

AKTUALNO / CURRENT

Prispevek slovenskega vedenja, znanja in znanosti k uspešnosti IFC v Portorožu v obdobju 2010 do 2020

The Contribution of Slovenian Know-How, Knowledge and Science to the Success of the IFC in Portorož from 2010 to 2020

V posebni izdaji Livarskega vestnika št. 57/2010 je prof. dr. Milan Trbižan, nekdanji dolgoletni predsednik in tudi častni predsednik Društva livarjev Slovenije, daljše obdobje redni univerzitetni profesor in predstojnik Katedre za livarstvo Oddelka za materiale in metalurgijo na Naravoslovnotehniški fakulteti Univerze v Ljubljani, ob 50-letnici izhajanja Livarskega vestnika predstavil zgodovino in pomen Mednarodne livarske konference – IFC – za razvoj livarske vede in gospodarske panoge livarstva. V prvi letošnji številki Livarskega vestnika (1/2021) je v prispevku pod naslovom »60 let osrednje livarske konference Društva livarjev Slovenije« tudi predsednica Društva livarjev Slovenije, mag. Mirjam Jan-Blažič, podala oris te pomembne dolgoletne mednarodne livarske poti v Sloveniji.

Glavni organizator IFC je bilo tudi v zadnjem 10-letnem obdobju Društvo livarjev Slovenije ob soorganizatorjih: Naravoslovnotehniška fakulteta, Oddelek za metalurgijo Univerze v Ljubljani, in Fakulteta za strojništvo Univerze v Mariboru. Organizatorji so zadržali tradicionalno lokacijo v Portorožu in konferenco redno vsako leto organizirali v sredini septembra. Obe univerzi sta ob tem tudi glavna pokrovitelja konference in sodelujeta v organizacijskem odboru, ki mu je v celotnem obdobju predsedovala predsednica Društva livarjev Slovenije mag.

In a special issue of Livarski vestnik, no. 57/2010, Prof. Dr. Milan Trbižan, former long-term chair and honorary president of the Slovenian Foundrymen Society, former full-time university professor and chair of the Chair of Foundry at the Faculty of Natural Sciences and Engineering, Department of Materials and Metallurgy, University of Ljubljana, presented the history and the importance of the International Foundry Conference – the IFC – for the development of foundry as a science and the development of the foundry as an industry. In this year's first issue of Livarski vestnik (1/2021), in an article entitled "60th anniversary of the major foundry conference by the Slovenia Foundrymen Society", the president of the Slovenian Foundrymen Society, Mag. Mirjam Jan-Blažič, outlined this long-term international course in the foundry sector in Slovenia.

The chief organizer of the IFC during the last 10-year period was the Slovenian Foundrymen Society with a number of co-organizers: the Faculty of Natural Sciences and Engineering, Department of Materials and Metallurgy, University of Ljubljana, and the Faculty of Mechanical Engineering, University of Maribor. The organizers have traditionally held the conference in Portorož regularly every year mid-September. Both universities are also the main sponsors of the conference and participate in the organizing committee, chaired throughout the period by the president of the Slovenian Foundrymen Society, Mag. Mirjam Jan-Blažič. Also, throughout the period, the activities of the chairman of the programme and scientific committee of the conference was performed by honorary Prof. Dr. Alojz Križman



zasl. prof. dr. Alojz Križman, predsednik programsko-znanstvenega odbora IFC



mag. Mirjam Jan-Blažič,
predsednica organiza-
cijskega odbora IFC

Mirjam Jan-Blažič. Prav tako je v celotnem obdobju delo predsednika programskega in znanstvenega odbora konference opravljal zasl. prof. dr. Alojz Križman z Univerze v Mariboru. Pri pripravi konference pa je imela ves čas zelo pomembno vlogo celotna Katedra za livarstvo Oddelka za materiale in metalurgijo

na čelu z njenim predstojnikom rednim prof. dr. Primožem Mrvarjem ter Katedra za metalurško in procesno tehniko s sodelavci in njenim vodjem rednim prof. dr. Jožetom Medvedom. Brez usklajenega sodelovanja tudi ne bi bilo mogoče opraviti tega obsežnega dela v podporo celotni panogi livarstva. Člani obeh kateder so bili tudi organizacijski asistenti pri izvedbah vseh desetih mednarodnih konferenc v tem obdobju. Dokaz o strokovnem spoštovanju tradicionalnega Mednarodnega livarskega posvetovanja v Portorožu (International Foundry Congress – kratica IFC) je vsakoletno zavidanja vredno število udeležencev iz tujih držav, ki so bili vedno znova presenečeni nad strokovno ravno referatov. Vsi predavatelji so morali predhodno obvezno poslati kratek vsebinski povzetek predavanj, ki je bil nato objavljen v zborniku posvetovanja v slovenskem in angleškem jeziku. Vsak udeleženec posvetovanja je prejel ta zbornik ob registraciji udeležbe. Prav tako so bili predavatelji dolžni pred začetkom konference poslati celotno vsebino predavanja v digitalni obliki, ki so ga vsi udeleženci prejeli na disku ali pomnilniškem ključku USB. V celotnem obdobju so bila predavanja tematsko razdeljena: prvi dan 8 do 10 plenarnih predavanj, vezanih na osnovna vprašanja o livarski stroki in njenem razvoju, ter drugi dan skupina referatov s področja jeklene litine in litin na osnovi železa in skupina referatov s področja neželeznih zlitin. Celotna konferenca je bila običajno omejena na skupno 36 govornih predstavitev s prezentacijo besedila in slik. Neuvrščeni referati, ki niso bili sprejeti v uraden govorni program, so imeli možnost grafične predstavitve s prikazom plakatov. Vsa plenarna predavanja so bila omejena na čas 30 minut,

from the University of Maribor. In the preparation of the conference, the entire Chair of Foundry of the Department of Materials and Metallurgy, headed by chair, Full Prof. Dr. Primož Mrvar, and the Department of Metallurgical Processing Techniques with associates and its chair, Full Prof. Dr. Jože Medved. Without coordinated collaboration, it would not have been possible to carry out this extensive work supporting the entire foundry industry. Members of both departments also assisted in the organization of all ten international conferences in the period.

The evidence of professional respect for the traditional International Foundry Conference in Portorož (IFC) is the enviable number of participants, who are always surprised by the expertise of the papers presented, that attend from abroad every year. Every lecturer was required to send a short summary of the lecture, which was then published in the proceedings of the conference in both Slovene and English. Each participant in the consultation received the proceedings upon registration. Also, before the start of the conference, the lecturers were required to provide the entire content of the lecture in digital form, which was then received by all participants on a hard drive or USB memory stick. Throughout, lectures were thematically divided; on the first day, 8 to 10 plenary lectures related to basic issues of the foundry sector and its development were held, while on the second day, a string of papers in the field of steel and iron-based alloys as well as in the field of non-ferrous metals was presented. The entire conference was generally limited to a total of 36 lectures with presentation which included both text and images. Unlisted contributions that were not accepted into the official lecture program were given the opportunity of a graphic presentation with posters. All plenary lectures were limited to 30 minutes and all other lectures to 20 minutes. In total, in the entire period from 2011 to 2020, an incredible total of 473 presentations were given (incl. both lectures and posters), of which 147 (or 31%) presentations were by Slovenian authors. The volume of such an extent is in part related to 2019 when we organized simultaneously with the 59th IFC also the World Foundry Organization (WFO) Technical Forum, where a total of 104 presentations divided into five categories were given.

vsa ostala pa na čas 20 minut. Skupno je bilo v celotnem obdobju 2011–2020 predstavljenih z vsemi predavanji in plakati kar neverjetnih 473 prezentacij, od tega 147 predstavitev slovenskih avtorjev, kar je 31 % vseh predstavitev. Tako velik obseg je delno vezan tudi na leto 2019, ko smo sočasno z 59. IFC organizirali tudi Tehniški forum Svetovne livarske organizacije in je bilo v petih skupinah podanih skupno kar 104 predstavitev.

V strokovnem smislu pa je vedno izpostavljeno vprašanje slovenskega znanja in znanosti ter njuna vloga pri razvoju. Livarstvo kot stroka je opredeljeno kot interdisciplinarna tehniška veda. Klasifikacija raziskovalnih ved po ARRS ne izpostavlja livarstva kot raziskovalne vede, področja oz. podpodročja. V osnovi bi ga lahko uvrstili v področje 2. Tehnika, ki v svojih podpodročjih navaja: pod 2.02 Kemijsko inženirstvo, 2.04 Materiali, 2.04.02 Kovinski materiali, 2.10 Proizvodne tehnologije in sistemi, 2.10.02 Izdelovalna tehnologija, 2.10.05 Industrijski inženiring. Evropska klasifikacija raziskovalne dejavnosti (CERIF-CERS) je v primeru livarstva sprejemljivejša in širša, saj pod šifro T 000 izpostavlja program Tehnološke vede in med njimi navaja: T150 Tehnologija materialov in pod T450 Kovinska tehnologija, metalurgija, kovinski izdelki. Torej lahko livarstvo uvrstimo v osnovni program Tehnoloških ved T 000 in livarstvo kot panogo štejemo v T450. Mednarodna livarska konferenca – IFC Portorož – zajema skladno z uradnim priročnikom OECD Frascati Manual iz leta 2015 vsa tri osnovna področja raziskav in razvoja (RR) skladno z uradnim dokumentom OECD: predstavitev temeljnih raziskav, uporabnih raziskav in eksperimentalnega razvoja. Kot majhna država smo tako lahko ponosni, da smo sposobni organizirati mednarodno livarsko konferenco, ki izpolnjuje vsa merila OECD.

Na področju plenarnih predavanj, ki so jih predstavili predstavniki Univerze v Mariboru, Univerze v Ljubljani in Društva livarjev Slovenije je treba izpostaviti naslednje osebe: zasl. prof. dr. Alojz Križmana, Univerza Maribor, ki je bil 9-krat prvi avtor in 9-krat soavtor, redni prof. dr. Primož Mrvar, Univerza Ljubljana, 9-krat prvi avtor in 6-krat soavtor, mag. Martin Debelak, Gospodarska zbornica Slovenije, 1-krat prvi avtor in 9-krat soavtor, mag. Mirjam Jan- Blažič

In a professional sense, however, the issue of Slovenian knowledge and science and their role in the development is always exposed. Foundry as a profession is defined as an interdisciplinary technical science. The classification of research sciences under ARRS does not describe foundry as a research science, class or subdivision. Basically, it could be classified under class 2. Engineering sciences and technologies, the subdivisions of which list: under 2.02 Chemical engineering, 2.04 Materials science and technology, 2.04.02 Metallic materials, 2.10 Manufacturing technologies and systems, 2.10.02 Manufacturing technology, 2.10.05 Industrial engineering. In foundry, the Common European Research Classification Scheme (CERIF-CERS) is more acceptable and broader, as under code T 000 it highlights the Technological Sciences programme, listing among the technological sciences: T150 Materials technology and T450 Metal technology, metallurgy, metal products. This means that foundry can be included in the basic programme of Technological Sciences T 000 while foundry as an industry can be considered part of T450. In line with the official OECD Frascati Manual from 2015, the International Foundry Conference – IFC Portorož covers all three basic R&D (research and development) areas in accordance with the official OECD document: presentations of basic research, applied research and experimental development. As a small country, we can be extremely proud to be able to organize an international foundry conference that meets all of the OECD criteria.

In the field of plenary lectures presented by the representatives of the University of Maribor, the University of Ljubljana and the Slovenian Foundrymen Society, the following persons should be pointed out: Honorary Prof. Dr. Alojz Križman, University of Maribor, who was first author 9-times and co-author 9-times, Full Prof. Dr. Primož Mrvar, University of Ljubljana, 9-times first author and 6-times co-author, Mag. Martin Debelak, Chamber of Commerce and Industry of Slovenia 1-time first author and 9-times co-author, Mag. Mirjam Jan-Blažič, Slovenian Foundrymen Society, 10-times co-author, Assoc. Prof. Dr. Rebeka Rudolf, University of Maribor, 2-times first author, Full Prof. Dr. Jože Medved, University of Ljubljana, 7-times co-author, and

Društvo livarjev, 10-krat soavtor, izr. prof. dr. Rebeka Rudolf, Univerza v Mariboru, 2-krat prvi avtor, redni prof. dr. Jože Medved, Univerza v Ljubljani, 7-krat soavtor, in as. dr. Mitja Petrič, 5-krat soavtor. Že seznam najpomembnejših sodelujočih avtorjev kaže na dobro sodelovanje Društva livarjev Slovenije in univerz v Ljubljani in Mariboru ter Gospodarske zbornice Slovenije. V celotnem obdobju 2011–2020 so bili vedno podani podatki o obsegu proizvodnje. Leta 2010 je proizvodnja slovenskih livarn znašala skupaj 164.715 ton, leta 2019 195.629 ton, kar predstavlja porast za 19 %. V tem obdobju je prišlo do bistvenih strukturnih sprememb v proizvodnji ulitkov iz posameznih zlitin: standardna siva litina -14,9 %, duktilna siva litina +70,2 %, temprana litina +26,7 %, jeklena litina -93,28 %, Al-zlitine +10,6 %, Zn-zlitine +285,7 %, Cu-zlitine -15,6 % ter Mg-zlitine -10 %. Iz 10-letne primerjave je tako razviden velik porast proizvodnje ulitkov iz: zlitin Al in zlitin Zn ter duktilne sive litine in sočasno popoln zastoj pri izdelavi ulitkov iz zlitin Mg in zaradi stečaja livarne jekla Litostroj izrazito znižanje izdelave ulitkov iz jeklene litine.

V plenarnem predavanju »Znanje in inovacijski potencial kot osnova prihodnosti slovenskega livarstva« je bila kot stalnica izpostavljena usmeritev livarn v proizvodnjo z visoko dodano vrednostjo, ki pa zahteva visoko raven izobraževanja, sodelovanje z uglednimi univerzami v tujini ter povezave z Inštitutom za kovinske materiale in tehnologije, ki ima status centra odličnosti za sodobne kovinske materiale. Prav tako so izpostavljene možnosti izdelave kompleksnih komponent, ki zahtevajo visoko stopnjo obdelovalne in spajalne tehnike. Težišče raziskav samih materialov je usmerjeno v visokokakovostne Al-zlitine in nodularno sivo litino. Kot posebna skupina raziskav sta bila predstavljena program tehnologije metastabilnih materialov s kovinsko osnovo in pa liti kompoziti s keramično utrjevalno fazo ter možnostjo izdelave interpenetracijskih kompozitov. Predstavljene so bile raziskave magnezijeve zlitine in dodatkov keramične utrjevalne faze.

V dobro obiskanih plenarnih predavanjih so predstavniki obeh univerz izpostavili tehnološke dosežke in zahtevne ulitke ter inovacijske dosežke naslednjih slovenskih livarskih podjetij: LTH ulitki d.o.o., Ljubljana in Škofja Loka,

Ass. Dr. Mitja Petrič, 5-times co-author. The list of the most important participating authors already indicates the quality of cooperation between the Slovenian Foundrymen Society and the Universities of Ljubljana and Maribor as well as the Chamber of Commerce of Slovenia. For the entire 2011–2020 period, data on production volumes were presented. In 2010,

the production of Slovenian foundries totalled to 164,715 tons vs. 195,629 tons in 2019, constituting a 19% increase. During this period, significant structural changes in the production of castings from individual alloys occurred; standard gray iron -14.9%, ductile gray cast iron +70.2%, malleable cast iron +26.7%, steel alloy -93.28%, Al alloys + 10.6%, Zn alloys +285.7%, Cu alloys -15.6% and Mg alloys -10%. The 10-year comparison shows a large increase in the production of castings produced from: Al and Zn alloys and ductile gray cast irons, and at the same time a complete standstill in the production of castings from Mg alloys and due to the insolvency of the steel foundry Litostroj, resulting in a marked reduction in the production of steel castings.

In the plenary lecture "Knowledge and Innovation Potential as the Basis for the Future of the Slovenian Foundry", the focus of foundries on high value-added production was highlighted, however, which requires a high level of education, cooperation with reputable foreign universities and connections with the Institute of Metals and Technology, boasting the status of a center of excellence for modern metals. The opportunities of producing complex components that require a high level of machining and joining technique are also exposed. The research of materials is focused on high-quality Al alloys and ductile gray iron. As a special group of research, the programme of technology of metastable materials with a metal base and cast composites with a ceramic hardening phase was presented along with the possibility of the production



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največja slovenska livarna aluminijevih ulitkov; ETA Cerkno d.o.o., tovarna elektrotermičnih aparatov in livarna sive litine; Kovis livarna d.o.o., livarna sive in nodularne litine, Štore; Mariborska livarna Maribor d.d., Maribor, izdelovalec ulitkov iz aluminijevih zlitin; Valji, proizvodnja valjev in ulitkov d.o.o., Štore; Livar d.d., Ivančna Gorica, največji slovenski izdelovalec ulitkov iz sive in nodularne litine; OMCO Metals Slovenija d.o.o., izdelovalec ulitkov za steklarsko industrijo ter ulitkov iz sive litine in bakrovih zlitin; Akrapovič d.d., Ivančna Gorica, livarna precizijskega litja titanovih in nikljevih zlitin; Talum, Tovarna aluminija d.d., PE Livarna livarski izdelki iz zlitin Al; Magneti Ljubljana d.d., Ljubljana, izdelava ulitih delov za proizvodnjo trajnih magnetov; Zlatarna



Janko Čevka, Exoterm d.d., dolgoletni aktivni sodelavec IFC

Celje d.o.o., Celje, litje preciznih izdelkov na bazi plemenitih litin in izdelava nanomaterialov; DIFA d.o.o., livarna in obdelava tlačnih ulitkov Al, Škofja Loka; Titus d.o.o., livarna cinkovih zlitin in izdelava livnih strojev, Dekani; HIDRIA, PE Hidria Alutec, Idrija in Koper, livarna in obdelava ulitkov Al; Croning Livarna d.o.o., Ravne na Koroškem, Livarna

Titan d.o.o., Kamnik, livarna temperane litine. S tem je izpostavljeno strokovno sodelovanje obeh univerz z številnimi industrijskimi podjetji, ki izdelujejo in obdelujejo zahtevne lite komponente.

V smislu reindustrializacije je ekspertna evropska komisija za metalurgijo v Evropi pripravila program Metalurgija v Evropi v obdobju 2012–2022 in ob strateškem pomenu kovinskih materialov uvrstila metalurgijo med prioriteta razvojna področja. V Sloveniji je bil imenovan Strateški svet za metalurgijo, v katerem sodelujeta tudi obe univerzi, med drugim so vanj vključeni tudi trije člani, tesno povezani z livarstvom in IFC Portorož (iz Univerze v Ljubljani: prof. dr. Jože Medved in prof. dr. Primož Mrvar z Univerze v Mariboru: zasl. prof. dr. Alojz Križman). Strateški svet vodi predsednik uprave Talum, Tovarna aluminija d.d., Kidričevo, Marko Drobnič. Livarstvo je bilo na

of interpenetration composites. Research on magnesium alloys and ceramic hardening phase additives was presented.

In well-attended plenary lectures, the representatives of both universities highlighted the technological achievements and complex castings as well as the innovations by the following Slovenian companies engaged in the foundry industry: LTH ulitki d.o.o. Ljubljana and Škofja Loka, the largest Slovenian foundry of aluminum castings; ETA Cerkno d.o.o., electrothermal appliances production factory and gray iron foundry; Kovis livarna d.o.o., gray and ductile iron foundry, Štore; Mariborska livarna Maribor d.d. Maribor, manufacturer of aluminium alloy castings; Valji d.o.o. proizvodnja valjev in ulitkov d.o.o. Štore; Livar d.d. Ivančna Gorica, as the largest Slovenian manufacturer of gray and ductile iron castings; OMCO Metals Slovenija d.o.o., manufacturer of castings for the glass industry and gray iron and copper alloy castings; Akrapovič d.d. Ivančna Gorica, foundry for precision casting of titanium and nickel alloys; Talum, Tovarna aluminija d.d. PE Livarna, Al alloy foundry products; Magneti Ljubljana d.d., Ljubljana, production of cast parts for the production of permanent magnets; Zlatarna Celje d.o.o., Celje, casting of precision precious metal-based products and production of nanomaterials; DIFA d.o.o., foundry and processing of Al pressure castings, Škofja Loka; Titus d.o.o., zinc alloy foundry and casting machinery production, Dekani; HIDRIA, PE Hidria Alutec, Idrija and Koper, foundry and processing of Al castings; Croning Livarna d.o.o., Ravne na Koroškem, Livarna Titan d.o.o., Kamnik, foundry of malleable cast iron. This highlights the professional cooperation of both universities with many industrial companies that produce and process complex cast components.

In terms of reindustrialization, the prominent European metallurgy committee prepared the programme Metallurgy Europe for the period between 2012 and 2022, classifying metallurgy based on the strategic importance of metallic materials among priority development areas. In Slovenia, a Strategic Council for Metallurgy was appointed in the context of which both universities also participate. More specifically, it also includes three members closely associated with foundry and IFC Portorož (from the University

osnovi dela Strateškega sveta zajeto v Strategiji pametne specializacije RS in v povezovalni verigi: proizvodnja kovinskih materialov, izdelava orodij-izdelava ulitkov-mehanska, toplotna in površinska obdelava-izdelava obdelanih ulitkov in sklopov. Za livarstvo je bilo opredeljeno področje RR: oblikovanje kovinskih materialov in zahtevnih izdelkov z litjem (celoten prispevek je bil predstavljen na IFC leta 2015). Integracija livarske stroke v razvojni program 2015–2025 je tako tudi rezultat skupnega dela obeh univerz ter Inštituta za kovinske materiale in tehnologije. Prav tako je bila v tem letu na IFC predstavljena izdelava referenčnih vzorcev za potrebe proizvodnje na področju kovinskih materialov z litjem vzorcev na bakreno ploščo, ohlajeno s tekočim dušikom.

V celotnem razvoju slovenskega livarstva ima ključno mesto visokotlačno litje (HPDC) aluminija. Pri ulitkih s kompleksno geometrijo in dimenzijsko natančnostjo je izjemnega pomena ustrezno načrtovanje elementov ulivnega in napajalnega sistema in obvladovanje vseh robnih pogojev v procesni verigi. Predstavnik obeh univerz (P. Mrvar in A. Križman) sta s sodelavci Mariborske livarne v skupni predstavitvi izpostavila primer virtualne obravnave ulitka ohišja menjalnika z izbiro tehnologije in izračunom procesa ter primerjavo z eksperimentalno pridobljenimi vrednostmi. Uporabljeni so bili računalniška tomografija in 3D-meritve.

Obe univerzi, povezani z gospodarstvom, sta soustanoviteljici Strateško-razvojnega partnerstva Materiali kot končni produkti – SRIP MATPRO, ki sta ga pri Gospodarski zbornici Slovenije ustanovila Združenje kovinske industrije in Združenje kemijske industrije. Za livarstvo so bila opredeljena naslednja bistvena prednostna področja: tlačno litje zlitin Al, napredne tehnologije litja, izdelava ulitkov ob integrirani simulaciji optimizacije proizvodnje ulitkov. Ob tem je potrebno izkoristiti naslednje primerjalne prednosti: visoka stopnja prilagodljivosti, vključenost v globalne verige vrednosti in mreže, učinkovita izraba surovinskih in energetskih virov, visoka stopnja recikliranja, tesno sodelovanje gospodarskih družb in institucij znanja. Na osnovi partnerstva med univerzami, raziskovalnimi inštituti in gospodarstvom je po mnenju avtorjev A. Križmana in P. Mrvarja

of Ljubljana, Prof. Dr. Jože Medved and Prof. Dr. Primož Mrvar, and from the University of Maribor, Honorary Prof. Dr. Alojz Križman). The Strategic Council is chaired by the President of the Management Board of Talum, Tovarna aluminija d.d., Kidričevo, Mr. Marko Drobnič. Based on the work of the Strategic Council, the foundry was included in the Smart Specialization Strategy of the Republic of Slovenia and included in the connection – the production of metals, tool making-casting-mechanical, heat and surface treatment-production of machined castings and assemblies. The following R&D area was determined for the foundry sector: Design of metals and sophisticated products via casting (the full paper was presented at IFC in 2015). The integration of foundry into the 2015-2025 development programme is therefore also the result of the joint efforts of both universities and the Institute of Metals and Technology. Similarly, during the same year, the production of reference samples for production needs in the field of metals by the casting of samples onto a copper plate cooled with liquid nitrogen was presented at the IFC.

High-pressure die casting (HPDC) of aluminum occupies a prominent place throughout the entire development of Slovenian foundry. In the case of castings with complex geometries and strict dimensional accuracy requirements, it is highly important to properly design the elements of the casting and supply system as well as to manage every boundary condition in the process chain. Representatives of both universities (P. Mrvar and A. Križman) as well as their colleagues from Mariborska livarna highlighted in a joint presentation the case of virtual processing of a gearbox housing casting by incl. selected technology and process calculation as well as comparison with experimentally obtained values. Computed tomography and 3D dimensional measurements were utilized.

Both universities associated with the economy are the co-founders of the Strategic Research and Innovation Partnership Materials as end Products (SRIP MATPRO), which was established at the Chamber of Commerce and Industry of Slovenia by Metal Processing Industry Association and the Chemical Industries Association. The following focal priority areas

treba strmeti k višji ravni inovacij in proizvodnji zahtevnejših ulitkov z višjo dodano vrednostjo. To sta oba navedena avtorja izpostavila tudi v plenarnem prispevku »Celovito načrtovanje in obvladovanje kompleksnih ulitkov v tehnologiji tlačnega litja«.

Posebna pomena med plenarnimi prispevki je predstavitev avtorskega prispevka v letu 2018 avtorjev A. Križman, P. Mrvar, M. Jan-Blažič in M. Debelak z naslovom »Smernice razvoja slovenskega livarstva«. Slovenska livarska industrija je v več kot 90 % vezana na izvoz v razvite države. S tem je primorana slediti vsem razvojnim trendom in se povezovati v mreže s svojimi odjemalci in uporabniki ulitkov. Ob tem so izrednega pomena izobraževani sistemi ter inventivnost kadra, ki lahko sledijo današnjim razvojnim trendom. Prav tako so pomembni inventivnost posameznikov in inventivni sistem podjetij, ki lahko zagotavljajo sodelovanje z najzahtevnejšimi odjemalci kot partnerji. Izpostavljena je tendenca prenosa znanja na področja različnih uporabnih

materialov z namenom doseganja trajnostnega razvoja v krožnem gospodarstvu. Na istem posvetovanju je bil s strani avtorjev Univerze v Mariboru (R. Rudolf, A. Križman in I. Anžel) ter soavtorjev Zlatarne Celje predstavljen plenarni prispevek »Nanotehnologija kot tehnologija prihodnosti«. Predstavljena je možnost vključevanja



prof. dr. Rebeka Rudolf
(Univerza Maribor in
Zlatarna Celje)

nanotehnologije v izdelavo novih pametnih materialov (jeklo, stekla, nanosi, medicina, stomatologija, elektronika, elektrotehnika itd.).

V letu 2019, ko sta sočasno potekala 59. IFC in Tehnični forum Svetovne livarske organizacije, sta avtorja dveh slovenskih univerz (A. Križman, Maribor, in P. Mrvar, Ljubljana) s soavtorji predstavila za tako številno obiskan in zahteven kongres predavanje z naslovom »Usmeritev slovenskih livarn v tehnično zahtevne, termično, mehansko in površinsko obdelane ulitke kot sestavne in kompleksne dele za neposredno vgradnjo v končne izdelke«. Izpostavljena je bila

have been identified for the foundry sector: die casting of Al alloys, advanced casting technologies, casting production with integrated casting production optimization simulation. The following comparative advantages need to be exploited: a high degree of flexibility, participation in global value chains and networks, efficient use of raw materials and energy resources, high recycling rate, close collaboration between companies and knowledge institutions. In the opinions of authors A. Križman and P. Mrvar, based on the partnership between universities, research institutes and the economy, it is necessary to strive for a higher degree of innovation and the production of more complex castings with higher added value. This was again highlighted by the authors with co-authors in the scope of the plenary contribution dubbed "Comprehensive Planning and Management of Complex Castings in High-pressure Die-casting".

Among the plenary contributions, in 2018, the presentation by authors A. Križman, P. Mrvar, M. Jan-Blažič and M. Debelak titled "Guidelines for the Development of Slovenian Foundry". In more than 90%, the foundry industry in Slovenia is tied to export to developed countries. As a result, it is bound to follow all the trends in development and to network with its customers and users of castings. That is why the educational systems and cadre ingenuity are of particular importance in order to keep up with today's trends in development. Also essential are the ingenuity of individuals and of enterprise systems, which are capable of providing for the collaboration with the most demanding customers in a partnership sphere. The tendency to transfer knowledge to various useful material fields in order to provide for sustainable development in the circular economy is exposed. At the same conference, the authors from the University of Maribor (R. Rudolf, A. Križman and I. Anžel) as well as co-authors from Zlatarna Celje presented the plenary paper, "Nanotechnology as the technology of the future". The opportunity of integrating nanotechnology in the production of new smart materials (steel, glass, coatings, medicine, dentistry, electronics, electrical engineering etc.) was presented.

In 2019, when the 59th IFC and the World Foundry Organization Technical Forum were held simultaneously, authors from two Slovenian

izjemno visoka zahteva po kakovosti ulitkov ter visoki stopnji obdelave in merski natančnosti, ki je ključna zahteva za omogočanje neposredne vgradnje v končni tržni proizvod. To je mogoče doseči samo z visokim vložkom različnih znanj, končno zahtevno kontrolo dimenzij in lastnosti z vrhunsko opremo ter seveda tržno konkurenčnostjo cene. Prikazani so bili ulitki petih slovenskih livarn (LTH Castings, Mariborska livarna Maribor, TALUM PE Ulitki, Kovis-Livarna, ETA Cerkno).

Tudi v letu 2020 sta obe univerzi prispevali dve plenarni predavanji. Kot prvo A. Križman (MB) in P. Mrvar (LJ) z naslovom »Slovensko livarstvo: iz tradicije v prihodnost, zasnovano na znanju, ustvarjalnosti in inovativnosti«. Tradicija slovenskega livarstva izhaja iz 4. stoletja pr. n. št. z litjem sekiric iz bakra v kalupe iz gline na lgu pri Ljubljani. Zgodovina livarstva je povezana z litjem zvonov v livarnah v Ljubljani, Celju in Gorici. Najstarejši še ohranjen zvon je bil ulit v Celju leta 1550. Posebno zgodovinsko vrednost pa ima razvoj litja tankostenskih ulitkov, ki ga je razvil J. V. Valvasor s svojim najbolj znanim ulitkom kipa sv. Marije iz posebne bakrove zlitine z deležem Zn 16 % ter legirnimi dodatki Sn in Pb. Ulitek stoji še danes kot izjemna kulturna znamenitost na Marijinem spominskem stebru pred cerkvijo sv. Jakoba v Ljubljani. Prispevek o tem postopku litja je J. V. Valvasor objavil angleškem jeziku leta 1687 v *Philosophical Transactionys of Royal Society* in pet let kasneje leta 1692 v latinskem jeziku v najstarejšem znanstvenem glasilu *Acta Eroditorum* v Leipzigu. Te objave veljajo za najstarejše znanstvene objave slovenske znanosti tehniških ved.

Trendi razvoja slovenskih livarn so danes zasnovani na digitalizaciji in avtomatizaciji proizvodnje, visoki stopnji mehanske, površinske in termične obdelave ter visoki merski natančnosti. Prikazani so bili tudi primeri zelo zahtevnih ulitkov podjetij Akrapovič d.d., Ivančna Gorica, s primerom vakuumskega litja izpušnih cevi iz Ti zlitin; TALUM Kidričevo s primerom zahtevnega ulitka iz Al-zlitine z nizkotlačnim litjem za motorno industrijo; Livar d.d., Ivančna Gorica, računalniška modifikacija geometrije proizvoda pokrovov iz sive litine; Mariborska livarna Maribor d. d., primer zahtevnega ulitka antivibracijskega elementa nosilca motorja z notranjim zgorevanjem. Drugo plenarno

universities (A. Križman, Maribor, and P. Mrvar, Ljubljana) and their co-authors presented the lecture for a packed hall of knowledge-thirsty attendees dubbed, "Orientation of Slovenian foundries into technically complex, thermal, mechanically and surface-treated castings as integral and complex parts for direct installation into finished products". Exposed was the extremely high demand regarding the quality of castings as well as the high level of processing and measurement accuracy, which are necessary for the direct installation into the final market product. This can only be achieved through a thorough investment of various skills, final rigorous control of dimensions and properties using state-of-the-art equipment and, of course, a competitive price. The castings by five Slovenian foundries (LTH Castings, Mariborska livarna Maribor, TALUM PE Ulitki, Kovis-Livarna, ETA Cerkno) were presented.

Also, in 2020, both universities contributed two further plenary lectures. The first by A. Križman (MB) and P. Mrvar (LJ) with co-authors dubbed, "Slovenian Foundry: from tradition to the future based on knowledge, creativity and innovation". The tradition of Slovenian foundry dates back to 4th century BC when at Ig near Ljubljana, copper axes were cast into clay molds. A related part of the history of foundry is related to the casting of bells in foundries in Ljubljana, Celje and Gorizia. The oldest surviving bell was cast in Celje in 1550. Of particular historical value is the development of thin-walled castings J.V. Valvasor, whose most famous casting of the statue of St. Mary is made from a special copper alloy with a Zn content of 16% and alloying additives Sn and Pb. The casting is still displayed as an exceptional cultural landmark at St. Mary's memorial pillar in front of the church of St. Jakob in Ljubljana, Slovenia. A paper on the casting process was published by J.V. Valvasor in English in 1687 in the *Philosophical Transactionys of the Royal Society* and five years later in 1692 also in Latin in the oldest scientific journal, *Acta Eroditorum*, in Leipzig. These publications are considered to be the oldest scientific publications of Slovenian technical sciences.

Nowadays, the development trends of Slovenian foundries are based on digitalization and automation of production, a high level of

predavanje na IFC 2020 je pripravila univerza v Mariboru (R. Rudolf prvi avtor, soavtorji P. Majerić, Ž. Jelen in A. Križman) in je nosilo naslov »Prenos nanotehnologije na industrijski nivo na primeru nanodelcev zlata kot primer dobre prakse v Zlatarni Celje d.o.o.«. Nanodelci iz zlata imajo izjemne lastnosti, npr. optične, inertnost in biokompatibilnost. Njihova uporaba je predvidena predvsem v medicini, zato je izdelava in uporaba povezana z zelo strogimi zahtevami uporabnikov. Ena izmed tehnologij izdelave nanodelcev zlata temelji na ultrazvočni razpršilni pirolizi – USP, ki je osnovana na ultrazvočnem razprševanju raztopine želenega materiala v kapljice aerosola. Inertni nosilni plin prenaša nastale kapljice v reakcijsko peč, kjer potekajo faze sinteze v končne nanodelce. V odvisnosti od hitrosti izhlapevanja lahko izdelamo različne oblike in velikosti nanodelcev. V Zlatarni Celje se želi z raziskavami preiti na industrijsko raven izdelave nanodelcev.

Predavanja predstavnikov univerz in raziskovalnih inštitutov z navedbo prvih avtorjev iz sekcije jeklolitina in železove litine ter livarske tehnologije na IFC v obdobju 2011–2020.



prof. dr. PRIMOŽ MRVAR
(Univerza v Ljubljani)

P. Mrvar (ULj) je s soavtorji z obeh univerz in podjetja Livar iz Ivančne Gorice na IFC 2014 podal zelo zahtevno temo z naslovom »Tehnologija izdelave in karakterizacija gradientnega ulitka«. Predstavljena je bila kombinacija horizon-

talnega centrifugalnega litja legirane bele litine, legirane s kromom (površina valjev), in gravitacijskega litja jedra iz sive litine s kroglastim grafitom. Vmesna plast ima strukturo sive litine z lističastim grafitom. Mikrostrukturne komponente so bile določene kvantitativno in kvalitativno. S pomočjo računalniških programov so bili narejeni izračuni gostote za vsako posamezno mikrostrukturno komponento. Različna gostota mikrostrukturnih komponent je posledica centrifugalnih sil. Izračunane in izmerjene so

mechanical, surface and thermal processing and high measurement accuracy. Examples of highly complex castings for the following companies were also presented: Akrapovič d.d. Ivančna Gorica with an example of vacuum casting of exhaust pipes from Ti alloys; TALUM Kidričevo as an example of a demanding casting made of Al alloy, with low-pressure casting for the motor industry; Livar d.d. Ivančna Gorica, computer modification of the geometry of gray iron covers; Mariborska livarna Maribor d.d., an example of the complex casting of an anti-vibration element for an internal combustion engine bracket. The second plenary lecture at IFC 2020 was prepared by the University of Maribor (R. Rudolf, first author, co-authors P. Majerić, Ž. Jelen and A. Križman) and dubbed "Transfer of nanotechnology to the industrial level – as an example of good practice in Zlatarna Celje d.o.o. on the case of gold nanoparticles". Gold nanoparticles have outstanding properties, e.g. optical, inertness and biocompatibility. Their use is expected primarily in medicine, meaning that their production and application is associated with stringent requirements. One of the technologies for making gold nanoparticles is based on ultrasonic spray pyrolysis – USP, which encompasses the ultrasonic spraying of a solution of the desired material into aerosol droplets. The inert carrier gas transfers the resulting droplets to the reaction furnace where the synthesis phases until the final nanoparticles take place. Depending on the evaporation rate, different shapes and sizes of nanoparticles can be obtained. Zlatarna Celje aims to move the research to the industrial level of nanoparticle production.

Lectures by representatives of universities and research institutes with indications of the first authors from the section: steel, cast iron and foundry technology at IFC in the period between 2011 and 2020.

At IFC 2014, P. Mrvar (ULj) with co-authors from both universities and Livar from Ivančna Gorica presented a very demanding topic dubbed "Manufacturing technology and characterization of gradient casting". A combination of horizontal centrifugal casting of white cast iron alloyed with chromium (cylinder surface) and gravity casting of a gray cast iron

bile notranje napetosti v ulitku in pojasnjen vpliv nehomogenosti porazdelitve karbidov v prvi in drugi plasti kot tudi vpliv jedra na mehanske lastnosti ulitka.

P. Mrvar je s soavtorji z obeh univerz na IFC 2018 predstavil predavanje »**Nova siva litina za transport staljenih zlitin Al**«. Prikazana sta bila razvoj in preizkušanje nove sive litine z dobro obrabno obstojnostjo in odlično toplotno prevodnostjo, ki jo je mogoče uporabiti za komore za tlačno litje. Preiskovana siva litina je bila preizkušena v tehnološki industrijski praksi, pri čemer je bilo izvedeno vrednotenje tribološkega procesa na površini cevi. Stroški proizvodnje elementa za komore iz nove prilagojene litine so bili zmanjšani za eno tretjino.

Predavanja predstavnikov univerz in raziskovalnih inštitutov kot prvih avtorjev iz sekcije neželeznih zlitin na IFC v obdobju 2011–2020.

Če sta univerzi in raziskovalni inštituti relativno slabo vključeni v sekciji jeklenih litin in litin Fe, pa je število odličnih prispevkov na področju livarstva neželeznih kovin zelo visoko; zato se bomo omejili le na 10 znanstveno in razvojno najbolj aktualnih prispevkov.

P. Mrvar (ULj) je s soavtorji na IFC v letu 2011 predstavil prispevek »**Nove možnosti izdelave kompleksnih komponent s tlačnim litjem in spajanjem**«. Pri spajanju ulitkov iz zlitin Al se vse pogosteje uporablja torni mešalno varjenje (FSW). Namen postopka je spajanje delov z različnimi lastnostmi na mestih, povezanih s strožjimi zahtevami. Dovajanje toplote pri tem spajanju je manjše kot pri standardnem talilnem varjenju, kar pomeni manjše deformacije in zaostale napetosti. Glavna težava je temperaturna porazdelitev okoli spoja med zlitino Al in čistim Al. Porazdelitev temperature je bila izračunana z metodo končnih elementov.

J. Medved je s fakultetnimi sodelavci (ULj) na 52. IFC podal predavanje »**Termodinamično modeliranje kot pomoč pri optimiranju materialov Al in tehnologij**«. Termodinamska karakterizacija livnih zlitin Al z izračunanimi in eksperimentalno pridobljenimi podatki povečuje razumevanje zlitin na osnovi Al. Pomembna je uporaba različnih kombinacij

core with spherical graphite was presented. The intermediate layer has a gray cast iron structure with flake graphite. The microstructural components were determined both quantitatively and qualitatively. With the help of computer software, density calculations were completed for each individual microstructural component. The different densities of microstructural components are the result of centrifugal forces. The internal stresses in the casting were calculated and measured and the influence of the non-homogeneity of the carbide distribution in the first and second layers as well as the influence of the core on the mechanical properties of the casting were interpreted.

At IFC 2018, **P. Mrvar with co-authors from both universities** gave the lecture titled, »**New cast iron alloy for transport of molten Al-alloys**«. The development and testing of a new gray cast iron with good wear resistance and excellent thermal conductivity characteristics that can be used for die casting chambers were presented. The investigated gray iron was tested in a practical technological-industrial setting whereby the evaluation of the tribological process on the pipe surface was also undertaken. The cost of production of a chamber element from new custom cast iron was reduced by a third.

Lectures by representatives of universities and research institutes as first authors from the section for non-ferrous alloys at IFC in the period between 2011 and 2020.

Even though the universities and research institutes are relatively poorly represented in the steel and Fe castings section, the number of excellent contributions in the field of non-ferrous metal castings is extremely high, which is why we have limited ourselves to only the 10 most scientifically and developmentally relevant contributions.

In 2011 at the IFC, **P. Mrvar (ULj) and co-authors** presented the article dubbed, »**New possibilities in the production of complex components via die casting and joining**«. Friction stir welding (FSW) is becoming more commonly used in the joining of Al-alloy castings. The objective of the procedure is to join parts with different characteristics in locations associated with more stringent requirements. In this type

elementov v določenih temperaturnih področjih za pridobivanje podatkov o tvorbi različnih faz. Določali so sestavo, vrsto in delež posameznih faz ter poteke ravnotežnih in neravnotežnih procesov kot tudi karakterističnih temperatur. S termično analizo so bile pridobljene informacije o termodinamičnih lastnostih, faznih premenah in izločanju faz, ki jih lahko uporabimo za zbirke podatkov in simulacije. Bistvene so natančne termodinamične lastnosti zlitin kot osnova za nadaljnje preiskave in aplikacije.



dr. Mitja Petrič (Univerza v Ljubljani)

M. Petrič je s fakultetnimi sodelavci (ULj) na 53. IFC predstavil temo »Meritve električne upornosti zlitin Al-Si«. Problem je vezan na izbiro ustreznega materiala za elektrode glede na tehniko štirih vzorcev zlitin Al in Al-Si. Elektrode med meritvami oksidirajo, kar poviša upornost in daje nepravilne rezultate.

Preiskovani so bili različni materiali in izbrane aluminijeve elektrode. Prednost je v tem, da med ulivanjem ne nastopajo vmesne faze. Razvita je bila merilna naprava skupaj z merilno celico za meritve električne upornosti med strjevanjem »in situ«. Analizirane so bile različne Al-Si-zlitine. Ugotovljeno je bilo višanje upornosti z rastjo vsebnosti silicija.

J. Medved je s fakultetnimi sodelavci (ULj) in (UM) na 54. IFC izpostavil temo, ki je širše koristna za livarstvo aluminija, z naslovom »Fazna ravnotežja v aluminijevih livarskih zlitinah v odvisnosti od vsebnosti Si in Fe«. Železo v zlitinah Al predstavlja težavo ne toliko zaradi zvišanja trdote, ampak povečanja krhkosti. Raziskana so bila fazna ravnotežja v zlitinah Al-Si in vpliv razmerja železo/silicij. Pri preiskavi so uvajali železno žico v iz čistih komponent izdelano zlitino AlSi12Cu (Fe) pri temperaturi 750 °C in različnih časih raztapljanja. Za ugotavljanje značilnih temperatur procesa taljenja in strjevanja in s tem sproščanja toplote je bila uporabljena metoda simultane termične analize (STA). Z uporabo programa Thermo-Calc so bili izvedeni termodinamična simulacija napovedovanja faznega

of joining, the heat charge is lower compared to standard fusion welding, resulting in reduced deformation and less residual stresses. The main problem is the temperature distribution near the junction between the Al alloy and pure Al. The temperature distribution was calculated via the finite element method.

At the 52nd IFC, **J. Medved with faculty associates from (ULj)** gave the lecture dubbed, **“Thermodynamic modeling as a support for optimization of aluminium materials and technologies”**. The thermodynamic characterization of Al-cast alloys with calculated and experimentally obtained data improves the understanding of Al-based alloys. It is imperative to use different combinations of elements in specific temperature ranges in order to obtain data on the formation of various phases. The composition, type and proportion of individual phases was determined along with the course of equilibrium and non-equilibrium processes as well as characteristic temperatures. The thermal analysis has granted insight into thermodynamic properties, phase transformations and phase precipitation that can be used for databases and simulations. The precise thermodynamic properties of alloys are the basis for further research and applications.

At the 53rd IFC, **M. Petrič with faculty associates from (ULj)** gave the lecture titled, **“Measurement of electrical resistance of Al-Si alloys”**. The issue is related to the selection of a suitable electrode material in line with the technology of four samples of Al- and Al-Si alloys. During measurement, the electrodes oxidize, increasing the resistance and yielding incorrect results. Various materials and selected aluminum electrodes were investigated. The advantage is that no intermediate phases occur during casting. A measuring device was developed together with an “in situ” measuring cell for the measurement of electrical resistance during solidification. Various Al-Si alloys were analyzed. It was determined that the resistance increases with the increased Si content.

At the 54th IFC, **J. Medved with faculty associates from (ULj) and (UM)** presented a topic useful throughout the aluminium casting industry titled, **“Phase equilibrium in aluminium cast alloys depending on Si and Fe content”**. Iron in Al-alloys pose a problem

ravnotežja nastalih faz železa in vrednotenje eksperimentalnih podatkov kot tudi izračun za fazne diagrame pri različnih razmerjih Fe/Si. **M. Petrič je s fakultetnimi sodelavci (ULj) in (UM) na 55. IFC podal raziskovalno temo »Meritve dimenzijskih sprememb med strjevanjem zlitin Al-Si«.** Predstavljeno je bilo strjevanje AISi12-zlize z uporabo različnih tehnik, kot so termična analiza, dilatometrijska analiza in termodinamični izračuni s programsko opremo Thermo-Calc. Metalografske raziskave so bile izvedene z optično mikroskopijo in mikroskopijo SEM. Fazne analize so izdelane z EDS. Analizirani so bili štirje vzorci: osnovna zlitina AISi12 brez dodatkov, zlitina ALTi5B1 z udobjenjem zrn, modificirana osnovna zlitina AISi10 in osnovna zlitina. Analizirane so bile mikrostrukture in izvedena dilatometrična analiza, ki je pokazala razlike v krčenju osnovne litine in modificiranih litin, kjer je ugotovljeno manjše krčenje.



dr. Maja Vončina (Univerza v Ljubljani)

M. Vončina je s soavtorji s fakultete (ULj) in zainteresiranim podjetjem Hidria Rotomatika, na 56. IFC predstavila skupno raziskavo z naslovom »Vpliv livarskih napak na električne lastnosti ulitka iz aluminija«. Dosedanja tehnologija visokotlačnega litja aluminijevih kratkostičnih kletk rotorja

indukcijskega elektromotorja je sicer zadovoljila zahtevam po visoki produktivnosti, ne pa tudi končni učinkovitosti elektromotorjev. Zato je bila izvedena raziskava vpliva nečistoč in poroznosti na električne lastnosti ulitkov iz Al s sestavo: Al99,99; Al99,7; in Al99,5; pri različnih pogojih litja, in sicer v vakuumu in na zraku. Med strjevanjem sta bili merjeni temperatura ter električna prevodnost ulitka. Vzorci so bili analizirani z optičnim mikroskopom z namenom analize poroznosti in z vrstičnim elektronskim mikroskopom z namenom analize faz in nečistoč. Na osnovi navedenih analiz je bil pojasnjen vpliv deleža nečistoč in poroznosti na električne lastnosti ulitega aluminija.

not due to the increase in hardness, but instead increased brittleness. Phase equilibria in Al-Si alloys and the influence of iron v. silicon ratio were researched. In the research, iron wire was introduced into an AISi12Cu (Fe) alloy made from pure components at the temperature of 750 °C and at different melting times. The Simultaneous Thermal Analysis (STA) method was used to determine the typical temperatures of the melting and solidification processes and consequently heat release. Using the Thermo-Calc software, a thermodynamic simulation of the phase equilibrium prediction of the generated iron phases was carried out along with the evaluation of experimental data and the calculations for phase diagrams for different Fe/Si ratios.

At the 55th IFC, **M. Petrič with faculty associates from (ULj) and (UM)** gave the lecture named, **“Measurement of dimensional changes of AlSi alloys during solidification”**. Examined was the curing of AISi12 using various techniques such as thermal analysis, dilatometry and thermodynamic calculations using Thermo-Calc. Metallographic investigations were carried out via optical and SEM microscopy. Phase analyzes were performed using EDS. Four samples were analyzed: AISi12 base alloy without additives, ALTi5B1 alloy with grain refinement, modified AISi10 base alloy and base alloy. Microstructures were analyzed and dilatometry was performed, showcasing the differences in the shrinkage of base cast iron and modified cast iron, where a lesser degree of shrinkage was determined.

At the 56th IFC, **M. Vončina with co-authors from the Faculty (ULj) and the participating undertaking Hidria Rotomatika**, presented the joint research dubbed, **“Influence of foundry defects on the electrical properties of Al-castings”**. The current technology of high-pressure die casting of aluminum induction electric motor short-circuit cages has met the requirements for high productivity, however, the target efficiency of electric motors has not. As a result, the study was conducted on the influence of impurities and porosity on the electrical properties of Al castings with the following composition: Al99.99; Al99.7; and Al99.5; under different casting conditions, i.e. vacuum and atmospheric. During solidification,



prof. dr. FRANC ZUPANIČ
(Univerza v Mariboru)

F. Zupanič (UM) je s sodelavci s fakultete na 57. IFC predstavil raziskavo »Uporaba fokusiranega ionskega snopa pri karakterizaciji livnih zlitin Al«. Mikrostrukture livnih zlitin Al vsebujejo številne mikrostrukturne sestavine mikro- ali nanovelikosti. Za metalografsko analizo se najpogosteje uporabljajo

standardne metode, kot so svetlobna mikroskopija, vrstična in presečna elektronska mikroskopija ter rentgenska difrakcija. Dodatne informacije o mikrostrukturi pa nam omogočajo metode dvojnega snopa: fokusiranega ionskega snopa (FIB) in elektronskega snopa (SEM). Pri FIB pospešeni ioni (običajno galijeji) ob trku z vzorcem izbija atome in tako odstranjujejo material. Pri tem nastajajo različni signali, ki se lahko uporabljajo za slikanje s SEM. Predstavljena je raziskava FTB-SEM pri metalografskih raziskavah livnih zlitin Al. Možni so prečni prerezi na točno določenih mestih ter odkrivanje razporeditve in oblike mikrostrukturnih sestavin pod površino vzorca. Možna je tudi 3D-rekonstrukcija mikrostrukture.



prof. dr. Jožef Medved
(Univerza v Ljubljani)

J. Medved je s sodelavci s fakultete (ULj) in strokovnjakom iz podjetja Talum d.d. na 58. IFC podal skupno raziskavo »Vpliv manjšega dodatka legirnih elementov na livarske Al-zlitine«. Predstavitev je obravnavala modeliranje inovativnih zlitin Al z boljšimi lastnostmi za visokotemperaturne

aplikacije. Podana je bila analiza vpliva dodatka Zr in Mo na strjevanje AlSiMgMn-zlitine z uporabo termodinamičnih izračunov, termične analize in diferencialne kalorimetrije. Za določanje mikrostrukture preiskovanih zlitin pa sta bila uporabljena optična mikroskopija in elektronska vrstična mikroskopija z energijsko disperzijsko

the temperature and electrical conductivity of the casting were measured. The samples were analyzed using an optical microscope for the purpose of porosity analysis and with a scanning electron microscope for the purpose of phase and impurity analysis. Based on these analyses, the influence of impurities and porosity on the electrical properties of cast aluminum was interpreted.

At the 57th IFC, **F. Zupanič (UM) with the associates from the faculty** presented the research dubbed, **“Application of a focussed ion beam by characterization of casting Al-alloys”**. The microstructures of cast Al-alloys contain numerous microstructural components in the micro and nano ranges. Standard methods, e.g. light microscopy, scanning and transmission electron microscopy as well as X-ray diffraction, are used mostly in metallographic analysis. Additional information on the microstructure is obtained via the dual beam methods: focused ion beam (FIB) and electron beam (SEM). In FIB, accelerated ions (as a rule gallium) eject atoms upon impact with the sample, eliminating material. This generates various signals that can be used in SEM imaging. The FTB-SEM research in metallographic studies of Al-cast alloys is presented. Cross-sections at precisely defined locations and the detection of the distribution and shape of microstructural components below the sample surface are possible. 3D-reconstruction of the microstructure is also possible.

At the 58th IFC, **J. Medved with associates from the faculty (ULj) and the expert from Talum d.d.**, presented the joint study, **“Impact of small addition of alloying elements on Al alloys”**. The presentation addressed the modeling of innovative Al alloys with improved properties for high-temperature applications. An analysis of the influence of the addition of Zr and Mo on the solidification of AlSiMgMn using thermodynamic calculations, thermal analysis and differential calorimetry was presented. Optical microscopy and electron scanning microscopy with energy-dispersive X-ray spectroscopy were used to determine the microstructure of the investigated alloys. The chemical composition, type and amount of phases as well as solidification temperatures of laboratory and industrial samples of alloys were analyzed. With the addition of Zr, a new

spektroskopijo. Analizirana je bila kemična sestava, vrsta in količina faz ter temperatura strjevanja laboratorijskih in industrijskih vzorcev zlitin. Z dodatkom Zr se v zlitini oblikuje nova igličasta faza. Dodani Mo je vključen v fazo AlFeMnSi, pri čemer delno oblikuje novo fazo AlFeMnMoSi z drugačno morfologijo.

B. Zeka je s sodelavci s fakultete (ULj) je na skupnem 59. IFC in Tehničnem forumu Svetovne livarske organizacije predstavil raziskavo **»Razvoj novih livarskih zlitin na osnovi Al z dodatkom Li«**. Dodatek litija k Al predstavlja zmanjšanje teže ulitka, saj vsak ut.% Li, dodan k Al, zmanjša gostoto za 3 % in zviša modul elastičnosti. Raziskan je bil učinek dodatka Li v količini 1,46 ut.% k zlitini AlSi7Mg (7,05 %Si in 0,35 %Mg). Zlitina ima po naravnem staranju zmanjšano gostoto in višjo trdoto. Z raziskavo je bilo dokazano, da se z dodatkom Li spremenijo mikrostrukturne in mehanske lastnosti. V strukturi nastane nova faza AlSiLi, ki izboljša trdnost zlitine. Z vrstično elektronsko mikroskopijo in rentgensko difrakcijo je bilo potrjeno, da dodatek Li vodi mikrogradnike AlLiSi, α -Al in β Si.

J. Medved (ULj) je s soavtorji iz Inštituta za kovinske materiale in tehnologijo z ULj ter podjetja Talum d.d. Kidričevo na skupnem 59. IFC in Tehničnem forumu Svetovne livarske organizacije predstavili raziskavo **»Kemijska, mehanska in toplotna obraba orodij ob stiku z livnimi zlitinami Al«**. Tlačno litje je eden najpomembnejših livarskih postopkov. Med postopkom prihaja do neposrednega stika in s tem do kemične interakcije med orodjem iz jekla in talino. To vodi do mehanske in toplotne obrabe orodij. Visoka produktivnosti postopka zahteva visoko odpornost orodja. V raziskavi sta bila uporabljena vzorca iz jekel UTOPMO1 in RAVNEX XD, in sicer za analizo odpornosti proti obrabi ob stiku z litino Al99,7 in AlSi12. Izdelana je bila laboratorijska naprava za testiranje orodnih jekel pri dveh različnih temperaturah v času 4 ure pri 75 vrtljajih na minuto. Posledica interakcije je rast reakcijske plasti. Odpornost orodnega jekla UTOPMO1 je v zlitini AlSi12 v primerjavi z zlitino Al99,7 veliko boljše kot odpornost jekla RAVNEX HD. Prav tako velja ugotovitev, da se debelina interakcijskega sloja poveča s naraščajočo temperaturo.

needle phase is formed in the alloy. The alloying Mo is included in the AlFeMnSi phase, partially forming a new AlFeMnMoSi phase with a different morphology.

At the joint 59th IFC and World Foundry Organization Technical Forum, **B. Zeka with associates from the faculty (ULj)** presented the research labelled **“Development of new Al-based alloys with the addition of Li”**. The addition of lithium to Al constitutes a reduction in the weight of the casting since each wt.% Li added to Al reduces density by 3% while increasing the elastic modulus. The effect of the addition of Li in the total of 1.46 wt.% to AlSi7Mg (7.05% Si and 0.35% Mg) was investigated. The alloy has a reduced density and a higher hardness following natural aging. Research has shown that the addition of Li changes the microstructural and mechanical properties. A new AlSiLi phase is formed in the structure, improving the strength of the alloy. Via scanning electron microscopy and X-ray diffraction, it was confirmed that the addition of Li leads the micro constituents AlLiSi, α -Al and β Si.

At the joint 59th IFC and World Foundry Organization Technical Forum, **J. Medved (ULj) with co-authors from the Institute of Metals and Technology, ULj and Talum d.d. Kidričevo** presented the research **“Chemical, mechanical and thermal wear of tools in contact with Al alloys”**. Die casting is one of the most important casting processes. During die casting occurs the direct contact and thus the chemical interaction between the steel die and the melt. This causes mechanical and thermal wear of the dies. High process productivity requires high tool resistance. Samples made of UTOPMO1 and RAVNEX XD steels were used in the research to analyze the wear resistance upon contact with Al99,7 and AlSi12 alloys. A laboratory device was fabricated for the testing of tool steels at two different temperatures for 4 hours at 75 rpm. The interaction results in the growth of the reaction layer. The resistance of UTOPMO1 tool steel in AlSi12 is much better versus Al99.7 compared to the resistance of RAVNEX HD steel. It is also true that the thickness of the interaction layer increases with temperature.

V nadaljevanju vam predstavljamo najpomembnejša predavanja predstavnikov slovenskih livarskih podjetij v obdobju 2011–2020 kot prispevek k razvoju znanja in tehnološkega napredka ter uspešnosti mednarodne livarske konference v Portorožu.

Na področju jeklo-litine in železove litine ter livarske tehnologije predstavljamo naslednje prve avtorje, podjetja, iz katerih prihajajo, in leto predstavitve:



Bojan Črtalič
(FerroČrtalič d.o.o.)

B. Črtalič (FerroČrtalič d.o.o., Dolenjske Toplice) in soavtorji, 2012: Izjemne tehnološke rešitve razigljavanja in čiščenja livarskih izdelkov z avtomatizacijo, robotizacijo in novimi tehnologijami, razvitimi v podjetju.

Prva rešitev razigljavanja drobnih in preciznih ulitkov iz zlitin Zn je sicer konvencionalna. Razvoj je bil narejen na zelo preciznih kosih, namenjenih masovni proizvodnji telefonov, elektronskih komponent in navigacijskih naprav, ki zahtevajo zelo natančno rokovanje in rešitve. Uvedena je bila popolna avtomatizacija procesa brez prisotnosti upravljavca. Druga rešitev razigljavanja je bila predstavljena na primeru zaporednega zalaganja z robotom in zaporedne avtomatske operacije peskanja posameznih mest na izdelku vse do robotske vizualizacije. Študije so pokazale veliko prednost čiščenja z mikro peleti iz suhega ledu in v določenih primerih tudi s suhim snegom.

J. Pristavec (EXOTERM-IT, Kranj) in soavtorji, 2013: Razvoj ter optimizacija livarske tehnologije ulitka iz nodularne litine z uporabo numerične simulacije.

Prikazan je bil proces razvoja ter optimizacije tehnologije litja zahtevnega ulitka z ročno izdelavo forme iz mešanice kremenčevega peska in vodnega stekla z neto težo 3.400 kg in bruto težo 4.560 kg iz nodularne litine EN-GJS-400 -15. Livni sistem je bil najprej določen na osnovi standardnega preračuna geometrijskih modulov kritičnih delov ulitka. S standardno rešitvijo zahtevnega ulitka ni bilo mogoče izdelati brez

Hereinafter, we present the most important lectures of representatives of Slovenian foundry companies in the period between 2011 and 2020, as contributions to the development of knowledge and technological progress as well as the success of the international foundry conference in Portorož.

In the field of steel foundry as well as cast iron and foundry technology, we present the following first authors, the companies they are employed with and the year of the presentation:

B. Črtalič (FerroČrtalič d.o.o. Dolenjske Toplice) and co-authors, 2012: Exceptional technological solutions for deburring and cleaning of foundry products via automation, robotics and new technologies developed in the company.

The first solution for degreasing small and precise castings from Zn-alloys is conventional. The development was made on very precise pieces intended for the mass production of telephones, electronic components and navigation devices that require very precise handling and solutions. Full process automation without the operator's presence has been introduced. Another deburring solution was presented based on the example of sequential loading using a robot and sequential automatic sandblasting operations of individual product areas, all the way to robotic visualization. Studies have indicated a great advantage of cleaning with dry ice micro pellets and in certain cases also dry snow micro pellets.

J. Pristavec (EXOTERM-IT, Kranj) and co-authors, 2013: Development and optimization of ductile iron casting foundry technology using numerical simulation.

The development and optimization process of casting technology for demanding castings with manually produced moulds from a mixture of quartz sand and sodium silicate with a net weight of 3,400 kg and a gross weight of 4,560 kg from ductile iron EN-GJS-400 -15 is presented. The casting system was first determined on the basis of a standard calculation of the geometric modules of the casting's critical parts. However, with the standard solution, it was not possible to produce a complex casting without defects. As a result, a more efficient computer simulation process for the calculation of critical parts of the casting was investigated. The Magma 5v5.20

napak. Zato se je pristopilo k učinkovitejšemu postopku računalniške simulacije preračunov kritičnih delov ulitka. Uporaben je bil paket Magma 5v5.20, ki se vključuje že v razvojno fazo načrtovanja in nato v samo optimizacijo tehnologije litja ter predvidene končne lastnosti ulitka. Bistveni elementi izboljšave so bili na zunanjem obodu zahtevnega ulitka z uporabo hladilnih kokil in usmerjenim strjevanjem ter znižanjem temperature litja. Izrazito je bil zmanjšan izmet, skrajšan čas izdelave ter znižani stroški.

D. Mitrović (Livar d.d., Ivančna Gorica) in soavtorji, 2014: Učinek vibracij in lokalne ohlajevalne hitrosti na evtektoidno premeno v sivi litini s kroglastim grafitom.

Študija je izpostavila vpliv vibriranja in hitrosti ohlajevanja na evtektoidno transformacijo v litini EN-GJS-500-7. Ulitki so bili uliti v podjetju Livar z uporabo avtomatske horizontalne linije za sveži pesek, in sicer na standarden način ulivanja. Raziskana je bila evtektoidna transformacija. Uporabljene so bile metode metalografskih raziskav z optičnim mikroskopom in različne rastrske kalorimetrične metode, izvedene meritve trdote različnih debelin ulitkov in meritve nateznih trdnosti ter morfologije grafitnih delcev in mikrostrukturnih komponent. S simulacijo strjevanja in termično analizo so bile določene strjevalne značilnosti ter ohlajevalne krivulje.

U. Klančnik (Valji d.o.o., Štore) in soavtorji, 2015: Karakterizacija modificirane indefinite litine za izdelavo delovne plasti valjev.



dr. Matej Drobne
(Valji d.o.o.)

Za doseganje zahtevanih končnih lastnosti plasti ulitih valjev je ključno doseganje ustrezne lite strukture. Za zagotovitev potreb po primerni granulaciji sestave drobnostnih modifikacij se dodajajo heterogene nukleacijske

kali, ki omogočajo razvoj zahtevanih struktur posameznih plasti. Predstavljen je bil učinek modificiranja taline s ferovanadijem in ferovolfomom. Modifikator je bil v curek taline med samim izpustom litine iz peči dodajan v obliki

software suite, which is already used in the planning development phase and during the optimization of casting technology as well as the anticipated final properties of the casting. The essential elements of improvement were located on the outer perimeter of the demanding casting using cooling moulds and directional solidification as well as by lowering of the casting temperature. Ejection was significantly reduced while production time and costs were reduced.

D. Mitrović (Livar d.d., Ivančna Gorica) and co-authors, 2014: Effect of Vibration and Cooling Rate Effect on Eutectoid Transformation in Spheroidal Graphite Cast Iron.

The research highlighted the impact of vibration and cooling rate on the eutectoid transformation of cast iron EN-GJS-500-7. The castings were cast at Livar using an automatic horizontal green sand line in a standard casting process. The eutectoid transformation was investigated. The methods of metallographic research with optical microscopy and various raster calorimetric methods were used, along with hardness measurements of different casting thicknesses and tensile strength measurements, as well as the morphology of graphite particles and microstructural components. Coagulation characteristics and cooling curves were determined in a solidification simulation and via thermal analysis.

U. Klančnik (Valji d.o.o., Štore) and co-authors, 2015: Characterization of a modified indefinite chill cast iron working layer in rolls.

In order to achieve the required final cast roll layer structure, it is crucial to provide for the suitable casting structure. To meet the need for appropriate granulation of the composition for fine-grained modifications, heterogeneous nucleation seeds are added, enabling the development of the required structures of individual layers. The effect of melt modification with ferrovanadium and ferrotungsten was presented. The modifier was added to the melt stream in the form of a fine-grained powder during the discharge of the cast iron from the furnace. Analyses of individual casting layers were carried out via optical microscopy and scanning electron microscopy equipped with an EDS analyzer. With proper alloying and inoculation, the achieved level of hardness was comparable to

drobnozrnatega prahu. Preiskave posameznih plasti ulitka so bile izvedene z optičnim mikroskopom ter z vrstičnim elektronskim mikroskopom, opremljenim z analizatorjem EDS. Ob pravilnem legiranju in modifikaciji je bila dosežena raven trdot, primerljiva z indefinitnimi litinami, ob hkratni ohranitvi deleža cementita v strukturi. Z analizo EDS je bila tudi dokazana prisotnost precipitativ na osnovi vanadija in volframa, ki v primerljivih kakovostih modifikacije niso bili dokazani.

B. ČUK (Siapro d.o.o., Most na Soči), 2016: Znižanje proizvodnih stroškov z regeneracijo bentonitnega peska.

V livarnah, ki uporabljajo bentonitne peske, se srečujejo s težavami prekomerne količine peska v obtoku in neprimerne granulacijske sestave peska, ki ima prevelik delež finih frakcij in inertnih snovi, iz česar izhajajo napake na ulitkih. Z raziskavami so prikazali, da lahko s primerno regeneracijo povratnega peska inertne snovi in fine frakcije vzdržujejo na ustrezni ravni in s tem zmanjšajo porabo peska tudi do 40 %. Ob tem se zmanjša tudi poraba bentonita in črnine. S takim pristopom se investicija v regeneracijo lahko povrne tudi že v dveh letih, kar pomeni močno zmanjšanje proizvodnih stroškov.

A. DROLČ (ETA Cerkno d.o.o.) in soavtorji, 2017: Posodobitev livnega sistema za litje tankostenskih ulitkov iz sive litine v pečene forme.

Ob izdelavi novega izdelka iz programa kaminskih delov se je livarna soočila z visokim deležem površinskih napak, ki jih ni bilo mogoče odpraviti. Prve korekcije tehnologije litja so še vedno izkazovale napake na vidnih površinah. Napak z značilno globoko črto ni bilo mogoče odpraviti. Domneva je bila, da so za napake krive previsoke hitrosti litja, neenakomerni pretoki litine v dovodnih kanalih in posledično visoke temperature na določenih izpostavljenih mestih. Zaradi tega je bilo narejenih več simulacij litja in na ta način s kombinacijo pridobljenih rezultatov izvedene simulacije nastanka teh napak. Na osnovi analiz teh simulacij je bil posodobljen ulivni sistem, ki je nato preprečil nastanek površinskih napak na vidnih mestih izdelanega ulitka.

A. TEKAČIČ (Kovis-Livarna d.o.o., Štore) in soavtorji, 2018: Pojav lamelnega grafita pod eksotermnimi napajalniki v ulitkih

indefinite alloys while the proportion of cementite in the structure was maintained. The presence of vanadium and tungsten-based precipitates which have not been identified in comparable modification qualities, was also demonstrated via EDS analysis.

B. ČUK (Siapro d.o.o., Most na Soči), 2016: Reduction of production costs via bentonite clay powder reclamation.

In foundries that use bentonite sands, they face problems with excess circulated sand and inadequate granular sand composition with an excessive proportion of fine fractions and inert substances, resulting in defects in castings. Research has shown that, with proper regeneration of recirculated sand, inert substances and fine fractions can be maintained at the appropriate levels while at the same time reducing sand consumption by up to 40%. At the same time, the consumption of bentonite and blacking is also reduced. Thanks to the approach, the investment into reclamation can be returned in as little as two years, resulting in a sharp reduction in production costs.

A. DROLČ (ETA Cerkno d.o.o.) and co-authors, 2017: Modernization of the casting system for the casting of thin-walled castings from gray cast iron into sand molds.

When producing a new product from the fireplace parts program, the foundry was faced with a high proportion of surface defects that could not be eliminated. The first adjustments of the casting technology still resulted in defects on visible surfaces. Defects with a characteristic deep line could not be remedied. It was assumed that the errors were the result of excessive casting speeds, uneven flow of cast iron in the gate and consequently high temperatures in certain exposed locations. As a result, several casting simulations were carried out. This way, based on a combination of the obtained results, simulations of the generation of such defects were performed. Based on the analysis of these simulations, the casting system was modernized, preventing the occurrence of surface defects in visible places of the manufactured casting.

A. TEKAČIČ (Kovis-Livarna d.o.o., Štore) and co-authors, 2018: Flake graphite formation under exothermic riser sleeves in ductile iron casting – causes and remedies

iz sive litine s kroglastim grafitom-vzroki in sredstva.

Mini napajalniki na osnovi eksotermnega procesa so na področju livarstva stroškovno izjemno pomembni, saj pri železovih zlitinah omogočajo povečanje izplenov in zmanjšanje poroznosti. Ob pozitivnih učinkih pa lahko ob tem nastajajo določene livarske napake. Predvsem je mogoče pri tem opaziti degeneracijo kroglastega grafita v lamelni grafit. Te napake se pojavljajo predvsem na predelih ulitkov, kjer so pod mini napajalniki večje debelostenske ravne površine. Namen raziskav je bil raziskati vzroke pojava degenerirane mikrostrukture ter zagotoviti ukrepe za preprečevanje teh napak. Izvršene so bile analize z optično mikroskopijo. Ugotovljeno je bilo, da prihaja pod mini napajalniki do zmanjšanja preostalega magnezija na površini ulitka. Raziskan je bil vpliv tehnoloških parametrov na nastajanje teh napak. Na osnovi teh analiz so bili določeni najustreznejši ukrepi za zmanjšanje navedenih napak oziroma za njihovo popolno preprečevanje.

M. Žbontar (EXOTERM-IT d.o.o.) in soavtorji, 2018: Uporaba tehnologije sol-gel v livarskih premazih.

Premazi na peščeni formi ali peščenem jedru omogočajo visoko temperaturno bariero med talino in formo in s tem preprečujejo medsebojne fizikalno-kemijske reakcije, kar posredno vpliva na izboljšanje površine ulitkov. Optimizacijo sestave premaza je mogoče doseči z dodajanjem komponente sol-gel, kar bistveno izboljša površino ulitka in reološke lastnosti premaza. Raziskan je bil učinek uporabe komponente sol-gel kot dodatka k premazu na vodni osnovi in cirkonskim polnilom. Preiskan je bil vpliv treh kemijsko različnih komponent sol-gel in različnih masnih razmerij med osnovnim premazom in komponento sol-gel na kakovost površine ulitkov. Uporabljena je bila metoda diferenčne vrstične kalorimetrije. Rezultati raziskav so pokazali, da uporaba komponente sol-gel v premazu izboljša površinsko kakovost ulitkov.

J. KOVAČIČ (Livar d. d., Ivančna Gorica) in soavtorji, 2019: Izdelava in karakterizacija legirane sive litine s kroglastim grafitom, ki je odporna na toplotno utrujanje.

Namen raziskave je bil izdelava legirane sive litine, ki je odporna na termično utrujanje, in

Mini exothermic process-based risers are extremely important in the foundry sector since they enable an increased yield and the reduction of porosity in iron alloys. However, these positive effects can be accompanied also by certain foundry defects. Above all, the degeneration of spherical graphite into lamellar graphite can be observed. These defects occur mainly in the areas of castings with large thick-walled flat surfaces under the mini risers. The objective of the research was to investigate the causes of the degenerated microstructure and to provide solutions for the prevention of such errors. Completed were optical microscopy analyses. It was determined that there is a reduction of residual magnesium on the surface of the casting under the mini risers. The impact of technological parameters on the occurrence of these errors was investigated. Based on these analyses, the most appropriate measures were determined to reduce the indicated errors or to prevent them entirely.

M. Žbontar (EXOTERM-IT d.o.o.) and co-authors, 2018: Application of Sol-Gel Technology in Foundry Coatings.

A mould or core coating creates a high thermal integrity barrier between the melt and the mould, preventing physico-chemical reactions, indirectly impacting the improvement of the surface of the castings. The optimization of the coating composition can be achieved by adding a sol-gel component that significantly improves the casting surface and rheological properties of the coating. Investigated was the effect of using a sol-gel component as an additive to a water-based coating and zirconium filler. The influence of three sol-gel components with different chemical compositions and weight ratios between the base coat and sol-gel component on the surface quality of the castings was investigated. The differential scanning calorimetry method was used. The results of the research indicate that the use of the sol-gel component in the coating improves the surface quality of the castings.

J. KOVAČIČ (Livar d.d. Ivančna Gorica) and co-authors, 2019: Production and characterization of gray cast iron with spherical graphite which is resistant to thermal fatigue

s tem uporabna tako pri sobnih kot pri povišanih temperaturah. V ta namen so uporabili feritno sivo litino, ki jo predpisuje standard ISO EN-GJS 600-10, ki so ji dodajali molibden v obliki predzlitine FeMo65. Med procesom strjevanja je bila izvedena enostavna termična analiza. Iz ulitih vzorcev pa so izdelali tudi vzorce, primerne za natezni preizkus. Na fizikalnem simulatorju metalurških stanj Gleeble 1500 D so pri temperaturi 600 °C z obremenitvijo 200, 500, 1.000, 2.000 in 4.000 ciklov testirali sedem vzorcev. Z emisijskim spektrometrom je bila analizirana kemijska sestava vzorcev in na stroju Instron 5985 izvedeni natezni preizkusi. Pregledana in analizirana je bila mikrostruktura prelomnih površin, s pomočjo svetlobnega in elektronskega mikroskopa so bili analizirani nastanek in napredovanje razpok kot tudi njihova usmerjenost ter gostota. Rezultati analiz in raziskav so omogočili optimalno karakterizacijo odpornosti na toplotno utrujanje.



Janez Pristavec
(Exoterm-IT d.o.o.)

**J. Pristavec
(EXOTERM IT d. o. o.,
Kranj) in soavtorji,
2020: Analiza in
optimizacija procesa
izdelave peščenih
jeder s pomočjo
numerične simulacije
in statističnih orodij.**

Izdelava radijev
na robovih dveh izvrtin
peščenega jedra
zahteva postopek v
dveh korakih. V prvem

se izdela segment jedra z odprtinami z radiji, v drugem pa se ta segment vstavi v jedrovnik s končno obliko jedra, tako se izdela celotno jedro po postopku coldbox. Ob tem je nastopila težava, da je v področju vnaprej izdelanega segmenta kritično mesto ostalo nezapolnjeno. Za odpravo težav je bila najprej izvedena analiza obstoječe tehnologije s programom MAGMASOFT in modulom MAGMAc+m. Ustrezni parametri so bili pridobljeni z metodo DOE in analizo rezultatov. Gonilna sila pri polnjenju jedrovnikov s peščeno mešanico je tlak zraka. Ugotovljen je bil nizek tlak v kritičnem področju, ki se ne zapolni s peskom. Z virtualno metodo so ugotavljali zapolnjenost kritičnega področja. S pomočjo programskega paketa vgrajenih statističnih orodij je bila izbrana

The purpose of the research was to produce an alloyed grey cast iron, which is resistant to thermal fatigue and is suitable for use both at room and at elevated temperatures. In the investigation, we used ferrite cast iron as defined by ISO EN-GJS 600-10, to which molybdenum was added in the form of FeMo65 master alloy. A simple thermal analysis was completed during the solidification process. From the cast samples, suitable samples for tensile testing were also produced. Seven samples were tested at a temperature of 600 °C at 200, 500, 1,000, 2,000 and 4,000 cycles on Gleeble 1500 D physical simulator of metallurgical conditions. The chemical composition of the samples was analyzed using an emission spectrometer and tensile testing was carried out using Instron 5985. The microstructure of fractured surfaces was examined and analyzed and the formation and progression of cracks, their orientation and density were analyzed via optical and electron microscopy. The results of analyses and research has made possible the optimal characterization of resistance to thermal fatigue.

**J. Pristavec (EXOTERM IT d.o.o.,
Kranj) and co-authors, 2020: Analysis and
optimization of the sand core manufacturing
process using numerical simulation and
statistical tools**

The generation of radii at the edges of two holes in a sand core requires a two-step process. In the first step, a segment of the core is created with openings with the radii and in the second, the same segment is inserted into the corebox with the final shape of the core and so entire core is produced via the coldbox process. Simultaneously, a problem arose where in the area of the prefabricated segment, the critical location remained unfilled. To solve the issue, an analysis of the existing technology was first carried out via MAGMASOFT software and the MAGMAc + m module. The relevant parameters were obtained via the DOE method and result analysis. The driving force when it comes to the filling of coldboxes with a sand mixture is air pressure. Low pressure was found in the critical area that was not filled with sand. The filling of the critical area was determined via a virtual method. The optimal combination of vents was determined with the use of a suite of built-

najboljša kombinacija zračnikov. To je omogočilo proizvodnja kakovostno ustreznih jeder.

Na področju livarstva barvnih kovin in z njimi povezanih tehnologij predstavljamo naslednje prve avtorje, podjetja, iz katerih prihajajo, in leto predstavitve:



mag. Andrej Megušar
(LTH Castings d.o.o.)

A. Megušar (LTH Ulitki d.o.o., Škofja Loka/Ljubljana), 2011: Optimizacija tlačnega litja z visoko zahtevo po estetskem videzu.

Uplinjači iz zlitin Al se običajno vgrajujejo na vidno mesto v prostoru motorja in s tem so povezane tudi estetske zahteve. Ulitki morajo imeti visoko kakovost površine ulitka, biti morajo brez

hladnih zvarov, nezalitosti ali toplotnih razpok. Optimizacija procesa tlačnega litja je v tem primeru potekala na naslednjih področjih:

- izdelana je simulacija toka taline od tališne peči do tlačnega orodja s ciljem zagotavljanja optimalne temperature taline ob vstopu v tlačno orodje in s tem odprave hladnih zvarov;
- optimizacija polnjenja livne votline in izboljšano prezračevanje tlačnega orodja s ciljem zmanjšanja nezalitosti;
- simulacija napetosti v tlačnem orodju med procesom litja za zmanjšanje toplotnih razpok in optimiranje temperirnega sistema v tlačnem orodju.

A. Megušar (LTH Ulitki d.o.o., Ljubljana) in soavtorji, 2012: Uporaba sistema »jet cooling« za lokalno usmerjeno strjevanje ulitkov iz Al-zlitine.

Tlačni ulitki iz zlitin Al imajo pogosto funkcijo nosilnega ali tesnilnega elementa, kar zahteva visoko kakovost strukture materiala. Prav tako ni vedno mogoče zagotoviti oblike, ki bi bila najboljša za proces tlačnega litja. Posledica je nastajanje poroznosti, ki je s klasičnim litjem ni mogoče vedno odpraviti. Zato lahko lokalno uporabimo usmerjeno strjevanje, ki v določenih

in statistical tools. This way, the production of quality cores was made possible.

In the field of non-ferrous metal foundry and related technologies, we present the following first authors, the companies they are employed with and the year of the presentation:

A. Megušar (LTH Ulitki d.o.o., Škofja Loka / Ljubljana), 2011: Optimization of the pressure die casting process of a carburettor with a great demand to look perfect

Al alloy carburetors are usually installed in a visible place in the engine compartment so they are subject to aesthetic requirements. Castings must have a high quality of the surface, with no traces of cold welds, non-filling or thermal cracks. In this case, the optimization of the die casting process was focused on the following areas:

- Simulation of the melt flow from the melting furnace to the die cast tool is made with the objective of providing for the optimal melt temperatures at the entrance to the die cast tool and thus the elimination of cold welds;
- Optimization of casting cavity filling and improved ventilation of the die cast tool with the objective of reducing non-filling;
- Simulation of stress in a die cast tool during the casting process to reduce thermal cracks and optimization of the tempering system in the die cast tool.

A. Megušar (LTH Ulitki d.o.o., Ljubljana) and co-authors, 2012: Application of Jet-Cooling System for Local Directional Solidification of Aluminium-Alloy Castings

Al alloy die castings often function as load-bearing or sealing elements, thus requiring a high quality material structure. Furthermore, it is also not always possible to ensure that the shape is best suited for the die casting process. The result is the formation of porosity, which cannot always be eliminated via conventional casting. Because of this, directional solidification can be used locally, improving the quality in certain parts of the casting. Local directional solidification was performed in the following steps:

1. The parameters of the die casting process with implemented forced cooling of cores were analyzed. A solidification simulation using these cores was generated.
2. Testing of the die casting tool with the

delih ulitka izboljša kakovost. Lokalno usmerjeno strjevanje je bilo izpeljano v naslednjih korakih:

1. Analizirali so se parametri procesa tlačnega litja z implementiranimi prisilno hlajenimi jedri. Izdelana je bila simulacija strjevanja pri uporabi teh jeder. Izvedeni so bili testi tlačnega orodja z implementiranim sistemom prisilnega hlajenja jeder.
2. Izvedeni so bili primerjalni testi in ovrednotene razlike s klasičnim tlačnim litjem. Implementacija prisilno hlajenih jeder je ob zmanjšanju poroznosti omogočila drobnejšo strukturo ter izboljšanje kakovosti na področju okoli jeder.

U. Eržen (LTH Castings d. o. o., Škofja Loka) in soavtor, 2014: Simulacija tlačnega litja s pomočjo programskega paketa Magma in vpliv na življenjsko dobo orodja.

V procesu tlačnega litja zlitin Al in Mg se za premazovanja tlačnih orodij v 90 % primerov uporabljajo premazi na vodni osnovi in le v 10 odstotkih t. i. mikro-mazanje. Slabost premazov na vodni osnovi je, da prihaja na gravuri orodij do temperaturnih šokov, kar ob nastanku napetosti pospeši nastanek razpok. Pri uporabi tehnologije mikro mazanja na površini gravurnih delov ne prihaja do temperaturnih šokov, vendar je odvajanje toplote, ki se akumulira v gravurnih delih orodja, bistveno slabše. Akumulirano toploto je treba iz orodja odvesti s pomočjo ustrezne izvedbe temperirnih kanalov. V ta namen uporabljajo v podjetju LTH Castings pri konstruiranju programskega paketa MaGma 5.2. Po kalibraciji programskega paketa lahko izdelajo simulacijo celotnega procesa litja. Pri tovrstni simulaciji je treba upoštevati kompletno geometrijo orodja in temperirnih kanalov kot tudi večje število ciklov litja. Na osnovi rezultatov simulacije lahko optimirajo geometrijo temperirnih kanalov in parametre procesa, s katerim lahko dosežejo toplotno uravnoteženost orodja. S tem lahko dosežejo daljšo življenjsko dobo orodja.

D. Sojer (Magneti Ljubljana d. d.) in soavtorji, 2015: Centrifugalna atomizacija kosmičev Nd-Fe-B za uporabo pri izdelavi trajnih magnetov.

Trajni magneti Nd-Fe-B so v široki uporabi pri aplikacijah, kjer se zahteva visoko magnetni proizvod z namenom zmanjšanja teže izdelka. Ti magneti se uporabljajo predvsem v

implemented core forced cooling system was carried out. Comparative testing was completed and the differences vs. classic die casting evaluated. The implementation of forced-cooled cores, while reducing porosity, made possible a finer structure and improved quality in the area surrounding the cores.

U. Eržen (LTH Castings d.o.o., Škofja Loka) and co-author, 2014: Simulation of die casting using the Magma software suite and the impact on tool life.

For the process of die casting of Al and Mg alloys, 90% of water-based coatings and only 10% of so-called micro-lubrications are used for the coating of die casting tools. The disadvantage of water-based coatings is that the engraving of the tools is impacted by thermal shock, accelerating the formation of cracks on the engraving parts of the tool following the stress build-up. When using micro-lubrication technology, there are no temperature shocks impacting the surface of the engraving parts, however, the heat dissipation that accumulates in the engraving parts of the tool is substantially reduced. The accumulated heat must be removed from the tool by means of a suitable design of the tempering channels. For this purpose, LTH Castings uses the MaGma 5.2 software suite in the construction process. After the calibration of the software suite, the company can generate a simulation of the complete casting process. In the context of the simulation, it is necessary to take into account the complete geometry of the tool and the tempering channels as well as the larger number of casting cycles. Based on the simulation results, the geometry of the tempering channels and the process parameters used to achieve the thermal balance of the tool can be optimized. This makes it possible to extend the life-span of the die casting tool.

D. Sojer (Magneti Ljubljana d.d.) and co-authors, 2015: Centrifugal atomization of Nd-Fe-B flakes used for the production of permanent magnets

Permanent Nd-Fe-B magnets are widely used in applications where a highly magnetic product is required in order to reduce the weight of the product. These magnets are used primarily in the automotive and wind turbine industries. In this case, conventional casting techniques

avtomobilski industriji in v industriji vetrnih turbin. Konvencionalne livne tehnike v tem primeru povzročajo nastanek Fe in velika področja obogatenih redkih zemelj. Litje trakov, melt spinning in centrifugalna atomizacija pa dajejo homogeno in drobno strukturo. Predstavljena je bila uporaba hitrega strjevanja s centrifugalno atomizacijo za pripravo kosmičev Nd-Fe-B. Raziskani so bili vpliv sestave zlitine in različnih procesnih parametrov centrifugalne atomizacije na mikrostrukturo hitro strjenih zlitin Nd-Fe-B. Uporabljene so bile klasične metalografske metode ter optična in rasterska elektronska mikroskopija. Podani so bili vplivi procesnih metod na mikrostrukturo kosmičev v litem stanju in magnetnih lastnosti tako pripravljenih magnetov.

M. Potočnik (LTH Castings d.o.o., Ljubljana) in soavtorji, 2018: Analiza vpliva parametrov tlačnega litja na ravnost ohišja elektronike.

V avtomobilski industriji se za ohišje električnega napajalnega sistema zahteva uporaba zlitin Al. Zelo tanke stene in sorazmerno velika površina ulitka predstavljajo zahteven tehniški izziv. Funkcionalnost tozadavnega ulitka zahteva ob samih karakteristikah še zelo visoko stopnjo ravnosti ulitka. Le ulitki, ki v celoti izpolnjujejo zahtevane pogoje, zagotavljajo ustrezno delovanje ter življenjsko dobo komponente. Predstavljena je bila analiza vpliva parametrov procesa tlačnega litja na zahteve izdelane komponente: časa strjevanja, temperature tlačnega orodja, časa hlajenja ulitka v vodi ter oblike dolivnega sistema. V podjetju LTH je bil s testiranjem v serijskih pogojih preverjen vpliv parametrov litja v serijskih pogojih. Rezultate meritev na 3D-koordinatnem merilnem stroju se je analiziralo po tehnologiji 6 sigma in izvedeno je bilo tudi 3D-skeniranje ulitka. Vpliv dolivnega sistema pa je bil analiziran s pomočjo računalniške simulacije.

J. Trček (Hidria d.o.o., Ljubljana, PE Alutec) in soavtor, 2019: Optimizacija 1. faze visokotlačnega litja

Za ulitke za avtomobilsko industrijo veljajo zelo stroge zahteve glede poroznosti in tesnosti ulitkov. Pri visokotlačnem litju zahtevnih ulitkov Al na kakovost ulitka vpliva že vsaka najmanjša sprememba. Postopek poteka v treh fazah: 1. faza – polnjenje komore in dovoda ob počasnem

result in the formation of Fe and large areas of enriched rare earths. Strip casting, melt spinning, and centrifugal atomization, however, result in a homogeneous and fine structure. Outlined is the use of fast solidification via centrifugal atomization for the preparation of Nd-Fe-B flakes. The influence of the alloy composition and different process parameters of centrifugal atomization on the microstructure of rapidly solidified Nd-Fe-B alloys was examined. Classical metallographic methods and optical and scanning electron microscopy methods were used. The impacts of process methods on the flake microstructure in the as-cast state and the magnetic properties of magnets prepared in such a way were presented.

M. Potočnik (LTH Castings d.o.o., Ljubljana) and co-authors, 2018: Analysis of the influence of die casting parameters on electronics housing flatness.

In the automotive industry, power supply system housings are made from Al alloys. The very thin walls and a relatively large surface area of the casting represent a demanding technical challenge. The functionality of the casting in question requires, in addition to other characteristics, an extremely high degree of flatness of the casting. Only castings that fully meet the required conditions guarantee the proper functioning and component life. Presented was an analysis of the impact of die casting process parameters: solidification time, die casting tool temperature, cooling time of casting in water and the design of the filling system on the requirements of the manufactured component. At LTH, the impact of serial casting parameters was examined via serial testing. The results of measurements on a 3D coordinate measuring machine were analyzed using Six Sigma methodology while 3D-scanning of the casting was also performed. The influence of the filling system, however, was analyzed with the help of a computer simulations.

J. Trček (Hidria d.o.o., Ljubljana, PE Alutec) and co-author, 2019: Optimization of the 1st HPDC phase

In castings for the automotive industry, the requirements for porosity and tightness of castings are stringent. In the high-pressure die casting of demanding Al castings, even the slightest of changes will impact the quality of the



Jaka Trček (Hidria d.o.o.)

premiku bata; 2. faza – polnjenje gravure in pretokov ob hitrem pomiku bata; 3. faza – visok končni tlak bata kot nadomestilo krčenja v gravuri. Pomembna kakovostna zahteva je preprečevanje poroznosti. Zračno poroznost lahko povzročimo z napačno nastavitvijo že v prvi fazi. S pomočjo simulacijskega programa Magmasoft so simulirali produkcijsko krivuljo. Izvedena je bila virtualna optimizacija prve faze in preizkušena na dejanskem procesu s testiranjem polnjenja ter izbrana rešitev, ki je bistveno zmanjšala poroznost ulitkov. Najboljši rezultati so bili doseženi s hitrostjo bata v 1. fazi 0,29 m/s.

M. Purg (Talum d. d., Kidričevo), 2019: Učinkovit poslovni model za inovativni razvoj in trajnostno rast na področju proizvodnje aluminijevih ulitkov v podjetju Talum d.d.

M. Purg
(Talum d. d., Kidričevo)

Podjetje Talum d.d. je razvilo svoj model povečanja proizvodnje izdelkov z višjo dodano vrednostjo, kamor prištevajo tudi proizvodnjo ulitkov. Razvoj proizvodnje ulitkov Al, ki je v zadnjih letih zelo intenziven, je zasnovan na treh različnih postopkih: visokotlačnem, nizkotlačnem in nagibno-

gravitacijskem kokilnem litju. Pospešen razvoj proizvodnje ulitkov je vezan na osnoven program raziskav in razvoja celotnega podjetja, ki sloni na lastnem modelu povečanja proizvodnje izdelkov z višjo dodano vrednostjo ob vključevanju dosedanje tradicije proizvodnje zlitin Al, avtomatizacije, izdelave orodij in proizvodne opreme ter celovitega vključevanja informacijske podpore. Prednost je tudi v prenosu obstoječega znanja v dodatne dejavnosti, ki zagotavljajo višjo vrednost. Talum ima specifična znanja in tehniške rešitve, ki omogočajo hitrejši razvoj

casting. The process takes place in three stages: Phase 1 filling of the chamber and inlet with slow piston movement. Phase 2 filling of engraving and flows with rapid piston movement. Stage 3 final high piston pressure to compensate for the shrinkage in the engraving. The prevention of porosity is an important aspect of quality requirement. Air porosity can be caused by the incorrect adjustment already during the first phase. The production curve was simulated using the MagmaSoft simulation software. The virtual optimization of the first phase was performed and tested on the concrete process by test filling while a solution was selected that significantly reduces the porosity of the castings. The best results were achieved with a piston speed of 0.29 m/s in phase 1.

M. Purg (Talum d.d., Kidričevo), 2019: An efficient business model for the innovative development and sustainable growth of the production of aluminum castings in Talum d.d.

Talum d.d. has developed its own model for increasing the production of products with higher added value, which also encompasses the production of castings. The development of Al casting production, which has become highly intensive in recent years, is based on three processes: high pressure die casting, low pressure die casting and tilting gravity die casting. The accelerated development of casting production is connected to the fundamental R&D programme of the total company, which is based on its own model of increasing the production of higher value-added products, incorporating the current tradition of production of Al alloys, automation, tooling and production equipment as well as the comprehensive integration of information support. The advantage is also in the transfer of existing knowledge into additional activities that provide higher value. Talum possesses specific knowledge and technical solutions that facilitate the development of new activities. Talum has also established an innovative and efficient development environment that, thanks to collaboration of other companies as well as educational and research institutions, provides for efficient development.

A. Gusel (Mariborska livarna Maribor d.d.) and co-author, 2019: Prediction and preventive correction of distortions of

novih dejavnosti. Talam je vzpostavil tudi inovativno in učinkovito razvojno okolje, ki ob sodelovanju drugih podjetij in izobraževalno-raziskovalnih institucij omogoča učinkovit razvoj.

A. Gusel (Mariborska livarna Maribor d. d.) in soavtor, 2019: Določanje in preventivna korekcija deformacij tlačno ulitih aluminijevskih izdelkov za avtomobilsko industrijo.

Ena glavnih težav pri litju geometrijsko kompleksnih izdelkov iz aluminijevskih zlitin so deformacije ulitkov. To še posebej velja pri zelo ozkih tolerancah izmer ulitkov, ki naknadno niso mehansko obdelani. Prav tako lahko težave povzročajo zaostale napetosti v ulitkih. Zato težavo rešujejo s predvidevanjem deformacij. V ta namen se upoštevajo praktične in računske deformacije ulitkov. Praktično je to mogoče z dejanskim litjem v prototipno orodje, teoretično pa z numeričnimi simulacijami s paketom Magmasoft. Primerjava med simulirano deformacijo in dejansko deformiranim delom se izvaja s postopkom 3D-skeniranja ulitka. V naslednjem koraku se izvede preddeformirani 3D-model, s katerim se želi izničiti deformacije. Končni cilj je uporaba korigiranega 3D-modela za izdelavo serijskega orodja, ki bi v serijski proizvodnji zagotavljalo oblikovno skoraj popolne dele.

K. Turk, (LTH Castings d. o. o., Ljubljana), 2020: Lasersko procesiranje visokotlačnih aluminijevskih ulitkov z namenom povišanja adhezivnosti površine.

Ohišja in pokrovi elektronskih komponent, proizvedeni s postopkom visokotlačnega litja, imajo pogosto visoke zahteve za čistost in adhezivnost površine tlačnega ulitka. Pri procesu tlačnega litja se na površino izdelka vnaša nečistoče, ki so posledica narave samega postopka in okolja livarne. Kljub kasnejšemu vibracijskemu loščenju izdelkov in pranju ulitkov se nečistoče s površine ne odstranijo v zadostni meri, ki bi zagotavljala ustrezno adhezivnost površine. Obstaja več postopkov za izboljšanje adhezivnosti površine. V tej raziskavi pa je bila uporabljena rešitev z laserskim procesiranjem površine tlačnega ulitka. S hitro pulzirajočim laserjem visoke moči in ustreznim oblikovanjem žarka ter fokusne pege laserja lahko dosežemo odstranitev nečistoč s površine in zelo plitko pretalitev zgornjega sloja površine, kar izboljša tudi korozijsko odpornost površine. Kljub vnosu

high-pressure die-cast aluminium parts for automotive industry.

One of the main issues in the casting of geometrically-complex aluminum alloy castings are the deformation of castings. This is especially true in case of very dimension tolerances of castings that are not subsequently machined. Similarly, they can also result in issues due to residual stress in castings. As a result, the issue is being solved via deformation prediction. For this purpose, practical and computational casting deformations are considered. In a practical sense, this is possible with actual casting into a prototype tool, and in theory, with numerical simulations with the Magmasoft software suite. The comparison between the simulated deformation and the actual deformed part is performed via 3D scanning of the casting. In the next step, a pre-deformed 3D-model is implemented in order to eliminate the deformations. The ultimate objective is to use a corrected 3D-model that would enable the production of a serial tool that ensures the production of parts in serial production of near-perfect dimensions.

K. Turk, (LTH Castings d.o.o., Ljubljana), 2020: Laser processing of HPDC aluminium parts with the aim of increasing surface adhesion.

Enclosures and covers for electronic components manufactured via high-pressure die casting often have strict requirements regarding the purity and adhesiveness of the die cast surface. In the die casting process, impurities are introduced onto the surface of the product, which are the result of the nature of the process itself as well as the foundry environment. Despite subsequent vibration polishing of the products and the washing of the castings, impurities are not removed from the surface to a sufficient extent in order to achieve adequate surface adhesion. There are several procedures that aim to improve surface adhesion. However, in this study, a solution with laser processing of the die cast surface was used. With a quick pulsing high-power laser and the appropriate beam and focal spot design, the removal of impurities from the surface and very shallow melting of the upper layer of the surface can be achieved, improving also the corrosion resistance of the surface. Despite the high energy input into the surface as

velike energije v površino se zaradi hitrosti pulziranja in kratkega časa pulza površina ne segreje, zato ni vpliva na geometrijo izdelka. Ustreznost postopka se potrjuje s postopkom testiranja sklopa v slani komori, testi odpornosti na korozijo, pregledom mikrostrukture in testom lepljenja, kjer se opazuje, ali prihaja do kohezivnega ali adhezivnega loma silikona.

N. Marčič (Mariborska livarna Maribor d. d.) in soavtorji, 2020: Optimizacija hlajenja tlačno ulitega dela z uporabo numeričnega izračuna.

Numerični izračuni livarskih procesov nam omogočajo vpogled v posamezno sekvenco litja in pomagajo odkriti in razumeti vzroke za nastale napake. Z razumevanjem vzrokov napak se lahko procesi učinkovito optimizirajo in novo tehnologijo preizkusimo najprej virtualno z izračunom z optimiziranimi robnimi pogoji. Prikazan je primer uspešne uporabe numeričnih izračunov za optimizacijo tlačno ulitega elementa. V tem primeru je prihajalo do težav s pregrevanjem posameznih delov orodja in jeder. Na podlagi natančne analize z numeričnim izračunom so bile predlagane spremembe hladilnega sistema. K reševanju izvedbe hlajenja se je nato pristopilo z numeričnim izračunom. Za učinkovito odvajanje toplote je bilo treba povečati površino hladilnega sistema na kritičnih mestih. Najbolj inovativen način je bil uporabljen na jedrih. Hladilni kanali so bili ustrezno približani površini jedra in s tem so izboljšali odvajanje toplote. Na kompleksnejših delih orodja je bila uporabljena kombinacija klasičnega vrtanja in varjenja za optimalno razporeditev hladilnih kanalov. Vse rešitve so bile najprej z numeričnimi izračuni preizkušene virtualno in po doseženem želenem temperaturnem polju v orodju so bile izvedene dejanske spremembe orodja.

Slovenska znanost je kreator znanja in znanje je bistveno za razvoj. Slovensko livarstvo je bilo kot panoga dokaj stabilno, z rastjo in tudi spremembami skladno z zahtevami trga in možnostmi. IFC Portorož je zaradi sodelovanja industrijske panoge s tujim trgom izjemnega pomena, saj spremlja aktualne spremembe ne le v tehnologiji, temveč tudi v ustvarjanju poslovnih mrež, ki jih panoga za obstoj nujno potrebuje. Univerza je mesto, kjer nastaja znanje, ki se prenaša na mlajše generacije. Vključevanje

a result of the pulsation speed and short pulse time, the surface does not heat up and does not affect the product geometry. The suitability of the process is confirmed via testing of the assembly in the salt chamber, corrosion resistance testing, microstructure examination and adhesion testing, where cohesive or adhesive silicone fracture is observed or occurs.



Mag. Andrej Mikložič,
zvesti udeleženec IFC iz
Mariborske livarne Maribor

N. Marčič (Mariborska livarna Maribor d.d.) and co-authors, 2020: Cooling optimization HPDC casted part using numerical calculation.

Numerical calculations of foundry processes provide insight into an individual casting sequence and help discover as well as understand the causes of the resulting defects. By understanding the causes of errors, processes can be efficiently optimized while the new technology is initially tested in a virtual setting via the calculation with optimized boundary conditions. An example of the successful use of numerical calculations for the optimization of a die cast element is presented. In this example, problems with the overheating of individual parts of the tool and cores arose. Based on a detailed analysis by means of numerical calculations, changes to the cooling system were proposed. The cooling issue was then subjected to a numerical calculation. For efficient heat dissipation, it was necessary to increase the area of the cooling system in critical locations. The most innovative method was used on the cores. The cooling channels were suitable close to the surface of the core, which increased heat dissipation. On more complex tool parts, a combination of classic drilling and welding was used for the optimal arrangement of cooling channels. Every solution was first tested virtually via numerical calculations while after the desired temperature field in the tool was reached, actual tool changes were implemented.

Slovenian science is the originator of knowledge and knowledge is essential for



Dr. Sebastijan Kastelic,
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študentov v projekte, ki jih vodi univerza, je osnova za hitrejše vključevanje v gospodarstvo. Vsakoletni livarski kongres v Portorožu ima tradicijo in sloves ter je ena prioritet v sodelovanju z lastnim gospodarstvom in mednarodnim prostorom. To danost dosedanjih generacij je treba spoštovati in s tem izkoristiti vse povezave,

ki so možne tudi prek IFC. 60 let IFC je vrednota, ki jo ima le malokatera industrijska panoga. Vsi, ki sodelujemo, bi morali to ceniti in se vključevati v čim uspešnejše in konkurenčne projekte. Če s tem povežemo še naš Livarski vestnik kot strokovno glasilo z 67-letno tradicijo, potem imamo ob dobrih izobraževalnih in raziskovalnih inštitucijah nekaj, kar daje panogi ugled in možnosti konkurenčnosti na vse zahtevnejšem globalnem trgu.

development. The Slovenian foundry industry has been quite stable, with growth and changes parallel to market requirements and opportunities. As a result of the collaboration of the industry with the foreign market, IFC Portorož is extremely important as it keeps abreast of current changes not only in technology, but also in the creation of business networks that the industry urgently needs to survive. The university is a place where knowledge originates and is passed on to younger generations. Involving students in university-led projects is the foundation that facilitates integration into the economy. The traditional annual foundry conference in Portorož is highly reputable and is considered one of the priorities in the context of collaboration both in the domestic market as well as internationally. This characteristic of previous generations must be respected and the connections that can also be made through the IFC taken advantage of. 60 years of the IFC is an achievement few industries are privy to. Every participant should appreciate this and strive to collaborate in the most successful and competitive projects accessible. If we wrap up by tying everything to our Livarski vestnik journal with 67 years of tradition, we get something, alongside good educational and research institutions, that gives the industry the reputation and opportunity for competitiveness in an increasingly demanding global market.

Vodja znanstvenega in programskega
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Zasl. prof. dr. Alojz Križman

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