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ABSTRACTS BOOK

13th INTERNATIONAL FOUNDRYMEN CONFERENCE

Innovative Foundry Processes and Materials



with PROCEEDINGS BOOK included on CD-ROM

Opatija, May 16th - 17th, 2013

**PROCEEDINGS BOOK,
13th INTERNATIONAL FOUNDRYMEN CONFERENCE
Innovative Foundry Processes and Materials**

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PREFACE

Faced to the global crisis, foundries in Europe have to increase their technical competence and economical competitiveness by costs rationalization and optimization of casting production. Each foundry should create its own technical solutions and use latest technological innovations in more efficient way. The increase of product quality and performance require implementation of modern technology and new production concepts in technical and managing respects. Prerequisite to overcome the global crisis is more efficient use of human resource, knowledge and actual scientific and expert attainments. According to this,

University of Zagreb Faculty of Metallurgy, Sisak, Croatia
in collaboration with
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has organized

13th International Foundrymen Conference

entitled

Innovative Foundry Processes and Materials

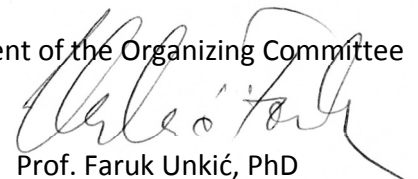
The objective of the Conference is to present the recent achievements in the production of ferrous and nonferrous castings and provide an international forum to exchange knowledge and experience related to foundry technology.

The scope of the Conference covers scientific, technological and practical aspects concerning research, development and realization of casting technology. Special attention will be focused towards the competition ability of foundries, environmental protection as well as subjects connected to properties and application of castings.

During the Conference 50 papers will be presented. Participants from 19 countries will participate in scientific, expert and commercial presentations. Proceedings book of the 13th International Foundrymen Conference includes summaries of the papers and papers *in extenso* in electronic format (CD). 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 alphabetically by the first author's surname.

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

President of the Organizing Committee



Prof. Faruk Unkić, PhD



THE HEAD OF ORIENTAL GOD (ATIS?)
bronza
2nd century AD
SISCIA (modern Sisak, Croatia)



ILLYRIAN HELMET
iron
6th century BC

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**INVESTIGATION OF THE THIRD PHASE IMPACT PRESSURE ON
DENSITY AND POROSITY OF HIGH-PRESSURE CASTING**

**ISPITIVANJE UTJECAJA TLAKA TREĆE FAZE NA GUSTOĆU I
POROZNOST ODLJEVAKA VISOKOTLAČNOG LIJEVA**

S. Babić

LIPOVICA d.o.o., Popovača, Croatia

Professional paper/Stručni članak

ABSTRACT

The paper presents the examination of the third phase impact pressure on the density and porosity of the casting in the high-pressure casting in terms of industrial production. Based on statistical analysis of test results, mathematical models have been performed depending related to the density of the third phase casting pressure. Recommendations for the optimal pressure selection of the third phase related to required quality of casting was obtained.

***Key words:** high-pressure die casting, third phase pressure, density, porosity*

SAŽETAK

U radu je prikazano ispitivanje utjecaja tlaka treće faze na gustoću i poroznost odljevka pri visokotlačnom lijevanju u industrijskim uvjetima proizvodnje. Na osnovi statističke obrade rezultata ispitivanja napravljeni su matematički modeli ovisnosti gustoće odljevka o tlaku treće faze i preporuke za odabir optimalnog tlaka treće faze obzirom na zahtijevanu kvalitetu odljevaka.

***Ključne riječi:** visokotlačni lijev, tlak treće faze, gustoća, poroznost*



HYDROGEN EMBRITTLEMENT AS CONSEQUENCE OF HYDROGEN DIFFUSION IN HIGH-STRENGTH LOW-ALLOYED STRUCTURAL STEELS

VODIKOVA KRHKOST KAO POSLJEDICA DIFUZIJE VODIKA U VISOKOČVRSTIM NISKOLEGIRANIM KONSTRUKCIJSKIM ČELICIMA

A. Begić Hadžipašić, J. Malina, S. Mitić

University of Zagreb Faculty of Metallurgy, Sisak, Croatia

Original scientific paper/Izvorni znanstveni rad

ABSTRACT

By the electrochemical experiments which provide the hydrogenation of specimens in conditions which simulate practice requirements, hydrogen embrittlement of high-strength low-alloyed structural steels as a result of hydrogen diffusion in steel materials was studied.

By the permeation experiments of hydrogen diffusion through the steel membrane of the modern multiphase structural TRIP-steel, lower diffusion coefficient was obtained in comparison to the conventional structural steel, suggesting that TRIP-steel has fewer traps for hydrogen. Optical microscopy has shown favorable microstructure of modern structural TRIP-steel compared to the conventional structural steel. Namely, the extremely fine-grained microstructure of TRIP-steel consists of ferrite, bainite and retained austenite, where the retained austenite is more favorable than martensite in terms of hydrogen embrittlement, because it has a higher solubility of carbon and hydrogen, and lower hardness. On the other hand, the microstructure of conventional structural steel is not fine-grained, but consists of larger ferrite grains with some cementite, known as an irreversible trap.

From the obtained results it can be concluded that representative of a modern high-strength structural steel showed higher resistance to hydrogen embrittlement compared to the conventional structural steel and can be considered more suitable structural material for application in conditions where contact with hydrogen is inevitable.

Key words: *high-strength structural steel, electrochemical methods, hydrogen diffusion, hydrogen embrittlement, microstructure*

SAŽETAK

Elektrokemijskim eksperimentima koji omogućavaju navođenje uzoraka simulirajući uvjete iz prakse, proučavana je vodikova krhkost visokočvrstih niskolegiranih konstrukcijskih čelika kao posljedica difuzije vodika u čeličnim materijalima. Permeacijskim eksperimentima difuzije vodika kroz čeličnu membranu modernog višefaznog konstrukcijskog TRIP-čelika dobiven je niži difuzijski koeficijent u odnosu na klasični konstrukcijski čelik, što upućuje na to da TRIP-čelik ima manje zamki za vodik. Optičkom mikroskopijom je utvrđena povoljnija mikrostruktura modernog konstrukcijskog TRIP-čelika u odnosu na klasični konstrukcijski čelik. Naime, izrazito sitnozrnata mikrostruktura TRIP-čelika sastoji se od ferita, bainita i zaostalog austenita, pri čemu je zaostali austenit s aspekta vodikove krhkosti povoljnija faza od martenzita, jer ima višu topljivost ugljika i vodika te nižu tvrdoću. S druge strane, mikrostruktura klasičnog konstrukcijskog čelika nije sitnozrnata, već se sastoji od većih zrna ferita s ponešto cementita, poznatog kao ireverzibilna zamka.

Iz dobivenih rezultata može se zaključiti da je predstavnik modernog visokočvrstog konstrukcijskog čelika pokazao veću otpornost prema vodikovoj krhkosti u odnosu na klasični konstrukcijski čelik te se može smatrati prikladnijim konstrukcijskim materijalom za primjenu u uvjetima gdje je kontakt s vodikom neizbježan.

Ključne riječi: *visokočvrsti konstrukcijski čelik, elektrokemijske metode, difuzija vodika, vodikova krhkost, mikrostruktura*



**THE INFLUENCE OF Ti ON THE SEQUENCE OF PHASE
PRECIPITATION IN RAPIDLY SOLIDIFIED Cu-Fe-Ti ALLOYS**

**UTJECAJ Ti NA REDOSLIJED PRECIPITACIJE FAZA BRZO
SKRUĆUJUĆIH Cu-Fe-Ti LEGURA**

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

Precipitation sequence and microstructure decomposition during heating of rapidly solidified Cu-Fe and Cu-Fe-Ti alloys have been investigated by the combination of four point electrical resistance measurement method, optical microscopy and scanning electron microscopy (SEM). Rapidly solidified samples, in the form of thin ribbons, were prepared by the single roll melt spun technique and heated in the protective atmosphere with constant heating rate to 800 °C. Sequence of the phase precipitation during heating was successfully followed by the in-situ electrical resistance measurement method. After recording the electrical resistivity temperature dependency in the entire temperature interval, separate samples were heated to various temperatures, slowly cooled and analyzed by scanning (SEM) electron microscopy. It was found that titanium reacts with iron and forms intermetallic phase TiFe. The microstructure transformation starts at a higher temperature than for binary Cu-Fe alloys and take place in a narrow temperature interval.

Key words: *rapid solidification, Cu alloys, precipitation, electrical resistance measurement*



REFA METHODS FOR ASSESSING AND OPTIMIZING PROCESSES IN FOUNDRIES - PRACTICAL APPLICATIONS IN FERRO-PREIS

REFA METODE ZA PROCJENU I OPTIMIZACIJU PROCESA U LJEVAONICAMA – PRAKTIČNA PRIMJENA U FERRO – PREIS-U

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Conference paper/Izlaganje sa znanstvenog skupa

ABSTRACT

Today in all industries including metallurgy global market demands continues development for more efficient methods of production and reducing costs in order to raise competitiveness. For this reason in 2012 the key production staff attended three-month REFA training.

REFA methods focus on optimizing work process as well as on the determination and evaluation of operational data. Some of REFA methods have been applied in Ferro Preis d.o.o.

- SDD method, which is based on a day of recording time and it, is a first step in determination of working norm.
- SMED method (single minute exchange die), goal is optimization of working process in exchanging model on line.
- 5S method (sort, straighten, shine, standardize, sustain), Cleanup working environment so that workers can be more productive and more secure.

All methods have the common procedures:

- Focus on specific objectives.
- Separation of individual phases.
 - Search for solution – creative phase.
 - Evaluation and selection of solutions.
- Interdisciplinary work.
- Visualization.
- Introduction of solutions and control of results.

Key words: REFA, SMED, 5S, SD, norming

SAŽETAK

Danas u svim granama industrije pa tako i metalurgiji globalno tržište zahtjeva kontinuirano razvijanje metoda za poboljšanje efikasnosti i smanjenje troškova s ciljem poboljšanja konkurentnosti. Iz tog razloga 2012. godine djelatnici na rukovodećim mjestima u proizvodnji i tehnologiji zajedno sa dijelom uprave pohađali su tromjesečnu REFA obuku.

REFA metode fokusiraju se na optimizaciji radnog procesa kao i utvrđivanju i procjeni podataka dobivenih snimanjem radnog procesa. Ovim radom bit će prezentirane samo neke od REFA metoda koje su primijenjene u proizvodnji.

- SDD metoda (slika radnog dana), bazira se na snimanju radnog dana te je to prvi korak za snimanje normativa.
- SMED metoda (promjena alata u minuti), optimizacija izmjene modela.
- 5S metoda, sistem za osiguranje i održavanje urednosti i čistoće radnih mjesta i okoliša.

Navedene metode imaju zajedničke karakteristike:

- Usmjerenost na konkretne ciljeve.
- Odvajanje pojedinačnih faza:
 - Traženje rješenja – kreativna faza.
 - Ocjenjivanje i izbor rješenja.
- Interdisciplinarni timski rad.
- Vizualizacija.
- Kontrola uvođenja rješenja i kontrola rezultata.

Ključne riječi: REFA, SMED, 5S, SD, normiranje



ANALYSIS OF THE INTERNAL CRACKS FORMATION IN THE ALUMINIUM ALLOY BILLET EN AW-6060 WITH THE ASPECT OF HEAVY AND LIGHT METAL CONTENTS

ANALIZA NASTANKA UNUTARNJIH PUKOTINA U TRUPCU ALUMINIJSKE LEGURE EN AW-6060 S ASPEKTA SADRŽAJA TEŠKIH I LAKIH METALA

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Preliminary note/Prethodno priopćenje

ABSTRACT

The composition of the melt in the default standardized limits, automatically controlled dynamic parameters of keeping the casting, and the consistency and repeatability of foundry operations, are often not sufficient to eliminate defects of aluminum billets made by the *Direct Chill* ("DC"). In this paper, the preventive effects on the development or progression of internal cracks in the billets were researched holding cullied AlFeSi brittle phases within tolerable limits by adjusting the composition of the melt.

For this purpose, (1) analysis of the chemical composition of the alloy EN AW-6060 lengthwise of the billet was performed with the objective of determining the relationship between light and heavy metals, and (2) an area of sensitivity emergence of internal cracks was determined. This study examined the AlMgSi alloys (EN AW-6060), from which the billets with diameters 178 mm and 203 mm were cast by *Wagstaff AirSlip* technique.

Key words: AlMgSi alloy (EN AW-6060), billet, internal crack, heavy metals, light metals

SAŽETAK

Sastav taline u zadanim normiranim granicama, automatski kontrolirana dinamika parametara vođenja lijevanja, te dosljednost i ponovljivost ljevačkih operacija, često nisu dovoljni za otklanjanje nastanaka ljevačkih grešaka na aluminijskim trupcima lijevanim *Direct Chill* („DC“) postupkom. U radu je istraživana mogućnost preventivnog djelovanja na nastanak ili napredovanja unutarnjih pukotina u trupcima držanjem izlučenih krtih AlFeSi faza u dozvoljenim granicama korekcijom sastava taline.

U tom cilju je: (1) ispitivan kemijski sastav legure EN AW-6060 po dužini trupca sa ciljem određivanja odnosa između lakih i teških metala, te je i (2) određeno područje osjetljivosti nastanaka unutarnjih pukotina. Analizirana je AlMgSi legura (EN AW-6060) iz koje su odliveni trupci promjera 178 mm i 203 mm tehnikom *Wagstaff AirSlip*.

Ključne riječi: legura AlMgSi (EN AW-6060), trupac, unutarnja pukotina, teški metali, laki metali



**QUALITY OF “IRON UNITS” FOR THE PRODUCTION OF DUCTILE
IRON CASTINGS - CASE STUDY: HEAVY SECTION FERRITIC
DUCTILE IRON**

**KVALITETA ULOŽNIH MATERIJALA ZA PROIZVODNJU
ODLJEVAKA OD NODULARNOG LIJEVA – ANALIZA SLUČAJA:
DEBELOSTIJENI ODLJEVCI OD FERITNOG NODULARNOG LIJEVA**

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*Subject review/Pregledni članak**

ABSTRACT

The production of sound castings in ductile iron is now well known by foundry-men. The present difficulty, for each foundry, consists in finding good “iron units” as steel scrap and pig iron with low level of trace and detrimental elements. The level of micro-alloys is increasing in the new steel scrap, mainly used for automotive and truck structures & bodies. The effects of these alloys on mechanical characteristics depend on their individual levels but also on their cumulative effects: pearlite or carbides percentage, low elongation or impact. Some elements modify the shape of the graphite nodules and directly affect the tensile and yield strengths.

By using quality indexes, this paper will present a tool for choosing the right raw material to produce ductile iron castings, mainly in ferrite grade. The comparison of different steel scraps becomes easier and this paper will present results for foundries working for automotive or windmill sectors. Using these tools, it becomes very simple to look the advantage of high purity iron versus basic pig iron. It is now possible to compare and to predict the result for different ductile bases iron and then to correct a liquid iron before magnesium treatment and pouring.

An example for the production of a heavy section ferritic ductile iron grade with good impact resistance at -20 °C & -40 °C will be illustrated in this paper. Two new quality indexes “RT-20 °C” & “RT-40 °C” initiated by the R&D department of RIO TINTO Iron & Titanium allow Foundrymen to predict the expected low temperature impact resistance values.

Key words: ferrite ductile iron, steel scrap, pig iron, heavy section, impact resistance, quality indexes, low temperature

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STUDY OF THE SURFACE DEFECTS ON GRAY IRON CASTINGS

PROUČAVANJE POVRŠINSKIH GREŠAKA NA ODLJEVCIMA OD SIVOG LIJEVA

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Preliminary note/Prethodno priopćenje

ABSTRACT

In this paper the production of complex geometry castings of gray iron with a high content of phosphorus and chromium was analyzed and possible causes of surface defects such as burn on the surface of the casting and the melt penetration in the sand mold was examined. The examined castings are from the production program of foundry Plamen d.o.o. Požega. A thermal and metallographic analysis was conducted and the effects of inoculation on the microstructure of castings were investigated. A simulation of casting and solidification process was performed and then compared with the real situation of the castings after cleaning.

The results showed that the chemical composition in relation to the casting thickness was well-chosen and that the cause of surface defects was inadequately design of gating system. It is recommended to optimize the gating system to balance of melt flow in the mold cavity and to avoid overheating of the mold and occurrence of the above defects.

Key words: *gray iron, surface defects, thermal and metallographic analysis, simulation of casting and solidification process*

SAŽETAK

U ovom radu analizirana je proizvodnja odljevaka kompleksne geometrije od sivog lijeva sa povišenim udjelom fosfora i kroma te su ispitani mogući uzroci nastanka površinskih grešaka tipa zapečenosti na površini odljevka i prodora taljevine u stjenku kalupa (penetracija). Ispitivani odljevci su iz proizvodnog programa ljevaonice Plamen d.o.o. Požega.

Provedena je toplinska i metalografska analiza te su ispitani učinci cijepjenja na mikrostrukturu odljevaka. Također je provedena simulacija lijevanja i skrućivanja odljevka koja je uspoređena s realnim stanjem odljevaka nakon lijevanja i čišćenja.

Dobiveni rezultati pokazali su da je kemijski sastav u odnosu na debljinu stjenke dobro odabran, te da je uzrok nastanka površinskih grešaka neadekvatno konstruiran uljevni sustav. Preporuča se optimiranje uljevnog sustava da bi se ujednačio dotok taljevine u kalupnu šupljinu i izbjeglo pregrijavanje kalupa i nastanak navedenih grešaka.

Ključne riječi: *sivi lijev, površinske greške, metalografska i toplinska analiza, simulacija lijevanja i skrućivanja*



MORE IMPORTANT IRON ORE MELTING PLANTS IN CROATIA

VAŽNIJE TALIONICE RUDE ŽELJEZA U HRVATSKOJ

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Subject review/Pregledni članak

ABSTRACT

The paper shows the circumstances of developing the building of iron ore melting plants in Croatia before and after the World War Two. Multicentury tradition and considering the blast furnace building trends in Central European countries provided a continuous progress in pig iron production. Up to 1985 it was not possible to realize the Yugoslav program of iron ore production development, based on unavoidable import of high quality iron ore, so other local iron ores that were not available in Croatia did not lose priority. Thus the plans of building a new blast furnace in Sisak, having a useful volume of 1386 m³, failed to be realized and production of pig iron was completely put to a stop in 1991.

Key words: *iron ore melting plant, historical review, stopping production*

SAŽETAK

U članku su prikazane prilike u kojima se razvijala gradnja talionica ruda željeza u Hrvatskoj prije i poslije Drugog svjetskog rata. Višestoljetna tradicija i uvažavanje trendova gradnje visokih peći u razvijenijim srednjeeuropskim zemljama osiguralo je kontinuirani napredak u proizvodnji sirovog željeza. Jugoslavenski program razvoja proizvodnje sirovog željeza na neophodnom uvozu kvalitetnije rude željeza do 1985. godine nije bilo moguće ostvariti pa su i dalje u prvom planu ostale domaće rude željeza s kojima Hrvatska nije raspolagala. Zbog toga su otpali planovi da se u Sisku gradi nova visoka peć korisnog volumena 1386 m³, a proizvodnja sirovog željeza potpuno prestaje 1991. godine.

Ključne riječi: *talionice rude željeza, povijesni pregled, prestanak proizvodnje*



QUANTITATIVE ANALYSIS OF MICROSTRUCTURAL CONSTITUENTS OF ALLOY EN AW-5083 SAMPLES AT DIFFERENT COOLING RATES

KVANTITATIVNA ANALIZA MIKROSTRUKTURNIH KONSTITUENATA UZORAKA SLITINE EN AW-5083 PRI RAZLIČITIM BRZINAMA HLAĐENJA

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

Within this work the effect of cooling rate of aluminum alloy EN AW-5083 on solidification kinetics of particular phases has been determined. By the casting of various shapes and dimensions of tested specimens of alloy EN WA-5083 and using different types of mold materials different cooling rates were obtained. Thereby, methods of the simple thermal analysis (STA) by casting in "Quik Cup" and mould with the conic shape and simultaneous thermal analysis by differential scanning calorimetry (DSC) were used.

By the quantitative analysis using energy dispersive spectrometer (EDS) the following microstructural constituents have been determined: intermetallic phases $Al_6(Fe, Mn)$ and Mg_2Si . Also, the presence of the pores has been determined. The total surface area of some intermetallic phases and pores and their mean particle size in dependence on the cooling rates obtained by experiment have been examined by light and scanning electron microscopy (SEM).

Key words: aluminum alloy EN AW-5083, thermal analysis, cooling rates, microstructural constituents, pores

SAŽETAK

U okviru ovog rada određivan je utjecaj brzine hlađenja na kinetiku izlučivanja pojedinih faza u aluminijskoj slitini EN AW-5083. Lijevanjem različitih oblika i dimenzija ispitnih uzoraka slitine EN WA-5083 i upotrebom različitih vrsta kalupnih materijala postignute su različite brzine hlađenja uzoraka. Pri tome su korištene metode jednostavne toplinske analize (JTA) lijevanjem u „Quik Cup“ lončice i lijevanjem u stožastu kokilu, te simultane toplinske analize metodom diferencijalne pretražne kalorimetrije (DSC).

Kvantitativnom analizom putem energijsko disperzivne spektrometrije (EDS) utvrđeni su sljedeći mikrostrukturni konstituenti: intermetalne faze $Al_6(Fe, Mn)$ i Mg_2Si , te je utvrđena prisutnost pora. Ukupni površinski udio pojedinih intermetalnih faza i pora, te njihova srednja površina čestica u ovisnosti o brzini hlađenja dobivenoj eksperimentom ispitana je svjetlosnim i pretražnim elektronskim mikroskopom (SEM).

Ključne riječi: aluminijska slitina EN AW-5083, metode toplinske analize, brzine hlađenja, mikrostrukturni konstituenti, pore



DUCTILE IRON FOR THE WIND POWER INDUSTRY

NODULARNI LIJEV ZA PROIZVODNJU VJETROELEKTRANA

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

The generation of electricity in the Europe from wind-powered turbines is increasing and the most important challenges for the wind turbine manufacturers are linked to the development of larger and more effective wind turbines. Cast iron is today used in central parts of a wind turbine construction and this is a growing market for Swedish foundries. The specifications and requirements applied for the cast iron components are among the most stringent used within the iron foundry branch. A problem for the production of these large components can be too high pearlite content in the metal matrix, thereby deteriorating mechanical properties. Because of this reason there are just a few iron foundries in Sweden that are able to cast the required high quality cast iron components.

The project work has focused on reducing the pearlite stabilizing blanks into the melt and to improve the inoculation process. The project has shown that systematic work with the melt composition and inoculation may provide a much improved structure and thus better properties.

Key words: *ductile iron, wind energy, pearlite content, inoculation*



TRANSPORT OF ORES AND METAL CASTINGS

TRANSPORT RUDAČE I ODLJEVAKA

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Conference paper/Izlaganje sa znanstvenog skupa

ABSTRACT

In the beginnings of metallurgy ore deposits were exploited seasonally and ore had to be transported to faraway settlements. However, early on well established routes started to be used to transport the ore to major settlements. The growth of the civilization need for metal caused ore processing to gradually move closer to ore deposits, initially in the form of mineral purification and soon afterwards as the local production of castings from molds in characteristic shapes that became a universal means of exchange.

Key words: *ore, transport, metal castings*

SAŽETAK

U početcima metalurgije rudna ležišta se sezonski koriste i rudaču treba dopreмати do udaljenih naselja. Ali već od najranijih vremena postoje ustaljeni putovi kojima se rudača prenosi do važnih naselja. S rastom civilizacijske potrebe za metalom prerada rudače se sve više bliži rudištima, isprva pročišćavanjem rudače, a ubrzo i samom proizvodnjom odljevaka u karakterističnim formama kao univerzalno sredstvo za razmjenu.

Ključne riječi: *rudača, transport, metalni odljevci*



**MICROSTRUCTURE AND MECHANICAL PROPERTIES OF WELDS
ON DUPLEX STEEL MADE BY THE UNDERWATER WET MMA
WELDING**

**MIKROSTRUKTURA I MEHANIČKA SVOJSTVA ZAVAREN OG
SPOJA DUPLEX ČELIKA DOBIVEN OG MOKRIM PODVODNIM REL
ZAVARIVANJEM**

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

Due to increased application of duplex steels in off-shore systems there is number of situations where underwater wet welding is needed for repair and maintenance purposes. However, there are very few investigations found in the literature about this matter. Fast cooling, high diffusible hydrogen, porosity etc. are the common problems when speaking about underwater wet welding. These problems are more sensitive when materials like duplex steel are used. In this article basic issues of underwater wet welding of duplex steels are presented. MMAW process was used for welding of samples in laboratory conditions. Mechanical and microstructural properties of welds are given. It is shown that if adequate welding parameters and filler materials are used good quality of underwater wet welds on duplex steel is possible to achieve.

Key words: *underwater wet welding, duplex steel, microstructure, mechanical properties*

SAŽETAK

Radi povećanja primjene duplex čelika pri izradi *off shore* postrojena povećava se i uporaba podvodnog mokrog zavarivanja. U literaturi se ne mogu pronaći detaljniji podaci o provedenim istraživanjima na navedenom području. Brzo hlađenje zavara, povećani sadržaj vodika u zavaru i pojava pora su uobičajene greške koje se mogu pojaviti pri podvodnom mokrom zavarivanju. Mogućnost pojave navedenih grešaka je puno veća kada se zavaruju duplex čelici. U članku su navedene osnovne postavke za zavarivanje duplex čelika. U eksperimentalnom dijelu rada provedeno je mokro podvodno zavarivanje navedenih čelika. Prikazane su vrijednosti mikrostruktura i dobivenih mehaničkih svojstava zavara. Pokazano je da je moguće primjenom odgovarajućih parametara zavarivanja i dodatnih materijala postići kvalitetne zavare iz duplex čelika.

Ključne riječi: *podvodno mokro zavarivanje, duplex čelik, mikrostruktura, mehanička svojstva*



APPLICATION OF EXPERIMENTS WITH MIXTURES IN PRODUCTION OF DUCTILE IRON

PRIMJENA POKUSA SA SMJESAMA U PROIZVODNJI NODULARNOG LIJEVA

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

It is well known that the composition of the metallic charge has a significant effect on the microstructure of ductile iron castings, and therefore on their properties. Experiments with mixtures allow determining the dependence of certain microstructural feature of ductile iron on the proportion of each component in the metallic charge and, most importantly, determining the optimum combination of the composition of metallic charge.

The influence of the composition of metallic charge and preconditioning on microstructure of ductile iron was analyzed in this paper. Using experiments with mixtures mathematical models for estimating the nodule count and ferrite and pearlite content in microstructure of ductile iron on the basis of portion of each component in metallic charge were formed. An example of numerical optimization of the composition of metallic charge in order to obtain the required microstructural features of ductile iron castings was shown.

Key words: ductile iron, microstructure, metallic charge, experiments with mixtures

SAŽETAK

Dobro je poznato da sastav metalnog uloška ima značajan utjecaj na mikrostrukturu odljevaka od nodularnog lijeva, a time i na njihova svojstva. Pokusi sa smjesama omogućuju da se utvrdi ovisnost pojedine mikrostrukturne značajke nodularnog lijeva o udjelu svake komponente u metalnom ulošku i, što je najvažnije, odredi optimalna kombinacija sastava metalnog uloška.

U ovom radu proučavan je utjecaj sastava metalnog uloška i predobrade na mikrostrukturu nodularnog lijeva. Pomoću pokusa sa smjesama formirani su matematički modeli za procjenu broja nodula/mm², te udjela ferita i perlita u mikrostrukтури nodularnog lijeva na osnovi udjela pojedinih komponenti u metalnom ulošku. Prikazan je primjer numeričke optimizacije sastava metalnog uloška u cilju dobivanja zahtijevanih mikrostrukturnih značajki odljevaka od nodularnog lijeva.

Ključne riječi: nodularni lijev, mikrostruktura, metalni uložak, pokusi sa smjesama



CAST BRONZE OF ANCIENT CIVILIZATIONS

LIJEVANE BRONCE DREVNIH CIVILIZACIJA

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Subject review/Pregledni članak

ABSTRACT

“Metals of antiquity” refer to the seven metals which humankind had identified and found use for in prehistoric times. These seven metals (gold, copper, silver, lead, tin, iron and mercury), are the seven metals upon which modern civilization was founded. The use of copper in antiquity is of more significance than other metals as the first tools and weapons were made from copper. Sometime later ancient metallurgists had discovered bronze. After the introduction of bronze, a wide range of castings also became possible.

In bronze making, alloying elements and their amount are generally designed to meet the properties required for fabrication and use. Bronze artefacts with variable percentages of As, Sn, or Pb, that could be intentional, varied with the region (available raw materials) and with the time (evolution of technology).

Due to the rarity and value of historical artefacts, it is generally unacceptable to obtain material for physical and chemical analysis by destructive methods. Although some notable exceptions exist, non-invasive methods are preferred.

This paper gives an overview of the chemical composition of bronze artefacts from different parts of the world, produced more than 2000 years ago. A short description of the methods used for the analysis is also shown.

Key words: *metals of antiquity, bronze artefacts, chemical composition*

SAŽETAK

Termin „metali antičkog doba“ odnose se na sedam metala koje je čovječanstvo otkrilo i koristilo u prapovijesti. Tih sedam metala (zlato, bakar, srebro, olovo, kositar, željezo i živa) su metali na kojima je ustanovljena moderna civilizacija. Primjena bakra u drevna vremena je značajnija od primjene ostalih metala budući da su od njega izrađivani prvi alati i oružja. Nešto kasnije drevni metalurzi su otkrili broncu. Korištenjem bronce postaju mogući razni načini lijevanja.

Legirni elementi i njihova količina koriste se na način da omoguće proizvodnju bronci kao i njihovu primjenu. Sadržaj legirnih elemenata arsena, kositra i olova koji su dodani namjerno, razlikuje se kod brončanih artefakata u različitim dijelovima svijeta (raspoloživost različitih sirovina) kao i u različitom periodu proizvodnje (napredak tehnologije).

Zbog rijetkosti i vrijednosti povijesnih artefakata u načelu je neprihvatljivo koristiti razorne metode za uzorkovanje i analizu. Iako postoje i takvi slučajevi ipak prednost imaju nerazorne metode ispitivanja.

U ovom radu dan je pregled kemijskog sastava brončanih artefakata iz različitih dijelova svijeta koji su proizvedeni prije 2000 i više godina. Dan je i kratki opis najčešće korištenih metoda ispitivanja.

Ključne riječi: *metali antičkog doba, brončani artefakti, kemijski sastav*



**MODELLING OF SOLIDIFICATION OF L-SHAPED STEEL CASTING
BY MEANS OF IMPLICIT AND EXPLICIT FINITE
DIFFERENCE METHOD**

**MODELIRANJE SKRUĆIVANJA ČELIČNOG ODLJEVKA L-OBLIKA
POMOĆU IMPLICITNE I EKSPPLICITNE METODE KONAČNIH
RAZLIKA**

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Preliminary note/Prethodno priopćenje

ABSTRACT

Simulation of solidification of L-shaped steel casting by means of numerical implicit alternating direction (IAD) and Saul'yev explicit finite difference method was performed. Both methods are of the second order with regard to the time and space, and they are unconditionally stable. The results obtained agreed relatively well and enable that on modern and scientific way improves solution for rational prediction of points where is possible defects occurrence in steel casting of relatively complex geometry.

Key words: *modeling of solidification, steel casting, numerical finite difference methods*

SAŽETAK

Provedena je simulacija skrućivanja čeličnog odljevka L-oblika pomoću numeričke implicitne metode promjenljivog smjera (IAD) i Saul'yevljeve eksplicitne metode konačnih razlika. Obje metode su drugog reda s obzirom na diskretizaciju prostora i vremena, te su bezuvjetno stabilne. Dobiveni rezultati relativno se dobro slažu i omogućuju da se na moderan i znanstveni način poboljša racionalno predviđanje mjesta gdje je moguća pojava grešaka u čeličnom odljevku relativno kompleksne geometrije.

Ključne riječi: *modeliranje skrućivanja, čelični odljevak, numeričke metode konačnih razlika*



**MICROSTRUCTURE AND PROPERTIES OF CASTED CuAlNi AND
CuAlNiMn SHAPE MEMORY ALLOYS**

**MIKROSTRUKTURA I SVOJSTVA LIJEVANIH CuAlNi I CuAlNiMn
SLITINA S PRISJETLJIVOSTI OBLIKA**

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Original scientific paper/lzvorni znanstveni rad

ABSTRACT

In this paper the results of analysis of microstructure and hardness of CuAlNi and CuAlNiMn shape memory as-casted state alloys is presented. Melting of the alloys was carried out in vacuum induction furnace in protective atmosphere of argon. Alloys were casted into ingots with 15 kg weight. Microstructural characterization was obtained by optical microscopy (OM) method and scanning electron microscopy (SEM) method equipped with energy dispersive spectrometry (EDS). Partially martensitic microstructure in CuAlNiMn alloy was observed, while the two phase microstructure in CuAlNi alloy was found. A hardness measurement was performed by Vickers method. Hardness of CuAlNiMn alloy was 333 HV 0.5 and CuAlNi alloy was 475 HV 0.5.

Key words: *shape memory alloys, microstructure, CuAlNiMn, martensite*



APPLICATION OF THERMOGRAPHIC METHOD IN DETERMINING THE ONSET OF PLASTIC DEFORMATION

PRIMJENA TERMOGRAFSKE METODE U ODREĐIVANJU POČETKA PLASTIČNE DEFORMACIJE

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

This paper presents the results of testing the beginning of plastic deformation of low carbon steel in tension test. Investigations were carried out on steel S320J. Tension test was performed on the testing machine Zwick 50kN, during which the surface of specimens was recorded by thermal imaging camera VarioCAM M82910. Surface of samples were coated with a thin black matte coating in order to obtain uniform emissivity factor. Obtained results show that the thermal camera can determine the beginning of the plastic deformation of steel.

Key words: *steel, thermography, beginning of plastic deformation*

SAŽETAK

U radu su prikazani rezultati ispitivanja početka plastične deformacije niskougličnog čelika pri statičkom vlačnom pokusu. Istraživanja su provedena na čeliku S320J. Statički vlačni pokus proveden je na kraljici Zwick 50kN, tijekom kojeg se površina uzoraka snimala termovizijskom kamerom VarioCAM M82910. Površina uzoraka je premazana tankim crnim mat premazom kako bi se dobio ujednačeni faktor emisivnosti. Dobiveni rezultati pokazuju da se termalnom kamerom može odrediti početak plastične deformacije čelika.

Ključne riječi: *čelik, termografija, početak plastične deformacije*



NUMERICAL SIMULATION OF FRICTION STIR WELDING FOR DISSIMILAR ALUMINIUM ALLOYS

NUMERIČKA SIMULACIJA ZAVARIVANJA TRENJEM ZA RAZLIČITE ALUMINIJSKE LEGURE

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Preliminary note/Prethodno priopćenje

ABSTRACT

Friction stir welding (FSW) was patented in 1991 at TWI. Since then the majority of research and industrial applications for joining aluminium alloys were made on wrought aluminium alloys, but lately several investigations are done also in FSW with casting alloys and also FSW with dissimilar alloys. FSW process also has big potential in casting industry. In this article investigation of FSW dissimilar joint made from casting aluminium alloy (AA413.0) and technical pure aluminium (AA1050) was done. This kind of joint can be used to make assembled casting, joined with FSW with aim to have casting with different material properties or to join HPDC with FSW to assemble casting with inner cavities.

In this article the temperature distribution of FSW joint of a cast aluminum alloy and pure technical aluminum is investigated. In the experimental work several FSW parameters were tested: tool speed, tool rotation, position of tool regarding the joint center. During joining the temperature was measured with thermocouple and the temperature distribution in steady state was calculated with FEM program Sysweld. For weld quality investigation tensile tests and hardness of joints were investigated.

Key words: *friction stir welding, AA413.0, AA1050, finite element method*



**LONG-TERM DIMENSIONAL CHANGES OF THE HIGH-ALUMINIUM
ZINC ALLOYS MODIFIED WITH Ti ADDITION**

**DUGOTRAJNE DIMENZIJSKE PROMJENE CINKOVIH LEGURA S
VISOKIM UDJELOM ALUMINIJA MODIFICIRANIH TITANOM**

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

The subject of the paper is dimensional changes in long time after supersaturation and quenching of the high-aluminium Zn-26 mass % Al – (0-2.2) mass % Cu – (0-1,6) mass% Ti (Zn-26Al-Cu-Ti). The structural stability of Zn-Al alloys with increased Al content is connected with stability of solid solution of zinc in aluminium α' , which is the main component of these alloys microstructure. Such a solution undergoes phase transformations which are accompanied, among others, by changes in dimensions and strength properties. The initial alloy was Zn-26Al-2.2Cu while in the alloys of modified compositions Cu was totally or partially substituted with Ti. The dimensional changes of the examined Zn-26Al based alloys were investigated using dilatometric (during first 48 hours after supersaturation and quenching) and manual measurements (during next period prolonged to about 1 year). On the basis of the performed examinations it was stated that the addition of Ti, besides structure refinement, decreases dimensional changes and simultaneously allows obtaining dimensional stability in a shorter period of time in comparison with the alloy without Ti addition. Furthermore, it decreases or eliminates the dimensional changes long time after supersaturation and quenching, which is beneficial for stability of castings dimensions.

Key words: *high-aluminium zinc alloys, phase transformations, dimensional stability, dilatometry*



THE INFLUENCE OF THE EMISSIVITY ON ENERGY EFFICIENCY OF FOUNDRY ALUMINIUM MELTING FURNACES

UTJECAJ EMISIJSKOG FAKTORA NA ENERGETSKU UČINKOVITOST LJEVAONIČKIH PEĆI ZA TALJENJE ALUMINIJA

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Subject review/Pregledni članak

ABSTRACT

Energy efficiency of foundry furnaces for aluminum melting is much lower than in most other furnace aggregates, especially because of low aluminum emissivity as well as low heat conductivity of molten aluminum, and low emissivity of conventional refractory at operating furnace temperatures. To intensify the heat transfer by radiation, and increase the furnace energy efficiency, in this paper the impact of changes in emissivity of combustion gases by fuel and air excess changes was analyzed. The work is intended to be the basis for determine the optimal types of available fuel, with respect to its chemical composition and the market price, in any particular case of foundry melting furnace.

Key words: *foundry furnace, aluminum melting, energy efficiency, emissivity*

SAŽETAK

Energetska učinkovitost ljevaoničkih peći za taljenje aluminijske je znatno niža u odnosu na većinu drugih pećnih agregata, poglavito zbog niskog emisijskog faktora aluminijske kao i slabe vodljivosti topline rastaljenog aluminijske te niskog emisijskog faktora klasične vatrostatne obloge na radnim temperaturama peći. Da bi se intenzivirao prijenos topline zračenjem, a time povisila energetska učinkovitost peći, u ovom radu analizira se utjecaj promjene emisijskog faktora dimnih plinova promjenom goriva i pretička zraka. Rad ima za cilj da se temeljem njega može u svakom pojedinom slučaju ljevaoničke talioničke peći odrediti optimalna vrsta raspoloživog goriva obzirom na njegov kemijski sastav i tržišnu cijenu.

Ključne riječi: *ljevaonička peć, taljenje aluminijske, energetska učinkovitost, emisijski faktor*



ANALYSIS OF ALUMINIUM SCRAP MELTING

ANALIZA TALJENJA ALUMINIJSKOG OTPADA

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Professional paper/Stručni članak

ABSTRACT

Aluminium production by electrolysis is highly energy-intensive process. However, it is possible by recycling of the aluminum scrap to save significant amounts of energy and simultaneously contribute to the elimination of waste metal from the environment. Also, this process can be optimized by reducing consumption of natural gas, i.e. of the fuel that is required for aluminum melting, and in this way to contribute to the reduction of production costs. Statistical analysis of the parameters of the melting process, obtained by measurements over the series of the individual melts, allows defining a more efficient aluminum production process. A prerequisite for the creation of process statistics is that the total technological process of preparation of the melt in the furnace has to be divided into individual phases, or characteristic time periods. In this way it is possible to define, on the basis of the measured and calculated data from the created energy balances, the parameters that characterize both a particular melt and the overall properties of the furnace. The carried out study consists of time, material, and energy analysis of certain periods in each of the investigated melts.

Key words: *melting furnace, aluminium scrap, energy consumption, optimization*



**RAPID PROTOTYPING – FUSED DEPOSITION MODELLING AND
INVESTMENT CASTING TECHNOLOGIES FOR MAKING
PROTOTYPE CASTINGS**

**BRZA IZRADA PROTOTIPA – IZRADA MODELA TALOŽNIM
STALJIVANJEM I TEHNOLOGIJE PRECIZNOG LIJEVA ZA IZRADU
PROTOTIPNIH ODLJEVAKA**

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Preliminary note/Prethodno priopćenje

ABSTRACT

The research focused on the production of prototype castings, starting from the drawing documentation up to the production of the casting itself. The Fused Deposition Modeling method was applied for the production of the 3D pattern. Our main objective was to find out, what dimensional changes happened during individual production stages starting from the 3D pattern printing, through a silicon mould production, wax patterns casting, making shells, melting out wax from shells and drying, up to the production of the final casting itself. 5 measurements of determined dimensions were made during the whole process, which were then evaluated mathematically.

Key words: rapid prototyping, an ABS pattern, a silicon mould, a casting, a dimensional stability



EFFECT OF NUMERICAL SIMULATIONS ON QUALITY AND COSTS IN FOUNDRIES

UČINAK NUMERIČKIH SIMULACIJA NA KVALITETU I TROŠKOVE U LJEVAONICAMA

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Professional paper/Stručni članak

ABSTRACT

This paper describes nodular cast iron casting technology optimization for RS Metali Ltd Virovitica foundry. Optimization was carried out using QuikCAST simulation program. Basis for sound castings are high quality melt, corresponding mold sand mixture and correctly dimensioned gating system. Directional solidification can be achieved by proper gating system design, feeding system and use of chills in order to transfer shrinkage porosity and shrinkage cavity in feeders, instead in castings. In this manner high quality castings can be achieved regardless the complexity of casting geometry. Results predicted by numerical simulations are inevitable due to better understanding of casting process, lower costs and shorter time of production and easier communication with customers.

Key words: *numerical simulation, nodular cast iron, directional solidification*

SAŽETAK

U radu je opisana optimizacija odljevaka iz nodularnog lijeva u ljevaonici RS Metali d.d. Virovitica pomoću programa za numeričku simulaciju QuikCAST. Osnovu kvalitetnog odljevka čine dobro pripremljena talina, odgovarajuća kalupna mješavina i pravilno dimenzioniran uljevni sustav. Pravilnim dimenzioniranjem uljevnog sustava, pojila i hladila postiže se usmjereno skrućivanje kojim se usahline i poroznost uslijed skrućivanja premještaju u pojilo, a ne zaostaju u odljevku. To omogućava izradu kvalitetnih odljevaka bez obzira na kompleksnost geometrije. Predviđanje procesa lijevanja numeričkom simulacijom u današnje vrijeme postalo je neizbježno zbog boljeg razumijevanja procesa lijevanja, smanjenja troškova proizvodnje, kraćeg roka isporuke proizvoda i olakšane komunikacije s kupcima.

Ključne riječi: *numerička simulacija, nodularni lijev, usmjereno skrućivanje*



SYNTHESIS AND CHARACTERIZATION OF GOLD NANOPARTICLES

SINTEZA I KARAKTERIZACIJA NANOČESTICA ZLATA

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

This paper deals with the synthesis of gold nanoparticles, which was carried out by a process called Ultrasonic Spray Pyrolysis (USP). This is a chemical reduction method with a relatively easy particle morphology control and availability of cheap precursors. In order to obtain gold nanoparticles with this method, a decomposition of HAuCl_4 , followed by a hydrogen reduction of Au_2Cl_6 takes place. The experiments were conducted with an atomization of a diluted solution of tetrachloroauric acid with an ultrasonic frequency of 0.8 MHz and 2.5 MHz. The temperatures for thermal decomposition of the solution were between 260 °C and 500 °C. This technology allowed us to prepare different fractions of gold nanoparticles with spherical, cylindrical, triangular, round and irregular shapes, with sizes ranging from 10 to 260 nm. The research revealed the role of precursor concentration and selection of proper ultrasonic frequency which influenced finally the size and shape of the produced gold nanoparticles. For the purpose of characterization, we used SEM and TEM with EDS analysis.

Key words: Au particles, ultrasonic spray pyrolysis, synthesis, characterization



**FORMATION OF ALFIN BOND BETWEEN RING CARRIER AND
ALUMINUM PISTON ALLOY**

**STVARANJE ALFINOG SPOJA IZMEĐU NOSAČA PRSTENA I
ALUMINIJSKE KLIPNE LEGURE**

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Preliminary note/Prethodno priopćenje

ABSTRACT

This paper presents the results of investigating an alfin bond between a ring carrier and aluminum piston alloy. The ring carrier is made of austenitic cast iron (Ni-Resist) in order to increase the wear resistance of the first ring groove and applied in highly loaded diesel engines. Ultrasound and metallographic examination of the quality of alfin bond was done. The test results show that, if proper conditions are met, preparations of the ring carrier can be made successfully as well as the formation of metal connection between the two materials of different quality.

Key words: *piston, piston alloys, ring carrier, alfin bond*



SIMULATION OF CRACK FORMATION IN ALUMINUM BILLETS RESULTING FROM DIRECT CHILL ELECTROMAGNETIC CASTING

SIMULACIJA NASTAJANJA PUKOTINE U ALUMINIJSKIM TRUPCIMA TIJEKOM POLUKONTINUIRANOG LIJEVANJA U ELEKTROMAGNETNOM POLJU

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Preliminary note/Prethodno priopćenje

ABSTRACT

In this paper, a mathematical-physical model for simulating Al-alloy casting in the DCEC system is given. It is based on finite element method. A simulator is built on top of the described model. Simulating Al-alloy casting in a crystallizer of the DCEC system is performed taking various parameters into account, which may variably affect the material structure uniformity. Presence of Lorentz force caused by an applied electromagnetic field is also simulated. Comparison of Al-alloy billets while varying the material uniformity is given. Results include calculated relevant parameters of all finite elements of the material, as well as simulated forces and stresses. According to these, pictures of cracks are generated in different stages forming the animation of billet casting. The probability of crack formation is estimated depending on various parameters of the process. Simulation has shown that relatively small variations in uniformity of the material lead to reducing the probability of cracks forming by an order of magnitude. Simulating casting in irregularly shaped mold is not covered with this paper.

Key words: *simulating casting, Al-alloy, cracks, billets, direct chill electromagnetic casting (DCEC)*



INFLUENCE OF HEATING AND COOLING CYCLE ON GREY IRON PROPERTIES

UTJECAJ CIKLUSA ZAGRIJAVANJA I HLAĐENJA NA SVOJSTVA SIVOG LIJEVA

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

It is known that heat treatment can modify the microstructure of the matrix, and the mechanical properties of grey cast iron. But, except during the heat treatment, grey iron heating and cooling cycle, can also occur during other production technologies such as enameling or eventually in the furnace hearth. In this paper, the influence of heating of the grey iron on the temperature of 800 °C (for 10 and 30 minutes) with air cooling. It was found that there is a change in the microstructure and, as the consequence, in mechanical properties, and that the changes are more intense with the increase of the holding time at the selected temperature.

Key words: *gray cast iron, heating, microstructure, hardness, strength*

SAŽETAK

Poznato je da se toplinskom obradom može mijenjati mikrostruktura matrice, odnosno mehanička svojstva sivog lijeva. No, ciklus zagrijavanja i hlađenja sivog lijeva osim pri toplinskoj obradi, može se javiti i pri ostalim tehnologijama obrade ovog materijala npr. emajliranju ili eventualno kod ložišta peći. U radu je ispitivan utjecaj zagrijavanja sivog lijeva na temperaturu 800 °C (u trajanju od 10 i 30 minuta) uz hlađenje na zraku. Utvrđeno je da dolazi do promjene mikrostrukture a kao posljedica toga i mehaničkih svojstava i to intenzivnije s porastom dužine držanja na temperaturi.

Ključne riječi: *sivi lijev, zagrijavanje, mikrostruktura, tvrdoća, čvrstoća*



DEVELOPMENT OF IMPROVED CAST SQUIRREL-CAGE OF ELECTROMOTOR

RAZVOJ POBOLJŠANOG LIJEVANOG KAVEZNOG ROTORA ELEKTROMOTORA

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Conference paper/Izlaganje sa znanstvenog skupa

ABSTRACT

A significant role today plays consumption and price of energy. Because of that the efficiency of electric motor is very important. Most of motors are made with high-pressure die-casting process of aluminium in rotor squirrel cage. Replacement of aluminium with copper in squirrel cage structure enlarges motor efficiency because of copper's superior electrical conductivity compared to aluminium. The aim of our research was to find out how does copper squirrel cage influence on phase equilibrium of rotor materials. The effect of a higher copper casting temperature (1230 °C) compared to aluminium casting temperature (750 °C) on non-oriented electrical steel laminations and die material was studying. Short die life is the limiting factor in achieving a cost effective die-casting operation in practice. Three samples of technically pure copper at each temperature were gravity casted in pre-heated dies. For comparison aluminium was also casted twice in pre-heated die. The rise in temperature at gravity casting was measured at two different places on the steel lamination surfaces. With the grain size determination we found out that the grain sizes in microstructure of steel laminations casted with copper were enlarged four times in comparison with grain size of noncasted steel laminations. With SEM and DSC analysis it was shown that iron from steel laminations diffused in casted copper. Measurements on rotor quality analyzer also confirmed highest resistance of copper after casting. Die material surface oxidized under influence of high temperature but there is no greater damage noticed. Copper contraction is smaller in comparison with aluminium and that was noticed at junction border between steel laminations and copper/aluminium.

Key words: rotor squirrel cage material, thermodynamics, cooper, electrical efficiency



CHUNKY GRAPHITE IN HEAVY SECTION CASTINGS- MECHANISMS OF FORMATION AND LEVERAGE FACTORS

ČVORIČASTI GRAFIT U DEBELOSTIJENIM ODLJEVCIMA - MEHANIZMI NASTANKA I UTJECAJNI FAKTORI

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Subject review/Pregledni članak

ABSTRACT

Ductile iron is used because of the very good mechanical properties, good machinability and good castability. In recent years, the production of ductile iron castings has increased considerably due to increasing application in the existing traditional market and expansion in the heavy section sector - castings such as wind turbine components and heavy transport vehicle parts. Properties of ductile iron are determined by its microstructure. In the production of massive, heavy section castings are many foundries faced with the problem of decreasing of mechanical properties due to the degeneration in the graphite formation. One of degenerate form of graphite is called chunky graphite, and the structure is visible as a local, branched and interconnected configuration of very fine particles of graphite with a cracked branch surface. This paper gives an overview of the results of studying the mechanisms of formation chunky graphite and influential factors that promote its formation. It also gives some examples from practice.

Key words: ductile iron, heavy section castings, chunky graphite, mechanisms of formation

SAŽETAK

Nodularni lijev koristi se zbog vrlo dobrih mehaničkih svojstava, dobre strojne obradivosti i dobre livljivosti. Posljednjih godina proizvodnja odljevaka od nodularnog lijeva znatno je porasla uslijed sve veće primjene na postojećem tradicionalnom tržištu, ali i ekspanzije u sektoru masivnih odljevaka - kao što su odljevci za vjetroelektrane i teška transportna vozila. Svojstva nodularnog lijeva određena su njegovom mikrostrukturom. Pri proizvodnji masivnih, debelostijenih odljevaka mnoge se ljevaonice suočavaju s problemom pada mehaničkih svojstava zbog degeneracije pri tvorbi grafita. Jedan od degeneriranih oblika grafita naziva se čvoričasti (chunky) grafit, a u strukturi je vidljiv kao lokalna, razgranata i međusobno povezana konfiguracija vrlo sitnih djelića grafita s ispucanom površinom grana. U ovom radu dan je prikaz rezultata proučavanja mehanizama tvorbe čvoričastog grafita te utjecajnih faktora koji potpomažu njegovu tvorbu. Također su prikazani i primjeri iz prakse.

Ključne riječi: nodularni lijev, debelostijeni odljevci, chunky grafit, mehanizmi nastanka



TECHNOLOGY AND PRODUCTION OF CAST FILTER HOUSING

TEHNOLOGIJA I PROIZVODNJA LIJEVANOG KUĆIŠTA FILTRA

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

In foundry practice, the calculations of foundry processes, using specific programmes in production, are of great importance, since this is a way to approach foundry process itself. In that sense, the production costs for tool manufacturing can decrease significantly. In this assignment, technology of pipe casting with a very small casting draft angle ($1,8^\circ$) was defined. In experiment, aluminium alloy AlSi7Mg0,6 was used. A programme to calculate foundry processes with finite element method (ProCAST) enabled researchers to perform the geometry of tools, including gating system, the choice of tool material with definition of boundary conditions (i.e. casting alloy, the temperature of pouring and tools and duration of casting). Duration of casting influences the whole production cycle, commencing from the beginning of casting process, and is defined by following sequences: casting, solidification and cooling of casting, tool opening, cast ejection, greasing and closing of the tool.

Regarding the geometry of the casting, we studied its gating system as well as materials for tool production. For that case, tool steel H13 and grey iron GG-20 were considered, mainly because of following characteristics: pouring temperature and thus achieved temperature field, development of normal stresses in tools and castings, as well as mechanical and physical characteristics of used materials in relation to temperature (i.e. yield strength, thermal conductivity, thermal coefficient of expansion). A comparison of temperature field between different geometries of side-parts, made from tool steel H13 or grey iron GG-20 has, as well been made. With regard to findings, we decided to use tool steel H13 on upper part of tool, that was integrated with shell core, for designing the inner surfaces of the casting. For designing the outer surfaces of the casting, on the other hand, we used grey iron GG-20.

Key words: casting technology, LPDC, Al alloys



VALORIZATION OF ELECTRIC ARC FURNACE SLAG BY THE GEOPOLYMERIZATION PROCESS

VALORIZACIJA ELEKTROPEĆNE TROSKE PROCESOM GEOPOLIMERIZACIJE

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

Electric arc furnace slag (EAFS) is a by product of iron and steel scrap remelting in the electric arc furnaces. This slag is considered as non-hazardous metallurgical waste, and currently investigations of its valorization are mainly focused to the possibility of its use as an aggregate in asphalt mixture production, or as an adsorbent for heavy metals uptake from waste waters.

The aim of this research was to investigate the possibility of EAFS valorization by the geopolymerization process. Geopolymerization is innovative technology, which involve transformation of a variety of aluminosilicate (natural or waste) materials in the useful product popularly called geopolymers which can be successfully applied in a civil engineering industry. This transformation occurs by alkali activation of solid aluminosilicate materials. Mixture of sodium or potassium hydroxide and commercial sodium or potassium water glass is mainly used as an alkali activator for geopolymerization process.

The EAFS used in this investigation was obtained from Steel Mill Nikšić in Montenegro during the production of low alloy steel. EAFS based geopolymers were synthesized by alkali activation with the mixture of NaOH and sodium water glass. Three different concentration of NaOH (7, 10 and 13 M) and three Na₂SiO₃/NaOH mass ratios (1, 1.5 and 2) were used.

The results have shown that EAFS may be successfully valorized by the geopolymerization process. Obtained geopolymers are characterized by the satisfactory compressive strength depending of the synthesis parameters.

Key words: *electric arc furnace slag, geopolymerization, compressive strength, alkali activation*



MANAGEMENT OF INTELLECTUAL PROPERTY IN PUBLIC RESEARCH ORGANISATIONS

UPRAVLJANJE INTELEKTUALNIM VLASNIŠTVOM U JAVNIM ISTRAŽIVAČKIM ORGANIZACIJAMA

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Conference paper/Izlaganje sa znanstvenog skupa

ABSTRACT

Intellectual property management is crucial for all organisations willing to actively participate in competitive research projects and innovation activities. This presentation will address the basic principles of intellectual property management in R&D projects, from research planning stages to the creation and exploitation of research results. The presentation also aims to stimulate discussion about models of strategic management of intellectual property within public research organisations.

Key words: *intellectual property, research and development, innovation, technology transfer*

SAŽETAK

Upravljanje intelektualnim vlasništvom značajno je za sve organizacije koje žele aktivno sudjelovati u kompetitivnim istraživačkim projektima i inovacijskim aktivnostima. Izlaganje će pokriti osnovne principe upravljanja intelektualnim vlasništvom u istraživačko-razvojnim projektima i to od faze planiranja istraživanja pa do nastanka i iskorištavanja rezultata. Cilj izlaganja je i poticanje rasprave o modelima strateškog upravljanja intelektualnim vlasništvom u javnim istraživačkim organizacijama.

Ključne riječi: *intelektualno vlasništvo, istraživanje i razvoj, inovacije, transfer tehnologije*



CAST IRON AND INTERACTION PARAMETERS

ŽELJEZNI LIJEV I PARAMETRI INTERAKCIJE

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Preliminary note/Prethodno priopćenje

ABSTRACT

Influence of parameters of interaction basic elements C, Si, Mn, S and P are thoroughly tested for steel and cast steel for the temperature 1873 K, but hardly ever for iron castings, where the content of C is up to 4.50 %, Si up to 3.50 %, and increased content of Mn, S, P, or other elements. Explanation of liquation only C ratio of C and Si, or by the degree of saturation (S_c) or carbon equivalent (CE), can only point to the outward form of the process, while the motor force of some of the process, during the creation of the melt and cast iron spill, the impact parameter interaction of these basic elements at 1573 K – 1673 K. Research on the phenomenon of oxidation during the preparation of the melt cast at 1873 and 1573 K – 1673 K indicate that the interaction parameter affects the course of oxidation multi reactions e.g. Mn at both temperatures. In addition, despite the same curve shape of the Mn oxidation at 1873 K affects the chemical composition of the melt is mainly temperature factor, and at 1573 K interaction parameter.

Therefore, in this paper, discussed and explored the impact of interaction parameters on the behave of the melt cast iron in the preparation and examination, compared with steel, the emergence of the phenomenon of opposite action temperature and composition and interaction parameters or the occurrence of liquation temperatures, for example at 1573 K – 1673 K, and the calculated interaction parameters and discussed the impact of these values, as opposed to the impact of the 1873 K in laboratory and industrial scale.

Key words: *cast iron, the interaction parameters, reaction equilibrium*



DEVELOPMENT AND OPTIMIZATION OF THE DUCTILE IRON CASTING TECHNOLOGY BY COMPUTER SIMULATION

RAZVOJ I OPTIMIZACIJA TEHNOLOGIJE LIJEVANJA ODLJEVKA OD NODULARNOG LIJEVA POMOĆU RAČUNALNE SIMULACIJE

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Professional paper/Stručni članak

ABSTRACT

The purpose of this paper is to present the process of developing and optimizing of the ductile iron casting technology with a use of computer simulation. The initial variant of technology was developed on traditional way and the solution was unsatisfactory. Since casting net weight is 3400 kg and the product is a small-scale, the use of computer casting simulation was the most efficient way. The traditional way, by using the "trial and error" method, would be much more expensive, besides that it would take much more time and production resources (technological as well as human).

Key words: *casting, ductile iron, metal casting, computer casting simulation*

SAŽETAK

Namjera ovog rada je prikazati proces razvoja i optimizacije tehnologije lijevanja odljevka iz nodularnog lijeva koja je provedena pomoću računalne simulacije. Prva osnovna varijanta tehnologije lijevanja razvijena je na "klasičan" način, ali na žalost nije dala zadovoljavajućeg rješenja. Pošto je neto težina odljevka 3400 kg i ne radi se o velikoserijskom proizvodu, najučinkovitije je bilo potražiti tehnološko rješenje pomoću računalne simulacije. Upotreba klasične metode "pokušaja-pogrešaka" bila bi u tom slučaju puno skuplja, a pored toga bi uzela puno više vremena i resursa u proizvodnji (tehnoloških i ljudskih).

Ključne riječi: *odljevak, nodularni lijev, lijevanje metala, računalna simulacija procesa lijevanja*



**APPLICATION OF RECENT SOFTWARE TOOLS FOR DESIGNING
AND PRODUCTION OF DIES AND CASTINGS BY HIGH PRESSURE
DIE CASTING**

**PRIMJENA SUVREMENIH PROGRAMSKIH PAKETA ZA
PROJEKTIRANJE I PROIZVODNJU KALUPA I ODLJEVAKA
VISOKOTLAČNIM LIJEVANJEM**

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Professional paper/Stručni članak

ABSTRACT

This paper presents the advantages of using modern tools MCAE in the construction of molds for pressure casting, as well as software for the simulation of the casting process and throughout the process of creating a product, from concept to production. In this paper a practical example, using CAE software tools (I-deas 12 NX, MAGMA 5 and GEOMAGIC) for the design, calculation and numerical simulation of casting, show the use and advantages of presented simulation of the classic design and experimental verification when designing engineering products industries.

Key words: *simulation of casting, MAGMA 5, pressure casting, design tools for casting*



**ENHANCED QUALITY IN ELECTRIC MELT GREY IRONS,
TYPICALLY FOR AUTOMOTIVE INDUSTRY CASTINGS**

**POBOLJŠANA KVALITETA TALJEVINE SIVIH LJEVOVA IZ
ELEKTROPEČI, NAMIJENJENE ZA PROIZVODNJU ODLJEVAKA U
AUTOMOBILSKOJ INDUSTRIJI**

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Conference paper/Izlaganje sa znanstvenog skupa*

ABSTRACT

Grey iron is still the most common foundry metallic material, at more than 45 % of total world castings production. Small and inefficient cupolas with their attendant process issues have been replaced by a new generation of acid lined, coreless induction furnaces (medium frequency/high specific power). This has revolutionized the iron foundries, but superheated electric melt irons with low S (< 0.05 %) and very low Al (< 0.005 %), typical for these furnaces solidify at high cooling rates in thin wall castings and are particularly prone to free carbides and undercooled graphite formation.

The paper reviews original data obtained by the authors, concerning the specific solidification pattern of these irons, and how superheating affects the iron quality with effective metallurgical treatments for use in these conditions. Solidification undercooling increased with increasing superheat, associated with significant changes in chemical composition, such as C, Si, Mn, Al and Zr, involved in the nucleation of graphite.

The concept in the present paper sustains a three-stage model for nucleating flake graphite [(Mn,X)S type nuclei]. There are three important groups of elements [deoxidizer / Mn, S / inoculating] and three technology stages in electric melt iron [superheat / pre-conditioning base iron / final inoculation]. Different materials were used for pre-treatment of the iron melt. Special attention was paid to maintain Al and Zr recoveries in the melting furnace for their effects on the iron structure.

A double treatment utilizing strong oxide forming elements, such as Al and Zr for preconditioning, followed by inoculation decreased eutectic undercooling parameters. This treatment improved graphite characteristics and avoided carbides. For foundry application, it is recommended to ensure (Mn,X)S compound formation, compatible for nucleating graphite with less eutectic undercooling. Attention is drawn to ensuring a control factor (% Mn) x (% S) equals 0.03 – 0.06, accompanied by 0.005 – 0.010 % Al and/or Zr content in inoculated grey irons.

Key words: *thin wall castings, grey iron, S, Al, Zr, Ti, electric melting, furnace superheating, preconditioning, inoculation, graphite nucleation, graphite morphology, carbides, thermal analysis*

*Presented at 70th World Foundry Congress, April 25th – 27th, 2012, Monterrey, Mexico.



**ANALYSIS OF HOT TEAR DEFECT IN STEEL FOUNDRY BY
COMPUTERIZED SIMULATIONS & SOME INDUSTRIAL CASE
STUDIES**

**ANALIZA TOPLIH PUKOTINA U LJEVAONICI ČELIKA POMOĆU
RAČUNALNE SIMULACIJE I NEKOLIKO INDUSTRIJSKIH PRIMJERA**

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Preliminary note/Prethodno priopćenje

ABSTRACT

This study reports an in house experience with the dangerous effect of hot tear in steel castings and its practical remedies. This is also a detailed guide line for the step by step analysis of hot tear defects and some tactful solution of this problem supported by computerized simulation software.

This report is based on industrial case studies of some of our export items (American Bogie Castings) and covers all possible causes generating hot tear and highlights some practical approaches to get rid of this defects and improve quality and save cost as this defect causes a lot of rejections or rework before use under stress conditions. In steel castings contraction takes place during solidification and hot tears are initiated at a temperature within the solidification range of the alloys that is some time before the solidus temperature is reached. Further opening and extension of tear can occur at lower temperature due to continuing contractions. Generally two conditions are necessary for hot tearing.

- a) there must be resistance to contractions.
- b) there must be variable temperature gradients within the casting section.

The low collapsibility of cores/ mould materials, higher percentage of sulphur and phosphorous, excessive large feeders used causing obstructions during contractions, faulty design of castings (i.e. wide variations in wall thicknesses), too high pouring temperatures etc. causes hot tears in steel castings are discussed here along with remedial measures.

Key words: hot tears, solidus and liquidus temperatures, solidification range, chromite sands, tie rods, anti cracker ribs/ cooling brackets, alpha set/ester cured core making system, simulations



**THE 8 RULES TO MANUFACTURE DUCTILE IRON WITH HIGH
IMPACT STRENGTH AT LOW TEMPERATURES (EN-GJS-400-18-LT)**

**OSAM PRAVILA ZA PROIZVODNJU NODULARNOG LIJEVA S
VISOKOM UDARNOM ŽILAVOSTI NA NISKIM TEMPERATURAMA
(EN-GJS-400-18-LT)**

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Professional paper/Stručni članak

ABSTRACT

What characterizes a ductile Iron with high impact strength? Ductile iron is available in a lot of different qualities with a wide range of applications. You can find unalloyed ductile irons and alloyed ductile iron or different materials like ADI, Ni-resist, high alloyed with Si, or Si-Mo in all kinds of applications in different sectors.

A ferritic ductile iron with high impact properties and corresponding tenacity at low temperatures (like ferritic steel), characterizes itself by its use in the Offshore-sector where climate-requests are expected from the material. Beside the good qualities of the material, the other remaining advantages are beautiful surfaces, freedom for the designer, good machinability and ductile iron is not as heavy as steel (~ 10 % lighter than steel).

So, this material finds more and more applications as well as its way in the wind-energy sector, in the ship-construction and crane-installation-construction. To manufacture this material, some important points should be obeyed as the chemical composition, the charge metal composition, melting procedure and suitable pouring process.

Key words: *EN-GJS-400-18-LT, ferrite ductile iron, impact strength, wind energy components*



PREDICTION OF QUENCHED AND TEMPERED CAST STEEL PROPERTIES

PROCJENA SVOJSTAVA KALJENOG I POPUŠTENOG ČELIČNOG LIJEVA

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

The influence of processing parameters, such as pouring temperature and cooling rate during the casting, as well as, application of hot working and pre-heat treatment, on yield strength and Charpy-V notch toughness of quenched and tempered steel was investigated. Experimental procedure of statistical analysis was done using the factorial experiment.

The research was focused mainly on Charpy-V notch toughness of carbon and low alloyed heat treatable steels.

It was found out that yield strength is insensitive to differences between applied manufacturing processes, but Charpy-V notch toughness is increased by application of both, hot working and proper pouring temperature. Also, Charpy-V notch toughness is increased by interactive effect between the appropriate cooling rate during the casting and application of hot working.

Test results of investigated mechanical properties were verified by microstructure analysis. It was found out that hot worked and normalized specimens have more refined microstructure than other non-treated specimens. ASTM grain size number of previous austenite of investigated steel treated by hot working was equal to N.6 - N.7, while ASTM grain size number of previous austenite of steel without hot working application was equal to N.4 - N.5.

Original relation for the prediction of quenched and tempered steel and cast steel Charpy-V notch toughness are developed. The developed relations were used for prediction of tensile strength, yield strength and Charpy-V notch toughness of quenched and tempered cast steel workpiece.

Key words: *computer simulation, quenching and tempering, cast steel, Charpy-V notch toughness*



CHARACTERIZATION OF LADLE FURNACE SLAG FROM THE CARBON STEEL PRODUCTION

KARAKTERIZACIJA TROSKE IZ LONAC-PEĆI PRI PROIZVODNJI UGLJIČNIH ČELIKA

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

In order to make a complete characterization of ladle furnace slag (LF slag, LFS), as nonhazardous industrial waste, and to solve its permanent disposal and/or recovery, bearing in mind both the volumes formed in the Croatian steel industry and experiences of developed industrial countries, a study of its properties was undertaken.

For this purpose, samples of ladle furnace slag, taken from the regular production process in the CMC Sisak d.o.o. between October 2010 and October 2011, were subjected to a series of tests.

The chemical composition of ladle furnace slag samples was investigated by means of a several different analytical methods. The results from the chemical analysis show that the approximate order of abundance of major components in ladle furnace slag is as follows: CaO, SiO₂, Al₂O₃, MgO, FeO, MnO, Cr₂O₃, P₂O₅, TiO₂, K₂O and Na₂O. The investigation of the mineralogical and micro structural composition of LF slags was taken by combination of X-Ray Diffraction Analysis (X-RDA) and Scanning Electron Microscopy (SEM), coupled with Energy Dispersive Spectroscopy (EDS). The results of the X-ray diffraction phase analysis show that the basis of the examined ladle furnace slag samples is made of a mixture of metal oxides, silicates and aluminates.

The metal concentration, anions, pH value and conductivity in water eluates was determined in order to define the influence of ladle furnace slag on the environment. The final results showed that the ladle furnace slag does not contain constituent which might in any way affect the environment harmfully.

The activity concentrations of ²²⁶Ra, ²³²Th and ⁴⁰K in ladle furnace slag were measured by γ spectrometric method using gamma-ray spectrometer with HPGe detector. The presence of radio nuclides and their activity showed that the analyzed slag can be used as supplement in the production of construction materials or as aggregate in road construction.

Key words: ladle furnace slag, mineralogical, chemical, radiochemical characterization



GATING SYSTEMS FOR AI CASTINGS POURED INTO CERAMIC MOULDS

ULJEVNI SUSTAVI ZA AI ODLJEVKE LIJEVANE U KERAMIČKE KALUPE

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Original scientific paper/lzvorni znanstveni rad

ABSTRACT

In contrast to casting to “conventional” sand moulds, for which calculating technique for an optimum design of the gating system is comparatively well-developed, a trial-and-error method is applied mostly at casting to ceramic shell moulds made by the investment casting technology. A technologist selects from gating systems of several types (that are standardized by the foundry mostly) just on the basis of his/her experience. However, this approach is not sustainable any more with ever growing demands on quality of castings and also the economy of their manufacturing as well as with new types of complex sizeable castings introduced to the production gradually (by new customers from the aircraft industry above all). The simulation software may be used as a possible tool for making the process of optimizing gating systems more effective.

Key words: *application of information technologies in the foundry industry, solidification, gating systems, ceramic moulds, simulation*



INFLUENCE OF DECOREMENT ANEALING ON THE MECHANICAL AND MICROSTRUCTURAL PROPERTIES OF AISi8Cu3 ALLOY

UTJECAJ ŽARENJA RADI ODSTRANJIVANJA JEZGRI NA MEHANIČKA I MIKROSTRUKTURNA SVOJSTVA AISi8Cu3 LEGURE

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

Hypoeutectic aluminum - silicon casting alloy such as AISi8Cu3 (EN 46 200 AC) are of primary importance for wide commercial applications in automotive industry for safety components, such as engine parts. Properties of alloys could be improved by the design of materials through the selection of the chemical composition, melt treatment by inoculation and modification, annealing and correctly developed casting technology. For complex geometry castings, such as turbochargers, it is necessary to provide heat treatment such as annealing after casting in order to obtain decorement. Rigorous regime with a relatively high temperature and long holding time indicates the microstructural changes in the material, thus indirectly affects the mechanical properties of the material. An important aspect for further improvement and application is to develop a better understanding of the microstructure and mechanical properties by comparison of the alloy microstructures and mechanical properties with and without performed subsequent heat treatment. The aim of this study was to determine the relationship between microstructure and mechanical properties of separately cast test samples AISi8Cu3 alloy within the characterization of materials by comparing the microstructural and mechanical properties with and without annealing. Metallographic analysis established following microstructural constituents: α_{Al} primary dendrites, eutectic ($\alpha_{Al} + \beta_{Si}$) and intermetallic phases based on copper stoichiometry $Al-Al_xCu-Si$, $Al_xMg_ySi_zCu_w$. Annealed microstructure has been changed as more uniformly distribution of primary aluminum dendrites, its copper enrichment, and therefore fragmentation of the past solidifying phases based on copper. Mechanical properties indicated an increase of the tensile strength and elongation after heat treatment.

Key words: Al-Si alloys, microstructure, mechanical properties, heat treatment

SAŽETAK

Podeutektičke aluminij – silicij lijevačke legure poput AISi8Cu3 (EN AC 46200) su od osnovne komercijalne važnosti zbog široke primjene za automobilske sigurnosne komponente poput dijelova motora. Svojstva legure nastoje se poboljšati dizajniranjem materijala putem odabira kemijskog sastava, obradom taljevine cijepljenjem i modifikacijom, toplinskom obradom i ispravno proračunatom tehnologijom lijevanja. Kod odljevaka kompleksne geometrije poput turbokompresora neophodno je nakon lijevanja provesti postupak toplinske obrade žarenjem radi odstranjivanja jezgre. Rigorozni režim s relativno visokom temperaturom i dužim vremenom zadržavanja indicira mikrostrukturne promjene u materijalu, a time indirektno utječe na mehanička svojstva materijala. Važan aspekt za daljnja poboljšanja i primjenu je razviti bolje razumijevanje mikrostrukturnih i mehaničkih značajki legure usporedbom mikrostrukturnih i mehaničkih značajki sa i bez primjene naknadne toplinske obrade. Cilj ovog rada bio je utvrditi povezanost mikrostrukturnih i mehaničkih svojstava odvojeno lijevanih ispitnih uzoraka AISi8Cu3 legure u okviru karakterizacije materijala usporedbom mikrostrukturnih i mehaničkih značajki sa i bez primjene naknadne toplinske obrade. Metalografskim metodama su ustanovljeni sljedeći mikrostrukturni konstituenti: primarni dendriti α_{Al} , eutektik ($\alpha_{Al} + \beta_{Si}$) i intermetalne faze na osnovi bakra stehiometrije Al_xCu , $Al_xMg_ySi_zCu_w$. Mikrostruktura nakon toplinske obrade doživljava promjene u smislu ravnomjernije raspodjele dendrita primarnog aluminija, obogaćivanja istog bakrom, te usitnjavanjem posljednjih skrućujućih faza na osnovi bakra. Mehanička svojstva ukazuju na porast vrijednosti vlačne čvrstoće i istezanja nakon toplinske obrade.

Ključne riječi: Al-Si legura, mikrostruktura, mehanička svojstva, toplinska obrada



THE IMPACT OF AIR POLLUTION FROM THE MINING-METALLURGICAL COMPLEX ON THE CONTENT OF TOTAL SULPHUR IN SOIL AND MOSS

UTJECAJ ZAGAĐENJA ZRAKA IZ RUDARSKO-METALURŠKOG KOMPLEKSA NA SADRŽAJ UKUPNOG SUMPORA U TLU I MAHOVINI

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

Air quality in the areas with mining-metallurgical processes is usually at an unsatisfactory level. The area of Bor and the surroundings (Eastern Serbia) have been known for exploitation and processing of sulphide copper ores for more than a hundred years. Long-term ore exploitation in the examined area has made a great impact on local environment. Emissions of waste gases (SO_x) and particulate matter (PM) are characteristic for these processes. Bor is a town which was built in the vicinity of the Mining-Metallurgical Complex "RTB Bor". Air quality control in this area is performed at the measuring sites in the urban-industrial zone by automatic and mobile stations. The measuring sites are located in the prevailing wind directions and at different distances from the dominant source of pollution. Long-term measurement results indicate an increased content of sulphur dioxide. Considering the increased concentrations of sulphur dioxide in the air, high concentrations of sulphates in atmospheric deposition were present. The highest annual concentrations of sulphates in the atmospheric deposition were detected in the urban-industrial zone in 2006 and 2008, since it is closest to the dominant source of pollution. Total sulphur concentrations were determined in samples of soil and moss. Higher concentration of the total sulphur in soil has been detected at the sampling site Ostrelj in the rural zone. Significantly higher concentrations of total sulphur in moss samples in the urban-industrial zone confirm the reliability of moss as a bioindicator of air pollution.

Key words: *air pollution, copper smelter, sulphuric compounds*



MICROSTRUCTURE CHARACTERIZATION OF DEEP CRYOGENIC TREATED DUCTILE CAST IRON AND ADI

KARAKTERIZACIJA MIKROSTRUKTURE DUBOKO HLAĐENOG NODULARNOG LIJEVA I AUSFERITNOG NODULARNOG LIJEVA

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

Application of deep cryogenic treatment in heat treatment processes of different types of steel showed significant influence on their mechanical and tribological properties. A lot of research on that field has been performed also on other kinds of material such as hard metal, grey cast iron, aluminum and aluminum alloys, etc. In this research influence of deep cryogenic treatment on microstructure of austempered ductile iron has been investigated. Base material for research was perlitic – ferritic ductile cast iron grade EN-GJS-600 (DIN GGG 60) which was austempered and deep cryogenically treated and afterward tempered on different temperatures. Microstructures of all samples were characterized in order to define the microstructural changes during deep cryogenic treatment. For that reason, metallographic specimens were etched with several etchants (KLEMM I, Vilella, Nital, Picral and SMB) and analyzed by use of light microscopy and field emission-scanning electron microscopy. Obtained results show that deep cryogenic treatment in combination with the different tempering temperatures affects the matrix microstructure of ductile cast iron and ADI, which has led to change in hardness and wear resistance of tested specimens.

Key words: *deep cryogenic treatment, ductile cast iron, ADI, microstructure, FESEM*



INFLUENCE OF ELECTRO SLAG REMELTING ON FRACTURE TOUGHNESS AND IMPACT TOUGHNESS OF 51CrV4 HIGH STRENGTH LEAF SPRING STEEL

UTJECAJ ELEKTROPRETALJIVANJA POD TROSKOM NA LOMNU ŽILAVOST I UDARNI RAD LOMA VISOKO ČVRSTOG ČELIKA 51CrV4 ZA LISNATE OPRUGE

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Original scientific paper/Izvorni znanstveni rad

ABSTRACT

It is well known that electroslag remelting (ESR) is an especially attractive process because it is a consumable electrode remelting process in which liquid metal droplets are refined with contact of a molten slag providing a cleaner, more uniform alloy with minimum segregation which has a major influence on the steel properties.

The durability of the springs is limited by plastic deformation, fatigue and fracturing. From this point of view, the use of spring steel with following properties is recommended: high ductility and toughness at operation temperature from -40 °C to +50 °C, good hardenability that provides required mechanical properties, even at maximum dimensions. This paper presents the results of investigation of the influence of ESR on the fracture and impact toughness of 51CrV4 leaf spring steel. Also, fractographic analysis was made on the fractured surface of K_{Ic} -test specimens with the FESEM and EDS analysis of the present segregations and non metallic inclusions. The results showed that the ESR procedure did not influence significantly on the fracture toughness but it had significant influence on the results of the Charpy-V notch impact test.

Key words: ESR, spring steel, heat treatment, fracture toughness, impact toughness

SAŽETAK

Poznato je da je postupak elektropretaljivanja pod troskom (EPT) postupak posebno atraktivan jer je to postupak u kojem rastaljeni metal u obliku kapljica dolazi u kontakt s rastaljenom troskom pri čemu dolazi do pročišćavanja čelika, a rezultat je čišća, ujednačena mikrostruktura s minimalno segregacija što povoljno utječe na svojstva čelika.

Trajnost opruga ograničena je plastičnom deformacijom, otpornosti na umor i krhkosti materijala. Iz tog aspekta preporučena svojstva materijala za izradu opruga su: visoka duktilnost i žilavost pri radnoj temperature od -40 °C do +50 °C te dobra prokaljivost koja osigurava zahtijevana mehanička svojstva i pri maksimalnim dimenzijama.

U ovom radu ispitan je utjecaj EPT postupka na lomnu i udarnu žilavost čelika 51CrV4 namijenjenog za izradu lisnatih opruga. Napravljena je fraktografska analiza prijelomnih površina te FESEM analiza sa EDS analizom segregacija i nemetalnih uključaka na prijelomnim površinama K_{Ic} uzoraka. Rezultati su pokazali da EPT nije značajno utjecao na vrijednost lomne žilavosti, ali je zato imao značajan utjecaj na rezultate udarnog rada loma.

Ključne riječi: EPT, čelici za opruge, toplinska obrada, lomna žilavost, udarna žilavost



**BIOLOGICAL WASTEWATER TREATMENT IN THE FOUNDRY
LIPOVICA d.o.o.**

**BIOLOŠKO PROČIŠĆAVANJE OTPADNIH VODA U LJEVAONICI
LIPOVICA d.o.o.**

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Professional paper/Stručni članak

ABSTRACT

In order to improve the quality of natural water systems, wastewater treatment is crucial. Wastewater treatment is a technological process that is carried out at the wastewater treatment plant. In the foundry Lipovica d.o.o. wastewater is treated by mechanical, physical, chemical and physical-chemical and biological processes. This article describes biological wastewater treatment in the foundry Lipovica d.o.o.

Key words: *active sludge, biological treatment, wastewater*

SAŽETAK

Da bi se poboljšala kakvoća prirodnih vodnih sastava, pročišćavanje otpadnih voda je presudno. Pročišćavanje otpadnih voda je tehnološki proces koji se provodi na uređajima za pročišćavanje. U ljevaonici Lipovica d.o.o. otpadne vode se pročišćavaju mehaničkim, fizikalnim, kemijskim i fizikalno-kemijskim te biološkim procesima. U ovom radu je opisan biološki način pročišćavanja otpadnih voda u ljevaonici Lipovica d.o.o.

Ključne riječi: *aktivni mulj, biološko pročišćavanje, otpadna voda*



HYDROGEN DISSOLUTION IN THE MOLTEN Al-Si ALLOYS

OTAPANJE VODIKA U RASTALJENIM Al-Si LEGURAMA

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ABSTRACT

Experimental study of the hydrogen dissolution in molten AlSi2, AlSi6 and AlSi14 alloys at 700, 800 and 900 °C in the atmosphere of pure hydrogen or H₂O – Ar (18 vol. % H₂O) were carried out. Volume content of H₂O in the atmosphere corresponds to the composition of combustion products of earth gas combustion in melting furnaces. Extraction method in pure argon with chromatographical analyse of H₂ was used. Experimental results were mathematically processed into the form of empiric dependence of hydrogen solubility and instantaneous hydrogen solubility rate on conditions of H₂ saturation. This processing represents kinetic and thermodynamic interpretation of measured results. Obtained data are useful for aluminium melting and casting practice.

Key words: *aluminium, silumin, hydrogen, solubility, rate of dissolution*



100 FOUNDRY'S RECOMMENDATIONS FOR PRODUCTION OF SOUND CASTINGS

100 LJEVAČKIH SAVJETA ZA IZRADU DOBRIH ODLJEVAKA

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Professional paper/Stručni članak

ABSTRACT

In this paper the complexity of casting production is presented, which good product depends on a variety of interrelated factors. A lot of expert knowledge and practical experiences are included in the paper that might help in production of good castings. 100 foundry's recommendations are stated. They show each individually as well in relation to each other how the casting production is complicated and demanding. These recommendations detect and instruct what conditions have to be fulfilled during casting production to achieve successful operation of the foundry. Listed are some of the casting defects and how they can be avoided.

Key words: *planning, casting, patterns, moulds, environmental protection*

SAŽETAK

U prezentaciji rada je predočena sva složenost ljevačke proizvodnje, čiji dobar proizvod ovisi o mnoštvu međusobno povezanih čimbenika. U rad je uneseno dosta stručnog i praktičnog iskustva, koji bi mogli barem malo pripomoći u izradi dobrog odljevka. Navedeno je 100 ljevačkih savjeta koji pojedinačno i međusobno povezani pokazuju kako je ljevačka proizvodnja složena i teška. Savjeti otkrivaju i upućuju što se treba poklopiti u ljevačkoj proizvodnji za uspješno poslovanje ljevaonice. Navedene su neke od ljevačkih pogrešaka i na koji način se mogu izbjeći.

Ključne riječi: *planiranje, odljevak, modeli, kalupi, zaštita okoliša*



**MANAGEMENT OF SELECTED PROPERTIES OF CAST IRON IN
FOUNDRY**

**UPRAVLJANJE ODABRANIM PARAMETRIMA U LJEVAONICI
ŽELJEZNOG LIJEVA**

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Professional paper/Stručni članak

ABSTRACT

Foundry is one of the oldest industry branches. In the evolution of human kind it played great role with always improving mechanical properties of metals and in using of newest knowledge, it still plays one of the key functions in all spheres of our lives. We meet everyday with the castings. It is the same if we sit in the car or we are eating the waffle. The production of every single casting needs individual approach for repeatedly achievement of desired material properties.

Hardness is one of the basic properties of metal materials in common. From hardness depends how easy, or how hard would be given material machined and what kind of materials, tools and machines would we need. In today world of planning it is a matter of course to demand the same hardness for given material, so that the same machinability could be ensured and costs and machined time were minimalized. To assure this condition in praxis is not always easy.

Key words: *ductile cast iron, hardness of castings, machinability, statistics*



CADMIUM IN ADVANCED MATERIALS NOWADAYS – PRO ET CONTRA?

KADMIJ U NAPREDNIM MATERIJALIMA DANAS – ZA ILI PROTIV?

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Subject review/Pregledni članak

ABSTRACT

The most important requests in advanced technologies today concern the problematic of environmental protection. Therefore, a lot of directives were incorporated in EU legislation processes in last decade. One of them is RoHS Directive which restricts the use of certain hazardous substances in electrical and electronic products: four heavy metals - lead, mercury, cadmium, and hexavalent chromium, as well as two brominated flame retardants (polybrominated biphenyls (PBB) and polybrominated diphenyl ethers (PBDE)). It was firstly adopted in February 2003 and took effect on 1 July 2006. Recently, updated and renewed version of this directive, so called ROHS II, became law on 21 July 2011, and it is expected to replace ROHS I from 2 January 2013 on.

In spite of presented legislatives, there are a lot of different advanced materials, developed in last period, which are based on mentioned toxic heavy metals, especially on cadmium. These metallic materials present i.e. batteries, coatings, Cd-based alloys, contact and nuclear materials, etc. So, there is the question – should we strictly obey the environmental legislation or be open to new classes of materials with improved characteristics to be applied in different branches of technology? This paradox was searched and explained in this paper in the example of cadmium metal.

Key words: *cadmium, environmental legislation, cadmium-based advanced materials*