AMI Light Metals Conference 2014 – Aluminum, Magnesium, and Titanium

By Neale R. Neelameggham, IND LLC, and Lionel Jean Michel and Dr. Hein Möller, CSIR

The Advanced Metals Initiative (AMI) Light Metals Conference 2014, held in October in South Africa, was hosted by the Council for Scientific and Industrial Research (CSIR). The event brought together researchers, government, and industry players for a *Bushveld Lekgotla** that sought to share, debate, and deliberate on the latest trends, research, and innovative solutions in the field of light metals. The conference was packaged to provide a forum for students, researchers, and industry players to discuss the progress over recent years in the development and application of technologies for the industrial light metal sector. Some 120 enthusiastic delegates attended the event, held at KwaMaritane near Rustenburg, South Africa.

The Light Metals Conference aimed to increase the value addition of local advanced metals in a sustainable manner through industry relevant research and development, technology transfer, and ultimately commercialization. Hein Möller, the symposium chair, noted that the conference was organized for interaction among industry, research groups at the CSIR, other organizations, and universities in the field of light metals—aluminum, magnesium, and titanium. The CSIR has been carrying out extensive work in the field of semi-solid casting of light metals for over 15 years, while providing turnkey solutions to the light metal industries on patented semi-solid metal forming and, in particular, rheo-high pressure die casting (R-HPDC) during 2003-2008.[1,2] R-HPDC technology—a rheo process, in which liquid metal is cooled into the liquid and solid two-phase region before shaping—has been shown to be beneficial in increasing the strength of die cast automotive magnesium alloys.[3] During the last decade, the CSIR has initiated and piloted the development of a continuous process for making titanium powder under the leadership of Dr. Dawie van Vuuren.[4]

Student Seminar

Prior to the main conference, a student seminar covering the full scope of the AMI took place, providing students the opportunity to share their work and enhance their presentation skills. Students presented papers on the four focus areas of the AMI: light metals (aluminum, titanium, and magnesium), precious metals, nuclear materials, and ferrous and base metals. A total of 21 papers from the 34 student presentations were offered on aluminum and titanium alloys,[5] as well as one paper on magnesium alloy composite ZE10 with silicon carbide.

Carlien Taute, from the University of Pretoria in collaboration with CSIR, presented on age hardening of R-HPDC aluminum alloy 6066. The wrought alloy was processed using semi-solid processing developed to make near net shape components, while avoiding hot tearing by rheo casting with heat treatment.

Chris Gilbert, University of Pretoria, presented work on laser-beam welding of semi-solid rheo cast aluminum alloy 2139 compared with friction stir welding (FSW). This aircraft aluminum alloy developed by Fleming for NASA consisted of copper, magnesium, and silver and is considered to be unweldable by conventional techniques. The newer techniques also indicate the need to control several of the welding parameters, including post-weld treatments to achieve the desired quality of welding.

Glenda Motsi, Tshwane University of Technology, Pretoria, discussed the tensile deformation mechanism of aluminum 5083 alloy with 4.5% magnesium, 0.7% Mn, 0.2% Si, and 0.3% Fe. SEM showed the micro cracking of intermetallics during tensile deformation. Agripa Hamweendo, of the University of Witwatersrand, Johannesburg, presented cold spray technology for light metals (aluminum, magnesium, and titanium) and porous structures, indicating the usefulness of this approach in the maintenance of repairable helicopter and aircraft light metal components, while using aluminum and other powders, such as WC, Ni, and alumina.

R. Pothier, NMM University, discussed the closed-loop temperature control of material plasticization during FSW of light metals.

Dryer Bernard, Nelson Mandela Metropolitan University, Port Elizabeth, outlined the findings on the influence of plate gap on the fatigue properties of FSW of aluminum 5182 with gaps as high as 20% of plate thickness. It was noted that in the FSW samples with root flaws, the flaw had to extend the entire width of the sample to reduce the weld life compared to flaws seen in MIG welded samples. The MIG welded joints attained 1.7×10^4 cycles at 138 MPa compared to 3.1×10^5 cycles at 138 MPa for friction stirred welds with a 1 mm gap between 20 mm thick plates.

One of the titanium focused papers, given by Jabu Skosana, discussed the wall heat transfer in a molten salt bubble column, which column is part of the CSIR technology being developed for making titanium powder. Besides seven presentations on the evaluation of casting molds and the physical properties of titanium alloy Ti-6Al-4V, there were three discussions of not-so-light titanium-platinum alloys, which have shape-memory characteristics, revealing South Africa's status as being number one in world platinum resources. These alloys contained high amounts of platinum up to 50 atomic percent, with the rest being titanium or titanium and cobalt.

Main Presentations – Industry and Research

The industry and research interaction segment of the conference was on the second and third day, which started with an introductory speech by Delon Mudaly, acting unit director at the CSIR. This was followed by the plenary talk on South Africa's aluminum foundry industry and its role in the world's automotive castings by Mark Krieg, executive director, Aluminum Federation of South Africa. He noted that aluminum production in South Africa during 2013 was close to 1 million tons using 66,000 tons of alloying additives (Figure 1). South Africa's total aluminum exports were near 590,000 tons. Imported additives are largely raw materials used to produce semi-fabricated products, i.e., 22,000+ tons of redraw rod for cable manufacture, a significant portion of extrusion billet, and some imported master alloys. Aluminum use was split as follows: architectural and construction – 22.5%, electrical – 21.6%, packaging – 15.9%, consumer durables – 3.9%, mining – 3.7%, transportation – 4.9%, automotive – 14.5%, military – 0.5%, chemical – 3%, general use – 4.0%, and deoxidation agent – 5.7%. Krieg said that South Africa has both Tier 1 and Tier 2 automotive supply foundries, along with some Tier 3 operations. Fig-

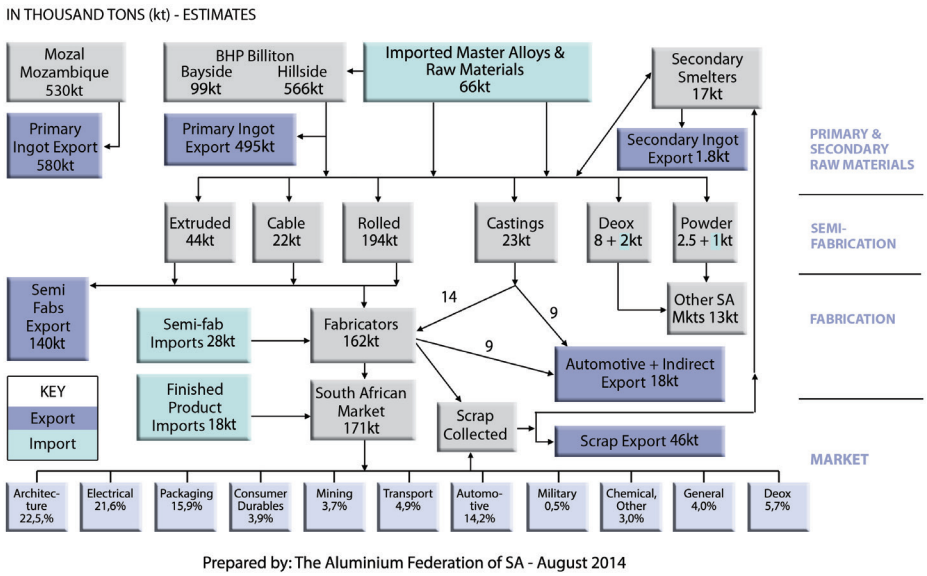

Figure 1. Flow chart of South African aluminum production in 2013.

Figure 2. A complicated core design for an automotive casting made in South Africa.

ure 2 shows a complicated core design for an automotive casting made in South Africa. He informed delegates that South Africa would be hosting an international conference on aluminum in March 2016 in Cape Town.

Roger Baxter, coo, Chamber of Mines, South Africa, presented a plenary talk on South African mining in 2030, discussing the economic issues related to minerals beneficiation in South Africa, giving a view of the future outlining the role of light metals from South Africa.

Seven more papers complemented the aluminum side of the light metal issues. Carl Reinhardt, Casting Services, from Durban, presented the worldwide competitiveness of the small number (180) of South African sand mold, permanent mold, and investment casting foundries. He showed financial models giving the theoretical savings calculations by using South African foundries. In a second paper, Reinhardt discussed die characteristics, such as gate, runner, and riser designs, along with appropriate thermal designs needed for high quality nonferrous die castings.

Filipe Pereira, Engineering Implementation Group, CSIR, outlined the operational cost analysis of a typical South African high pressure die casting, showing about 15 manufacturing cost components, while accounting for process, yield, and waste loss items. He showed the scale effect from die machine tonnage and tooling costs, and presented a cost accounting spreadsheet for a 200 ton die casting machine.

Pfarelo Daswa, CSIR, discussed the effect of natural pre-ageing time and T6 heat treatment on 6000 series aluminum alloys by R-HPDC. She showed that increasing the silicon content varied the observed effects of natural pre-ageing from positive to negative, which was attributed to clustering of solute atoms forming at room temperature. She presented how the T6 heat treatment had to be carried out in order to overcome the varying pre-ageing effects.

The corrosion behavior of anodized alloy A356 produced via R-HPDC using immersion testing in 3.5% sodium chloride solution was shown by Levy Chauke, CSIR. He noted that a partially anodized sample showed severe base metal corrosion, concentrated in the silicon-rich eutectic and surface liquid segregation zones.

Möller provided insights into utilizing wrought 6000 series aluminum alloys with R-HPDC technology, noting that high copper and excess silicon levels in the base alloy castings required the use of a two-step solution treatment to prevent incipient melting. He observed that the addition of titanium to these alloys minimized hot tearing.

Hiren Kotadia, EPSRC Centre, U.K., presented the use of a novel melt conditioned direct chill casting (MC-DC) of iron-rich aluminum alloys. A high shear device was submerged in the sump of the DC mold, causing intensive melt shearing to provide nuclei and uniformly distributed dispersed particles to give the desirable microstructure. He noted that such a technique is capable of giving an equiaxed grain refinement void of columnar growth and discussed the evolution of Mg_2Si and iron containing intermetallic phases in this regard.

Titanium: The bulk of the remaining presentations were focused on titanium metallurgy, with three plenary talks on titanium fabrication. Brian Gabbitas, University of Waikato, New Zealand, presented the first plenary talk, discussing recent advances of near-net shapes formed from titanium alloy powders, produced by a hydride-dehydride process using die powder compacts that were induction sintered followed by forging. Such fabrication techniques are outcomes of alternate technology evolving to overcome the high cost of conventional titanium fabrication from Kroll reduced sponge. Ashraf Imam, George Washington University, U.S., highlighted the use of a recently developed microwave sintering technique in making near-net shaped titanium powder metallurgical parts. Sintering can be carried out in an argon environment or under vacuum conditions, augmented by hybrid microwave and resistance heating conditions. Evaluations to optimize parameters controlling final density, microstructure, and properties were presented. Dawie van Vuuren, CSIR, presented the plenary paper on the up-and-coming technique of additive manufacturing of titanium alloy Ti-6V-4Al alloy powder. This paper was prepared by Froes and Dutta, highlighting some of the work carried out by Dutta's group at DM3D Technology, U.S. The authors noted, "Additive manufacturing (AM) technologies use the principle of creating a tool path, uploading this data in the machine, and building the part up layer-by-layer following the sliced model data using a heat source (laser, electron beam, or electric arc) and feed stock (metal powder or wire)." The paper provided property comparisons of using the three types of heat source on the finished parts.

Debbie Blaine, University of Stellenbosch, South Africa, presented articles co-authored with H. Bosman on the influence of powder particle size distributions on the properties of press and sintered titanium alloy preforms, as well as process models for the same. Silethelwe Chikosha, CSIR, presented techniques for characterizing titanium powder for flow, shear, and bulk properties using a rheometer. She noted that such parameter characterization by a simpler tool, such as the FT4 powder rheometer (used in the pharmaceutical industry) helps eliminate operator error when using multiple instrument measurements and particle size and flow properties, knowledge and control of which is important in making sound powder metallurgical parts. Sigqibo Camagu presented a paper by K. Mutombo, CSIR, on the interaction between fully stabilized zirconia or yttria-zirconia blend face coat on the investment casting of titanium alloys. Fei Yang, University of Waikato, New Zealand, discussed the requirements in the preparation of titanium alloy rods by powder compact extrusion techniques.

It is necessary to highlight the importance of the technology being developed at CSIR in making the titanium alloy powders via a cost effective continuous process using molten salt as the medium instead of molten sodium, which is being used as part of the Armstrong process being started up on a semi-commercial scale in Ottawa, IL, by Cristal Metals. Shaan Oosthuizen, CSIR, explained the challenges experienced in scaling up the CSIR-Ti process, which is a stepwise metallothermic reduction. This process is somewhat akin to the two-step batch Hunter sodium reduction practiced in the U.S. by reactive metals for several years until the early 1990s. The CSIR process is designed to be a continuous process instead of being a batch process, such as Kroll's magnesium reduction or the Hunter sodium reduction process noted previously.

Magnesium: Dawie van Vuuren made a comparison of alkali metal electrowinning processes with electrowinning of magnesium from magnesium chloride. CSIR in its present bench-scale to pilot-scale conversion uses unrecycled reducing metal and is evaluating an alternate reductant in their two stage process. One of the challenges realized by CSIR was that it was essential to develop an in-house expertise in handling large quantities of molten salt , such as types of pumps to use, and materials of construction, heat containment, etc. Once CSIR selects the reducing agent, they have plans to develop a technology for making that metal suitable for their needs from the recycled metal chlorides

South Africa has been involved in the development of a magnesium metal production technology from magnesium oxide at Mintek, a metallurgical research company, since the 1980s. Neale Neelameggham, IND LLC, discussed how to minimize carbon dioxide emissions in magnesium production in his plenary talk (co-authored with Robert E. Brown) and touched upon the Mintek process as well as the whole gamut of manufacturing magnesium from different compounds, including oxide, silicate, sulphate and chlorides. He noted that carbon dioxide emissions for present day commercial-scale magnesium production ranges between 17 and 22 kg CO_2/kg magnesium, and changing the process energy source to non-carbon fuel or alternative energy resources can easily bring the CO_2 emissions to a low value. The atmospheric air heating by water vapor and other thermal emissions should also be considered, as water vapor is a stronger greenhouse gas than CO_2, while appreciating that the atmospheric temperature is moderated by evaporative cooling of surface waters. He commented that it is unfortunate that several authors tend to hide inconvenient truths of energy consumptions in the various steps, while trying to market technologies to investors. He also introduced a novel thiometallurgical approach using sulphur as a fuel as well as utilizing magnesium sulfate as a sustainable raw material for metal production.

Karl Kainer, Institute of Materials Research, Helmholtz-Zentrum Geesthacht, Germany, presented H. Dieringa's work on the newly developed DieMag422, a creep resistant magnesium alloy containing barium (2%) along with aluminum (4%) and calcium (2%). This alloy is suitable for high pressure die casting.

Hein Möller concluded the symposium with a note of appreciation to all present informing them of the next Light Metals Technology conference, which would be held in Port Elizabeth, South Africa in July 2015.

Editors Note: For more information on the Light Metals Technology conference 2015, visit: www.lmt2015.co.za.

**Bushveld Lekgotla: A "bushveld" is a veld of South Africa with abundant shrubs and thorny vegetation. A "lekgotla" is a meeting place.*

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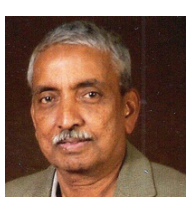

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