

# "Book of Abstracts of 18th International Foundrymen Conference: Coexistence of Material Science and Sustainable Tehnology in Economic Growth"

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## BOOK OF ABSTRACTS

# 18<sup>th</sup> INTERNATIONAL FOUNDRYMEN CONFERENCE

**Coexistence of material science and sustainable  
technology in economic growth**



## PROCEEDINGS BOOK

with papers *in extenso* included on USB

Sisak, May 15<sup>th</sup> – 17<sup>th</sup>, 2019

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ELKEM ASA, Oslo, Norway

**PROCEEDINGS BOOK****18<sup>th</sup> INTERNATIONAL FOUNDRYMEN CONFERENCE**

Coexistence of material science and sustainable technology in economic growth

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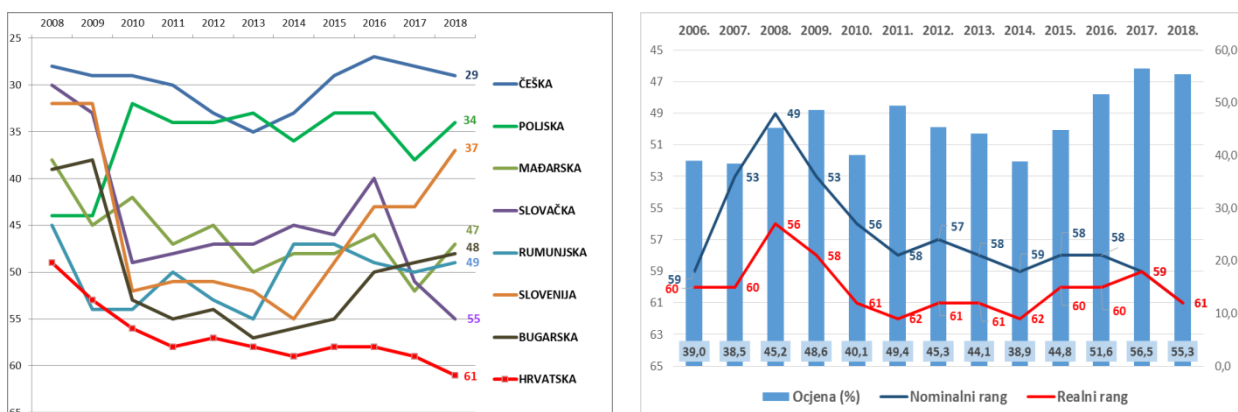
## PREFACE

**Foundry industry** as a base branch represents an important factor contributing to the economic potential of each country. Current market development as well as technical and economic objective, the production of high-quality, low-cost and environmentally friendly casting, requires application of recent and advanced materials, as well as production technologies, followed and supported by understanding of production process.

Production imperative is pointed into the recent technologies and improved materials for everyday usage in our homes, workplaces, as well as materials with special requirements for specific applications such as those for the automotive or space industry. Industrial activities, which are defined as strategic activities in the Republic of Croatia are **Metal Casting** and **Production of Final Metal Products**, recognized as *"economic growth drivers"* because they are expected to realize higher rates of growth and employment.

According to the data of the Central Bureau of Statistics (DZS) and Financial Agency (FINA) and on the basis of analysis of the Sector for Financial Institutions, Business Information and Economic Analysis of the Croatian Chamber of Commerce and for the last analyzed 2017, the primary production of metals in the structure of Croatian industrial production is only 1.35% due to lack of economically viable primary raw materials and market fluctuations in their prices but also of the lack of modern production capacities. However, the valorization and export component of finished metal products stands out with a high share of almost 8.78%. Overall, this represents **10.13% of the industrial production of the Republic of Croatia**.

Croatia is also included yearly World Competitiveness Yearbook issued by Institute for Management Development (IMD) in Lausanne. "The World Year of Competitiveness" has been published every year since 1989 for the purpose of analysing and ranking the nation's ability to create and maintain an environment that maintains the company's competitiveness. In 2018 report, Croatia has ranked at 61<sup>th</sup> place from 63 world economy. The IMD methodology is based on an analysis of 4 factors of competitiveness, namely: economic results, public sector efficiency, business sector efficiency and infrastructure, and 5 indices for each area. Also, an overview of the status of the Republic of Croatia in the period from 2006 to 2018 is presented in the following graph.

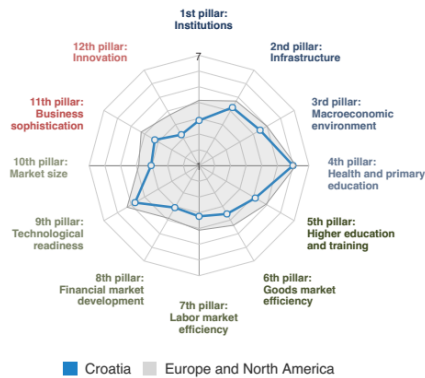


**IMD World Competitiveness Yearbook 2018**

An overview of the status changes suggests that the economic crisis with its negative effects since 2008 for many comparable countries ended in 2014, while the Republic of Croatia in 2018 shows no recovery. Economic results are based on high revenues from tourism but also on exports. Despite a skilled workforce, a high level of education and a reliable infrastructure, a bad business environment, a slow administration and the burden of parafiscal charges still dictate a relatively

low labor price. Progress can be expected through stronger collaboration between the academic community and the economy, with emphasis on investment in innovation, knowledge transfer and technology optimization, with the prerequisite for the management structure to recognize the importance of such cooperation. In addition, the "Competitiveness Report" for 2017-2018 goes to this year, according to which the Republic of Croatia shows a continuous decline and this year it has 74<sup>th</sup> position out of 137 world economies, as shown in the following graph.

Edition	2012-13	2013-14	2014-15	2015-16	2016-17	2017-18
Rank	81 / 144	75 / 148	77 / 144	77 / 140	74 / 138	74 / 137
Score	4.0	4.1	4.1	4.1	4.1	4.2



World Economic Forum, The Global Competitiveness Report 2017–2018

The problematic pillars of competitiveness are the continuity of business and innovation. The 5 most problematic factors for doing business in terms of efficiency valorization are identified: inefficient public administration, instability of legal regulation, tax regulations, and corruption and tax rates. These 5 factors can be regulated by public policy. Thereafter, there are four factors that the economy needs to recognize and impose as prerequisites for its competitiveness: inadequate capacity for innovation, availability of funding, limiting labor regulations, inadequately educated workforce. Identifying their own niche for competitiveness on the global market and following the stated public policy requirements for recognizing and incorporating them into development and funding strategies, as well as the education system in designing competent, creative and innovative workforce, can provide a synergy of positive moves towards increasing competitiveness.

Therefore, the importance of *coexistence of material science and sustainable technology in economic growth* reveals in collaboration between small and medium enterprises' (SMEs'), industry and higher education institutions (HEI). **International Foundrymen Conference** organized by University of Zagreb Faculty of Metallurgy, Sisak, Croatia in cooperation with University of Ljubljana Faculty of Natural Sciences and Engineering, Ljubljana, Slovenia, University North, Koprivnica, Croatia, Technical University of Košice Faculty of Materials, Metallurgy and Recycling, Košice, Slovakia, and ELKEM ASA, Norway found its significant position due to aforementioned reasons.

Coexistence of material science and sustainable technology in economic growth comprehends to recent technology and educated and skilled engineers. The Conference topics were designed as presentations of the current *"state of the art"* research in collaboration with industry, and production innovation with the aim to improve the competitiveness.

The scope of **18<sup>th</sup> International Foundrymen Conference (IFC)** covers scientific, technological and practical aspects concerning research, development and application of casting technology with the common perspective – increase of competitiveness. Special attention will be focused towards the

competitiveness ability of foundries, improvement of materials features and casting technologies, environmental protection as well as subjects connected to the application of castings.

During this Conference 35 paper will be presented. Book of Abstracts of the 18<sup>th</sup> International Foundrymen Conference includes summaries of the papers. The Proceedings book consists of papers *in extenso* published in electronic format (USB). Full length papers have undergone the international review procedure, done by eminent experts from corresponding fields, but have not undergone linguistic proof reading. Sequence of papers in Proceedings book has been done by category of papers in following order: plenary lectures, invited lectures, oral and poster presentation, and inside the category alphabetically by the first author's surname.

Within the Conference Student section is organized. This is an opportunity for industry to meet and recruit human resources as a main potential for business development. Coexistence of material science and sustainable technology in economic growth represent a knowledge transfer between small and medium enterprises' (SMEs'), industry and higher education institutions. Higher education at the Faculty of Metallurgy (HEI), conceived through the program and the learning outcomes, is based, inter alia, on promoting students' scientific and research work on applied topics, enabling ambitious and creative young people to become independent problem solvers, developing and supporting their curiosity, analytics and communication: **Graduates like the labour market need!**

This occasion represents an opportunity to discuss and increase the mutual collaboration between HEIs' and industry with the aim of information exchange related to advanced experience in foundry processes and technologies, gaining the new experience in presentation and / or teaching process within lifelong learning process.

The organizers of the Conference would like to thank all participants, reviewers, sponsors, auspices, media coverage and all those who have contributed to this Conference in any way.

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Assoc.Prof. Zdenka Zovko Brodarac, PhD



Monument to a Croatian poet Antun Gustav Matoš, Sisak, Croatia  
[https://hr.wikipedia.org/wiki/Datoteka: Sisak Matos monument.JPG](https://hr.wikipedia.org/wiki/Datoteka:Sisak_Matos_monument.JPG)



Nikola III Zrinski on a silver thaler minted in Gvozdansko, Croatia  
[https://en.wikipedia.org/wiki/Nikola\\_III\\_Zrinski](https://en.wikipedia.org/wiki/Nikola_III_Zrinski)

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CORROSION BEHAVIOR OF CuAlMn AND CuAlMnNi ALLOY IN 0.9% NaCl SOLUTION



## 18<sup>th</sup> INTERNATIONAL FOUNDRYMEN CONFERENCE

Coexistence of material science and sustainable technology in  
economic growth

Sisak, May 15<sup>th</sup>-17<sup>th</sup>, 2019

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### GRAPHITE DEGENERATION IN THE SURFACE LAYER OF Mg-TREATED IRON CASTINGS – INFLUENCING FACTORS AND PRACTICAL SOLUTIONS

Iulian Riposan<sup>\*</sup>, Mihai Chisamera, Stelian Stan, Mihail Firican

Politehnica University of Bucharest, Bucharest, Romania

Plenary lecture

Subject review

#### Abstract

Graphite degeneration, in terms of graphite becoming less compact, in the surface layer of Mg-treated cast irons is a common defect, which can occur with any moulding technique. This abnormal surface layer [0.1 to 3.0mm thickness] may be present in any casting section thickness. However, it becomes most critical for thin wall castings, where it can easily be more than 10% of the total thickness, but also is a concern in heavy castings, due to the prolonged solidification time extending the metal-mould interaction time. The surface layer with degenerated graphite has a similar effect to a notch in the casting, reducing all the properties, especially as the fatigue limit and impact resistance.

The objective of the present work is to summarize the obtained results using selected data from some of the previous papers plus some unpublished data. It was considered residual Mg content [from compacted to nodular graphite formation], mould media chemistry [with/without S-content], with/without mould coatings [with/without S-content, with/without desulphurization agents (CaO, MgO, Talc, Mg<sub>met</sub> or FeSiCaMg alloy)], with/without inoculation, at different inoculating variants.

Furan resin sand - PTSA mould, including sulphur, aggravated graphite degeneration, with the layer thickness increasing up to ten times compared to the Novolak resin coated sand moulds, without included sulphur, with higher surface layer thickness at lower Mg<sub>res</sub>. Lower graphite nodularity, higher the size of the surface layer with degenerated graphite.

The application of a S-bearing mould coating strongly promoted graphite deterioration, or conversely, limited this process using desulphurization type coatings. MgO, (CaO + MgO + Talc) or Mg-FeSi bearing coating protected the graphite shape at the metal – mould interface, decreasing the average layer thickness. The Mg-FeSi coatings had an additional role to desulphurization providing supplementary Mg to raise the nodularising potential. The graphite characteristics within the section of the analyzed samples evolved in a clear relationship with the changes in the degenerate graphite surface layer, for the prevailing solidification conditions.

Inoculation increased graphite nodularity in the surface layer and decreased the surface layer thickness, at a strong relationship between these two parameters. The Inoculation Specific Factor, ISF [the ratio between increased nodularity/decreased surface layer thickness and total inoculant consumption for this effect] was used to evaluate the efficiency of inoculation variants.

**Keywords:** nodular graphite, compacted graphite, graphite nodularity, casting skin, degenerated graphite layer, ferritic rim, inoculation, inoculation specific factor

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**Coexistence of material science and sustainable technology in  
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**DECOMPOSITION OF AUSTENITE IN AUSTEMPERED DUCTILE IRON SAMPLES  
ON ELEVATED TEMPERATURES**

**Hasan Avdušinović<sup>1\*</sup>, Almaida Gigović-Gekić<sup>1</sup>, Šehzudin Dervišić<sup>2</sup>**

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**Invited lecture**  
*Original scientific paper*

**Abstract**

Mechanical properties of metallic materials strongly depend on microstructure. Microstructure changing of metallic parts on elevated temperatures highly limits possibilities of their application. The research in this paper is focused on microstructure changing of austempered ductile iron samples in case of reheating in temperature range between 250 °C and 700 °C. Decreasing of volume fraction of carbon enriched austenite was a measure of decomposition process.

**Keywords:** *austempered ductile iron, phase transformation, ausferrite, carbon enriched austenite*

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**CORROSION MONITORING OF METAL RELEASE INTO ENVIRONMENT**

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**Invited lecture**

**Subject review**

**Abstract**

Corrosion of metallic materials are known as strongly non-linear process due to the dependence on several factors concerning application environment such as temperature, humidity, amount of rainfall, pH, concentration of pollutants etc. Prediction of corrosion phenomena by classical statistical or mathematical methods often appears unsatisfying which is due to the complexity associated with the numerous physical-chemical processes. Nowadays, one of key enable technology such as artificial neural network can achieve promising approach to get more precise results.

The aim of corrosion monitoring is in development of corrosion sensor for prediction of atmospheric corrosion of basic structural metallic materials such as steel, zinc, copper using hyphenation of screening electrochemical technique with artificial neural network. The signal of sensor is caused by the corrosion reaction and corrosion reaction of structural metals depends on series of metereochemical variables (temperature, relative humidity, time of wetness, concentration of main pollutants, exposition time). Thus, based on robust database of values from field we could predict corrosion behavior from known variables under local atmospheric sites.

**Keywords:** *corrosion monitoring, prediction of life-time, run-off of metals, atmospheric aggressivity*

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**PROGRESS IN ON-LINE OPTICAL EMISSION SPECTROMETRY (OES) DATA-  
DRIVEN INSPECTION OF INCLUSIONS IN ALUMINIUM ALLOYS**

**Varužan Kevorkijan<sup>1\*</sup>, Tomaž Šustar<sup>2</sup>, Irena Lesjak<sup>1</sup>, Marko Degiampietro<sup>1</sup>, Janez Langus<sup>2</sup>**

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**Invited lecture**

*Original scientific paper*

**Abstract**

Promising approach for fast inspection of inclusions in wrought aluminium alloys is the optical emission spectroscopy (OES). However, in order to separate the peaks corresponding to particular inclusions from the peaks obtained from various microstructural features in the matrix, an advanced filtering of the OES spectrum is necessary. The methodology developed in this work is based on big-data-driven predictions of whether the on-line analysing sample is good or bad. A sufficient amount of relevant data necessary for data-driven predictions was established by the systematic quality control of samples of AA6082 using optical and SEM microscopy and by analysing the same surface using OES. By following a machine-learning process, an algorithm was developed enabling the on-line division of the samples into good and bad, based on criteria received from the casting house. Although the obtained results are promising, the further improvements are necessary before this method could be validated.

**Keywords:** *wrought aluminium, quality prediction, inclusions analysis, optical emission spectroscopy, big data, machine learning*

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**THE IMPACT OF APPLYING PVD COATINGS ON SURFACE ROUGHNESS OF  
QUENCHED AND TEMPERED STEELS**

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**Invited lecture**  
*Original scientific paper*

**Abstract**

PVD coatings of hard compounds reduce adhesion and abrasion wear, and some types of coatings also reduce the friction factor. The temperature of the PVD process is lower than the tempering temperature of quenched and tempered steels, there are no deformations of parts and no additional stresses. During the heat treatment, the PVD process is performed at the end because the PVD coating does not require subsequent heat treatment. In this paper, the impact of the application of PVD coatings (cVlc and nACVlc) on the surface roughness of three quenched and tempered structural steels (45S20, C45E and 42CrMo4) was investigated. All the steels were heat-treated by normalization, quenching and tempering and hardening before the coating process. Measurement results were statistically analysed. Based on the conducted experimental tests it was determined that change in the surface roughness of quenched and tempered steels after application of the PVD coating depends on the previous heat treatment of the steel, the type of coating and initial roughness, and less on the type of steel.

**Keywords:** *PVD (Physical Vapour Deposition) coatings, quenched and tempered steels, surface roughness*

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**MICROSTRUCTURE AND SOLIDIFICATION BEHAVIOR OF THE Ga–Ge–Sb  
TERNARY ALLOYS**

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**Invited lecture**  
*Original scientific paper*

**Abstract**

Microstructure and solidification behavior of Ga–Ge–Sb ternary alloys were investigated experimentally, by using scanning electron microscopy with energy dispersive *spectroscopy* (SEM-EDS) and differential scanning calorimetry (DSC). Four ternary samples were prepared by melting of pure elements under an argon atmosphere. Phase transition temperatures of the investigated samples were determined by using DSC. The microstructure of the samples was analyzed and co-existing phases were identified. The results of microstructural and thermal analysis were compared with the results of thermodynamic calculation of phase equilibria and calculated equilibrium solidification paths. Good mutual agreement was observed. Two ternary eutectic reactions at 561.8 and 29.8 °C were predicted by thermodynamic calculations and confirmed by the results of thermal and microstructural analysis from the present work.

**Keywords:** *Ga–Ge–Sb ternary system, microstructure, thermodynamic calculation*

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**INTERACTION BETWEEN MOLTEN ALUMINIUM AND HOT-WORKING  
TOOL STEEL**

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**Invited lecture**  
*Original scientific paper*

**Abstract**

Hot-working tool steels are essential for production and processing of aluminium and aluminium alloys. The interaction between molten aluminium and hot-working tool steel is a result of chemical reaction at a phase boundary solid/liquid, causing the formation of intermetallic compounds. The consequence of molten aluminium flow along the tool surface is erosion or mechanical wear. In order to increase the lifetime of the tool it is necessary to examine and limit the interaction between tool steel and molten aluminium.

A laboratory device was designed to determine the interaction between tool steel and metallic melts. The experiments were carried out in melt of primary aluminium (purity of 99.7 mass %) and, for the comparison, in aluminium alloy AlSi12 at the temperature of 670 °C and 700 °C at 75 rpm and 150 rpm. The result of the interaction is the growth of a reaction layer, which is formed from intermetallic phases from system Al-Fe. It could be concluded that following parameters: temperature of the melt, the speed of rotating sample (rpm) and experiment duration time, have an impact on the wear of tool steel. Taking the results into consideration an interaction model between hot-working tool steel and molten aluminium was created.

**Keywords:** *interaction tool steel/molten aluminium, intermetallic phases from system Al-Fe*

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**POSSIBILITIES FOR PROVIDING OF UNIDIRECTIONAL SOLIDIFICATION OF  
COMPLEX CASTINGS IN THE TECHNOLOGY OF HIGH-PRESSURE DIE-CASTING**

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**Invited lecture**

**Subject review**

**Abstract**

In contemporary high pressure die casting (HPDC) foundries the mastery of each sequence in production cycle is the most important, where the strive to reliable master, as well as planning of composed molten metal, pouring and solidification process, ejection of castings, transport to the cooling place and cutting of gating system and overflows were done. For castings with a complex geometry and dimensional accuracy, the appropriate planning of pouring and feeding elements according to a heat economy of casting, rapid tooling and prototyping and then reliable manufacturing which includes the mastery of all the edge conditions in the process chain. In the paper the example of virtual analysis of casting from Al alloy will be presented with choosing of appropriate foundry technology HPDC, calculation of casting process which includes the filling process of cold chamber, model description of three phases at HPDC, flow of molten metal, solidification with considering the temporary air gap formation between the casting and tool, formation of stress and relaxation of it into deformations in each sequence, when the tool is opening, at ejection, cooling in water or on air and after cutting off the gating system. Since it is not always possible to produce the castings according to the principle of unidirectional solidification with a traditional approach, for the individual areas, which should be macroscopic dense (without porosity), the local squeezing process is performed in the sequence of the semi-solid state of the region. The location of the impression is marked by a local increase of pressure and a plastic deformation of the already solid part of the casting (solid shell). An example of a very detailed comprehensive treatment of these processes in the case of a real casting will be discussed. Further, the optimization of the processes of the local squeezing sequence and the overall solidification process will be presented. Comparisons will be made with calculations of volume defects, casting dimensions and deformations with experimentally obtained castings produced from LTH Castings' industrial technology practice. Proven complete master of high-pressure die-casting have the result of an important financial effect and decreasing of required time to start of serial production of castings.

**Keywords:** *high pressure die casting, unidirectional solidification, local squeezing, pressure analyses, shrinkage porosity*

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**NEW TESTS FOR CHEMICALLY BONDED FOUNDRY SANDS**

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**Invited lecture**

**Subject review**

**Abstract**

Chemically bonded sand cores and molds are more commonly referred to as precision sand systems in the high production automotive powertrain sector. Their behavior in contact with molten metal can lead to casting defects. Consequently, the interaction is of great interest and an important part of metal casting technology. The American Foundry Society (AFS) sand testing is based on physical, mechanical, thermal and chemical properties of the sand system. Foundry engineers have long known that certain AFS sand tests provide limited information regarding control of molding and casting quality. The inadequacy is due to the fact that sand casting processes are inherently thermo-mechanical, thermo-chemical and thermo-physical.

New AFS standardized testing has proven useful for laboratory measurement of these characteristics in foundry sand using a disc-shaped specimen. Similarly, the equivalent disc-shaped specimens are used for casting trials. In order to accomplish near-net-shape casting with minimal defects, it is necessary to understand both the properties of the sand system, as well as the interface of molten metal when different binders, additives and/or refractory coatings are used. The methodology for the following chemically bonded sand tests is described:

- Disc Transverse
- Impact
- Modified Permeability
- Abrasion
- Thermal Distortion
- Quick Loss on Ignition

The analysis and interpretation of data related to the new standard sand tests are discussed.

**Keywords:** *chemically bonded sand, permeability test, thermal distortion test, loss on ignition*

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**PREDICTION OF WORKING STRESS OF QUENCHED AND TEMPERED STEEL AND  
CAST STEEL SPECIMEN**

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**Invited lecture**

*Original scientific paper*

**Abstract**

In this paper, the prediction of working stress of quenched and tempered steel and cast steel shaft has been done. The method of simulation of working stress was applied in workpiece of complex form. The working stress was characterized by yield strength and toughness. Proposed method was successfully applied in optimization of the manufacturing of quenched and tempered engineering steel components.

Starting point in studying of the mechanical properties of steel castings can be the fact that the mechanical properties of steel castings are derived from the mechanical properties of ordinary steel metal matrix reduced by the influence of the typical as-cast structure, i.e. casting defects on those properties. Hardness and yield strength will be unaffected by most defects. Coarse as-cast microstructure of cast steel lowers ductility and toughness, i.e. impact energy and fracture toughness.

Estimation of hardness distribution can be based on time, relevant for structure transformation, i.e., time of cooling from 800 to 500 °C ( $t_{8/5}$ ). Hardness of quenched and tempered steel can be expressed as function of maximal hardness of actual steel, hardness of steel with 50 % of martensite in microstructure, according to the time and temperature of tempering. The algorithm of estimation of yield strength and toughness was based on hardness, HV.

**Keywords:** *steel, cast steel, heat treatment, mathematical modelling, mechanical properties*

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**CRACK PROPAGATION PREDICTION IN HETEROGENEOUS MICROSTRUCTURE  
OF NODULAR CAST IRON**

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University of Zagreb Faculty of Mechanical Engineering and Naval Architecture, Zagreb, Croatia

**Invited lecture**

*Original scientific paper*

**Abstract**

The crack propagation prediction occurring on the microstructural level of heterogeneous materials, such as nodular cast iron, is a very challenging problem. According to the results of recent investigations, the emerging phase-field approach to fracture has a strong potential in modelling the complex crack behaviour in a simple manner. In this study, recently developed phase-field staggered solution scheme with the residual norm stopping criterion has been employed for the fracture analysis of heterogeneous microstructure exhibiting complex crack phenomena. The microstructural geometries based on the metallographic images of the nodular cast iron and the material properties of an academic brittle material have been used in numerical simulations where the graphite nodules have been considered as porosities. The proposed algorithm efficiently recovers the complicated crack path driven by the complex microstructural topology.

**Keywords:** *phase-field fracture modelling, staggered algorithm, Abaqus, nodular cast iron, crack initiation and propagation*

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**DETERMINATION OF MECHANICAL PROPERTIES OF NIOBIUM MICRO-  
ALLOYED STEEL USING INSTRUMENTED INDENTATION TEST**

**Tamara Aleksandrov Fabijanić<sup>1\*</sup>, Mladen Franz<sup>1</sup>, Stoja Rešković<sup>2</sup>**

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**Oral presentation**

*Original scientific paper*

**Abstract**

Niobium Nb micro-alloyed steels belong to a group of structural steels. They are alloyed with a small content of Nb (0.02-0.1 wt.%) which has a significant influence on many properties. Nb exhibits a strong affinity for nitrogen N and carbon C and causes the formation of niobium carbide NbC, niobium nitride NbN and niobium carbonitride Nb(C, N) in a structure which prevents grain growth and slows the recrystallization process and thus contributes to precipitation hardening. The mechanical properties of Nb micro-alloyed steel with Nb content of 0.035 wt.% were researched using instrumented indentation test. The indentation was carried out using different loads to determine the effect of the applied load on the measured properties and to research the applicability of the method for this group of materials. Based on the slope of the force-penetration depth curve during the loading and unloading, the Martens hardness, indentation hardness, indentation modulus, Vickers hardness, elastic/plastic work and creep characteristic were determined.

**Keywords:** *Nb micro-alloyed steel, instrumented indentation test, mechanical properties*

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**THE INFLUENCE OF WATER MIST INJECTION ON THE FILM COOLING PROCESS  
OF CASTED TURBINE BLADES**

**Jakov Baleta<sup>1</sup>, Damijan Cerinski<sup>1\*</sup>, Fengsheng Qi<sup>2</sup>, Fang Wang<sup>2</sup>, Jin Wang<sup>3</sup>, Xuebin Wang<sup>4</sup>**

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**Oral presentation**

**Original scientific paper**

**Abstract**

Casted turbine blades are usually made of Ni-based super alloys, which are capable to withstand higher temperatures than other technical metal materials and have good corrosion resistance properties. The combustion efficiency highly depends on the temperature, but currently used turbine blades materials are not capable to withstand such conditions, therefore utilising the film cooling process is necessary. The influence of water mist injection on the film cooling process of casted turbine blades was numerically investigated. CFD simulations were performed to describe the interaction between the hot stream gas from the combustion chamber and the coolant jet from a cooling hole along with the water mist injection. The validation case with the cylindrical hole was compared to the experimental results and results from Large Eddy Simulation (LES) available in the literature. Temperature distributions were analysed and compared to the case with a laidback hole and console configuration to investigate the influence of injecting the water mist on cooling performance. The results showed the possibility of improving the film cooling performance by implementing the water mist injection system which allows the increase of the temperature in the combustion chamber, and consequently overall gas turbine efficiency.

**Keywords:** *CFD, casted turbine blades, film cooling, water mist injection*

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**COMPARISON OF MOLDING SAND TECHNOLOGY BETWEEN ALPHASET (APNB)  
AND FURAN (FNB)**

**Dipak Ghosh\***

Forace Polymers Pvt. Ltd, Haridwar, India

**Oral presentation**  
*Original scientific paper*

**Abstract**

The paper focuses on investigation of properties of two most widely used self-set sand binder systems across the Globe, APNB and FNB for making molds and cores in foundries to produce castings of different sizes involving wide range of metals and alloys, ferrous and nonferrous. This includes study of compression strength values of samples made out of molding sand at different binder addition level using new, mechanically reclaimed and thermally reclaimed sand. Strength values studied include dry strength (at room temperature) simulating different stages of mold handling, namely stripping and pre heating, followed by degraded strength after wash application in warm condition and then recovered strength after cooling of wash applied samples. Attempts have also been made to study hot and residual strength of samples at elevated temperature. Volume of gases generated for both binders in laboratory at 850°C have also been measured. Nature of gases including harmful BTEX and PAH generated on pyrolysis of FNB and APNB bonded sands are already documented in a publication [1]. This exercise has once again been repeated with latest binder formulations in use in two foundries in India and results are included in this paper.

***Key words:*** *Alphaset, Furan, foundries, sand, hot strength, residual strength, gases, environment*

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**APPROPRIATE MATHEMATICAL MODEL FOR STRESS CALCULATION BASED ON  
THE MEASURED VALUES OF DEFORMATION AND TEMPERATURE CHANGES**

Ivan Jandrlić<sup>1\*</sup>, Stoja Rešković<sup>1</sup>, Ladislav Lazić<sup>1</sup>, Tin Brlić<sup>1</sup>, Dušan Ćurčija<sup>2</sup>

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**Oral presentation**

*Original scientific paper*

**Abstract**

Presented mathematical model determines the stresses depending on the measured temperature changes and the associated deformations of the samples. Investigations were conducted by tensile testing machine Zwick 50 kN on the samples from low-carbon niobium microalloyed steel. The values of measured parameters were determined by using the methods of thermography and digital image correlation. The model is formulated on the basis of a multiple regression analysis of the relations between measured and calculated parameters. Verification and validation of the model showed a good agreement between the model and the system modeled.

**Keywords:** *stress, mathematical model, thermography, digital image correlation*

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**COOLING RATE ASSESSMENT DURING NONEQUILIBRIUM SOLIDIFICATION OF  
COMPLEX Al–Mn–BASED ALLOYS**

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University of Ljubljana Faculty of Natural Sciences and Engineering, Ljubljana, Slovenia

**Oral presentation**

*Original scientific paper*

**Abstract**

This work deals with the influence of alloying elements on the cooling rate and microstructure in complex Al–Mn-based alloys. Alloys were synthesized at 880 °C and cast into a copper mould with cylindrical casting cavity. The castings were characterized by light microscopy (LOM), scanning electron microscopy (SEM) and energy-dispersive x-ray spectroscopy (EDS). X-ray diffraction (XRD) and electron backscattered diffraction (EBSD) were used to determine the structure of the phases. The solidus and liquidus temperatures and enthalpies were determined with the differential scanning calorimetry (DSC). Cooling rate at the start of solidification was calculated by one-dimensional transient-heat-conduction analysis. Calculations showed negligible difference in the average cooling rate between investigated alloys. Nevertheless, the volume fraction of primary icosahedral quasicrystalline (iQc) phase, which had almost the same chemical composition in all investigated alloys, was far higher for the Al–Mn–Si–Zn–Ca–Sr alloy. Results showed significant difference in the solidification rate between investigated alloys. Solidification rates were estimated by measuring the secondary dendrite arm spacing (SDAS) and content of manganese in solid solution of  $\alpha$ -Al. The highest solidification rate was estimated for the Al–Mn–Si–Zn–Ca–Sr alloy. Additional elements such as magnesium, calcium and strontium have a big influence on the solidification path of investigated alloys. Higher mean solidification rate in alloy containing calcium, strontium and zinc was also calculated using Chvorinov's rule.

**Keywords:** *aluminium alloys, microstructure, cooling rate, solidification rate, Chvorinov's rule*

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**THERMODYNAMIC DESCRIPTION OF THE TERNARY Ge-Sn-Ag, In, Zn**

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**Oral presentation**

*Original scientific paper*

**Abstract**

This paper presents results of experimental examinations of alloys from ternary Ag-Ge-Sn, Ge-Sn-In and Ge-Sn-Zn systems. Differential thermal analysis (DTA), scanning electron microscope with energy dispersive spectroscopy (SEM-EDS) and x-ray diffraction (XRD) were used for the experimental investigation of the prepared samples. Alloys were from isothermal sections and vertical sections. Based on the experimental results, a thermodynamic description of the ternary Ag-Ge-Sn, Ge-Sn-In and Ge-Sn-Zn systems have been developed by using CALPHAD method. Reasonable agreement between experimental data and the calculated phase diagrams has been reached. The liquid projection and invariant equilibria have been calculated by using obtained thermodynamic parameters.

**Keywords:** *ternary Ag-Ge-Sn system, ternary Ge-Sn-In system, ternary Ge-Sn-Zn system, experimental tests, CALPHAD method*

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**EFFECT OF SUBSEQUENT HEATING ON THE MICROSTRUCTURE AND  
MECHANICAL PROPERTIES OF Nb MICROALLOYED STEEL**

**Ljerka Slokar Benić\*, Ivan Jandrić, Stoja Rešković**

University of Zagreb Faculty of Metallurgy, Sisak, Croatia

**Oral presentation**

*Original scientific paper*

**Abstract**

Effect of subsequent heating on the microstructure and mechanical properties of hot rolled niobium microalloyed steel was researched in this paper. Low carbon steel was microalloyed with 0.048 % niobium and it was heated at 1150 °C followed by cooling in the air. Researches were performed on two types of samples: low carbon steel microalloyed with niobium and subsequently heated microalloyed steel in the rolling direction as well as in the direction perpendicular to the rolling direction. Mechanical properties of all samples were determined by the static tensile test at testing rate of 5 mm/min. After that their microstructure was observed by scanning electron microscope. Results have shown a significant effect of subsequent heating on the microstructure, i.e. grain size as well as on the mechanical properties.

***Keywords:*** *subsequent heating, niobium microalloyed steel, microstructure, mechanical properties*

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**INFLUENCE OF MEDIUM ON CORROSION AND MICROSTRUCTURAL  
PROPERTIES OF HTCS-130 TOOL STEEL FOR HOT WORK**

**Sandra Brajčinović<sup>1</sup>, Anita Begić Hadžipašić<sup>1\*</sup>, Jožef Medved<sup>2</sup>, Stjepan Kožuh<sup>1</sup>**

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**Poster presentation**

*Original scientific paper*

**Abstract**

In this paper the corrosion resistance of tool steel for hot work in the industrial emulsion medium (Lenox Band-Ade semi-synthetic oil + water, in ratio 1:10), water and 3.5% NaCl medium was tested. By Tafel's extrapolation from polarization curves it was established that the tested tool steel showed extremely high corrosion rate in water and 3.5% NaCl medium in contrast to medium of Lenox Band-Ade emulsion. The double higher corrosion rate of tool steel is recorded in the chloride medium as opposed to that obtained in water, indicating that the tested steel is more corrosion resistant in water. The obtained results were confirmed by the method of electrochemical impedance spectroscopy. The sample of tool steel in the Lenox Band-Ade emulsion medium showed far greater value of charge transfer resistance  $R_{ct}$  than that obtained in the water medium and 3.5% NaCl, which means that the Lenox Band-Ade emulsion formed a thicker oxide layer that has the role of barrier in further penetration of aggressive ions from the solution.

The conducted SEM analysis after electrochemical measurements in 3.5% NaCl medium indicate the occurrence of pitting corrosion caused by breaking the passive surface of the material as a result of the action of aggressive ions from the solution. The EDS analysis of formed pits has been shown the increased oxygen content, but also the higher presence of sodium and chlorine, which accumulate in the pits, and come from the medium. Molybdenum and tungsten showed the highest presence in white deposits on the sample surface, which represent parts that did not completely cover with oxide layer, which is why the smallest oxygen content was recorded at these sites.

The obtained corrosion rate values in the water medium and the chloride medium indicate that the studied tool steel is poorly stable in water and chloride media, and because of that it can only be used in exceptional cases under conditions in which it will come into contact with water or chloride medium.

**Keywords:** *tool steel for hot work, pitting corrosion, corrosion rate, impedance, microstructure*

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**CORRELATION OF MECHANICAL AND MICROSTRUCTURAL PROPERTIES IN  
AS-CAST CONDITION OF EN AW-5083 ALUMINIUM ALLOY  
USING STATISTICAL ANALYSIS**

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**Poster presentation**  
*Original scientific paper*

**Abstract**

In the frame of this investigation, six (6) ingots of EN AW-5083 alloy have been casted by semi-continuous vertical Direct Chill process (DC). The idea behind the process was correlating mechanical properties (tensile strength) with microstructure of ingots (number of grains per unit area) in as-cast state using statistical analysis. The Latin square experimental design was used for statistical analysis. The ingot cross-sectional grain sizes and the mean grain number per unit area were determined at precise, statistically defined locations in the slice by means of semi-automatic method for measuring mean lineal intercept lengths. Additionally, determination of the ultimate tensile strength across the cross-sectioned slices of ingots was made. It revealed differences between ingots' fronts and rears for both microstructure and ultimate tensile strength. Comparison of obtained differences enabled the correlation between ultimate tensile strength and number of grains per unit and hypothesis was based on impact of disposition and number of grains on ultimate tensile strength. The results were processed using the StatSoft® STATISTICA 13.2. software package using charge, slice height and slice width as sources of variability. Comparison of obtained statistical results for both number of grains per unit and tensile strength in respect to the sampling position enabled further correlation between these two properties and it explained how casting process has direct impact on microstructure and, ultimately, on mechanical properties.

**Keywords:** *aluminium alloy EN AW-5083, direct chill casting, statistical analysis, microstructure, tensile strength*

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**MODERNIZATION OF THE LADLE TO IMPROVE FERROALLOY  
REFINING CONDITIONS**

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**Poster presentation**  
*Original scientific paper*

**Abstract**

A potential for reduction of heat losses from a refining ladle due to the use of refractory lining with higher thermal resistance as well as proposed modification of liquid ferrosilicon ladle refining with technical gases to improve its purity have been presented in the paper. It includes calculation results for insulation materials with low conductivity. Instead of Al 44 chamotte [1], two insulating materials, Promacrete PF 145/20 [2] and Carath FL 1500 [3] refractory concretes, have been selected and it is suggested that chamotte brick is replaced with porous chamotte in the insulation layer. Compressed gas should be delivered to liquid metal through a gas lance or, optionally, through a specially designed porous plug located in the ladle bottom (the gas lance was used in the experiments). Physical model studies have shown that the optimal depth of lance immersion should be 2/3 of the metal height in the refining ladle.

**Keywords:** *casting ladles, ferroalloys, improving purity of alloy*

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**INFLUENCE OF Mn ON THE CORROSION BEHAVIOR OF CuAlMn ALLOY  
IN NaCl SOLUTION**

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**Poster presentation**

*Original scientific paper*

**Abstract**

The corrosion behavior of different CuAlMn shape memory alloys (Cu-12%Al-4%Mn, Cu-12.3%Al-5.2%-Mn and Cu-12%Al-6%Mn) in 0.9% NaCl solution at pH = 7.4 and T = 37°C was investigated using open circuit potential measurements, polarization and electrochemical impedance spectroscopy methods. It has been found that the corrosion resistance of the tested samples at open circuit potential increases with increasing Mn content in the alloy, i.e. growing in the order of: Cu-12%Al-4% Mn < Cu-12.3%Al-5.2%Mn < Cu-12%Al-6% Mn. Namely, the corrosion current decreases in same order, while the polarization resistance and the resistance, thickness and compactness of the surface oxide layer increase. However, at high anodic potentials ( $E > 0.1$  V), the corrosion rate increases with Mn content in the alloy, and light microscopy investigations reveal pits on the surface of Cu-12.3%Al-5.2%-Mn and Cu-12%Al-6%Mn alloys, while Cu-12%Al-4%Mn surface is almost clear of any corrosion damage.

**Keywords:** *shape memory alloys, CuAlMn alloy, corrosion, polarization, electrochemical methods*

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**MICROSTRUCTURAL ANALYSIS OF COLD DRAWN CuAlMn SHAPE MEMORY  
ALLOY WIRE**

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**Poster presentation**

*Original scientific paper*

**Abstract**

The Cu-11.9Al-2.5Mn (wt. %) shape memory alloy was produced by vertically continuous casting technique obtaining bars of 8 mm in diameter which is applicable for plastic deformation. With the process of hot rolling and forging the 4.80 mm bar was produced. Afterwards, the obtained 4.80 mm bar was subjected to cold drawing process. After first run and after fourth run of cold drawing process the wire with diameter of 4.47 mm and 3.22 mm was produced, respectively. Optical microscopy (OM) and scanning electron microscopy (SEM) equipped with energy dispersive spectroscopy (EDS) shown the insight in the samples microstructure. The as-cast state sample has two phase ( $\alpha+\beta$ ) microstructure. After cold working process the two-phase (martensite+ $\alpha$ ) microstructure appears. As the result of the cold working process it can be noticed a texture inside the sample depending on cold drawing direction. The microhardness of samples increases as the wires diameter decreases.

**Keywords:** CuAlMn wire, shape memory alloy, microstructure, hot working, cold working

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**THE IMPACT OF MULTIWALL CARBON NANOTUBES ON THE PHOTOCATALYTIC  
PROPERTIES OF IMOBILIZED TiO<sub>2</sub>**

**Igor Jajčinović<sup>1\*</sup>, Ivan Brnardić<sup>1</sup>, Stjepan Kožuh<sup>1</sup>, Kristina Tolić<sup>2</sup>**

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**Poster presentation**

*Preliminary note*

**Abstract**

Industry development, Earth's population growth, ever increasing need for greater pharmaceuticals production causes irreversible changes in the environment. Photocatalysis is a process that leads to complete decomposition of pharmaceuticals to non-hazardous degradation products under the influence of solar radiation in the presence of a photocatalyst. A photocatalyst, such as titanium dioxide (TiO<sub>2</sub>), is required for photocatalysis. The efficiency of using TiO<sub>2</sub> is limited due to the high energy banned zone (3-3.2 eV) so only UV-A light, which makes up 5% of solar radiation, activates the photocatalyst. In order to overcome the problem of prohibited zones and to shift the light response threshold of TiO<sub>2</sub> into the visible part of the spectrum, different methods can be used. One of the methods showing the potential is the use of multiwall carbon nanotubes (MWCNT).

In this paper a TiO<sub>2</sub> / MWCNT composites with various concentrations of MWCNT were prepared. The concentrations of MWCNT ranged from 1.5, 5, 10, 25, 50 and 100 wt. % MWCNT relative to the mass of TiO<sub>2</sub>. It was observed that the concentration of MWCNT affects the photocatalytic activity of the composite obtained. Photocatalytic activity was followed by a degradation of salicylic acid, in a pilot reactor followed by UV-VIS spectrometry, as a modal solution and an example of a pharmaceuticals present in the water. The prepared catalysts were characterized by scanning electron microscopy (SEM) equipped with an energy dispersive X-ray spectroscopy (EDX).

**Keywords:** *photocatalysis, TiO<sub>2</sub>, multiwall carbon nanotubes*

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**INVESTIGATION OF IRON CONTAINING INTERMETALLICS IN AISi12 ALLOY  
WITH  $w(\text{Mn}/\text{Fe}) = 0.99$**

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**Poster presentation**  
*Original scientific paper*

**Abstract**

The precipitation of iron-rich intermetallic phases in AISi12 alloy with manganese/iron weight ratio  $w(\text{Mn}/\text{Fe}) = 0.99$  was investigated. Calculation of solidification sequence under equilibrium conditions, obtained using Computer Aided Thermodynamic Diagram Calculation, comprehended precipitation of  $\alpha\text{-Al}_{15}(\text{FeMn})_3\text{Si}_2$  and  $\beta\text{-Al}_5\text{FeSi}$ . However, the microstructural investigations performed using light and electron microscopy indicated the lack of  $\beta\text{-Al}_5\text{FeSi}$  in needle-like morphology. The intermetallic phases in Chinese script, transitional and polyhedral morphology were found, respectively. The results of Energy Dispersive Spectroscopy showed the minimum difference in the chemical composition between the intermetallic phases in Chinese script and polyhedral morphology due to high  $w(\text{Mn}/\text{Fe})$  weight ratio.

**Keywords:** AISi12, solidification sequence calculation, morphology of iron-rich intermetallic phases,  $w(\text{Mn}/\text{Fe})$  ratio

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**THE EFFECT OF ANNEALING TIME ON MICROSTRUCTURE AND IMPACT  
ENERGY OF STAINLESS STEEL AISI 316L**

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**Poster presentation**

*Original scientific paper*

**Abstract**

In this work the results of microstructural analysis and impact energy testing of austenitic stainless steel AISI 316L were carried out. Investigations were performed before and after annealing at 850 °C. Annealing time in this investigation varied from 30 to 90 minutes. After annealing, the samples were cooled in room temperature air. Microstructural analysis of initial rolled and different annealed states was performed by optical microscopy (OM) and scanning electron microscopy (SEM) equipped with device for energy dispersive spectroscopy (EDS). Impact tests were performed on Charpy V-notch specimens at room temperature. Initial rolled state of investigated steel showed the presence of typical elongated polygonal grains austenite and delta ferrite while annealed states showed the presence and evolution of sigma phase in microstructure. Impact energy value of initial rolled state was 260 J and by increasing annealing time it decreases.

**Keywords:** *stainless steel, microstructure, heat treatment, annealing, impact energy*

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**SELECTED PARAMETERS THAT INFLUENCE EMISSION FORMATION DURING  
ALUMINUM MELTING**

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**Poster presentation**  
*Original scientific paper*

**Abstract**

The aim of the present paper is to point out the emissions generated by the aluminum melting process in melting furnaces, especially CO, CO<sub>2</sub>, NO<sub>x</sub>, based on the analysis of selected parameters. Measurements were made on the experimental equipment to analyze such a process. One of the available methods for reducing emissions is the oxygen enrichment of the combustion air. The results of the study show that the enrichment of the combustion air with oxygen leads to a reduction in CO<sub>2</sub> emissions, but undesirable CO emissions have been observed throughout the aluminum heating and melting process. The conclusions of this particular investigation are very useful for practice and point to the importance of analysis of this kind of processes.

**Keywords:** *combustion, enrichment of the air, melting of aluminum, drum furnace, emissions*

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**INVESTIGATION OF THERMAL PROPERTIES OF THE Ga–In AND Ga–Sn  
EUTECTIC ALLOYS**

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**Poster presentation**

*Original scientific paper*

**Abstract**

The application of phase change materials (PCMs) has grown rapidly in the field of thermal management and thermal energy storage. Low melting point metals (LMPMs) and eutectic alloys represent new category of PCMs, which has certain advantages over commercial nonmetallic PCMs like high thermal conductivity and high volumetric latent heat. Two most important criteria for PCMs selection are melting point and the latent heat of melting. In this study, melting and solidification temperatures and latent heat of melting and solidification of the Ga–In and Ga–Sn eutectic alloys were measured using differential scanning calorimetry (DSC). Undercooling tendency of the studied alloys, which is also important criterion for the PCMs selection, was investigated using heating and cooling DSC cycles. Experimentally determined results were compared with the results of thermodynamic calculations according to the CALPHAD (calculation of phase diagram) method and good agreement was observed.

**Keywords:** *Ga–In alloy, Ga–Sn alloy, eutectic alloy, latent heat of melting*

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**PERMANENT MOULD CASTING OF ALUMINIUM ALLOY FORK**

**Ivana Mihalic Pokopec, Ines Mance, Davor Cesarec, Branko Bauer\***

University of Zagreb Faculty of Mechanical Engineering and Naval Architecture, Zagreb, Croatia

**Poster presentation**

*Professional paper*

**Abstract**

Permanent mould casting process is used for its high productivity of castings with high requirements on mechanical properties and surface quality. Carefully set technological parameters lead to efficient and defect-free castings. Computer simulations have nowadays become a necessary tool in both industrial design and manufacturing. Simulation of filling and solidification was carried out using ESi QuikCAST software to determine influence of casting parameters on final quality of cast fork. AlSi10Mg alloy was used. The results of computer simulations were then analysed and compared with the actual castings.

**Keywords:** *permanent mould casting, aluminium alloy, casting simulation*

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**EFFECT OF UV IRRADIATION ON THERMAL AND MECHANICAL PROPERTIES  
OF MATERIALS**

**Vesna Ocelić Bulatović<sup>1\*</sup>, Dajana Kučić<sup>2</sup>, Antonio Ivančić<sup>3</sup>, Lucija Kefurt<sup>3</sup>**

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**Poster presentation**

*Original scientific paper*

**Abstract**

Due to environmental concern and environmental protection a great attention has been developed for degradable polymers, especially in packaging industries that is greatly responsible for large accumulation of polymer waste. A possible solution to reduce the considerable amount of polymer waste while maintaining low prices and good quality of the products is to induce a certain level of biodegradability by blending synthetic polymers with biodegradable polymers such as starch. So, on the other hand it is very important to accelerate and enhancement their biodegradability. One of the well-known and simple methods is UV irradiation or heat treatment that leads to the formation of functional groups in hydrophobic polymer chains making them sensitive to further microbial attack thus accelerating their biodegradability.

The objective of this work is to investigate the effects of UV irradiation on the properties of biodegradable blends of low-density polyethylene, LDPE, and thermoplastic starch, TPS. The thermoplastic starch was prepared by melting with glycerol as a plasticizer in a single screw Brabender extruder, while the biodegradable blends, LDPE/TPS, were prepared using a Brabender kneading chamber and compression molded in a hydraulic press. The prepared biodegradable blends with a different proportion of individual components were submitted to treatment with UV irradiation (wavelength 290 nm) for 30 days. The changes in mechanical properties, such as tensile strength and elongation at break have been investigated. Also, thermal changes of the biodegradable blends have been measured using the differential scanning calorimetry and the thermogravimetric analysis. UV irradiation causes photooxidative degradation mainly in the amorphous regions of the blends due to the direct absorption of photons on the surface of the polymer chain which results in breaking of the polymer chains, branching, networking, producing free radicals and reducing the molecular weight, causing deterioration of thermal and mechanical properties.

**Keywords:** *biodegradable blends, UV irradiation, thermal properties, mechanical properties*

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**WASTE OIL MANAGEMENT IN CROATIA FOR THE PERIOD 2007 – 2016**

**Tahir Sofilić<sup>1</sup>, Ivan Brnardić<sup>1\*</sup>, Una Sofilić-Šimić<sup>2</sup>, Laila Gumhalter-Malić<sup>3</sup>**

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**Poster presentation**

*Review*

**Abstract**

This paper describes the course of introducing and implementing regulations ensuring efficient waste oil (lubricating oils and edible oils) management, as well as results obtained based on ten years of experience in monitoring and reporting on the management of this special waste category. According to the results for period from 2007 to 2016, between 5 390 t (5 989 000 L) and 7 068 t (7 853 000 L) of waste lubricating oils were collected in the Republic of Croatia.

The quantities of waste edible oil collected in the same period indicate low amounts compared to the estimated annual quantities of fresh edible oil placed on the market, i.e. supposed quantities of waste edible oil collected vary, from 718 t (798 000 L) to 2 145 t (2 383 000 L).

**Keywords:** *waste oils, lubricating oils, edible oils, waste management*

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**THE CHARACTERISTICS AND ENVIRONMENTAL ASPECTS OF MAGNESIUM  
THIXOMOLDING VERSUS DIE CASTING PROCESS**

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**Poster presentation**

*Review*

**Abstract**

Magnesium is an increasingly popular metal used in the design of lightweight constructional components. The applications in the automobile and electronics sector are rising in the past several years. The common magnesium production technology is die casting. One of the advanced manufacturing processes for magnesium is thixomolding. The thixomolding process is applied to the metal in semi-solid state.

This paper describes the underlying chemical and physical phenomena of thixomolding, the technical process and machinery, the characteristics of the produced workpieces, and different applications of thixomolded parts. The number of thixomolding manufacturers by different regions and recent years is presented and an outlook on future developments is given.

Thixomolding is compared to die casting, which is the prevailing technology for magnesium processing. The difference in energy consumption is presented, as well as the cost of the used amounts of gasses. The environmental impact of different gasses used, expressed as the CO<sub>2</sub>-equivalent or the gasses' toxicity is presented. Some gasses used in die casting have a strong environmental imprint: sulfur hexafluoride is a very potent greenhouse gas; sulfur dioxide is a well-known air pollutant and also corrosive for the equipment and hydrofluorocarbon HFC-134a has a high global-warming potential. On the other hand, the thixomolding process uses the inert gas argon, without a global warming potential.

**Keywords:** *thixomolding, die casting, magnesium, global warming, environment*

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**THE EFFECT OF THE AGING PROCESS ON THE DIFFERENT PROPERTIES OF THE  
EN AW-6082 ALUMINUM ALLOY**

**Uroš Stamenković\***, Svetlana Ivanov, Ivana Marković, Vesna Grekulović, Jasmina Petrović,  
Milica Bošković

University of Belgrade Technical Faculty in Bor, Bor, Serbia

**Poster presentation**  
*Original scientific paper*

**Abstract**

The aim of this paper is the investigation of the effect of natural aging and pre-aging on an EN AW-6082 aluminum alloy by studying its mechanical, physical and microstructural properties. These properties were investigated during different aging treatments. Firstly, the effect of natural aging on investigated properties was studied, after which the influence of natural aging (room temperature pre-aging) on the artificial aging was investigated. The results showed that the hardness values increased gradually with the duration of natural aging. During the natural aging the hardness gradually increased up to around 30 %, while electrical conductivity decreased for about 1 MS/m in all naturally aged samples compared to the quenched one. Room temperature pre-aging had no effect or even negative effect on measured properties of subsequent artificially aged samples. This means that pre-aged samples during artificial aging had the same or lower hardness values compared to the only artificially aged samples. The same conclusions were drawn for the electrical conductivity measurements. Optical microscopy investigation confirmed the existence of precipitated phases and their distribution in the structure.

**Keywords:** *aluminum alloys, EN AW-6082, natural aging, pre-aging, artificial aging, hardness, electrical conductivity, microstructure*

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**INFLUENCE OF DEEP CRYOGENIC TREATMENT ON THE MECHANICAL  
PROPERTIES OF ADI AUSTEMPERED AT THE LOWER AUSFERRITIC RANGE**

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**Poster presentation**

*Original scientific paper*

**Abstract**

The application of deep cryogenic treatment in heat treatment processes showed excellent results in improving mechanical and tribological properties of variety of materials, especially tool steels, hard metals and grey iron and also nodular cast iron austempered in the upper ausferrite temperature range. This paper presents the results of the investigation of the influence of deep cryogenic treatment with subsequent tempering on the tensile strength and Charpy impact test at three different temperatures of the ductile cast iron grade EN-GJS-600-3 austempered at the lower ausferrite temperature range. The results show that austempering process influenced the tensile strength increase but deep cryogenic treatment with tempering did not have any significant influence on the tensile strength or the Charpy impact test results.

**Keywords:** *deep cryogenic treatment, ADI, lower ausferrite, tensile strength, Charpy impact test*

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**CORROSION BEHAVIOR OF CuAlMn AND CuAlMnNi ALLOY IN 0.9% NaCl  
SOLUTION**

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Gudić<sup>1</sup>, Mirko Gojić<sup>2</sup>**

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**Poster presentation**

*Original scientific paper*

**Abstract**

Corrosion behavior of CuAlMn and CuAlMnNi alloy ribbons, produced by melt spinning method, were investigated by electrochemical methods such as open circuit potential measurement, linear and potentiodynamic polarization method. Investigations were performed in deaerated 0.9% NaCl solution (T = 37 °C pH = 7.4). Results of electrochemical investigations have shown that CuAlMnNi alloy have higher values of polarization resistance and smaller values of corrosion current density, but in higher anodic potentials region anodic current density for CuAlMn is lower than for CuAlMnNi alloy which indicates higher dissolution of CuAlMnNi alloy. After polarization measurements CuAlMn and CuAlMnNi ribbon surfaces were investigated with light microscope and with SEM/EDS analysis and results have shown that CuAlMnNi alloy is prone to pitting corrosion, while the surface of CuAlMn alloy is partially covered with corrosion product without existence of pits.

**Keywords:** *corrosion, polarization, shape memory alloys, SEM/EDS analysis*

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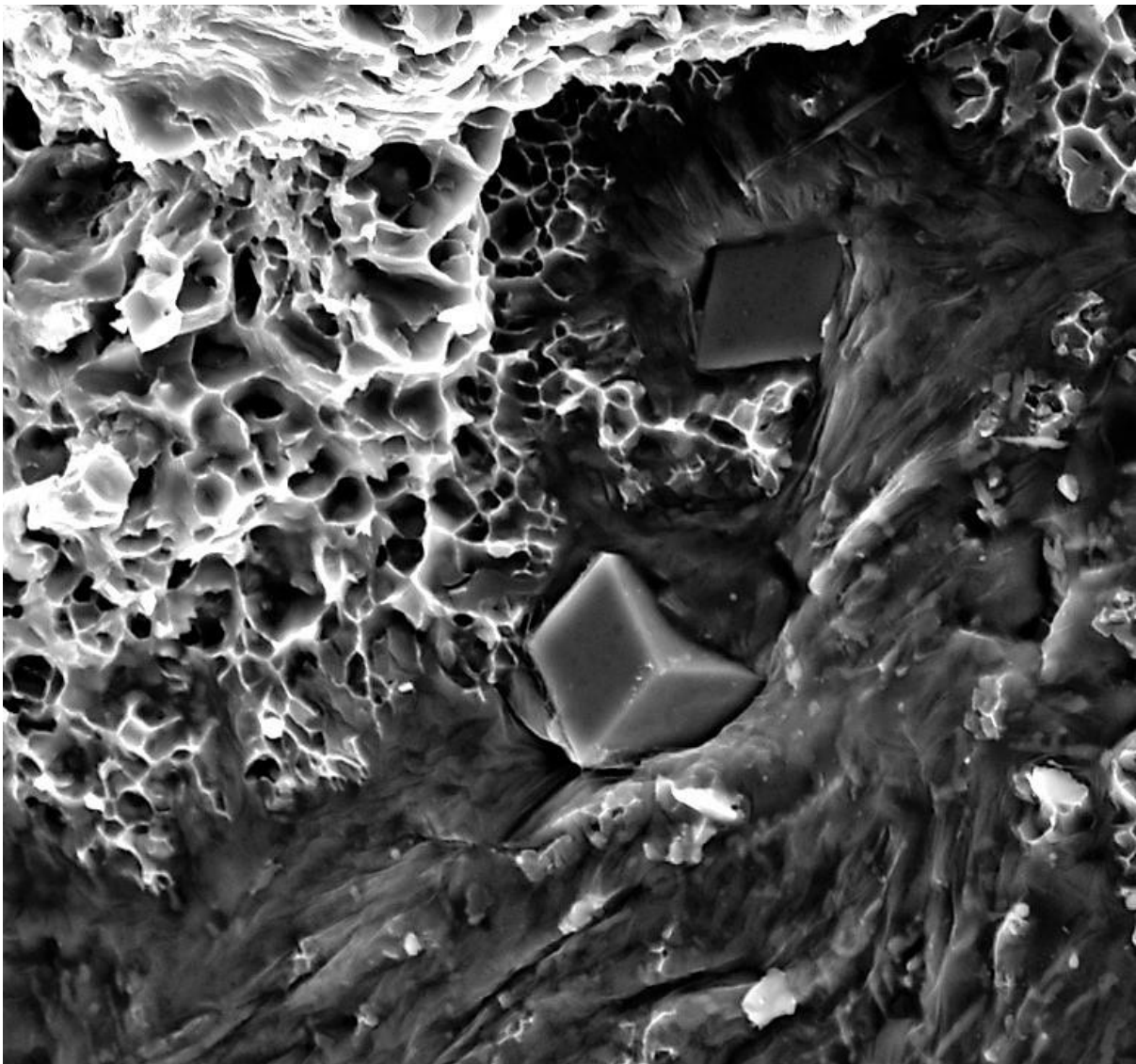


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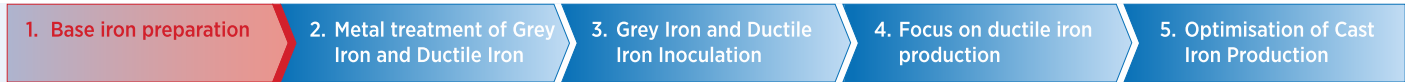
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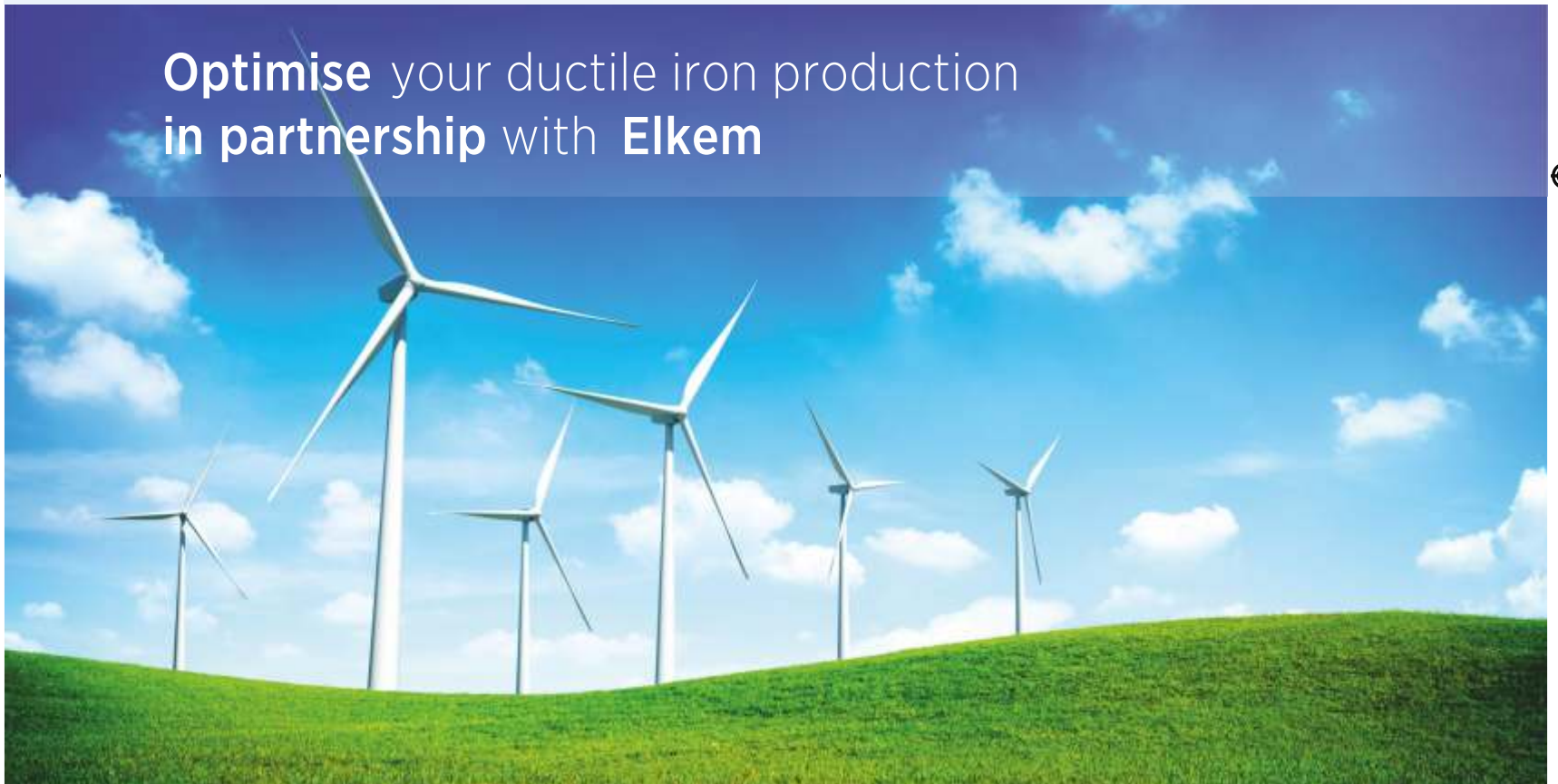
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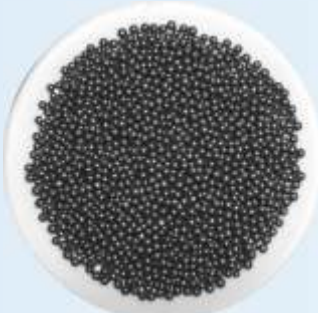




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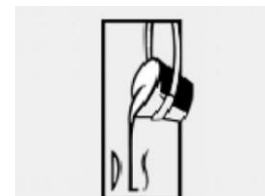
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