in literature and now are applied to the specific case of a weld whose mechanical resistance has been reduced due to hydrogen embrittlement. The first model discussed in the article works with hydrogen diffusion described using Fick's law, then looks for a relationship between time, hydrogen concentration and the decrease in mechanical properties. In this case, the model works with increasing hydrogen concentration (and pressure induced by it, which causes a local growth of strain) in the micro-cavity around a large non-metallic inclusion and uses a model proposed in fracture mechanics to describe fracture formation. In the second model we work with the nucleation of nano-voids. This approach can be justified by observation of nano-scale voids on fracture surface. And also by the facts (I) that the plastic deformation leads to production of vacancies and (II) vacancies are stabilized by the presence of hydrogen atoms and (III) stabilized vacancies create hydrogen-vacancies complexes. The third approach is based on the model proposed by Anand, who proposed a model in which, when a certain internal variable is exceeded, inelastic stretching occurs in the direction of maximum principal stress. The article discusses the advantages and disadvantages of these models, which are compared with the experiment. In the case of the first model is obviously only usable for the reverse simulation of the process, i.e. for its use it is necessary to know the maximum dimensions of inclusions and other inhomogeneities in the material.

Keywords: hydrogen embrittlement; welded joint; cold cracking; hydrogen-vacancies complex

Residual life estimation of damaged structures exposed to high pressures and temperatures

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Abstract

This paper deals with the damage growth in High-Pressure Turbine (HPT) cooling holes of the case assembly made of Inconel 718. Several marks (cuts) were made on cooling holes into parent material during the service due to the non-skilled use of Electrical Discharge Machining (EDM) in the workshop. After a certain time, the case assembly returned to the workshop with all EDM marks cracked. Since HPT case assembly is not repairable and the only method for fixing this issue is its replacement with the new or used one (which might be pretty expensive), it was decided to use numerical analysis to estimate Paris coefficients for used Inconel 718, since the number of cycles and crack growth from the initial position were known, based on data obtained from the workshop. Firstly, finite element method (FEM) based numerical analysis was conducted in order to simulate crack propagation to match the one observed in the workshop, and then a multi-objective genetic algorithm – implemented thru response surface optimization – was used to obtain required Paris coefficients. The objectives of this optimization were the crack length and the corresponding number of cycles of crack growth. Obtained Paris coefficients were then used to estimate the residual life of HPT case assembly.

Keywords: high-pressure turbine; Inconel 718; Electrical Discharge Machining; Paris coefficients

Influence of temperature on crack initiation and crack growth resistance of welded joint constituents for steel SA-387 Gr. 91 welds subjected to cyclic loads

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Abstract

This paper presents the analysis of influence of temperature on the fracture resistance of welded joint constituents in welds made of alloyed Cr-Mo steel SA-387 Gr. 91, focused on the application of high-cycle fatigue and fatigue crack growth parameters. Weller curves were drawn in order to determine the dynamic strength for $2x10^6$ cycles, along with determining of Paris equation coefficients *C* and *m* and fatigue threshold value, ΔK_{th} for room and elevated temperatures (575°C).

Resistance to crack initiation decreased with an increase in temperature, i.e., the tendency towards fracture increases for both parent material (PM) and welded joint specimens. All specimens were tested at loads which exceeded the dynamic strength of the welded joints, and their fracture occurred either in the heat affected zone (HAZ) or the weld metal (WM), whereas specimens tested at load levels close to the dynamic strength fractured in the HAZ.

Fatigue crack growth rate (da/dN) increases with the temperature and it was highest for specimens with crack in the WM, i.e., these specimens had weakest resistance to crack growth, whereas lowest da/dN rates were recorded for specimens with cracks in the PM, suggesting their resistance to crack growth was the best of all three cases. Highest fatigue threshold (ΔK_{th}), i.e., best resistance to propagation of the existing cracks, was observed in specimens with a crack in the PM and HAZ. Lowest fatigue threshold was observed in specimens with a crack in the WM. These values decreased with an increase in temperature, for all cases, as can be seen in table 1.

Table 1. Parameters of Fatigue Crack Growth - crack tip in BM, WM, HAZ

Specimen	Temperature °C	ΔK_{th}, MPam$^{1/2}$	Coefficient, C	Exponent, m	da/dN, m/cyc, ΔK=25 MPam$^{1/2}$
BM - 1s	20	17.6	$3.56 \cdot 10^{-13}$	3.69	$5.13 \cdot 10^{-8}$
BM - 2s		17.4	$2.31 \cdot 10^{-13}$	3.88	$6.13 \cdot 10^{-8}$
BM - 3s		16.9	$1.08 \cdot 10^{-13}$	3.33	$4.88 \cdot 10^{-8}$
BM - 1p	575	13.9	$6.00 \cdot 10^{-12}$	3.22	$1.90 \cdot 10^{-7}$
BM - 2p		14.1	$5.49 \cdot 10^{-12}$	3.18	$1.53 \cdot 10^{-7}$
BM - 3p		14.4	$3.00 \cdot 10^{-11}$	2.65	$1.52 \cdot 10^{-7}$
WM - 1s	20	16.5	$5.93 \cdot 10^{-11}$	2.47	$1.68 \cdot 10^{-7}$
WM - 2s		14.3	$2.15 \cdot 10^{-12}$	3.46	$1.48 \cdot 10^{-7}$
WM - 3s		17.2	$1.76 \cdot 10^{-11}$	2.79	$1.40 \cdot 10^{-7}$
WM - 1p	575	12.4	$6.68 \cdot 10^{-10}$	2.31	$1.13 \cdot 10^{-6}$
WM - 2p		13.1	$2.59 \cdot 10^{-11}$	3.46	$1.78 \cdot 10^{-6}$
WM - 3p		11.6	$1.74 \cdot 10^{-10}$	2.80	$1.43 \cdot 10^{-6}$
HAZ - 1s	20	17.2	$3.33 \cdot 10^{-13}$	3.88	$8.84 \cdot 10^{-8}$
HAZ - 2s		17.4	$1.78 \cdot 10^{-13}$	4.06	$8.43 \cdot 10^{-8}$
HAZ - 3s		17.7	$4.03 \cdot 10^{-13}$	3.77	$7.51 \cdot 10^{-8}$
HAZ - 1p	575	13.9	$1.69 \cdot 10^{-10}$	2.33	$3.06 \cdot 10^{-7}$
HAZ - 2p		13.7	$2.60 \cdot 10^{-10}$	2.20	$3.09 \cdot 10^{-7}$
HAZ - 3p		14.3	$2.19 \cdot 10^{-10}$	2.23	$2.87 \cdot 10^{-7}$

Keywords: crack; alloyed steel; welded joints; dynamic strength: fatigue crack growth parameters

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Temperature influence on composite material behaviour

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Abstract

Composite materials, which are increasingly used in various industries, are significantly lighter than standard homogeneous materials such as metals, but the structure of composites is far more complex and requires a different approach to the design of parts. The basic concept is to produce a structure that can achieve specific performance requirements. However, their performance can be significantly affected by environmental factors, such as temperature.

The purpose of this review study is to compile and evaluate the literature that has already been published on the impact of temperature on the behavior of composite materials. The paper begins by discussing the physical and mechanical properties of composite materials and how they are affected by temperature. The report also emphasizes the testing procedures utilized to look into how temperature affects the behavior of composite materials. The impact of temperature on the failure mechanisms of composite materials is also covered in the paper.

The report ends by summarizing the key findings and outlining potential future research directions in the area. The review highlights the need for further research to better understand the temperature influence on behavior of composite materials and develop new testing methods to accurately simulate the conditions encountered in practical applications.

Keywords: composite materials; temperature; failure mechanism

Influence of seawater immersion on fatigue strength of GFRP composites with through-holes

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Abstract

Composite materials are used in various engineering applications, such as marine, aerospace, civil, offshore, sports and automobile industries, due to their high specific strength and high specific stiffness and high resistance to fatigue and corrosion. The marine environment involves adverse conditions that lead to a decrease in the structural integrity of engineering composites, and, under cyclic load, fatigue is one of the main concerns in the design of critical structures and mechanical components.

This paper studies the effect of seawater immersion in fatigue behaviour of GFRP composites with through-holes. Rectangular cross-section specimens with a 5mm-diameter central hole were immersed in seawater for different immersion times (0, 230, and 910 days). Fatigue tests were performed under uniaxial cyclic loading using a stress ratio equal to 0.1 under constant-amplitude. The strain fields around the hole were monitored, in-situ, utilising a 3D digital image correlation system. A three-dimensional progressive damage model was implemented using the finite element method to simulate the stress-strain response and the failure patterns by combining the Puck's failure criterion for ultimate failure analysis of the laminates and the Fick's first diffusion law to estimate the seawater absorption rates. Based on a strain energy density consideration, the proposed model was applied to predict the fatigue life for different immersion times.

The effect of seawater immersion on fatigue behaviour can be inferred from the S-N curves shown in Figure 1. As can be seen in the figure, after 230 days, the fatigue resistance reduced relative to the control samples (not immersed in sea water). However, a significant reduction of fatigue durability has been found for immersion times of 910 days. At a maximum cyclic stress of 143 MPa, i.e. the average stress for the tested interval, the fatigue life for the samples immersed 230 days was about 66% of that of the control samples. This reduction raised to 95% for 910 days. Such results are explained by the water absorbed by material due to diffusion and/or capillarity of the fibres and, once inside the material, it leads to the matrix expansion with the consequent occurrence of microcracks and/or micro-stresses in the composite. In addition, debonding between resin and fibres is also expected, which, together with the matrix degradation, compromise the load carrying capacity of the composite [1-2]. These damaging effects affect not only the fatigue strength but also the strain fields near the hole region. The evolution of the maximum values of the first principal strain (I) around the hole, recorded using the DIC system during the tests, clearly show a progressive increase of the damage as the loading cycles are applied (see Figure 2). It was seen that the damage patterns were similar for all cases, but they were speeded up for higher immersion times, which agrees with the results of the S-N curves plotted in Figure 1. Regarding the fatigue life predictions, as exhibited in Figure 1, the numerical S-N curves were in very good agreement with the experimental S-N curves, regardless of the immersion time.

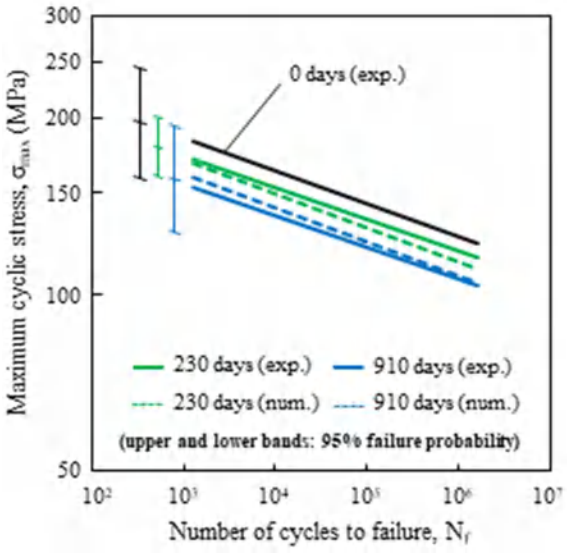

Fig. 1. Stress amplitude versus number of cycles to failure (S-N curves) for the tested composites (R = 0.1).

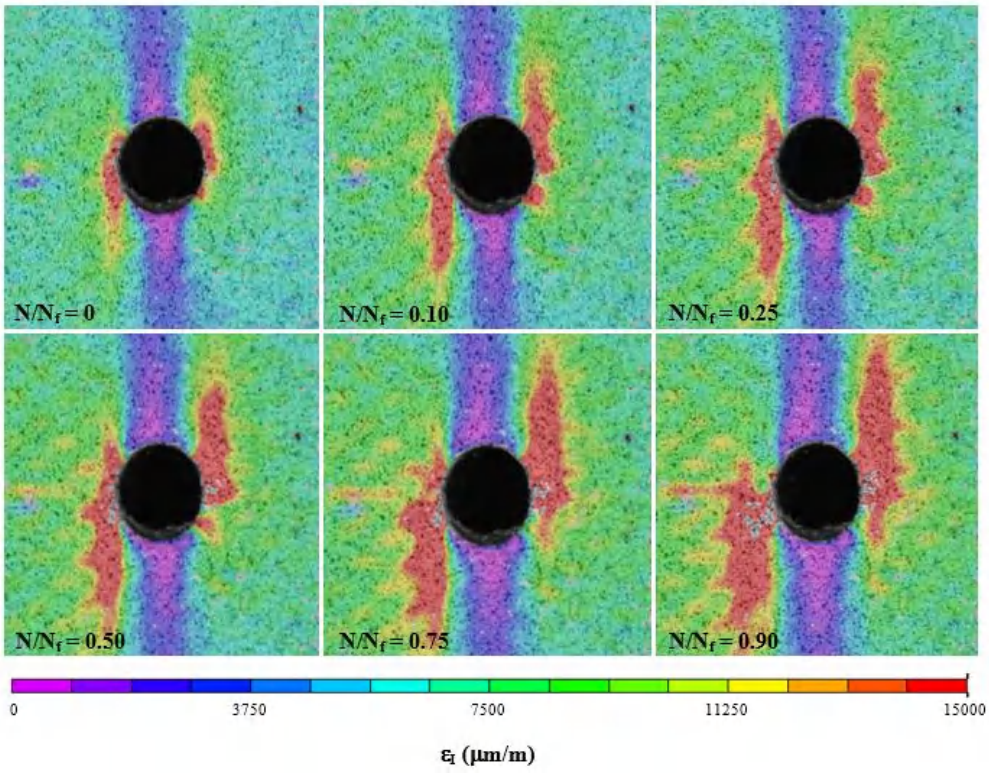

Fig. 2. Evolution of the first principal strain field (ε_1) near the hole with the dimensionless life (N/N_f) for 0 days of immersion. The images were captured at the maximum applied stress of each cycle.

Keywords: composite laminates; seawater effect; fatigue behaviour; digital image correlation

Experimental studies on crashworthiness analysis of a sandwich composite panel under axial impact: A comprehensive review

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Abstract

Fiber reinforced polymer composites are commonly used in the aircraft industry for structurally crucial applications, such as crash management. Furthermore, carbon fiber composite have shown great performance in the design of light-weight thin walled energy absorber structure. This study aims to present an in depth review of the crashworthiness analysis of a sandwich composite structure that represent a section of fuselage structure under axial impact loading. In this paper, the key experimental setups of various types axial impact impact event will be explained. Several numerical methods to replicate the impact loading event are also reviewed, including constitutive material and failure assumption, boundary conditions, and analysis methods. Some of the numerical benchmark analyses were also performed to explore the energy absorption behaviour in detail. Furthermore, a schematic plan for the further experimental studies on the drop-weight impact under varying crushing weights will be presented. Dynamic impact loading is one of the most important types of loading that needs to be researched for composite sandwich structures, as it can lead to significant decreases in strength and hidden damages that may develop inside the structures without being noticed.

Keywords: crashworthiness; Sandwich composite structure; Finite Element Method; Drop-weight impact

Analysis of composite profile under loading conditions using finite element method

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Abstract

Composite materials, which are increasingly used in various industries, are significantly lighter than standard homogeneous materials such as metals, but the structure of composites is far more complex and requires a different approach to the design of parts. The basic concept is to produce a structure that can achieve specific performance requirements. To accurately analyze the mechanical behavior of such composite profiles, it is essential to use a reliable numerical analysis.

In this paper, an analysis of a composite profile using the finite element method (FEM) has been shown. In this case, the composite profile was modeled as a fiber-reinforced polymer. Numerical simulation has been done to calculate the stress field distribution under different loading conditions.

The results of the study demonstrated the effectiveness of the FEM for analyzing composite profiles. The stress and deformation distribution within the composite profile were accurately predicted by the FEM. The study's findings offer insights into the mechanical behavior of composite profiles and show the value of the FEM approach.

Keywords: composite materials; Finite Element Method; Fiber-Reinforced Polymer

Mechanical characteristics of compressive specimens obtained by SLS technology

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Abstract

The purpose of this research is to investigate the mechanical properties of Additive Manufacturing (AM) parts. The 3D printer used in this study is Fuse 1 (FormLabs, Summerville, MA), which utilizes the SLS (Selective Laser Sintering) technology. This technology allows the production of objects with different shapes and dimensions simultaneously, provided that they are printed at a minimum distance of 5 [mm] apart. The powder layer thickness during printing was 110 microns. The mechanical characteristics of a specific type of specimen, which conforms to the ISO 604 standard for compressive specimens, were examined. The compressive specimens have dimensions of Ø10x20 [mm]. Four batches of specimens were produced, each differing in printing orientation (i.e. horizontal and vertical) and printing location (i.e. printed on the edge and in the middle of the powder bed). The material used for printing the specimens is polyamide (PA 12), which has a compressive strength is 13/24/55 MPa at 1%/2%/5%. The specimens were subjected to a standard tensile testing machine (SHIMADZU AGS-X 100kN) after printing.

Furthermore, the results of the testing also showed significant variations in the compressive strength of the specimens at different levels of elongation. At 1% and 2% elongation, the compressive strength values displayed large deviations, which suggests that the parts may not be able to withstand high levels of deformation at these points. However, at 5% elongation, the values were much closer to the expected values found in the literature.

Keywords: SLS technology; compression specimens; PA 12; printing orientation

Mechanical properties of ABS resin material

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Abstract

Considering that additive manufacturing technology, also known as 3D printing, has evolved significantly in recent decades, it has become necessary to comprehensively and in detail study the properties and structural details of the different materials used for these processes. Among the seven different AM technologies, vat photopolymerization technology was chosen in this research, especially stereolitography (SLA) and digital light processing (DLP) for 3D printing processes. Thermoplastic polymer material acrylonitrile butadiene styrene (ABS) is a widely used material for plastic printing along with polylactic acid (PLA), but in this study ABS was chosen in the form of the resin material. So far, this type of material has not been sufficiently studied, and the aim of this research was to determine the mechanical properties and differences in behavior of the same material printed with two different technologies. The geometry of samples is set based on the ISO 527-2 standard for tensile testing of polymeric materials, with 45° print orientation, grid infill pattern and 100% infill density. Tensile tests were performed at a loading rate of 1 mm/min on the Shimadzu universal testing machine. In addition, 2D and 3D microscopy were performed to obtain a more comprehensive picture of the behavior of the ABS resin. It can be seen that both technologies produce though specimen's which can be seen in the area under the stress-strain curve, although the SLA specimens could be subjected to higher stress and the DLP specimens could persist longer strain. SLA printing technology expresses 60% lower value for elongation at break compared to DLP, while the SLA maximum strain value is 40% lower than DLP value. Therefore, it can be concluded that printing technology has the greatest influence on elongation as one of the mechanical properties studied.

Keywords: 3D printing; ABS resin; 45° print orientation; mechanical properties; tensile testing; 2D microscopy

The Risk assessment of 3D printing FDM technology

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Abstract

Additive manufacturing or 3D printing is used nowadays in a variety of industries including aerospace, automotive, medicine, architecture etc. It is also extensively used for educational purposes. 3D printers are now used even in everyday life - by people without technical education. Although the application of 3D printing is widespread, its effects on human health and precautions are still not discussed in details. This article will be focused on the risk assessment of one of the most popular 3D printing techniques - Fused Decomposition Modeling (FDM). During FDM 3D printing movable printing head is used to melt a thermoplastic wire (filament), and to apply it layer by layer, forming model which is predeveloped in Computer Aided Design (CAD) software. Due to the low cost, the most frequently used 3D printing materials are Acrylonitrile Butadiene Styrene (ABS) and Polylactic Acid/Polylactide (PLA). A side product of filament melting is evaporation of chemicals, which exact amout and composition is still not precisely established (as it depends on 3D printing conditions). FDM printing can also produce unhealthy levels of nanoparticles (particle in the range between 1 to 100 nanometres), Volatile Organic Compounds (VOCs) and gaseous material emissions. This article discuss the dangers and harms of FDM with performed basic risk assessment according to the Kinney methodology. Also, the protective measures which need to be applied during the 3D printing are proposed – taking into account the identified and quantified risks.

Keywords: 3D printing; FDM; risk assessment; work safety; hazardous chemicals

Composite plates with Nomex honeycomb core modeling for Dynamic integrity at the mesoscale level

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Abstract

In many industries, nowadays, traditional materials are being replaced with composites. This is primarily because engineered composite materials can be tailored to optimally suit the desired structure-function(s). In recent years, especially in the aerospace industry, one of the structural building blocks is composite plates with cores, that render a very light, rigid, and strong structure. Nomex cores are widely used in fly-worthy and load-bearing primary structural aircraft components. However, the analysis and modeling of these structures represent a challenging task since at the material level, the orthotropic nature has to be taken into account followed by very complex core geometries. For many linear static analyses, equivalent material models can be used, however, these models fail to predict correct results in non-linear, dynamic, and fatigue analyses.

In the present work, the methodology for a composite plate with Nomex core material modeling is presented at the mesoscale level. The structure investigated consists of face sheet carbon composite plates (2D), mainly for normal stress load bearing, Nomex honeycomb core (T412 paper with chopped aramid fibers in phenolic matrix, manufactured using expansion Process process), and carbon composite leading and trailing edges (3D orthotropic composite). It is assumed that the Nomex core mainly carries shear stresses. This material model is further used to perform dynamic (modal) analysis on a composite structure with complex geometry as presented in the following figure:

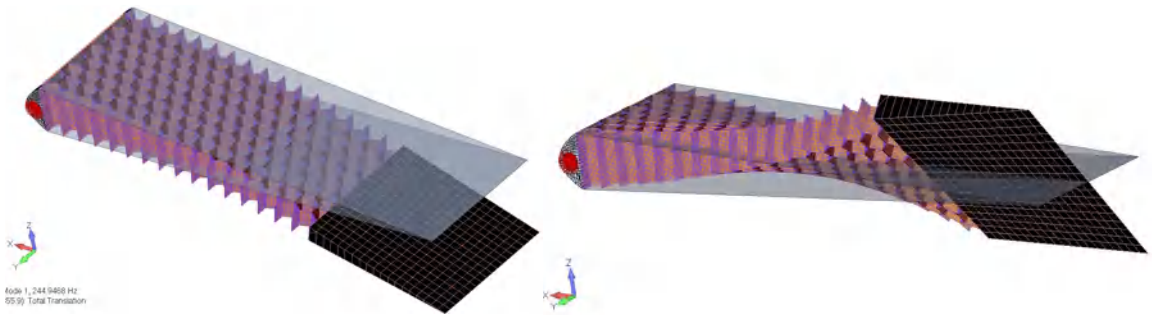

Fig. 1 The model of aircraft structures made of Nomex

Comparing the results obtained (for simply supported beam, and tested as per ASTM standards), reported in the literature, good agreement between the proposed material model and experimental results is obtained. However, material modeling and geometry modeling using the FEA approach is very tedious and require relatively demanding computing resources.

Keywords: Nomex honeycomb core; carbon composite; material model

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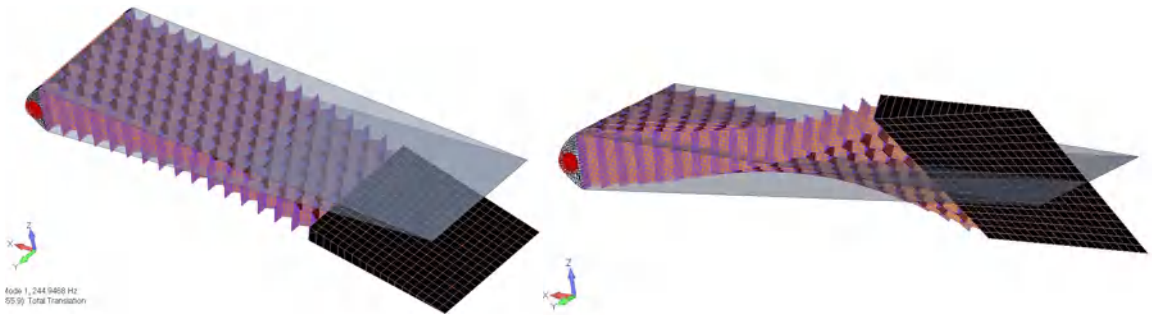

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Keywords: Nomex honeycomb core; carbon composite; material model

Fatigue lifetime analysis of polyurethane components

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Abstract

Rubber and polymeric materials are commonly used in various suspension systems mainly due to their hyperelastic characteristics, which include low weight, corrosion resistance and, above all, a high capacity for vibration damping and energy absorption. By shaping various mechanical parts and material modifications (composites, layered structures, hybrid joints), it is possible to achieve the appropriate stiffness characteristics. In the paper, two hardness configurations: 80ShA and 90ShA, respectively, were designed for fatigue analysis. Fatigue tests were performed using the displacement control mode method for two displacement ratios Rd=0, Rd=-1. Based on experimental fatigue results and FEM results for exemplary engineering components, a hybrid approach was proposed for experimental-numerical estimation of fatigue lifetime. For this purpose Wang-Brown criterion was used and modified. Results of fatigue lifetime prediction are shown in Fig. 1. The proposed approach allows to predict fatigue lifetime with higher accuracy than existing approaches like the peak strain/stress approach and WB model.

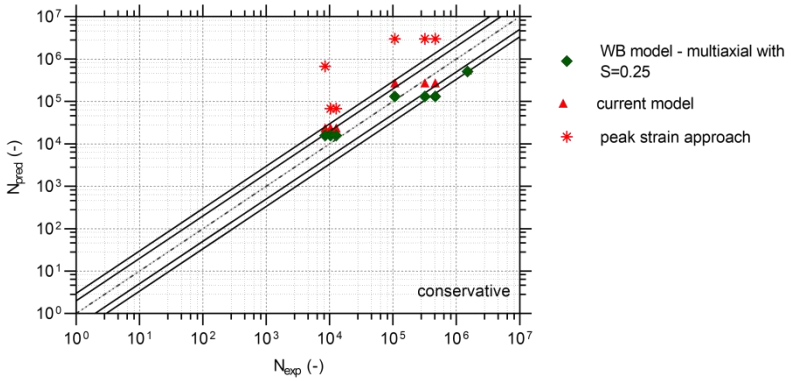

Fig. 1. Fatigue lifetime predictions for polyurethane components – hardness 90ShA.

Acknowledgements:

The publication has been prepared as a part of the Support Programme of the Partnership between Higher Education and Science and Business Activity Sector financed by City of Wroclaw.

Keywords: elastomers; fatigue; FEM; polyurethane; lifetime prediction

Sponsor details

This section of the Book of Abstracts is dedicated to detailed information about our sponsors, their history and activities. The Organizing Committee of the *Second International Symposium on Risk analysis and Safety of Complex Structures and Components* - IRAS 2023 would like to take this opportunity to once again express our gratitude to the sponsors, and their efforts and support in organizing of our conference!

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O kompaniji

MONT-R sa dve decenije poslovanja, od osnivanja 2003. godine do danas, postala je jedna od vodećih izvođačkih kompanija na teritoriji Republike Srbije koja je prisutna konstantno u nekolicini evropskih država (Nemačka, Slovenija i Bosna i Hercegovina) u oblasti izvođenja mašinskih radova, inženjeringa i proizvodnje čelične konstrukcije i opreme pod pritiskom.

Naš raznovrstan portfolio obuhvata: proizvodnju, montažu, remontno, tekuće i interventno održavanje najsloženijih i strateški važnih industrijskih postrojenja, termoelektrana, rafinerija, petrohemijskih postrojenja i metalurških kompleksa.

Kompanija broji više od 300 zaposlenih, koji su kvalifikovani i kompetentni za obavljanje poslova na kojima su raspoređeni. Kontinuirani rad kolektiva koji je potkrepljen implementiranim standardima sistema menadžmenta kvaliteta (ISO 9001, ISO 14001, 45001) uz razne druge standarde (EN ISO 3834-2, EN ISO 17663, EN ISO 17025 i dr.), sa posedovanjem različitih ličnih specijalizacija i profesionalnog znanja 25 inženjera i tehničara predstavljaju osnov pokretanja svih projekta, njihovog planiranja i realizacije. Komletan tim zaposlenih raspoređeni su na poslovima kao što su: inženjeri gradilišta, planiranja montaže i zavarivanja, inženjeri za bezbednost i zdravlje na radu, poslovođe montaže i zavarivanja, inženjeri kvaliteta, bravari i zavarivači.

Naša osnovna delatnost se ogleda kroz sledeće oblasti rada i angažovanja:

- Inženjering i projektovanje,
- Mašinska montaža,
- Remont i održavanje,
- Izrada i prefabrikacija opreme,
- Osiguranje kvaliteta i kontrola kvaliteta,
- Laboratorija za akustična ispitivanja.

Pored tržišta Republike Srbije, MONT-R danas aktivno učestvuje na projektima u Nemačkoj (preko 150 angažovanih radnika), Sloveniji i BiH.

About company

MONT-R, with two decades of history, from its establishment in 2003 until today, has become one of the leading contractor in Serbia, which is constantly present at European market (Germany, Slovenia, Macedonia, Bosnia and Herzegovina) in the field of mechanical works, engineering and production of pipelines, steel structures and equipment under pressure.

Our diverse portfolio includes: production, assembly, overhaul, current and intervention maintenance of the most complex and strategically important industrial plants, thermal power plants, refineries, petrochemical plants and metallurgical complexes.

The company has more than 300 employees, who are qualified and competent to perform the tasks they are assigned to. The continuous work of the collective, which is supported by the implemented standards of the quality management system (ISO 9001, ISO 14001, 45001) along with various other standards (EN ISO 3834-2, EN ISO 17663, EN ISO 17025, etc.), with the possession of various personal specializations and professional knowledge of 25 engineers and technicians is the basis for the initiation of all projects, their planning and implementation. A complete team of employees are assigned to jobs such as: site engineers, assembly and welding planning, occupational safety and health engineers, assembly and welding supervisors, QA & QC Management, locksmiths and welders.

Our core business activity is reflected in the following areas of work and engagement:

- Engineering and design,
- Mechanical erection,
- Overhaul and maintenance,
- Equipment manufacture,
- Qality assurance & quality control,
- Laboratory for acustic testing

Besides serbian market, MONT-R currently actively participates in projects in Germany (over 150 engaged workers), Slovenia and Bosnia and Herzegovina.

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О компанији

Привредно друштво ***ТанкМонт д.о.о. Београд*** настало је 2005. године статусном променом фирме Метал Монтажа која је имала свој радни век дуг 9 година. Делатност фирме је дефинисана као пројектовање, извођење и инжењеринг, мада се углавном бави извођењем металних конструкција. Танкмонт поседује производни погон површине 4 000 m^2 у Старим Бановцима, опремљену савременим машинам за префабрикацију свих типова челичних конструкција. Такође, за монтажу располаже са свом неопходном опремом и механизацијом.

Привредно друштво Танкмонт д.о.о. Београд је ускоспецијализовано за изградњу великих резервоара за складиштење нафте и нафтних деривата и лидер је у тој области не само на територији Републике Србије него и региона. Послови изградње резервоара обављали су се највише на територији Руске Федерације, Републике Србије, Републике Хрватске, Државе Кувајт. Због различитих територија на којима послује, Танкмонт д.о.о. Београд примењује прописе и стандарде држава у којима ради.

Танкмонт д.о.о. Београд је изградио преко 300 резервоара запремине од 100 m^3 до 160.000 m^3. Осим резервоара, претежна делатност фирме је израда технолошких цевовода за транспорт нафте и гаса, као и цевовода мањих пречника предвиђених за противпожарне системе са припадајућом опремом. Успешно учествује на изради и монтажи челичних конструкција, хала и свих типова носећих конструкција.

Привредно друштво Танкмонт д.о.о. Београд поседује **лиценце**: И040Г1, И047Г1 И030Г1, И030М1, И031М1.

Од **сертификата** поседује: ISO 9001: 2015, ISO 14001:2015, ISO 45001:2018, EN 1090 exc 4, ISO 3834-2, PED 2014/68/EU, ISO 50001:2015

About company

Commercial company ***TankMont Ltd. Belgrade*** was formed in 2005, following the status change of the company Metal Montaža, which was in business for 9 years. Company activities were defined as design, construction and engineering, although its main activity involved the construction of metal structures. TankMont possesses a manufacturing facility with a total surface are of 4.000 m^2, located in Stari Banovci, equipped with state-of-the-art machines for prefabrication of all types of steel structures. In addition, it also possesses all of the equipment and mechanisation necessary for installation.

Commercial company TankMont Ltd. Belgrade is highly specialised in building of large oil and oil derivative storage tanks, and is the regional leader in this field. Most of our work involving the building of tanks were performed in Russia, Serbia, Croatia and Kuwait. Due to conducting business in different countries, TankMont Ltd. Belgrade works in accordance with regulations and standards of all these countries.

TankMont Ltd. Belgrade has built over 300 tanks, with volume ranging from 100 to 160.000 m^3. In addition to tanks, the company's main activity involves the construction of technological pipelines for oil and gas transportation, as well as small-diameter pipelines used for fire protection systems and equipment. TankMont also has a successful tradition of designing and installing of steel structures, industrial halls and all types of load-bearing structures.

Commercial company TankMont Ltd Belgrade possesses the following licences: I040G1, I047G1, I030G1, I030M1, I031M1

It also possesses the following certificates: ISO 9001: 2015, ISO 14001:2015, ISO 45001:2018, EN 1090 exc 4, ISO 3834-2, PED 2014/68/EU, ISO 50001:2015

САНАЦИЈА И ИСПИТИВАЊЕ МЕТАЛА доо
Предузеће за санацију и испитивање метала без разарања

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О компаниji

Preduzeće ***Sanacija i ispitivanje metala d.o.o.*** *Beograd* je osnovano 08.01.2018. godine. Osnovna delatnost preduzeća je 7120 – Tehničko ispitivanje i analize. Specijalnost firme je ispitivanje NDT metodama radnih kola – turbina (sva tri tipa, Kaplan, Pelton i Frensis) i sanacija istih, po sopstvenoj tehnologiji (pogotovo sanacija prslina). Prisutni smo na tržištu Srbije, Crne Gore, Bosne i Hercegovine i Severne Makedonije. Takođe se bavimo ispitivanjem i sanacijom hidromehaničke opreme, fabričkim prijemima (FAT) i ispitivanjima, kao i rešavanjem mašinskih problema na hidroelektranama. Saradnici kompanije su učestvovali u FAT-ovima za HE Zvornik, RHE Bajina Bašta, HE Đerdap I, HE Bajina Bašta, HE Perućica, itd. Firma trenutno broji 4 stalno zaposlena. Saradnja sa kupcima i dobavljačima je korektna u smislu da kupci ne premašuju rok plaćanja koji je utvrđen ugovorom, kao što ni Sanacija i ispitivanje metala doo to ne čini. Sanacija i ispitivanje metala uglavnom sarađuje sa elektroprivredama:

- JP Elektroprivreda Srbije Beograd
- Elektroprivreda Crne Gore AD Nikšić
- MH Elektroprivreda Republike Srpske MP a.d. Trebinje
- JP Elektroprivreda Hrvatske zajednice Herceg Bosne d.d.
- JP Elektroprivreda Bosne i Hercegovine d.d. Sarajevo
- AD Elektrani na Severna Makedonija Skopje

Sanacija i ispitivanje metala doo se razvija u jednu modernu internacionalnu kompaniju, koja je prisutna na tržištu Balkana. Takođe, sarađujemo sa dosta firmi u Srbiji, zajedničkim učešćem na tenderima (neki od partnera u Srbiji: ATB FOD DOO Bor i ATB SEVER doo Subotica, Institut IMS a.d. Beograd, Mašinski fakultet Univerziteta u Beogradu, Elektrotehnički institut Nikola Tesla AD, Institut Mihajlo Pupin d.o.o. i mnogi drugi.)

About company

Sanacija i ispitivanje metala d.o.o. is a private company whose main activity is non-destructive testing of metals (NDT) and rehabilitation of hydroelectric power plant turbines. Almost the entire scope of the company's activity is focused on the hydroelectric power plants of the Republic of Serbia and the neighbouring countries.

The company has the technology for and experience with rehabilitation of all three types of turbines (Francis, Pelton and Kaplan). In addition to cavitation rehabilitation, we have been entrusted with rehabilitation of cracks in all three types of turbines in major hydroelectric power plants in the neighbourhood: DJERDAP Hydro-Electric Power Plant (HEPP) – Republic of Serbia (Kaplan turbines (1X190 MW + 5X211 MW), BAJINA BAŠTA HEPP – Republic of Serbia, (Francis turbines, 4 x 105 MW) and PERUĆICA HEPP – Republic of Montenegro (Pelton turbines, 5 x 40 MW, 2 x 60 MW).
In 2018 we rehabilitated and tested 27 turbine runners of all 3 types.
In 2019 we rehabilitated and tested 41 turbine runners of all 3 types.
In 2020 we rehabilitated and tested 32 turbine runners of all 3 types.
In 2021 we rehabilitated and tested 32 turbine runners of all 3 types.

Without fake modesty, not many companies, either in our region or further beyond, can pride themselves on such performance. In addition, we also do NDT examination and rehabilitation of hydromechanical equipment on HPP in Serbia and Balkan.

Our experience also includes providing technical conditions for HEPP revitalization, acceptance of equipment for HEPP modernization and revitalization in factories: VOITH St. Polten, Austria; LMZ – Sankt Petersburg, Russia; ANDRIZ - Ravensburg, Germany; LITOSTROJ - Ljubljana, Slovenia, etc.

ZAVOD ZA ZAVARIVANJE
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O zavodu

Zavod za zavarivanje je nezavisna organizacija, osnovan 1958. godine kao specijalizovana ustanova za profesionalno pružanje usluga u zavarivanju.

Na jedanaestoj redovnoj skupštini Međunarodnog instituta za zavarivanje (IIW), održanoj 1958.god. u Beču, Jugoslavija postaje punopravni član ove najznačajnije svetske asocijacije u zavarivanju, zastupljena od strane Zavoda za zavarivanje, koji je i danas predstavnik Srbije u IIW-u.

Ove godine Zavod slavi 65 godina uspešnog poslovanja kao lider u ispitivanjima sa i bez razaranja, hemijskim i fizičkim ispitivanjima, kontrolisanju opreme i postrojenja, poslovima imenovanih tela za opremu pod pritiskom, obuci i sertifikaciji osoblja za ispitivanje bez razaranja, zavarivača, obuci međunarodnih inženjera, tehnologa i inspektora zavarivanja kao prvi ATB u Srbiji, sertifikaciji kompanija u oblasti zavarivanja kao jedini ANBCC u Srbiji ovlašćen od strane IIW-a, reparaturi delova, alata, mašina.

Sledeći zahteve međunarodno razvijenih sistema za ocenjivanje usaglašenosti, sve poslove obavljaju posebne organizacione celine – Laboratorija akreditovana u skladu sa zahtevima standarda SRPS ISO/IEC 1702, Kontrolno telo akreditovano u skladu sa zahtevima standarda SRPS ISO/IEC 17020 i Sertifikaciono telo akreditovano prema SRPS ISO/IEC 17024.

Specifična znanja, višedecenijsko iskustvo, visokoobučeno osoblje i najsavremenija oprema su kombinacija koju Zavod za zavarivanje uvek može da ponudi, što dokazuje i primenjuje na velikim projektima Elektroprivrede Srbije, Naftne industrije, izgradnji gasovoda, toplovoda, aktivnostima za potrebe Vojske Srbije, procesne industrije, tehnološkim postrojenjima, konstrukcijama i opremi.

About institute

Welding institute is an independent organization, founded in 1958 as a specialized institution for providing of professional welding services.

During the eleventh regular meeting of the International Institute for Welding (IIW), which took place in Vienna in 1958, Yugoslavia became a full member of this world-leading welding association, being represented by the Welding Institute, which still remains the Serbian representative in the IIW to this day.

This year, the Institute is celebrating 65 years of successful business, as the leader in non-destructive testing, chemical and physical tests, equipment and installation control, activities related to notified bodies for pressure equipment, training and certifying of NDT staff, welders, international engineers, technologists and welding inspectors, as the first ATB in Serbia, along with certification of companies in the field of welding and repairing of parts, tools and machines, as the only ANBCC in Serbia, appointed by IIW.

Following the requirements of internationally developed systems for evaluation of compliance, all business is conducted by specific organizational units - Laboratory which is accredited in accordance with standard SRPS ISO/IEC 1702, Notified Body accredited in accordance with standard, and Certification Body, accredited according to SRPS ISO/IEC 17024.

Specific knowledge, decades worthy of experience, highly trained staff and state-of-the-art equipments represent a combination which Welding Institute can always offer, which is proven by our involvement in large-scale projects with Electric Power Industry of Serbia, oil industry, heating and gas pipelines, activities related to the Serbian Army, processing industry, technological facilities, various structures and equipment.

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O kompaniji

Trokut Test Srbija je prisutan na tržištu od 2012. godine nudeći opremu renomiranih svetskih proizvođača iz oblasti mehaničkih ispitivanja, kontrole kvaliteta, hemijska analiza, metrologija, metalografija, ispitivanja bez razaranja (ultrazvuk, radiografija, magnetna ispitivanja, ispitivanja penetrantima), prediktivno održavanje kao i sistemi za automatizaciju procesa u proizvodnji.

Naš stručni tim kao i podrška dobavljača Vam stoji na raspolaganju kako bismo našli adekvatno rešenje za Vaše potrebe ispitivanja, testiranja kao i optimizacije i unapređenja proizvodnje.
Detaljnije o proizvodima i našoj kompaniji se možete informisati i putem sajta www.trokuttest.com.

About company

Trokut Test Serbia has been present on the market since 2012, offering equipment from renowned global manufacturers in the field of mechanical testing, quality control, chemical analysis, metrology, metallography, non-destructive testing (ultrasound, radiography, magnetic testing, penetrant testing), predictive maintenance as well as systems for automation of production processes.

Our expert team along with suppliers support is at your disposal in order to find an adequate solution for your needs of examination, testing as well as optimization and improvement of production.

You can find out more about the products and our company on our website www.trokuttest.com.

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O kompaniji

WELD-ING d.o.o. je specijalizovano preduzeće za pružanje usluga iz oblasti zavarivanja, akreditovano sertifikaciono telo za sertifikaciju osoba (zavarivača, lemioca i operatera zavarivanja) i akreditovano kontrolno telo za kvalifikaciju tehnologija zavarivanja i validaciju uređaja za elektrolučno zavarivanje, sertifikovanu školu zavarivanja - centar za obuku i probe zavarivača.

Pored navedenih WELD-ING pruža inženjering i konsalting usluge iz oblasti zavarivanja, reparaturno zavarivanje i navarivanje pohabanih i havarisanih delova, uređaja i opreme u svim industijskim granama (građevinska, rudarska i transportna mehanizacija, termoenergetska oprema kao i delova industrijskih motora i mašina), izradu i montažu (cevovoda, posuda pod pritiskom, konstrukcija, postrojenja u termoenergetskim, petrohemijskim i objektima crne metalurgije).

Stručni tim WELD-ING-a pružiće vam pomoć u rešavanju svih problema iz oblasti zavarivanja, a višegodišnje iskustvo i porodična tradicija dugi niz godina, kao i konstantno praćenje i primena najnovijih dostignuća, tehnologija, materijala i opreme je garancija kvaliteta izvedenih radova.

About company

WELD-ING d.o.o. is a specialized company for the provision of services in the field of welding, an accredited certification body for the certification of persons (welders, brazers and welding operators) and an accredited control body for the qualification of welding technologies and validation of electric arc welding devices, a certified welding school - a center for training and testing of welders. In addition to the above, WELD-ING provides engineering and consulting services in the field of welding, repair welding and welding of worn and damaged parts, devices and equipment in all industries (construction, mining and transport machinery, thermal energy equipment as well as parts of industrial engines and machines), manufacturing and assembly (pipeline, pressure vessel, construction, plants in thermal energy, petrochemical and ferrous metallurgy facilities).

The expert team of WELD-ING will help you in solving all problems in the field of welding, and many years of experience and family tradition for many years, as well as constant monitoring and application of the latest achievements, technologies, materials and equipment, is a guarantee of the quality of the work performed.

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О факултету

Машински факултет Универзитета у Београду је институција националног значаја и представља основ развоја машинске науке и индустрије у Србији. Најстарија је и највећа високошколска и научна установа у нашој земљи у области машинства. На факултету тренутно студира укупно око 3000 студената, а дипломира око 400 годишње. Факултет има близу 400 запослених, од тога око 200 у настави. Факултет реализује програме образовања током читавог живота, као и друге програме стручног усавршавања ван оквира студијских програма, у складу са Законом о високом образовању и Статутом Машинског факултета

Машински Факултет је високошколска установа која обавља образовну, научну и истраживачку делатност у складу са Законом и Законом о научноистраживачкој делатности. Факултет обавља делатност високог образовања кроз академске и струковне студије у свом седишту и у складу са својом матичношћу, која произилази из акредитованих студијских програма (у области машинског инжењерства).

У оквиру делатности високог образовања Факултет обавља научноистраживачку, експертско-консултантску и издавачку делатност, а може обављати и друге послове којима се комерцијализују резултати научног и истраживачког рада. Факултет реализује програме образовања током читавог живота, као и друге програме стручног усавршавања ван оквира студијских програма, у складу са Законом и Статутом.

Делатност Факултета организује се и обавља у оквиру организационих јединица и то:

- Организационе јединице наставно-научне делатности
- Организационе јединице научноистраживачке и стручне делатности
- Организационе јединице ненаставних делатности
- Акредитоване организационе јединице

About faculty

Faculty of Mechanical Engineering, University of Belgrade is an institution of national importance and is the basis for the development of mechanical science and industry in Serbia. The oldest and largest educational and scientific institution in the country in the field of mechanical engineering. Faculty of Mechanical Engineering, University of Belgrade, performs basic, applied, and scientific research to improve education research in the areas of production engineering and computers applications, machinery (transport, construction and mining machinery), agricultural mechanical engineering, motor vehicles and trailers (transport, labor and special) effectiveness of mechanical systems, thermodynamics, thermal power, hydropower, railway engineering, shipbuilding, aviation, military mechanical engineering, weapons systems, and cosmic technology, process technology, automated management, plant design and factory plants, warehouses, transportation and process systems, industrial engineering, management, bioengineering, biomedical engineering, nanotechnology, food engineering, applied mechanics, applied fluid mechanics, theory of mechanisms and machines, general machine construction, combustion, applied theory of elasticity, feed materials, mechanical materials, tribology, welding, machine elements and design, applied mathematics, physics, electrical engineering, automatic processing data, labour and environment.

Faculty of Mechanical Engineering also participates in organizing of scientific conferences and seminars, cooperation with educational, scientific and other organizations at home and abroad.

Our insitution is also involved in performing teaching educational and research activities aimed at improving science and collaboration with industry and other organizations to solve basic, applied scientific problems, studies, expertise and other professional and scientific.

Inovacioni centar
mašinskog fakulteta u Beogradu

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O organizaciji

Inovacioni centar Mašinskog fakulteta u Beogradu je organizacija koja na originalan i sistematski način primenjuje sopstvene i tuđe naučne rezultate i savremene tehnološke procese radi poboljšanja postojećih ili stvaranja novih proizvoda, procesa i usluga. Dosadašnje aktivnosti Inovacionog centra obuhvataju izvođenje različitih projekata, kao i konsultantske poslove vezane za kontrolu kvaliteta, procese veštačenja, sertifikaciju proizvoda itd. U daljem radu računamo na konstantno usavršavanje svih postojećih timova i nabavku nove opreme, što će omogućiti dalji razvoj laboratorijskih centara čime se otvaraju mogućnosti za proširenje svih oblika saradnje, kao i učestvovanje u nacionalnim razvojnim projektima i programima međunarodne saradnje.

U skladu sa modernim zahtevima, uz vrhunski stručni kadar, obezbeđeni su odgovarajući prostor, oprema, internet komunikacija, laboratorije i druga sredstva neophodna za ostvarivanje programa i realizaciju projekata.

Inovacioni centar poseduje adekvatnu opremu za naučno-istraživački rad i rešavanje konkretnih razvojnih problema različitih privrednih delatnosti i organizacija, pre svega u sledećim oblastima:

- Mašinstvo i industrija softvera
- Materijali i hemijske tehnologije
- Informacione tehnologije
- Biotehnologija
- Energetika

Inovacioni centar je partner po izboru mnogih vodećih svetskih preduzeća, malih i srednjih preduzeća koji traže tehnološke izazove. Pomažemo preduzećima da podignu svoju vrednost kroz prilagođeni razvoj, dizajn, QA i konsultantske usluge.

About organization

Our main goal is application of scientific, technical and technological knowledge and invention in order to create and release new and improved products, processes or services. We are adept for various fields of research. Due to modern demands, we provided cutting edge equipment, laboratories and other means for our experts and specialists to use. Our activities include realisation of various projects, as well as consulting related to quality control, expertise, certification of products etc.

In the future, we reckon upon constant training and specialisation of our teams, acquisition of new equipment which will allow further development of our laboratory centers, extension of all aspects of cooperation and participation in national projects and programs of international cooperation. Our plan includes faster training of scientists who will be able to participate in scientific and development research. We have to continually improve our knowledge base, focusing on acquiring and use of the latest scientific results and technologies.

Realisation of our research will allow direct influence of knowledge in faster industry development and creation of innovative and attractive products, which will lead to improvement of quality and competitiveness of domestic products and services on the international market, as well as development of infrastructural systems in Serbia.

We possess equipment for scientific research and solutions for development problems in various branches of industry, primarily in the following fields:

- Mechanical industry and software design
- Materials and chemical technologies
- IT
- Biotechnology
- Energetics

Our facilities, equipment and other means for applied, developing and innovative research are based in the building of the Faculty of Mechanical Engineering, Belgrade University.

Operational Safety Centre at Bay Zoltan Nonprofit Ltd (BZN) ranked among the Top 50 Research Infrastructures in Hungary

About institute

The Bay Zoltan Nonprofit Ltd. for Applied Research (BZN) is a leading applied research institution in Hungary established by the government in 1993. BZN carries out research and development activities in three technical divisions characterized by market-like features. The aim of the divisions' innovative activity is to develop and adapt technologies, subsequently transferring them to the market with added value. The Engineering Division (BAY-ENG) locates in Miskolc and within this, the Department of Structural Integrity and Production Technologies and the Department of Mechanical Testing deal with problems related to the reliable and safe operation of different structures and components.

In order to integrate testing and engineering modeling opportunities related to the operational safety of engineering structures, components and vehicles **Operational Safety Centre** has been established. It includes a wide range of mechanical, non-destructive, and structural testing, as well as engineering simulation and virtualisation methods. The Centre is ranked among the **Top 50 Research Infrastructures in Hungary**.

The accredited **Mechanical Testing Laboratory**, which can be considered a uniquely well-equipped facility in Hungary, conducts standard and non-standard qualification testing of base materials and products and other tests related to product and technology development, with a wide variety of mechanical, composition and structural testing included. In addition, the MTL develops methods and procedures for material testing, and analyses failure processes of structural materials and complex failure cases.

The **Digital Reality and Engineering Simulation Laboratories** support the development of digital reality applications for education, training, work support, virtualization of industrial environments and research into driver assistance systems and also support the product- and technology development, offer expertise on the failure processes of engineering materials and operational safety issues. It integrates activities/capacities supported by up-to-date information technologies and advanced modelling tools, which leads over the whole development process in the virtual space. By means of up-to-date computer park and simulation software tools the optimisation of the production process and the product can be conducted, the differences between the real and test environment can be analysed, the realistic digital twin can be set up and the behaviour during the operation can be assessed.

The **Non-destructive Testing Laboratory** deals with the application of different non-destructive testing methods, as well as with the development of NDT methods, analysis of the effectiveness of the testing methods by the means of modeling and elaboration of testing plans.

One of the new profiles of the Centre is the study of *tribological processes*, including wear, surface fatigue, lubrication properties, friction, and the lifetime of contact surfaces of machine components and drivetrain components. The key equipments in the tool park are Optimol SRV5 for multifunction linear and rotary tribometer tests, Olympus DSX1000 for surface morphology, wear performance determination, AntonPaar MCR501 rheological analysis of lubricants, scanning electron microscopy JSM-IT700HR and sliding-rolling surface contact high cycle failure testing two-roller system.

Multi-engine driveline test bench is the other unique brand-new capability. Test bench is serving validation of drivelines from conventional to hybrid or electrically driven drivelines, as axles or transmission gearboxes, on the fields of passenger and commercial vehicles, truck, bus and agricultural ranges. Also capable to perform testing with the built-in electric motors. A wide range of test procedures can be performed like functional (lubrication, heat up performance or tribological testing, NVH) or extended durability testing (even up to 1000 hrs). Testing can be run with the full gearbox/axle environment, including cooling (driveline own or external forced air cooling). Input drive is having 250kW up to 7k Nm and two breaking motors are having 150kW and 14k Nm of each. Any input shaft direction (tilted in 2 directions) can be incorporated. Further on battery pack simulation energy source for electric drives planned in the near future, 200-800 V supply.

The latest investment is a *multiaxial and multibody test rig* that allows us to carry out multi-axial and multi-body physical simulation of static and fatigue loads, enabling unique, high-quality testing opportunities at national and international levels for R&D collaborations and industrial needs. The equipment consists of the following components: 5 hydraulic servo cylinders (2 x 25 kN, 2 x 40 kN, 1x 63 kN maximal tensional load), a freely variable frame system, a 5x8 m T-slot work table, a high-performance hydraulic power supply, a cooling unit, test control hardware units and software.

Thus, the Centre can provide special and complex services to industrial partners and is involved in international research and development projects focusing on the areas detailed above.