MODERN TRENDS IN MATERIAL ENGINEERING

PING 2019

PROCEEDINGS

10. - 13. 9. 2019

PILSEN, CZECH REPUBLIC

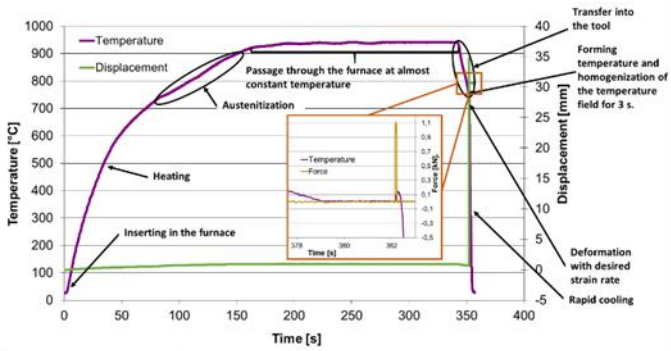
Regional Technological Institute
EXPERIMENTAL FORMING LABORATORY

The Experimental Forming Laboratory works on heat treatment and thermomechanical treatment of metals and on testing new concepts in physical simulation of metalworking leading to optimization and integration of manufacturing processes. This effort can lead to extraordinary properties in materials and to greater effectiveness of manufacturing technologies.

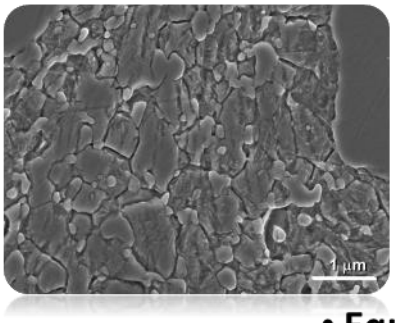
Unconventional thermomechanical treatment of steels and alloys

Development of new thermomechanical treatment sequences and processes for high-strength low-alloy steels and alloys.

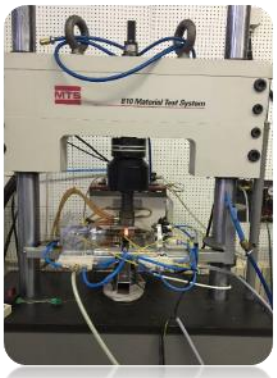
Sophisticated microstructures produced by means of unconventional metallurgical treatment for excellent strength and stress-strain characteristics.



Design of unconventional and unusual microstructures



Development of new metalworking processes is focused on creating unusual microstructures in ordinary materials. The new microstructures lead to enhanced properties, such as wear, corrosion, creep and fatigue resistance.



KEY EQUIPMENT

- **Thermomechanical simulator**
- **Equipment for developing incremental forming processes**
- **CNC cutting machine – waterjet and plasma cutting**
- **MEBW-60/2 electron beam welder**
- **Equipment for bending and brake bending of precision sheet metal parts**
- **FASTCAM SA-X2 high-speed camera**

Ing. Štěpán Jeníček
Head of Experimental forming laboratory
tel.: +420 377638761
e-mail: jeniceks@rti.zcu.cz

www.rti.zcu.cz

Proceedings PING 2019 - Modern trends in material engineering

Editors: Doc. Ing. Ludmila Kučerová, Ph.D.
Dr.-Ing. Hana Jirková, Ph.D.
Ing. Štěpán Jeníček

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Contacts

University of West Bohemia
Faculty of Mechanical Engineering – Regional Technological Institute – PING Conference
Univerzitní 8
306 14 Plzeň
Czech Republic
Phone: +420 377 638 762
E-mail:jeniceks@rti.zcu.cz

www.ping.zcu.cz

FACULTY OF MECHANICAL ENGINEERING
UNIVERSITY OF WEST BOHEMIA

REGIONAL TECHNOLOGICAL INSTITUTE

PING 2021

Fifth PING Conference

Modern trends in material engineering

7–10 September 2021

Pilsen, Czech Republic

Conference Focus

The conference will focus on recent trends and findings in the field of material engineering. The conference will cover metallography and microstructure analysis (light, electron microscopy, X-ray diffraction phase analysis), forming, heat treatment, additive manufacturing (3D printing), mechanical testing, defectoscopy, physical testing (DTA, dilatometry, etc.), modelling and simulation. The conference will provide a unique opportunity to share the latest information and knowledge and discuss them with other experts in the field.

Conference Topics

- Metal forming
- Heat treatment and thermomechanical processing of metals
- High-strength steels
- Non-ferrous metals
- Mechanical testing and thermophysical measurement
- Modelling (of processes and materials) and simulations in heat treatment and metal forming
- Use of microscopy and X-ray methods in research and in dealing with process issues
- Characterisation of microstructures produced by heat treatment and thermomechanical processing
- New techniques and methods in metallography
- Nanomaterials - not limited to mechanical engineering
- Additive manufacturing (3D print)

We look forward to meeting you at the PING 2021 Conference.

CONFERENCE THEMES, DEADLINES, CONFERENCE FEE, INSTRUCTIONS FOR AUTHORS, REGISTRATION, SUBMISSION OF ABSTRACTS, PAYMENT AND OTHER INFORMATION: WWW.PING.ZCU.CZ

Table of Content

Session: Mechanical testing and thermophysical measurement

Session: Microscopy

Session: Modelling and simulations in heat treatment and metal forming

Session: Nanotechnology and nanomaterials

Session: Non-ferrous metals

Dear reader,

I proudly present the abstracts collection of fourth conference PING 2019 – Modern Trends in Material Engineering. I wish to express my sincere thanks to all authors who have contributed to this conference and all who present their articles to the audience during the conference. I would also like to thank the editorial board members and all colleagues for their work.

In total of 60 abstracts represent the articles which deal with several topics, this time focused on mechanical testing, thermophysical measurement, heat and mechanical treatment, forming, ferrous/nonferrous metals, nanomaterials and nanotechnologies, microscopy and, last but not least, on additive manufacturing. It is a wide range of engineering topics and I hope our conference PING will be more and more attracting for high quality submissions and an ever-growing readership.

Next conference focusing on modern trends in material engineering will begin on 7th September 2021, and I look forward to seeing again a wide range of interesting topics. Now back to the PING 2019 - enjoy it!

Pavel Žlábek

Head of RTI laboratories

Additive manufacturing of maraging steel on low alloyed high strength TRIP steel

Corresponding author:

Ludmila Kučerová, skal@rti.zcu.cz, University of West Bohemia, Regional Technological Institute

Co-authors:

Štěpán Jeníček, Ivana Zetková

Abstract:

Hybrid parts were successfully produced by additive manufacturing of maraging steel 18Ni 300 grade on the top of low alloyed advanced high strength steel. High strength steel was alloyed by 0.2% C, 1.5% Al, 0.5% Si, 1.5% Mn and micro alloyed by 0.06% Nb (all in weight %). The steel was prepared in the form of bars either directly in as-forged and air cooled state or after two step heat treatment typical for TRIP (transformation induced plasticity) steels. Subsequent additive manufacturing of maraging steel was carried out by selective laser melting (SLM) in the EOS M290 machine using parameters recommended for tool steels by printer supplier. Suitable post processing heat treatments were applied to hybrid parts to relive residual stresses and to achieve desired mechanical properties. Hybrid parts were subjected either to solution annealing or to two step heat treatment with the second hold in the temperature region of bainitic transformation. The best combination of ultimate tensile strength of 860 MPa and total elongation of 19% was obtained for hybrid part where high strength steel underwent two step steel heat treatment prior to additive manufacturing and no post-processing was carried out after additive manufacturing. The joints were characterised by light and scanning electron microscopy, hardness measurement across the interface and tensile test of the joint area. Detail characterisation of interface area microstructure and local chemical composition was carried out.

Key words:

Selective laser melting, maraging steel, hybrid joints, high strength steel

Innovative manufacturing technology of components of machine from amorphous materials

Corresponding author:

Wirginia Pilarczyk, wirginia.pilarczyk@polsl.pl, Silesian University of Technology

Co-authors:

Aleksandra Małachowska, Andrzej Ambroziak

Abstract:

The presented invention is a technology of manufacturing amorphous elements with the use of selective laser melting (SLM). Iron-based bulk metallic glasses (BMGs) are a promising group of materials, which is not widely used due to problems with obtaining the necessary cooling rates in case of complex structures. The proposed technology is characterized by a small liquid metal pool (<100 μm) and thus allows to achieve a cooling speed of 104-106, which is much higher than those needed for amorphization. At the same time, the incremental character of process allows to obtain elements of almost any shape and size. However, the problem is the large thermal gradients, which in combination with the brittleness of most metallic glasses result in cracks or even delamination in the manufactured elements. In addition, there is heating of already manufactured layers by subsequent layers. Therefore, in order to obtain satisfactory results it was necessary to optimize such factors as: input material, thickness of sintered layer, laser speed and power, distance between individual exposures of the beam or scanning speed (laser beam movement). These parameters directly influence the energy density that is delivered to the sintered powder layer and which determines the structure, mechanical properties and quality of the surface.

Key words:

Additive manufacturing, selective laser melting, amorphous material, glass forming ability, powder

Effect of processing parameters on microstructure and properties of CuSn10P1 alloy fabricated by SLM

Corresponding author:

Marcin Polak, marcinp@imn.gliwice.pl, Łukasiewicz Research Network - Institute of Non-Ferrous Metals

Co-authors:

Adrian Radon, Lukasz Hawelek, Patryk Wlodarczyk, Malgorzata Kaminska, Malgorzata Osadnik, Barbara Juszczyk, Wojciech Burian, Aleksandra Kolano-Burian

Abstract:

The interest in Cu-Sn alloys is associated with excellent flexibility, wear and corrosion resistance, and high mechanical strength. CuSn10P1 alloy has the widest applications among Cu-Sn alloys and is widely used in the shaft sleeve, bearing, gears, valves, etc. The properties of this alloy are strongly depended to the manufacturing process. Usage of the traditional casting causes the intergranular segregation and crystallization of primary α-Cu phase in a coarse mesh dendritic structure. This, in turn, manifest itself in poor properties, limiting its uses in industry. According to that new manufacturing methods should be used to improve the properties of this alloy.

In this work, CuSn10P1 alloy was successfully produced using selective laser melting (SLM). The powder size was between 20-63 μm and its humidity during the process was lower than 5%. The four printing strategies were selected to investigate the impact of printing parameters on the microstructure and mechanical properties of the prints. The optimal processing conditions were chosen on the basis of optimization of laser power and scanning speed. The different process parameters result in the changes of the microstructure, especially porosity and the presence of microcracks. On the basis of the analysis of wavelength-dispersive X-ray spectroscopy, it was confirmed, that all chemical elements are evenly distributed after selective laser melting. The segregation of tin and copper can be also observed, however only under remelting of the same layer.

Key words:

Additive manufacturing, 3D printing, Cu-Sn alloys, selective laser melting

Residual stress investigation in additively manufactured samples

Corresponding author:

Jaroslav Vavřík, jvavrik@comtesfht.cz, COMTES FHT a.s.

Co-authors:

Josef Hodek

Abstract:

In the present study, additively manufactured (AM) samples were analysed by the Contour method in order to determine residual stresses. The Contour method is destructive and its big advantage is that there is no size limitation of the sample and this method is able to predict residual stress even in such depths where other methods are unable. Residual stresses were evaluated in three stainless steel samples (35x35x35 mm, 25x25x25 mm, 15x15x15 mm), which were prepared by the method of direct energy deposition (DED) using Insstek MX-600 AM machine. DED is the method where continuously flowing powder is completely melted by high power laser and after that, the powder/melt is rapidly solidified on the substrate. In order to protect from oxidation during the deposition, argon is used as a shielding gas that has fed continuously during the process of printing. The process of DED generates structures with a minimum amount of pores. Austenitic stainless steel 316L was chosen for this experiment because there is no presence of phase transformations during the deposition that reduces the complexity of the process. Evaluation of the Contour method was carried out based on the sectional surface area measured by Optical Precision Measuring Machine ATOS capsule scanner developed by GOM Company and analysis using FEM software MSC Marc.

Key words:

Contour method, additive manufacturing, residual stress, 316L stainless steel,

Heat treatment process effect on the fatigue properties of selected steels

Corresponding author:

Vladimír Chmelko, vladimir.chmelko@stuba.sk, Slovak University of Technology in Bratislava, Faculty of Mechanical Engineering

Co-authors:

Berta, I., Margetin, M.

Abstract:

Heat treatment of steels is a technological process used to increase the strength of steels. There is a wide variety of different heat treatment procedures. The choice of a suitable technological process depends mainly on the chemical composition and the target properties of the material being processed.

The relatively less explored area is the effect of heat treatment on the cyclic properties of steels. The paper will present the results of cyclic tests on two different steels. Cyclic properties of C55 steel will be analysed before and after heat treatment procedure. For high strength steel 34CrNiMo-6, the effect of the heat treatment process itself on the resulting cyclic loading properties will be analysed. Experimental results will be supported by microstructure analysis of investigated materials.

Key words:

Heat treatment, fatigue properties, steels

Ultra-low-cycle fatigue of pipeline steels

Corresponding author:

Abílio de Jesus, ajesus@fe.up.pt, Faculty of Engineering, University of Porto and INEGI - Institute of Science and Innovation in Mechanical and Industrial Engineering

Co-authors:

J. C. R. Pereira, A. A. Fernandes

Abstract:

Pipelines and piping components when subjected to extreme loading conditions (e.g. earthquakes, hurricanes, support settlements, industrial plant shutdown) undergo large plastic deformations, associated with widespread yielding, leading to fracture, either due to monotonic loading or ultra-low-cycle fatigue (ULCF). ULCF is neither satisfactorily understood nor conveniently investigated compared to the monotonic ductile or low-cycle fatigue damage mechanisms. Having in mind the existing gaps in the knowledge about the ULCF, the ULCF European project, coordinated by FEUP, aimed at developing innovative computational methodologies for the simulation of steel material fracture under both monotonic and ultra-low-cycle fatigue, based on a significant experimental program including small and large-scale tests. This presentation makes an overview of the main results of the project, which includes: i) Database of small-scale testing data covering the X52, X60, X65, X70 and X80 piping steel grades. Smooth and special notched specimens were tested under both monotonic and cyclic (LCF & ULCF) loading. Dedicated monotonic tests were performed to assess the anisotropic behaviour of some materials (X70/X80). Combined multiaxial loading conditions were also investigated. ii) Database of full-scale testing results covering same materials also tested under small-scale conditions was generated. Monotonic and ULCF tests of pipe components were performed. ULCF tests included buckled and dented pipes, elbows and straight pipes. iii) New constitutive models for both monotonic and ULCF loading were proposed. Besides the Barcelona model, alternative approaches were investigated. Further constitutive refinements of non-linear monotonic damage and enhanced anisotropic models, were also studied. iv) Developed constitutive models were calibrated and validated using experimentally derived testing data.

Key words:

ULCF project, constitutive models, numerical simulation, small-scale testing, large-scale testing, design rules

Design and fatigue testing under VHCF conditions

Corresponding author:

Luis Reis, luis.g.reis@tecnico.ulisboa.pt, IDMEC, Instituto Superior Tecnico, Universidade de Lisboa

Co-authors:

Pedro R. Costa, D. Montalvão, Manuel de Freitas

Abstract:

Fatigue damage has special relevance on the life span of mechanical components and structures, as it takes responsibility for the majority of the registered structural failures. Although its mechanisms have been the subject of continuous research, the growing need for greater lifespans forced the understanding of the behavior of materials under very high cycle loadings, also known as Very High Cycle Fatigue.

On the other hand the behavior of materials under multiaxial fatigue has been the subject of research and development, but not in the region of very high cycles, due to the inexistence of appropriate machinery to perform these tests. The authors of this work have already a large experience on the performance of multiaxial fatigue tests under axial/torsion loading under servo-hydraulic fatigue testing machines and on very high cycle fatigue tests.

In this work, a device designed to produce biaxial, axial/torsional loading fatigue testing using a single piezoelectric axial exciter is presented, as well as the instrumentation used on the preliminary testing of this device. The device is comprised of a horn and a specimen, which are both attached to the piezoelectric exciter. The steps taken towards the final geometry of the device, including special designed horn and specimen are presented.

Experimental testing of the developed device is carried out using thermographic imaging, strain measurements and vibration speeds, and indicates good behavior of the different tested specimens, from different type of materials.

Key words:

Fatigue testing, design, VHCF

Fatigue behavior of additive manufactured materials: an investigation into feedstock-process-structure-property-performance relationships

Corresponding author:

Nima Shamsaei, shamsaei@auburn.edu, Department of Mechanical Engineering, National Center for Additive Manufacturing Excellence (NCAME), Auburn University

Abstract:

The booming interest in additive manufacturing (AM) and its great potential has spurred industry to adopt this advanced technology. AM can produce net-shaped parts with complex geometries that are often impossible to fabricate through traditional subtractive methods. Additionally, AM has introduced the ability to fabricate internal geometries, functionally graded materials, and can generate assembled moving parts in one step. However, for these additively manufactured parts to be trusted in load-bearing and/or safety-critical applications, their structural integrity must be well understood, especially under cyclic loading. Bridging this gap is a complex undertaking, as there are many challenges specific to characterizing the behavior of additively manufactured parts. For example, the mechanical properties of AM laboratory specimens may not be representative of those associated with service parts; this is primarily due to differences in geometry/size, which can affect the thermal histories experienced during fabrication. The variation in thermal history affects the defects inherent to additively manufactured parts such as surface roughness, porosity, and lack of fusion between subsequent layers that can negatively impact the fatigue resistance. Because of these AM-specific challenges, the current global standards for mechanical testing methods, specimen design procedures, post-manufacturing treatments, etc., may need to be revised for additively manufactured parts. This presentation will provide an overview of the challenges facing the scientific community with regards to producing trustworthy additively manufactured service parts and demonstrate the need for establishing AM feedstock-process-structure-property-performance relationships.

Key words:

Fatigue behavior, additive manufacturing

Effects of hot forging on the shape and size of prior austenite grain in HS 6-5-2 high-speed steel

Corresponding author:

Soňa Benešová, sbenesov@kmm.zcu.cz, West Bohemia University

Co-authors:

Vojtěch Průcha, Vilém Veselý, Miloslav Kesl

Abstract:

Microstructure analysis was performed on rolled bars of high-speed steel after two and three forging cycles, each cycle comprising one upsetting and one drawing out operation. High-speed steels belong to difficult-to-form materials with a narrow forging temperature interval. Forging above the maximum forging temperature may lead to grain coarsening. Below the minimum forging temperature, deformation resistance of the material increases, and the workpiece may fail. Using numerical modelling, special forging dies were designed and effective strain distribution was calculated for an axial cross-section plane in specimens after two and three forging cycles. The purpose of the analysis was to identify the relationship between the amount of effective strain and the shape and size of austenite grain after forging. The size of prior austenite grains was measured using the linear intercept method which is based on the Snyder-Graff method. Grain shapes were characterized in terms of circularity, which is the difference between the shape in question and a circle. With increasing amount of strain, the grains in the material became finer, as undissolved carbides impeded grain growth. In as-received rolled condition, the austenite grain size was G9. After three forging cycles, it was smaller, G11 (the higher the number, the smaller the grains). Circularity characterizes the complexity of a grain shape. After deformation, strongly non-circular grains were found in the material, although a certain portion of grains retained their round shapes. This was reflected in greater variance of circularity after the forging cycles.

Key words:

High-speed steel, forging, austenite grain size, circularity

Influence of heat treatment on properties of SD251-PH1 composite produced by additive SLM technology

Corresponding author:

David Bricín, bricda@kmm.zcu.cz, University of West Bohemia

Co-authors:

Zdeněk Jansa, Josef Somr, Andrea Elmanová, Antonín Kříž

Abstract:

This study evaluates how heat treatment affects the structure and properties of the engineered composite material SD251-PH1. This material was formed by mixing two powder blends in a weight ratio of 90 wt. % WC-Co powder SD251 with 10 wt. % of a PH1 steel precipitation hardenable powder. Samples were prepared from this mixture on an additive device of the SLM type using parameters in which their structure was formed by different types of porosity. The printed samples were then divided into groups. Some of them were left and the rest were used for heat treatment based on the norm ASM 5659. Light and electron microscopy metallographic analysis together with X-ray diffraction analysis were then used to evaluate structural and phase changes in the volume of the prototype samples. These analyses were performed before and after heat treatment. The main attention was paid to changes in the phase composition of the samples. In addition, changes in the size and shape of the pores and tungsten carbide (WC) grains were studied. The metallographic analysis was supplemented by an evaluation of the changes in their mechanical properties and wear resistance. Vickers hardness measurements and the ball on disc test were used for this purpose. The experiments showed that the selected heat treatment processes precipitated new structural phases which differed from the original sample structure in terms of shape, size, chemical composition, and mechanical properties.

Key words:

SLM technology, heat treatment, WC-Co, porosity, phase transformation

Influence of chemical composition and parameters of heat treatment on the mechanical properties and microstructure of TRIP steels

Corresponding author:

Dagmar Bublíková, dagmar.bublikova@seznam.cz, University of West Bohemia, Regional Technological Institute

Co-authors:

Hana Jirková, Štěpán Jeníček, Jiří Vrtáček

Abstract:

Good mechanical properties of steels, in which appropriate heat treatment can produce mixed hardening structures, make them candidates for a broad range of applications, namely in the automotive industry. TRIP steels (in which transformation-induced plasticity operates) with a carbon content of approximately 0.2% are one such class of steels. Heat treatment of these steels comprises two stages. The first involve heating to the intercritical region between the A1 and A3. It is followed by cooling to a bainitic transformation temperature and holding. The resulting mixed microstructure consist of ferrite, bainite and retained austenite. Thanks to the presence of ferrite and retained austenite, the ultimate strength and elongation can reach 1500 MPa and 25-40%, respectively. The experiments presented in this paper were performed on two steels whose chemistries were specially adjusted to support formation of TRIP microstructure. The main difference between them was the level of chromium. Intercritical annealing was carried out on both steels. Aspects of interest included mainly the effect of the cooling rate above the bainitic transformation temperature and the holding time on mechanical properties and final microstructure. The heat treatment led to microstructures ferrite, bainite and retained austenite. The strength was under 1100 MPa and elongation reached 28%.

Key words:

TRIP steels, retained austenite, X-ray diffraction, intercritical annealing

Heat treatment strategies for hot-rolled and cold-rolled medium-Mn sheet steels

Corresponding author:

Adam Grajcar, adam.grajcar@polsl.pl, Silesian University of Technology

Co-authors:

Mateusz Morawiec, Adam Skowronek, Jakub Dykas

Abstract:

Heat treatment strategies for advanced high-strength medium-Mn sheet steels are addressed. A review of the available thermal cycles for cold-rolled and hot-rolled sheets are presented. The benefits from the intercritical annealing following hot-rolling or cold-rolling are emphasized. The examples of intercritical annealing for the hot-rolled sheets of initial martensitic microstructure are provided. The heat treatment was performed in a temperature range of 680-720°C for various times from 1 to 5 hours. The material used in the experiment was a medium-Mn steel containing 0.16% C, 4.7% Mn, 1.6% Al, 0.2% Mo, 0.2% Si. The scope of the research included dilatometer tests, hardness tests and microstructural characterization. The effects of temperature and time on a stabilization of retained austenite are assessed. Intercritical annealing performed at 700 and 680°C allowed forming some stable retained austenite in the microstructure. Moreover, some coiling simulations for hot-rolled strips are described.

Key words:

Medium-Mn steel, intercritical annealing, hot-rolled steel, retained austenite

Influence of higher partitioning temperatures on mechanical properties of heat treated high-strength steel alloyed with 1.3 % chromium

Corresponding author:

Tomáš Janda, jandat@rti.zcu.cz, University of West Bohemia, Regional Technological Institute

Co-authors:

Michal Peković, Kateřina Rubešová, Adam Stehlík

Abstract:

This paper deals with the innovative Quenching and partitioning (QP) heat treatment (HT) of low-alloyed chromium steel, and is especially focused on the higher temperatures of partitioning as well as longer holding times and its influence on mechanical properties of the material. As part of the experiment various HT, metallographic analysis, hardness measurement, X-ray diffraction phase analysis (to determine retained austenite content), tensile test and Charpy impact test were performed. In QP treated specimens the best combination of UTS and elongation was observed after quenching in 200 °C salt bath and partitioning at 250 °C for 30 minutes. This specimen showed the UTS above 1900 MPa, elongation of 14 % and also good impact toughness (34 J). Equally good values of impact toughness (36 J) were also observed in the specimens partitioned at 300 °C or 320 °C for holding times up to 30 minutes. On the other side longer partitioning times at the temperature of 320 °C affected the elongation and impact toughness negatively.

Key words:

QP process, high strength steel, retained austenite, mechanical properties, microstructure

Effect of chromium on bainite transformation and microstructural evolution in austempered unconventional steels 42SiCr and 42SiMn

Corresponding author:

Štěpán Jeníček, jeniceks@rti.zcu.cz, University of West Bohemia, Regional Technological Institute

Co-authors:

Ivan Vorel, Michal Peković, Adam Stehlík, Oldřich Kroupa

Abstract:

Enrichment of austenite with carbon in the course of austempering is a fundamental mechanism which leads to incomplete bainite transformation. Higher carbon content in untransformed austenite, together with the presence of silicon, is understood to lead to stabilization of austenite. As a result, austenite does not decompose and carbide precipitates do not form which are otherwise present in conventional bainitic microstructures. Although evidence of the beneficial effects of silicon and carbon on austenite stabilization in unconventional CFB steels is irrefutable, the present experiments showed that an addition of chromium plays a very important role in achieving incomplete bainite transformation. This paper deals with the effect of the chromium level on bainite transformation and microstructural evolution in unconventional steels 42SiCr and 42SiMn during austempering.

Key words:

Austempering, silicon, chromium, stability of untransformed austenite

Combination of press-hardening and isothermal holding in the treatment of high-strength steel

Corresponding author:

Hana Jirková, hstankov@rti.zcu.cz, University of West Bohemia, Regional Technological Institute

Co-authors:

Kateřina Opatová, Štěpán Jeníček, Ludmila Kučerová

Abstract:

Today, high-strength parts for the automotive industry are mainly produced by the press-hardening technology. In order to reduce costs, savings in production and optimal materials are sought. One option involves the use of high strength steels of various chemical compositions. Two high strength steels were studied in the present experiment. The first one was CMnSi steel, a typical low-alloy TRIP steel with a carbon content of 0.2 %; alloyed with manganese and silicon. The second one was 42SiCr steel, a member of the group of martensitic steels, with a carbon content of 0.42 %. In addition to manganese and silicon, this steel is also alloyed with chromium. The CMnSi steel has not proved to be very sensitive to changes in process parameters, achieving an ultimate tensile strength of more than 950 MPa and an elongation of over 10%. 42SiCr steel was found to respond to both heating temperature and deformation, showing different mechanical properties. With the right combination of process parameters, an ultimate tensile strength of over 2100 MPa was achieved.

Key words:

Press-hardening, AHSS, TRIP steel, Q-P process

Effect of Mn addition on serrated plastic flow behaviour in high-strength multiphase steels with retained austenite

Corresponding author:

Aleksandra Kozłowska, aleksandra.kozlowska@polsl.pl, Silesian University of Technology

Co-authors:

Barbara Grzegorczyk, Marcin Staszuk, Adam Grajcar

Abstract:

The effect of manganese addition (from 3 to 5%) on the serrated plastic flow behavior in medium manganese TRIP steels was investigated in static tensile tests performed in a temperature range of 20-200°C. The Portevin-Le Chatelier (PLC) effect was observed in a steel containing the higher Mn content. The effect of deformation temperature on the critical strain for the serrated flow was noted. The relationships between the manganese content, deformation temperature, mechanical properties and the appearance of serrated flow were characterized.

Key words:

Medium-Mn steel, Portevin–Le Chatelier phenomenon, influence of manganese content, advanced high-strength steel

Material challenges of steam turbine blades operated in wet steam region - part 1

Corresponding author:

Jiří Kučera, kuceraj@kke.zcu.cz, University of West Bohemia, Department of Power System Engineering

Abstract:

Condensing tails of almost all steam turbines operate in wet steam region. The impacts of water droplets on material of the steam turbine moving blades are causing the erosion of the material. The situation is even worse for steam turbines which already have saturated or just slightly superheated steam at their high pressure inlet. Such turbines are used not only in nuclear power plants, but also in concentrated solar thermal power plants (CSP) and in waste-to-energy power plants (WtE). The process of moisture generation inside of the steam turbine will be described so as the mechanics of impacts of the water droplets on the material of the steam turbine moving blades. As to avoid or at least limit the erosive potential of the droplets impacts on the material of the steam turbine moving blades, various types of active and passive protective measures could be taken. These measures will be presented in detail. As to balance the power output fluctuations of currently build renewable power plants, the fossil power plants are currently often operated with decreased load. Such operation may then induce backward flow in last turbine stage, which may subsequently cause severe dangerous erosion on outlets of last stage blades.

Key words:

Wet steam, blade erosion, protective measures

Effect of soaking temperature on the microstructure and mechanical properties of heat treated Al-Si-Nb TRIP steel

Corresponding author:

Ludmila Kučerová, skal@rti.zcu.cz, University of West Bohemia, Regional Technological Institute

Co-authors:

Karolína Burdová, Adam Stehlík

Abstract:

Two-step heat treatment with bainitic hold at 425 °C was applied to low alloyed high strength steel with partial substitution of silicon by aluminium. The steel was further micro-alloyed by niobium. Various soaking temperatures in the range of 750-1250 °C were used to analyse the effect of soaking hold on mechanical properties and microstructure of the steel. According to calculations in JMatPro, the temperatures below 900 °C should lie in an intercritical (tow phase) region, while the temperature of 900 °C should be the first one to ensure full austenitization of this steel. To dissolve different portion of niobium into solid solution, higher soaking temperatures were also used. Tensile strengths of 780-1069 MPa and total elongation of 22-46 %.

Key words:

Heat treatment, TRIP steel, retained austenite

Stabilization of austenitic stainless steel used in nuclear industry – project introduction

Corresponding author:

Josef Mach, machj@rti.zcu.cz, University of West Bohemia, Regional Technological Institute

Co-authors:

Jiří Vrtáček, Kateřina Opatová

Abstract:

Austenitic stainless steels used for the production of primary circuit components in nuclear engineering must exhibit not only good corrosion resistance but also adequate mechanical properties at elevated temperatures. The main problem with these steels is their susceptibility to intergranular embrittlement when exposed to elevated temperatures in the range of 350 °C to 750 °C. Higher temperatures triggers the precipitation of chromium carbides at the grain boundaries, causing a local decrease in chromium content and so intergranular corrosion of the steel. Therefore such steel must be stabilized by addition of titanium or niobium and appropriate heat treatment (solution annealing and stabilization). To define and describe the principles taking place in the stabilization annealing of 18/10 austenitic stainless steel stabilized by titan an experiment was proposed. This experiment includes various modes of heat treatment (with a range of different temperatures and holding times) as well as different parameters of previous processing. The effect of these parameters on the microstructure and its mechanical properties will be investigated in cooperation with ŠKODA JS, a.s. under the project TJ02000274. The aim of the project is to achieve required mechanical properties, especially to increase the hot yield strength value and contribute to shortening the stabilization process. Besides a hot tensile test (at 350 °C), a metallographic analysis will be carried out focusing on the precipitation of the phases arising during the annealing. Using image analysis the distribution, size and shape of the particles will be evaluated. In addition to light microscopy, scanning electron microscopy (SEM) will also be used.

Key words:

Austenitic stainless steel, stabilization annealing, hot tensile test, precipitation

Evolution of microstructure and texture in FeCoCr(Al, Mn)0.25 magnetic high entropy alloy during thermomechanical processing and its mechanical properties

Corresponding author:

Zaid Ahmed, zaid442@gmail.com, University of West Bohemia, Regional Technological Institute

Co-authors:

Dan Sathiaraj, Satheesh Kumar, Arout Chelvane, Jens Freudenberger, Ludmila Kučerová

Abstract:

Since last decade, HEAs have gained tremendous importance due to its superior mechanical and functional properties when compared to conventional alloys. Among the different functional alloys FCC structured FeCoCr(Al, Mn)0.25 alloy possessing high magnetic saturation, high Curie temperature, low coercivity coupled with excellent tensile ductility is introduced recently. In this study, the cast and homogenized FeCoCr(Al, Mn)0.25 alloy is thermomechanically processed by cold rolling (93% reduction) and subsequent annealing at varying temperatures (800C, 900C, 1000C and 1100C for 1hr). The effect of thermomechanical processing conditions on the microstructural evolution is characterized by Electron backscattered diffraction (EBSD) studies and correlation is established between mechanical properties and evolution of microstructure and crystallographic texture.

Key words:

Magnetic high entropy alloy, thermomechancial processing, electron backscattered diffraction (EBSD), microstructure and texture

Coiling simulations of medium-Mn sheet steels using dilatometry

Corresponding author:

Mateusz Morawiec, mateusz.morawiec@polsl.pl, Politechnika Śląska

Co-authors:

A. Skowronek, W. Pakieła, A. Grajcar

Abstract:

The work presents the results of coiling simulations of two medium manganese steels containing 3 and 5% Mn. The steels were subjected to the heat treatment including an austenitization at 1000°C for 300s and next isothermal holding at temperatures of 750, 700, 650 and 500°C for duration of 5 hours. The results of dilatometric analysis showed that in case of the 3Mn steel the ferritic transformation occured during the isothermal holding at 750 and 700°C. The amount of ferrite created during this step at 750°C was smaller compared to 700°C. Lowering the temperature to 650°C led to a transformation lack during the holding time. At 500°C a bainitic transformation occurred. Increasing the manganese content resulted in prolonging the incubation time before any transformations. For the 5Mn steel for all isothermal holding temperatures no transformation occurred within 5 hours. The conclusion was that manganese shifted significantly the ferritic and bainitic regions to longer times.

Key words:

Medium-Mn steels, dilatometric analysis, phase transformation kinetic, AHSS

Induction hardening of steels with use of the device for incremental forming of round bars HDQT-R 30-12

Corresponding author:

Michal Peković, pekovicm@rti.zcu.cz, University of West Bohemia, Regional Technological Institute

Co-authors:

Jiří Vrtáček, Tomáš Janda, Julie Volkmannová

Abstract:

Induction hardening technology is mainly used for processing parts where high hardness, as well as wear-resistance and ductile core, is required. Normally induction hardening is used for spur gears, wind turbine rings, and bearings. Innovative induction hardening processes are also developed for complex automotive components such as camshafts and crankshafts. In this process, steel is heated by passing high-frequency alternating current through a coil which is considered as the primary winding of the transformer. The area where heat-treated material lies or passing through is considered as a short circuit secondary winding. Device for incremental forming of round bars HDQT-R 30-12 is equipped with such heat treatment modules which can be used for heat treatment after rolling of rods or even without rolling. Heating of steel bars is provided by five induction coils, which can heat the material faster than the chamber furnace, and there is less oxidation of the material surface. This paper shows the microstructural and hardness results from testing 42CrMo4 steel, 13CrMo4 steel, and S235JR steel after heating at different inductor coil power settings with subsequent hardening into the water bath.

Key words:

Induction hardening, quenching, AHSS, hardness

Influence of temperature and speed of the laser head on the final structure surface hardened steel ČSN 12050 (EN 10083-2 steel 1.1191)

Corresponding author:

Pavel Peukert, Pavel.Peukert@vuts.cz, VÚTS, a.s.

Co-authors:

Martin Švec

Abstract:

Laser technologies are listed as unconventional methods of machining and heat treatment, which allows many advantages. In the area of heat treatment the laser technology allows a wide range of surface hardening. It provides a very fast and effective approach where the region of influence of the material is quit narrow. It is also possible to hardening parts and materials which were not possible to process with the conventional processes. To get the required depth and quality of the hardened layer it is necessary to set up properly the laser process parameters (temperature in the process area, feed rate of the laser head, etc.), which varies for different materials. The paper presents a test for optimal process parameters for surface hardening of the material ČSN 12050 (EN 10083-2 steel 1.1191). The surface structure for temperatures of 900, 1100, 1200 and 1300°C and laser head feed rates of 0.003, 0.005 and 0.007 m/s were tested. Best results were obtained for a temperature of 1300°C and a feed rates of 0.003 m/s.

Key words:

Laser, heat treatment, surface hardening, unconventional methods

The influence of hot forging on the size and frequency of carbides in HS 6-5-2

Corresponding author:

Vojtěch Průcha, vprucha@kmm.zcu.cz, University of West Bohemia, Department of Material Science and Technology

Co-authors:

Soňa Benešová, Vilém Veselý, Miloslav Kesl

Abstract:

This paper follows on from a paper entitled “Effects of hot forging on the shape and size of prior austenite grain in HS 6-5-2 high-speed steel” which was devoted to a microstructure analysis of slugs from rolled bars of a high-speed steel after two and three forging cycles, each cycle comprising one upsetting and one drawing out operation, and explored the shape and size of prior austenite grains. This paper therefore explores the volume fraction and density of carbides of different sizes in relation to locations within a forged workpiece. The first location was the centre of a specimen with the largest strain $\varepsilon ef = 8.1$ (after two forging cycles) and $\varepsilon ef = 9.9$ (after three forging cycles). Another location was at the periphery of the specimen, with a strain of $\varepsilon ef = 1.6$ after two forging cycles and $\varepsilon ef = 3.2$ after three cycles. Micrographs of carbide particles were taken using a scanning electron microscope and examined with NIS Elements image analysis software. The majority of carbides were sized between 0.2 and 2 μm. Larger particles were rare. The carbides which are less than 1 μm in size do not shrink in response to increasing strain and their quantity does not change appreciably. Carbides with a size of 1-2 μm show a different behaviour. In the central region of specimens, where strain is the largest, their amounts are much larger than in less-worked regions. The percentage of carbides in the matrix is larger in the heavily-worked region. The 1-2 μm carbides are probably products of carbide dissolution during forging and subsequent reprecipitation from austenite. Earlier investigations (reported in the above-mentioned paper) revealed that with increasing strain austenite grains become finer and less circular, and therefore the aggregate grain boundary area expands. Precipitation of carbides, which reduces the surface energy of grain boundaries, is thus favourable in terms of energy.

Key words:

HS 6-5-2, forging, size of carbides, effective strain

Effects of deformation on the behaviour of chromium carbides in tool steel studied by use of semi-solid forming

Corresponding author:

Kateřina Rubešová, krubesov@rti.zcu.cz, University of West Bohemia, Regional Technological Institute

Co-authors:

Michal Peković, Hana Jirková, Martin Bystrianský

Abstract:

Induction hardening technology is mainly used for processing parts where high hardness, although conventional treatment of tool steels is ordinarily used in industrial practice, engineers continue to seek new procedures to rid tool steels of objectionable primary sharp-edged chromium carbides, which impair toughness. Fortunately, research into metal forming yielded new methods of modifying the microstructure of hypereutectoid steels. Using these methods, mechanical properties can be improved by virtue of eliminating objectionable sharp-edged carbides. These carbides resist dissolution and their size and shape make them undesirable microstructural constituents. Although they do improve wear resistance of the matrix, they also impair toughness and may act as stress concentrators. The microstructures produced by a sequence involving semi-solid processing and subsequent forming operations were different from conventional semi-solid-processed microstructures. In the former microstructures, the prior carbide network was broken up, dispersed, and became a strengthening constituent. Brittleness which plagues materials with prominent carbide networks was thus removed.

The experimental material used in this study was X210Cr12 tool steel. Two semi-solid processing temperatures were used: 1240°C and 1260°C. There were two holding times: 30 minutes and 60 minutes. Another variable was the number of reductions. The resulting microstructures were examined with respect to individual sequences and reductions applied. Detailed microstructure analysis was carried out using a scanning electron microscope (SEM). Chemical compositions of carbides were determined by means of EDS (Energy Dispersive X-ray Spectroscopy). Microhardness was measured in order to gather comprehensive materials data. The purpose of the study was to identify trends, if any, in microstructural property evolution in response to the above-described processing sequence.

Key words:

Semi-solid processing, primary chromium carbides, tool steel, carbide refinement

Material challenges of steam turbine blades operated in wet steam region - part 2

Corresponding author:

Jakub Vlasák, jakub.vlasak@doosan.com, Doosan Škoda Power

Abstract:

Water droplet erosion of the steam turbine blades is one of the serious problems affecting lifetime of steam turbines. Last stage blades operated in wet steam region are exposed to erosion degradation which causes serious problems affecting lifetime of steam turbines. It is crucial understand an erosion process and testing and modelling of the erosion resistance of various materials has key importance in choice of proper materials for steam turbine blades (steels and Ti alloys). Suitably chosen material or proper surface treatment of the material can minimise risk of damage and increase lifetime of the steam turbine. Doosan Škoda Power disposes with unique erosion rig providing close simulation of liquid droplet erosion process. Based on the experimental testing of erosion resistance of various materials, erosion model providing prediction of the material volume loss of the blades operated in wet steam has been created. The erosion model is used to analyse the erosion damage prediction and lifetime estimation of the last stage blades. Doosan Škoda Power is focused on development and testing of passive erosion protection as a laser hardening, Physical and chemical vapour deposition, stellite laser cladding.

Key words:

Water droplet erosion, erosion protection, blade materials

Rolling of ingots of third-generation high-strength steels into sheets

Corresponding author:

Jiří Vrtáček, vrtacekj@rti.zcu.cz, University of West Bohemia, Regional Technological Institute

Co-authors:

Hana Jirková, Michal Peković, Ladislav Tříska

Abstract:

One of the essential branches of today's engineering production involves production of sheet stock by rolling. The majority of steel sheet stock is used in the automotive industry. In recent decades, this sector has been striving to reduce vehicle emissions. One of available solutions involves the use of advanced high-strength steels whose chemical composition and strengthening mechanisms make it possible to build the car body with thinner sheet blanks than before. Two advanced high-strength steels containing 0.2 wt. % carbon and additions of manganese, silicon and different levels of aluminium were used for rolling trials in which ingots were converted into 1.8 mm sheet by combined hot and cold rolling. This procedure was found to produce strengths in excess of 1000 MPa combined elongation of more than 15%.

Key words:

Hot and cold rolling, high strength steels, multiphase microstructure

The potential of application of Ni-layer for enhancement of utility properties of freight wagons

Corresponding author:

Zuzana Andršová, zuzana.andrsova1@tul.cz, Technical university of Liberec

Co-authors:

Pavel Kejzlar, Totka Bakalova, Michal Petrů, Petr Podzimek

Abstract:

The construction of 4-axled freight wagons used for transportation of bulk materials is limited with respect of minimal angle allowing emptying the bulk cargo and limited lifetime caused by abrasion caused by intensive wear between the wagon wall and transported cargo. A potential of application of protective chemically-deposited Ni-layer was evaluated based on tribological testing.

Key words:

Railway freight wagons, wear resistance, surface treatment

Small punch testing of Fe-Al based alloys with Ti and Nb additions

Corresponding author:

Petr Dymáček, pdymacek@ipm.cz, Institute of Physics of Materials of Czech Academy of Sciences

Co-authors:

Ferdinand Dobeš, Milan Jarý, Yvonna Jirásková, Naděžda Pizúrová, Martin Friák

Abstract:

Three Fe-Al-based alloys, a binary with 22 at. % of Al, a ternary with 22 at. % of Al and 7 at. % of Ti and a quaternary with 22 at. % of Al, 4 at. % of Ti and 4 at. % of Nb prepared by arc melting to small button type ingots were studied by small punch test and small punch creep test in order to obtain the high temperature tensile and creep properties. Evaluation of the results shows a significantly improved strength at high temperatures and creep resistance of the ternary and quaternary alloys compared to the binary alloy. The observation of the punched discs fracture surfaces related to the initial microstructure also helps to better understanding of the deformation and fracture behavior of these alloys at high temperatures.

Key words:

Small punch test; intermetallics; iron aluminide, creep

Optimization of test specimen dimensions for thermal power station exposure device

Corresponding author:

Eva Chvostová, eva.chvostova@gmail.com, COMTES FHT a.s.

Co-authors:

Pavel Konopík, Ladislav Horváth

Abstract:

Degradation of metallic materials can decrease mechanical properties of metal constructions and components in thermal power plants during their operation and consequently lead to loss of safety and reliability. It is difficult to remove material from the pressure system of the equipment being operated. Therefore, the effort is to design, produce and subsequently install exposure channels, which will allow to remove and evaluate samples of exposed material without intervention into the pressure system. The exposure device for pressures and steam temperature in supercritical blocks, which would contain sufficient test material to produce conventional test specimens, is unrealistic in size, energy and economics. The way is to optimize the dimensions of the exposure device according to the miniaturized test specimens, which, in addition to the tensile test and the structural evaluation, can also carry out other required tests, such as bending impact tests with transition temperature, fracture toughness and fatigue tests. This paper deals with optimization of test specimens for the internal dimensions of the exposure device and shows the applicability of small sample methodologies for selected materials.

Key words:

Exposure device, miniaturized test specimens, material degradation

The effect of mechanical surface pre-treatment on the strength of the adhesive joint of high strength sheets

Corresponding author:

Pavel Kejzlar, pavel.kejzlar@tul.cz, Technical University of Liberec

Co-authors:

Lukáš Voleský, Tomáš Pilvousek

Abstract:

Nowadays, in the car body parts production, the quenching is often replaced by adhesive joints. The adhesive joints have a lot of advantages – they allow to keep the protective layer, enable to join different material and prevent from the formation of heat affected zones. With respect to passenger's passive safety, plenty of car body parts are manufactured of high strength steel sheets. The body parts are hot-formed at a temperature of 900 °C to the desired shape followed by subsequent rapid quenching to achieve the required strength. The sheets are covered with an AlSi 60/60 layer which should protect them from high-temperature oxidation during the forming process. However, brittle intermetallic interlayers form during the high-temperature treatment due to the reaction of iron from the substrate with Al/Si from the protective cover, which negatively affects the final strength of adhesion joint. The paper deals with the comparison of different possible ways of removing the layer on the final strength.

Key words:

Adhesive joint, cohesion, strength

The experimental investigation of behaviour of expanded polystyrene (EPS)

Corresponding author:

Omid Khalaj, khalaj@rti.zcu.cz, University of West Bohemia, Regional Technological Institute

Co-authors:

Seyed Mohammad Amin Ghotbi Siabil, Seyed Naser Moghaddas Tafreshi, Miloslav Kepka, Tomáš Kavalir, Michal Křížek, Štěpán Jeníček

Abstract:

Low-strength substrates and anthropogenic soils are always an issue in civil engineering. Based on the soil layer types, several methods could be used to improve the basic/foundation layer however it would be difficult to make sure if the specified requirements are achieved. Nowadays, Expandable Polystyrene (EPS) as a lightweight material found as a substitution for traditional methods like soil replacement, soil mixing, using piles driving and other treatment techniques. This paper will demonstrate the static properties of EPS foams in a view point of construction material which will be a key for the future study of these materials. A series of compression tests were carried out on different types of EPS foam to study the effect of EPS geofoam density on the mechanical behaviour of these materials.

Key words:

Expanded Polystyrene (EPS), Geofoam, Strain rate, Uniaxial loading

Flash pulse phase thermography for a paint thickness determination

Corresponding author:

Lukáš Muzika, muzika@ntc.zcu.cz, University of West Bohemia, New Technologies - Research Centre

Co-authors:

Michal Švantner

Abstract:

The contribution describes a fast contactless measurement of a paint thickness non-uniformity using flash pulse thermography. Specimens sprayed by a paint were thermally excited by a flash lamp and temperature responses were recorded by an infrared camera. The recorded sequences were post-processed with Fast Fourier Transform to obtain phase angles. Differences in the resulting images showed phase differences which corresponded to a paint thickness non-uniformity. Furthermore, the phases were correlated with the thickness by means of calibration curve so that the paint thickness could be determined with flash pulse phase thermography measurement. The method showed a promising potential in the contactless evaluation of the paint thickness. Average error of the thickness determination was less than 10 % for samples with paint thickness from 41 to 74 μm on AISI 304 substrate. Advantages, disadvantages and limitations of described method were discussed.

Key words:

IRNDT, flash pulse thermography, thickness measurement, quality control

Characterization of Low Cycle Fatigue Parameters of Rotor Steel using Sub-sized Specimens

Corresponding author:

Radek Procházka, radek.pro.rp@gmail.com, COMTES FHT a.s.

Co-authors:

Pavel Konopík

Abstract:

The paper is dealing with strain controlled cyclic testing method employing a novel strain-control technique based on digital image correlation (DIC) in low-cycle fatigue (LCF) region. The cyclic behaviour of 22CrMoNiWV 8-8 rotor steel was investigated on sub-sized round specimens with a diameter of 2 mm in gage length and total length of 20 mm. These results were compared with results obtained using conventional specimens designed in accordance with the ASTM E606 standard. The attention was paid to confirm the suitability of the proposed sub-sized geometry, testing set up and procedure. The test procedure and results obtained enabled to record hysteresis loops, construct Manson-Coffin curves and obtain cyclic material properties in LCF region.

Key words:

Low cycle fatigue, sub-sized specimen, digital image correlation

Static and dynamic testing of a bogie

Corresponding author:

Jan Tittel, tittejan@rti.zcu.cz, University of West Bohemia, Regional Technological Institute

Co-authors:

Miloslav Kepka, Petr Heller

Abstract:

The development process of railway bogie frames consists of three stages. The first stage involves stress calculations, the second stage comprises static and fatigue tests and the third one is focused on validating fatigue life data by stress monitoring during test runs on an actual track. The aim of this research is static and dynamic testing of a functional bogie model by hydraulic cylinders and subsequent evaluation of measured values. The load is determined according to the requirements specified in CSN EN 13749, Railway applications – Wheelsets and bogies – Method of specifying the structural requirements of bogie frames. In the fatigue test, the loads are composed of the static load, the quasi-static load, and the dynamic load. The bogie frame is a weldment made of S355 steel sheets, which has two transoms and two side rails ending with suspension brackets. It should be noted that the fatigue strength of a welded frame under dynamic loading is limited by the resilience of the welded joints. Attention is therefore paid to analyzing these joints. The development experience derived from this new bogie can be used to optimize the production of rolling stock. In the present experiments, the frame was examined using NDT to detect possible defects.

Key words:

Fatique, durability, testing, bogie frame, strain gauge, NDT

Microhardness measurement on heterogeneous joints

Corresponding author:

Milan Vnouček, milan.vnoucek@skoda-js.cz, Škoda JS a.s.

Abstract:

The paper deals with measurement of microhardness on heterogeneous welds using automatic hardness tester. The hardness is measured in the welded and heat affected area of the sample. This procedure is confronted with measurement on a homogeneous material with known forming directions.

Key words:

Microhardness, heterogeneous joints, automatic micro hardness tester

Intermetallic phases in 3D printed INCONEL 718

Corresponding author:

Dagmar Jandová, jandova@ntc.zcu.cz, University of West Bohemia, New Technologies - Research Centre

Abstract:

Microstructure of 3D printed INCONEL alloy consists of elongated austenitic grains with high density of precipitates. Three types of intermetallic phases, all with the Ni3X stoichiometry, were identified using transmission electron microscopy and energy dispersive X-ray microanalysis. Fine equiaxed gamma' and disc-shape gamma'' particles were spread within grains, while coarse plate-like delta phase pined grain boundaries. The metastable gamma', gamma'' phases and equilibrium delta phase can be represented as Ni3(Al,Ti) with the L12, Ni3(Nb,Al,Ti) with the DO22 and Ni3Nb with DOa unit cell respectively. The coherent gamma' and gamma'' phases nucleate independently of one another; Al and Ti atoms in solid solution promote gamma' precipitation, while Nb increases density of gamma'' phase. The incoherent delta phase forms at grain boundaries as a transformation product of gamma'' during 3D printing process and/or subsequent heat treatment. The both gamma' and gamma'' phases contribute to precipitation strengthening of the alloy. Delta phase stabilizes grain size and improve strength, however its uncontrolled growth can deteriorate stress rupture properties.

Key words:

Inconel 718, intermetallic phase, precipitation, TEM

Methodology for observation of maraging tool steel after 3D printing using FIB and STEM mode

Corresponding author:

Kateřina Opatová, opatovak@rti.zcu.cz, University of West Bohemia, Regional Technological Institute

Co-authors:

Ludmila Kučerová, Ivana Zetková

Abstract:

The components of the maraging tool steel produced by 3D printing are further heat-treated after printing. It is a stress relief annealing and precipitation hardening since it is martensitic precipitation-hardenable steel. During this process, in the steel microstructure, precipitates of Ni3Ti and Fe2Mo or Fe7Mo are formed, which significantly contribute to an increase in ultimate tensile strength, hardness, and toughness. To understand the precipitation processes, it is necessary to describe the particles in detail. However, they are very small in size and cannot be examined properly by a light microscope (LM) or by scanning electron microscope (SEM). A possible way to investigate and describe these precipitates is to produce a thin lamella using a focused ion beam (FIB) in the electron microscope chamber, where scanning transmission electron microscopy (STEM) is subsequently used for observation. A lamella was prepared from the DMLS (Direct Metal Laser Sintering) printed part by an ion beam for observation in STEM mode. The experiment took place at the Zeiss AURIGA scanning electron microscope, equipped with an ion gun and also provided with STEM capabilities for thin samples. The lamella preparation methodology was gradually optimized to achieve sufficient resolution during observation of these very fine microstructures produced by 3D printing.

Key words:

FIB, STEM, maraging steel, 3D printing

TEM and SEM investigation of AZO thin film microstructure

Corresponding author:

Petra Šotová, sotova@ntc.zcu.cz, University of West Bohemia, New Technologies - Research Centre

Co-authors:

Petr Novák, Rostislav Medlín

Abstract:

The aim of this work is describing of structure of sputtered transparent conductive aluminium-doped zinc oxide (AZO) thin films. The main attention was focused on their lateral size and orientation of the grains. The structual properties of the samples were studied by scanning electron microscope (SEM) and localy also by transmission electron microscope (TEM). The SEM analysis was used for investigation of surface morphology. Digital Micrograph and NIS-Elements were used to define the grain boundaries, which strongly affects the electrical properties. The TEM analysis of cross-section reveal that the sputtered films have a columnar structure whose lateral size increases with distance from the substrate. There were also calculated the interplanar spacing for each grain in HR-TEM images. In this work there were also the angles between the grains and substrate measured, so based on data we can estimate dependancy on the size of the angle. The data suggest that planes with a low angle of inclination from the substrate grow to the surface and outgrow the planes with a high angle of inclination. The low-oxygen AZO film was studied for the quantity of dislocations, according to the choosen HR-TEM image the dislocation density was about 10^16 nm^(-2). These data will be furtherly exploited in future research.

Key words:

Thin film, AZO, microstructure, SEM, TEM

Design and optimization of a closed die forging of nickel-based superalloy turbine blade

Corresponding author:

Jakub Kotous, jkotous@comtesfht.cz, COMTES FHT a.s.

Co-authors:

Václav Kubec, Pavel Salvetr, Michal Duchek, Miroslav Majer

Abstract:

The nickel-based superalloys belong to widely used materials for most demanding industrial applications. The design and the experimental verification of manufacturing technology of NIMONIC 80A turbine blade is presented in this paper. A finite element (FEM) simulation was exploited for the closed die forging technology optimization. Based on the precision material model and boundary conditions, the deformation behaviour in the range of hot working temperatures was studied. The process conditions including the strain rates were preset according to the industrial scale practise. Based on the FEM simulation results the necessary tools were manufactured and the experimental closed die forging of turbine blades was performed. Subsequently, a heat treatment of forged blades was carried out. The minimum of 1300 MPa tensile strength was achieved. A metallographic survey was carried out to verify the structure homogenity.

Key words:

NIMONIC 80A, turbine blade, FEM simulation, closed die forging

Optimization of workability technological testing for open-die forging

Corresponding author:

Jakub Kotous, jkotous@comtesfht.cz, COMTES FHT a.s.

Co-authors:

Václav Kubec, Michal Duchek

Abstract:

The valid technology design of open-die forging of alloys with poor workability always presents a challenge. A method of a fast designation of open-die forging conditions is described in this paper. The simplified forging test was considered to assess the limit states during the open-die forging. As such, it should be employed in industrial scale foundries. A V-shaped testing die was designed using the finite element (FEM) simulation. The V-shaped geometry is convenient in terms of strain evaluation. A rectangular steel block was tested in a wide range of working temperatures. Based on the test results the limit states can be designated. Thus, the risk of material failure can be avoided or minimized. Experimental test results further serves for the FEM simulation validation.

Key words:

Open die forging, workability, technological testing, FEM simulation

CFD simulation of the multiphase heat transfer during the quenching process

Corresponding author:

Jan Novosád, jan.novosad@vuts.cz, VÚTS, a.s

Co-authors:

Pavel Peukert, Norbert Pomp, Pavel Klouček

Abstract:

The paper presents the results of the CFD simulation of quenching process for the ring shape sample. The aim of the work is to develop and validate the methodology for multiphase CFD simulation including the boiling during the quenching process. CFD simulation is provided in ANSYS Fluent. The Lee model is used for modelling the phase change during the quenching process. The first step consider the simulation of cooling of the ring sample when the correct model parameters will be found. Validation of results is performed by comparison with experimental data. Experimental was realized inside the own designed quenching bath device filled with quenching polymer. The general description of the experimental setup is included in the paper. The CFD results are cooling curves, i.e. variation of solid temperature on time. The Lee model parameters especially the evaporation frequency was tuned. Thin polymer film on the solid surface was considered to bring the results closer to the experimental data. The comparison between experiment and CFD shows very good agreement for higher temperatures, which covers the boiling stage. On the other hand for lower temperatures worse match of results was found caused probably by the sensitivity on the inlet velocity profile settings. Some recommendations for future work were defined.

Key words:

Multiphase, CFD, Fluent, quenching, polymer

Optimization of metallic glasses for additive technologies. The role of entropy and enthalpy in formation of amorphous structure

Corresponding author:

Adrian Radon, adrianr@imn.gliwice.pl, Łukasiewicz Research Network - Institute of Non-Ferrous Metals

Co-authors:

Aleksandra Kolano-Burian, Lukasz Hawelek

Abstract:

Until now, many different methods of amorphous alloys design were proposed. Generally, they are associated with the trial and error approach. In this group of methods, the influence of different chemical elements on the glass forming ability can be determined empirically based on the results of the analysis of many different alloying systems. However, this approach is time-consuming and cannot be implemented in the industry.

Recently, due to the development of additive technologies, new alloying systems with high glass forming ability are sought. The usage of common alloys systems is significantly limited. Therefore, a new approach to determining the optimal chemical composition, which also can be used to describe the crystallization (especially nanocrystallization) process is required. According to that, the thermodynamic approach for alloy design was introduced and described in this work. The analysis of different parameters, such as configurational entropy, mismatch entropy, mixing enthalpy and enthalpy formation of intermetallic phases can be successfully used to determine the optimal chemical composition of alloys with high glass forming ability. Moreover, the proposed approach can be used to understand the crystallization process from the melt, amorphous phase, nanocrystallization process and influence of chemical elements on the glass forming ability in many alloying systems. In this work results of the analysis performed for different Fe-based alloys are presented. Determined influence of chemical elements, such as: copper, cobalt, silicon on the glass forming ability on the basis of the analysis of thermodynamic parameters is related to the changes in the entropy and enthalpy.

Key words:

Amorphous alloys, enthalpy, entropy, glass forming ability

Small-and wide-angle X-ray scattering (SAXS/WAXS) in materials science

Corresponding author:

Petr Bělský, pbelsky@ntc.zcu.cz, University of West Bohemia, New Technologies - Research Centre

Abstract:

Small-angle X-ray scattering (SAXS) is a well-established characterization method for microstructure (in particular, nanostructure) investigations in various materials. It examines electron density differences to provide information about structural inhomogeneities, particles or pores with size from the near atomic scale (~ 1 nm) to the scale of tens or at maximum around 200 nm in case of desktop SAXS instruments or up to micron scale (at maximum ~15 um) in case of synchrotron SAXS instruments. Wide-angle X-ray scattering (WAXS) experimental setup is usually similar to that of SAXS – the difference is that the X-ray scattering/diffraction under higher scattering angles is examined. WAXS gives information about sub-nanometer-scale structure of material, i.e., crystallinity/amorphousness. At New Technologies – Research Centre (NTC) of the University of West Bohemia, SAXSess instrument by Anton Paar (Austria) is available in a configuration enabling to investigate nanostructures on the scale from approximately 1 to 25 nm. The SAXS/WAXS method, its possibilities and the applications of SAXS/WAXS in materials science will be introduced in general. Our SAXSess instrument and selected applications for which the method was applied at NTC so far, will be presented. It includes e.g. investigation of nucleation of a new phase in metakaolin, structure analysis of Nafion-based polymer membranes and other membranes for hydrogen fuel cells and vanadium redox batteries, polyvinyl alcohol-based membranes, and analysis of size distribution changes of Pt catalysts in fuel cells after operational tests.

Key words:

SAXS, WAXS, materials science

Evaluation of microstructural and thermal properties of sol-gel derived silica-titania based porous glasses

Corresponding author:

Kalim Deshmukh, deshmukh.kalim@gmail.com, University of West Bohemia, New Technologies - Research Center

Co-authors:

Tomáš Kovářík, Tomáš Křenek

Abstract:

In recent years, the synthesis of sol-gel derived porous glasses has drawn widespread attention owing to the convenience and versatility of the sol-gel method. The sol-gel synthesis process mainly involves hydrolysis and condensation of precursors followed by drying and stabilization. The characteristics such as pore structure, morphology and compositions of sol-gel derived glasses significantly affect their final properties. In the present study, silica-titania (Si-Ti) based porous glasses with different compositions were synthesized using the sol-gel method. Metal alkoxides such as tetraethoxysilane (TEOS) and titanium isopropoxide (TIP) were used as a source as the source for silica and titania respectively. Nitric acid (HNO3) was used as catalysts to trigger the hydrolysis reaction and polyethylene glycol (PEG) was used as a polymeric component to induce phase separation. The influence of different processing parameters on the microstructural and thermal properties was investigated. The microstructure of the synthesized Si-Ti based porous glasses was investigated using Scanning electron microscopy (SEM) and the thermal characteristics were evaluated using thermogravimetric analysis (TGA) and thermomechanical analysis (TMA). The main objective of this study is to ascertain the application of sol-gel derived Si-Ti porous glasses as a potential biomaterial for bone tissue regeneration. To understand this facet of Si-Ti porous glasses, the biological performance will be investigated and their porous architecture will be explored in relation to their interaction with the bioactive nanoparticles.

Key words:

Sol-gel method, Si-Ti glasses, microstructure, thermal properties

Catalytic reduction of NO with CO over Supported Fe-Based Catalysts

Corresponding author:

Fatemeh Gholami, gholami@ntc.zcu.cz, University of West Bohemia in Pilsen, New Technologies - Research Centre

Abstract:

The catalytic activity of a series of La-Fe catalysts supported on activated carbon was studied for selective catalytic reduction of NO by CO. Increasing the amount of La in the catalyst structure causes an increase in the Fe2+/Fe3+ ratio. The results showed that by increasing the La amount in catalysts, the catalytic activity of the AC-supported catalysts was enhanced because of the synergistic interactions between surface oxygen vacancies and Fe2+ species in the AC-supported catalysts. Due to the high catalytic performance of MnOx, the NOx conversion of Mn@La3-Fe1/AC catalyst was improved to 92.67% at the absence of oxygen at 400 °C. The Mn promoted La3-Fe1/AC catalyst showed the highest NOx conversion of 93.8% at 400 °C in the presence of 10% excess oxygen. Compared with other prepared catalysts, the Mn@La3-Fe1/CNT catalyst showed the highest activity due to the higher Fe2+/Fe3+, which confirmed by XPS analysis. The double exchange behavior of Mn3+ and Mn4+ can increase the number of SOV and increase catalytic redox properties.

Key words:

NOx removal, Selective catalytic reduction, CO-SCR

The structure and magnetic properties of rapidly quenched Fe72Ni8Nb4Si2B14 alloy

Corresponding author:

Lukasz Hawelek, lukaszh@imn.gliwice.pl, Lukasiewicz Research Network - Institute of Non-Ferrous Metals

Co-authors:

Patryk Wlodarczyk, Marcin Polak, Przemyslaw Zackiewicz and Aleksandra Kolano-Burian

Abstract:

In this work, the influence of heat treatment process on structure and magnetic properties for rapidly quenched Fe72Ni8Nb4Si2B14 alloy are reported. Firstly, for amorphous ribbons the onsets of crystallization process for bcc-Fe type phase (primary crystallization) and bct-Fe3B type phase (secondary crystallization) are defined by thermal analysis using heating rate of 10°C/min. Then basing on measured values the classical heat treatment process (with heating rate 10°C/min) in vacuum for wound toroidal cores is optimized to obtain best soft magnetic properties (B(H) dependencies and magnetic core loss Ps) at frequency 50 Hz. For heat treated samples the X-ray diffraction method is used to determine the unit cell parameters of bcc-Fe type nanocrystallites as well as their average crystallite size. Therefore, for optimal heat treated sample the complex magnetic permeability in the frequencies 106 -109 Hz for temperature range from -50°C to 100°C is measured and in the frequencies 104 -108 Hz at room temperature.

Key words:

Metallic glass, soft magnetic materials, material characterization

The effect of NPs addition on the photocatalytic and antibacterial effectivity of composite TiO_2/SiO_2 paint

Corresponding author:

Michaela Jakubičková, michaela.jakubickova@gmail.com, Technical University of Liberec, Faculty of Mechatronics, Informatics and Interdisciplinary Studies

Co-authors:

Michaela Petržílková, Bulgantamir Amartuvshin, Lenka Kejzlarová, Pavel Kejzlar

Abstract:

TiO_2 in the anatase allotropic modification is well known for its photocatalytic activity. When the anatase is irradiated by UVA light, it forms an electron-hole pair which can participate in redox reaction. Thus, anatase-based layers are suitable for decomposition of organic compounds. Surface self-cleaning ability as well as antimicrobial efficacy are therefore key features for TiO2 based layers. The present paper deals with a study of ZnO, CuO and Ag NPs addition on the antibacterial and photocatalytic effectivity of TiO_2/SiO_2 paint.

Key words:

Titanium dioxide, photocatalyst, anatase, ZnO,CuO, Ag, nanoparticles

Characterization and corrosion behavior of TiO_2 thin films deposited onto Mg-based alloy for orthopedic applications

Corresponding author:

Aneta Kania, aneta.kania@polsl.pl, Silesian University of Technology, Institute of Engineering Materials and Biomaterials

Co-authors:

Wirginia Pilarczyk, Magdalena M. Szindler

Abstract:

Metallic biomaterials are widely used in medicine. However, the material used for biomedical applications shall comply with the following factors: biotolerance, corrosion resistance and mechanical properties [1]. Magnesium alloys have been recently investigated as potential candidates for orthopedic implants because of good mechanical properties [2]. Nevertheless, magnesium, as a major mineral in human body, is characterized by poor corrosion resistance. Therefore, various protective coatings are used to slow down the corrosion process [3].

The article presents the investigation results of a structure and properties of TiO_2 thin films (about 300 nm thick) deposited onto MgCa4Zn1Gd1 alloy using sol-gel and magnetron sputtering methods.

The structure observations of thin oxide films in scanning electron microscopy (SEM) are shown. The phase analysis was made with X-ray diffractometer. The structural studies were confirmed by Raman spectrometer. Moreover, roughness measurements in atomic force microscopy (AFM) are discussed. The results of corrosion resistance of TiO_2 films using the potentiodynamic and immersion tests are also presented.

The analysis of investigation results has shown that the surface of TiO_2 applied by magnetron sputtering is characterized by smaller and more uniform grains compared to the TiO_2 film deposited by sol-gel. The results of structural testing determined the structure of TiO_2 thin films as an anatase. The sol-gel coated film has slightly higher roughness parameters (Ra = 11.2 nm; RMS = 15.1 nm) compared to the layer applied using PVD (Ra = 7.1 nm; RMS = 9.2 nm). The immersion test results have shown that the alloy with TiO2 film applied by sol-gel is more corrosion resistant

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[2] M. Peron, J. Torgersen, F. Berto, Mg and its alloys for biomedical applications: exploring corrosion and its interplay with mechanical failure, Metals 7 (2017) 252.

[3] A. Kania, W. Pilarczyk, R. Babilas, Selected properties of ZnO coating on Mg-based alloy for biomedical application, Acta Phys. Pol. A 133 (2018) 222-224.

Key words:

TiO2 thin films, structure analysis, roughness measurements, electrochemical and immersion tests

Hierarchically porous aluminosilicate substrates as a promising carriers for photocatalytic nanoparticles

Corresponding author:

Tomáš Kovářík, toko@ntc.zcu.cz, University of West Bohemia, New Technologies - Research Centre

Co-authors:

Tomáš Hervert, Jiří Hájek, Tomáš Křenek, Kalim Deshmukh, Jaroslav Kadlec

Abstract:

Recently, wastewater treatment has become a critical issue due to particular concerns for sustainable environment, climate change and industrial growth. There has been a need for readily available and inexpensive solutions between research and industry. Porous aluminosilicate materials based on geopolymer systems have proven their effectiveness as adsorbents, ion-exchangers, membranes, anti-microbial filters, pH buffers and stabilizers for water treatment residues. Furthermore, catalysts and/or catalyst supports for pollutant degradation in liquid phase reactions have been studied. High permeability, surface area, chemical resistance and mechanical strength are essential for these applications. Here we present a facile synthesis routes based on replica technique and sol-gel pipetting of highly porous substrates with open cells and water-floatable spherical beads with closed porosity. Characterization of prepared structures was performed with respect to their porous architecture, surface properties and mechanical integrity. Scanning electron microscopy (SEM) and micro-computed tomography (micro CT) revealed the relationship between the inner/outer structure and the open/closed porosity ratio. Thermal behavior was studied by thermogravimetric (TGA) and differential thermal analysis (DTA) up to 1000 °C and 1300 °C, respectively. In addition, mechanical stability was determined and a procedure for coating nanoparticles with respect to their photocatalytic activities was proposed.

Key words:

Porosity, carriers, photocatalysis

Titanium-based porous materials with nanostructured bioactive surface for enhanced osseointegration

Corresponding author:

Tomáš Křenek, tkrenek@ntc.zcu.cz, University of West Bohemia, New Technologies - Research Centre

Co-authors:

Tomáš Kovářík, Denitsa Docheva, Theresia Stich, Jaroslav Kadlec

Abstract:

Despite the great progress that has been achieved in orthopedics biomaterials, fixation of implants to the bone host remains a problem. Mismatch of Young's moduli of the biomaterials and the surrounding bone has been identified as a major reason for implant loosening following stress shielding of bone. However, the implanted material must be strong enough and durable to withstand the physiological loads placed upon it over the years. A suitable balance between strength and stiffness has to be found to the best match of bone behaviour. Titanium and its alloy (Ti6Al4V) have elastic moduli less than 50% of that commonly used Co–Cr implants so that their use helps reduce the extent of stress shielding.

One consideration to achieve this has been the development of materials that exhibit substantial surface or total bulk porosity in medical applications.

Moreover, bioactive surface chemical composition and suitable surface morphology on micro- and nanoscale level is necessary for efficient osseointegration.

Here we report on novel concept of hierarchically functionalized titanium based biomaterials consists in (i) laser induced surface porosity, (ii) micro/messoporous bioactive glass fillers, (iii) chemical activation and/or ablative deposition of bioactive CaTiO3 nanoparticles. Prepared biomaterials were analyzed using SEM/EDX, XRD, Raman spectroscopy and test in terms of cell cultivation in order to reveal biocompatibility, cell viability and osseointegration ability.

Key words:

Biomaterials, titanium, porosity, nanostructured surface, chemical activation, cell viability

Composition and morphology of composite coatings

Corresponding author:

Jan Novotný, jan.novotny@ujep.cz, Jan Evangelista Purkyně University in Ústí nad Labem, Faculty of Mechanical Engineering

Co-authors:

Štefan Michna, Martin Jaskevič

Abstract:

This article focuses on the selection of fillers for composite coatings according to their key properties, sample composition and particle morphology. Properties that we want to improve with coatings are especially durability, abrasion resistance and heat resistance. TiO_2, Al_2O_3, WC a W were selected as suitable materials. XRD and XRF analysis was performed on selected fillers to determine the exact composition and crystallographic structure. Furthermore, the samples were milled in a ball mill, sieved according to the size of the fraction and SEM analysis was performed for each fraction to determine the particle morphology.

Key words:

Composite coatings, particle morphology

Preparation and characterization of PVA nanocomposites with bio-functionalized nanodiamonds

Corresponding author:

Tomáš Remiš, tremis@ntc.zcu.cz, University of West Bohemia, New Technologies - Research Centre

Co-authors:

Tomáš Kovářík, Petr Bělský, Jaroslav Kadlec

Abstract:

Poly (vinyl alcohol) (PVA) has a long and successful history of applications in the biomedical and pharmaceutical area. At the forefront of multidisciplinary research in nanomedicine, carbon nanomaterials have demonstrated unprecedented potential for a variety of regenerative medicine applications. Nanodiamonds (NDs) are a unique class of carbon nanoparticles that are gaining increasing attention to their biocompatibility, highly functional surfaces, optical properties and intriguing physical properties. In this work, we have developed advanced PVA and NDs based nanocomposite membrane in a single step using a solution-casting method from an aqueous medium and achieved high dispersibility of NDs in the PVA matrix. The resulting nanocomposites have excellent properties derived from NDs and PVA. It has been found that thermal and mechanical properties increase dramatically with increasing NDs content, suggesting a strong chemical interaction between NDs and PVA. We assume that NDs will be a suitable nano-filler for PVA membranes. This work examines properties of PVA matrix reinforced with NDs particles and their potential application in biomedical field.

Key words:

Nanodiamonds, nanocomposites, membranes, poly (vinyl alcohol), TGA, DMA, DSC, SAXS/WAXS, SEM

The effect of SiO_2 NPs addition on lubrication properties of 10W-40 engine oil

Corresponding author:

Ondřej Seibert, ondra.seibert@centrum.cz, Technical University of Liberec

Co-authors:

Pavel Kejzlar, Totka Bakalová

Abstract:

Proper lubrication of mechanical parts in the car engines shall minimize the wear of friction pair and thus to ensure long lifetime. Another goal of the lubrication is to decrease coefficient of friction and thereby reduce energy losses. Many publications are devoted to nanoparticle addition into simple oil (e.g. paraffin) but there is only limited attention to more complex lubricants as synthetic oils. In addition, there is paid very little attention to the stability of resulting suspensions. Present paper deals with the effect of different ways of SiO_2 NPs addition into the advanced synthetic oil on the wear ratio of friction pair using ball-on-disc tribological test.

Key words:

Tribology, SiO_2, wear, oil additives

Advanced oxidation processes

Corresponding author:

Lukáš Vála, valal@kmm.zcu.cz, University of West Bohemia

Co-authors:

Tomáš Křenek

Abstract:

There is a great interest in the synthesis of various nanosized green reusable catalysts which would better assist various chemical reactions in industrially important technologies. Heterogeneous catalysts are widely used in advanced oxidation processes. Its can remove organic pollutants in wastewater effluents by facilitting their degradation through ozonization, photolysis, semiconductor photocatalysis, electrochemical treatment and Fenton's oxidation. In the case of using Fenton´s oxidation. Pulsed laser irradiation of iron and cobalt sulfides in different enviroments allows laser ablation and generation of FeS, CoS2 nano/micro particles. The FeS and CoS2-based films deposited on Ta deposited on Cu were examined for their catalytic effect in Fenton degradation of methylene blue (MB). However, there is still necessary presence of additional H2O2 which is expensive for wider industrial application. Therefore, these substances are tested for their photocatalytic properties.

Key words:

Advanced oxidation processes, Fenton oxidation, pulsed laser irradation, iron and cobalt sulfides

The effect of application of the plaster as a mould material on the microstructure and properties of AlSi9 aluminium alloy

Corresponding author:

Tomasz Bucki, tbucki@tu.kielce.pl, Kielce University of Technology

Co-authors:

Magdalena Sidorko, Dana Bolibruchová

Abstract:

The study involved examination of the effect of mould material on the microstructure and mechanical properties of AlSi9 aluminium alloy castings. The castings were fabricated in: plaster-based moulds, dehydrated plaster-based moulds and steel mould. The structure of castings from plaster mould not subjected to dehydration process was characterized by significant porosity. This results indicated that as-cast plaster mould is not suitable for casting of AlSi9. Dehydrating of the mould led to significant reduction in the number of pores in the casting, small porosity was observed only locally in middle region of casting. No pores were observed in the structure of steel mould castings. Microstructure of dehydrated plaster mould castings and steel mould castings was analysed in a Scanning Electron Microscope. Both types of examined castings were characterized by typical microstructure containing a eutectic (α-Al and Si) with dendrites of α-Al and multicomponent phases locally distributed in the matrix. Mould material affected the size of microstructural constituents of observed specimens. Castings fabricated in steel mould showed considerable refinement of the eutectic and dendrites of α-Al in comparison with dehydrated plaster castings. Castings from dehydrated plaster mould had lower strength and smaller elongation than steel mould castings.

Key words:

Aluminium alloy, casting, mold, microstructure, mechanical properties, plaster

PEO layers on Mg-based metallic glass for decreasing hydrogen evolution

Corresponding author:

Katarzyna Cesarz-Andraczke, Katarzyna.Cesarz-Andraczke@polsl.pl, Silesian University of Technology, Institute of Engineering Materials and Biomaterials

Co-authors:

Alicja Kazek-Kęsik

Abstract:

The amorphous Mg-based alloys may be used as metallic biomaterials for resorbable orthopedic implants. The Mg-Zn-Ca metallic glasses demonstrate fast and variable in time corrosion rate in simulated body fluid. Due to phase composition of the Mg-based materials, the mechanism of corrosion is different. In this work as substrate for coatings the Mg66Zn30Ca4 alloy was chosen. In previous studies [1] the Mg66Zn30Ca4 metallic glass characterized good mechanical strength and high glass forming ability. This work reports on the surface modification of a Mg66Zn30Ca4 metallic glass by plasma electrolytic oxidation (PEO). Results of immersion tests in Ringer's solution allowed to determine the amount of evolved hydrogen in a function of time for base Mg66Zn30Ca4 metallic glass and sample with PEO coating. In comparison to the non-coated Mg66Zn30Ca4 alloy, the sample with PEO layer showed a significantly decreased hydrogen evolution volume. The hydrogen evolution rate of the studied samples decreased during the following immersion time. The possible reason of this phenomena is formation of corrosion products layers on surface samples, which act as protection layer.

This publication was partially financed by the statutory grant of the Faculty of Mechanical Engineering of the Silesian University of Technology in 2019.

Key words:

Amorphous magnesium alloys, corrosion rate, plasma electrolytic oxidation, hydrogen evolution

Intermetallics formation during hot dip galvanizing of high carbon steel

Corresponding author:

Peter Gogola, peter.gogola@stuba.sk, Slovak University of Technology, Institute of Materials Science, Faculty of Material Science and Technology

Co-authors:

Zuzana Gabalcová, Henrich Suchánek, Martin Kusý

Abstract:

From the moment of immersion, the reaction between molten zinc and solid steel starts forming intermetallic phases. This diffusion-controlled process is largely responsible for the final phase composition of zinc coatings. Several literature sources describe this phenomenon for interstitial free steels, but high-carbon steels are rarely being used as substrates. Therefore, in this work high-carbon steel substrates were used. Multiple samples were created by hot-dipping at various immersion temperatures ranging from 450 to 490 °C and times from 24 to 60 s to investigate mainly the morphology of the obtained intermetallic phase layers. Investigation was carried out mainly by SEM on 20 condition, where several hundred sites were investigated in total to achieve statistically relevant information. It was found that while increasing the immersion time influences mainly the thickness of individual intermetallic phase layers, the temperature influenced mainly their morphology. It was also observed that these results are significantly different compared to ones found in literature for interstitial free steels.

Key words:

Zinc, iron, intermetallic phases, high-carbon steel

Effect of revolutions number on mechanical properties of HPT processed copper

Corresponding author:

Daniel Melzer, dmelzer@comtesfht.cz, COMTES FHT a.s.

Co-authors:

I. Smirnov, A. Evstifeev, S. Rzepa, P. Konopík

Abstract:

This paper studies the effect of high-pressure torsion (HPT) method at ambient temperature on mechanical properties of material. The aim is to compare copper subjected to HPT for 2, 10 and 30-revolutions with coarse grain structured copper in a cold-rolled state. Miniaturized tensile tests were performed to evaluate anisotropy of mechanical properties within a disc product of HPT process. Also the strain rate sensitivity was examined. The results of mechanical tests demonstrate that increasing shear strain leads to ultra-fine grain structure (UFG) which resulted in increasing of material strength. The plasticity of material decreases correspondingly to that. With respect to character of HPT process, discs are known as non-homogenous products, where shear strain effect increases in radial direction from the centre section to the edge. Results show that with different number of HPT revolutions the anisotropy of mechanical behaviour is changing. With increasing number of revolutions the anisotropy within a single disc is increasing.

Key words:

SPD, HPT, Ultrafine-grained Structure, Miniaturized Tensile Test

The effect of carbon addition on the structure and high – temperature strength of Fe_3Al – based iron aluminide doped by niobium

Corresponding author:

Martin Švec, martin.svec@tul.cz, Technical University of Liberec

Co-authors:

Věra Vodičková, Pavel Hanus, Vojtěch Keller

Abstract:

A structural study as well as the determination of $\sigma_{0.2}$ compression yield stress at high temperatures have been performed on the Fe_3Al-based iron aluminide doped by Nb (5 at. %) and C (1.5 at.%). The carbon occurrence leads to the formation of three-phase structure. Fe3Al matrix, niobium carbides and (Fe,Al)2Nb Laves phase were observed in the structure of investigated alloys. Precipitates were inhomogeneously distributed in as cast state alloy. The annealing at 1000°C for 50 hours leads to more homogenously distribution of secondary phase particles and also to refinement of grain size. The strengthening mechanism of material at high temperatures was detected as a combination of strengthening by incoherent precipitates (NbC and Laves phase) and a solid solution hardening by Nb atoms. Effect of two reinforcing mechanisms together with homogeneously precipitate's distribution increase the values of $\sigma_{0.2}$ compression yield stress about 50 MPa in whole measured temperature range (600 – 800 °C) in comparison to similar intermetallic's system Fe-Al-Zr-C.

Phase composition of the alloy was studied by means of scanning electron microscopy (SEM) equipped by energy dispersive X-ray spectrometer (EDX). The electron backscattered diffraction (EBSD) was used for phase verification and grain size visualization.

Key words:

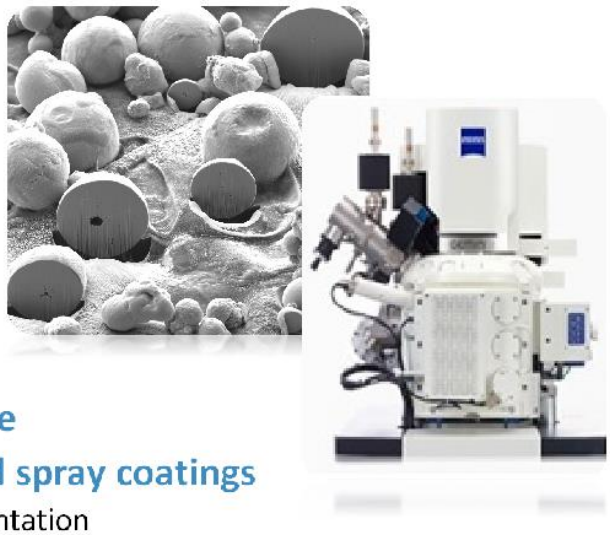
Fe_3Al – type iron aluminides, niobium and carbon addition, phase structure, heat treatment, high temperature $\sigma_{0.2}$ compression yield stress

Regional Technological Institute
METALLOGRAPHIC LABORATORY

The Metallographic Laboratory conducts research into transformation processes, microstructure evolution in response to heat treatment and thermomechanical processing, and high-temperature behaviour of materials. Its staff also study metal powders and microstructures produced by additive manufacturing. The equipment includes state-of-the-art microscopes, devices for in-situ deformation and thermal experiments and instruments for measuring local mechanical properties.

Microstructure analysis

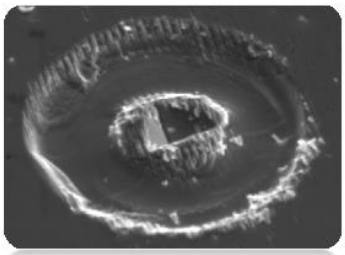
Microstructure characterization, measurement of the inclusion content, grain size, powder particle size distribution surface layer thickness, examination of microstructure and macrostructure of cast parts, forgings and welded joints and examination of microstructures after heat treatment, thermomechanical processing and additive manufacturing.

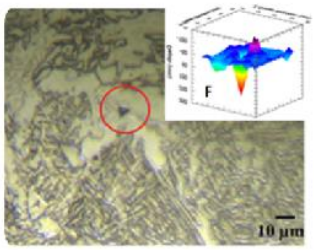


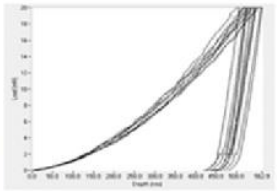
Identification of types and causes of failure

Assessment of surface layers, coatings and spray coatings

-> low-temperature and high-temperature nanoindentation
-> scratch testing, wear testing and pressure tests of micro-pillars
=> oxidation resistance, thermal stability, hardness at elevated temperatures, fatigue resistance



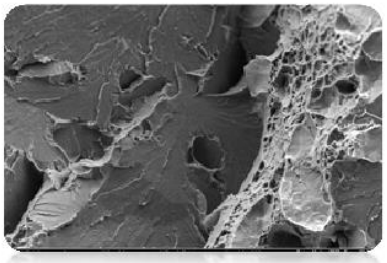


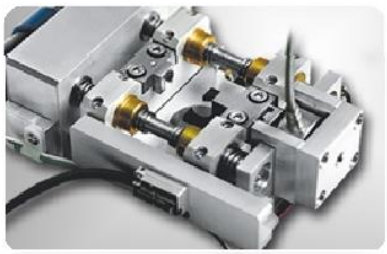


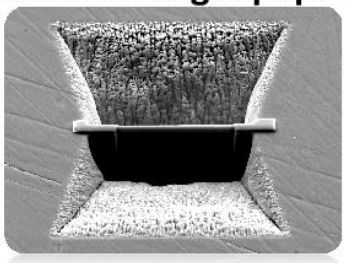
Ferrite - TRIP

KEY EQUIPMENT

- **Nanoindenter for measurement at temperatures up to 750°C**
- **Auriga Cross Beam SEM-FIB Workstation**
- **Deformation stage with heating capability up to 1200°C for SEM**
- **Non-destructive testing equipment**







doc. Ing. Ludmila Kučerová, Ph.D.
Head of Research and development of forming technologies program and of Metallographic laboratory
Tel.: +420 37763 8063; Mobil: 605 703 670
E-mail: skal@rti.zcu.cz

www.rti.zcu.cz

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