

“Magnesium Supply and Demand”

Tim Pretzer, Timminco Ltd.

Author will present published data as supplied by the International Magnesium Association regarding historical supply and demand for magnesium. Perspectives will also be offered regarding requirements for successful capacity growth in the future relative to cost, capital, political and infrastructure issues.

“Advances in China’s Magnesium Application Market”

Meng Shukun and Wu Xiuming, China Magnesium Association

China magnesium industry with Pidgeon Process has achieved new developments in recent 10 years in technology, process, equipment, technical & economical indexes and product developing and application as well. The paper also analyses the existing problems on environmental protection and utilization of energies. The authors propose that the future development of China magnesium industry should not rely on export, not only produce primary magnesium products, but develop and produce high value added magnesium products for export; should focus on the domestic market, enforce application of magnesium alloy, promote and push the development of domestic magnesium application market, encourage and support foreign enterprises to come to China and set up factories via joint venture and cooperation, take use of foreign advanced technology, equipment and China resources and labor to produce high end products, expand domestic demand for magnesium products besides exporting, strengthen its competitive edge in the international market.

“Advances in Magnesium Alloy Development”

Håkon Westengen and Per Bakke, Magnesium Competence Centre, Hydro Aluminium; Darryl Albright. Hydro Magnesium Market Development

Considerable effort has been made over the last decade to develop new magnesium die cast alloys. This has resulted in a series of new alloy compositions, targeting demanding market segments, in particular automotive applications. A prerequisite for success in the market is the fulfillment of the specific material properties required by the applications, however, a series of other technical and economical factors need to be fulfilled to make the new alloy a market success. The present paper discusses recent new alloy developments from a basic material angle, and points out further challenges. Main emphasis will be on die casting alloys for elevated temperature use as well as crash sensitive applications. Important aspects related to the overall value chain are discussed.

“Evaluation of High Temperature, Cast Magnesium Alloy, Front Engine Covers”

Dr. Alan P. Druschitz and Eric Showalter, INTERMET Corporation

A number of new magnesium casting alloys for high temperature applications are available. However, there is little published data from the testing of actual components. In this study, the castability, mechanical properties (tensile) and component performance (fastener/attachment point acceptability, bracket thread integrity, bracket distortion, resonance and fatigue durability) of front engine covers made from AZ91D, AJ62x, MRI-153M and aluminum alloy 380 are presented. The data demonstrated that bolt load compressive stress retention is a key area that needs to be addressed.

“Development of Intrinsic and Empirical Data for Proper Material Selection for Cam and Rocker Cover Applications”

Mike Dierks, Scott P. Meyer, Jim Doty, Spartan Light Metal Products

Over the years, top-of-engine components and in particular Cam and Rocker Covers have become a hot bed for material competition. Looking under the hood of the myriad of vehicles in any given parking lot, one will find plastic, aluminum, magnesium and even steel Cam and Rocker Covers. This paper will outline both intrinsic and empirical data relevant to material selection in Cam and Rocker Cover applications. The focus of this paper will be on plastic, aluminum and magnesium to the exclusion of steel. Data will be presented comparing these materials in areas most significant to the application. This data can be used to balance the tradeoffs and achieve the best design for each of the materials in question. With an apple-to-apple comparison of data at an intrinsic and empirical level, one will be able

to make and apple-to-orange comparison of optimal designs for each material to the same performance specification. As always value is in the eye of the beholder, however, conclusions will be drawn and presented as to which material is the best overall value.

“Energy Policy: Implications for Vehicle Materials

Thomas Gross

Continued dependence of transportation vehicles on conventional petroleum-based fuels has potentially serious environmental, security and economic impacts. Therefore, programs and policies that accelerate commercial success of vehicles with higher fuel economy are important and desirable. Research, development, demonstration and deployment of cost-competitive, safe, high-performing lightweight materials could make an important contribution in revolutionary vehicles with substantially higher fuel economy. Investments are needed for development work on competitive types of materials that have potential benefits.

“Audi Hybrid Magnesium Technology – A New Approach to the Lightweight Engine Block”

Dr. J. Böhme, Dipl.-Ing. J. Doerr, Dr. W. Schneider, Dr. B. v. Grossmann, Audi AG; Dipl.-Ing. K.D. Becker, VW Kassel; Dipl.-Ing. M. Fiedler, VW Braunschweig; Dr. U. Bischoff, VW Hannover; Dr. U. Holzkamp, VW Group Research

With this contribution Audi describes how in the future the lightweight material magnesium can also be used in engines subject to extreme loads if special detail design solutions and new creep-resistant alloys are adopted. To compensate for the drawbacks of magnesium, AUDI developed a new crankcase concept in which the magnesium structure is reinforced by targeted local material engineering in critical areas. The result of this development is a compact, multi-functional cylinder insert made of aluminium and incorporated into the magnesium block by a pressure die-casting process. It combines the typical functions needed in the engine block, namely cylinder wall, threads for the mounting of the cylinder head, threads for the mounting of the main bearing caps and water jacket (for engine cooling).

“Magnesium Application in the 7G-Tronic-Gear”

Andreas Barth, Daimler Chrysler

Since May 2003 Mercedes-Benz has been equipping several classes with the new 7 G-TRONIC automatic transmission with an outstanding performance such 7 gears, higher torque-carrying-capacity and reduced fuel-consumption. Although the transmission has increased torque-forces, Mercedes-Benz applies for the first time a Mg-die-casting gear-case and Al-bolts. In comparison to a common Al-gear-case with conventional steel-bolts the weight-save is 2,9 kg (6,5 lbs). DaimlerChrysler developed a new Mg-die-casting alloy AS 31 HP, which has a good cast-ability, corrosion-performance, heat-stability and a high dynamical strength due to its high ductility. The corrosion-resistance of Mg-parts can be improved by the use of special die-casting-lubricants. As Mg expands thermally higher than steel, the retention loss of steel bolts during drive-application is unacceptable. Therefore Al-bolts with a similar thermal expansion as the Mg-gear-case are used. The high ductility of AS 31 HP requires certain mechanical machining-parameters. Cost-saving and process-stable recycling-concepts for Mg-residuals deriving from the die-casting and mechanical machining were worked out.

“Use of Magnesium in Structural Crashworthiness Applications”

Arun Kumar and Eric Nelson, Altair Engineering Inc.; Tim Hubbert, Lear Corporation

In this paper, the authors demonstrate the use of magnesium in structural crashworthiness applications. The authors present the development of a die-cast structural magnesium instrument panel (IP) beam for an OEM company. Unlike traditional IP beams in service today, this magnesium IP beam participates in automotive crash events (such as FMVSS 208 and IIHS). The magnesium IP beam is a major load path and withstands a significant amount of crash loads during a crash event. Full-vehicle LS-Dyna simulations were performed to evaluate the magnesium IP beam performance in several crash scenarios. Test results from component testing performed on the magnesium IP beam structure is presented in this paper. Besides, the correlation established between the test results and simulation results is also presented here. Our experience developing this magnesium application demonstrates that magnesium is an excellent material for use in structural applications.

“Prototyping Strategies for Magnesium Die-Castings”

Thomas Ruden, Doug Finkhousen, and Carlos Engel, Lunt Manufacturing Co., Inc.

Since the early 1900's magnesium die-castings have been used in a wide bariety of structural applications in various markets the world over. Magnesium die-castings have found their way into uses where its physical properties are of primary importance, to statically-loaded applications such as covers, enclosures and housings, and for dynamically-loaded applications such as flywheels, automotive steering wheels, cross-car beams (I/P's)

and seating structures. And through the years, each die-casting application has gone through the prototyping and development process.

To engineers who specify magnesium die-castings for their products for the first time, in some cases it may not always be clear what prototyping options are available – and which one's are the most useful. In order to help bridge this information gap, this paper reviews the many alternatives available for prototyping magnesium die-castings. Additionally, the paper considers the performance needs of prototypes (physical, static and dynamic) and presents alternate strategies that engineers can adopt for their prototype process.

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“Elektron 21 – A New Aerospace Magnesium Alloy”

Paul Lyon and Dr. Tim Wilks, Magnesium Elektron

Sand cast magnesium alloys have been used in aerospace applications for many years, and a series of new alloys has steadily improved the temperature-property envelope. However most of these alloys have poor corrosion performance and so are deemed not suitable for new applications.

The development of yttrium containing alloy Elektron WE43 by Magnesium Elektron sort to produce a high performance alloy with good corrosion performance. This was achieved, but the alloy can suffer from casting difficulties if strict operational parameters are not adhered to. This can have an adverse impact on part cost.

To overcome these problems, Magnesium Elektron has developed a new magnesium alloy Elektron 21, with properties and corrosion performance close to Elektron WE43 whilst having a much improved founding characteristic. This paper will compare and contrast the performance of the new alloy with the historic alloys.

“Semi-Solid Processing of Magnesium Alloy Components”

S.E. LeBeau, M.W. Walukas, R.F. Decker, Thixomat, Inc.

Lightweight construction using magnesium is in competition with lightweight construction using aluminum, plastics, or steel. Semi-solid processing of magnesium alloys provides the opportunity to adjust the microstructure of magnesium alloys to optimize their performance for the high temperature and structural requirements demanded by the automotive industry. A comparison of three distinct process methods to produce SSM magnesium components, namely, the billet reheating or thixocasting, slurry-on-demand or rheocasting, and injection molding or Thixomolding® is presented. The traditional thixocasting, or billet reheating process, is gaining little commercial acceptance to magnesium alloys due to the unfavorable economics tied to this multi-step process. The newly developed slurry-on-demand methods are described with a renewed interest being displayed on these alternative SSM processes. The ability to use normal foundry metal and the potential for recycling process waste is driving the economics of these processes to a more favorable position. The current commercial status of Thixomolding® is presented along with recent focused efforts on the production of magnesium structural components via Thixomolding®. Studies on fatigue and high temperature alloy creep properties for Thixomolded® components are reviewed. Development of hot runner systems is presented along with recent improvements in Thixomolding® equipment by the machine builders. The projected increases in magnesium consumption in automotive applications can only be accomplished through a cooperative development effort, on an international level, between the automotive OEM producers and their supplier base. Only by adopting an integrated approach that includes the elements of design, prototyping, modeling, improved magnesium alloy development and improved manufacturing processes can the forecasts for magnesium be achieved. The projected increases in the use of magnesium can only be accomplished by a rigorous process of bringing together the entire spectrum of engineering skills involved in bringing new products to market.

“The NIST/ATP Program on Cost Reduced Magnesium Die Castings Using Heated Runners”

Naiyi Li, Ronald P. Cooper, Raymond M. Silva and James E. deVries, Ford Motor Company; Nanda Gopal, Intermet Corp.; Christopher W. Lee, Synventive Molding Solutions; Craig Nelson, IdraPrince Inc.

Magnesium is increasingly becoming an attractive alternative to steel, aluminum, and polymer composites for vehicle weight reduction due to its ability to meet vehicle performance requirements. During the last decade, the magnesium foundry industry has grown rapidly, however the material and manufacturing process costs of magnesium die-casting has impeded large-scale implementation into the automotive industry. As a result, Ford Motor Company initiated a Cost Reduced Magnesium Die Castings Using Heated Runners (CORMAG) program in partnership of the Advanced

Technology Program (ATP) of the National Institute of Standards and Technology (NIST). The CORMAG program's goal is to develop low-cost magnesium die-casting technology for structural automotive applications to achieve improved quality and productivity, and low-cost die-cast components. This paper presents an overview of the CORMAG program. It also depicts advanced manufacturing technology developed and provides technical results based on a mule casting produced from AM60B alloy.

“New Continuous Casting Process for Magnesium Alloys”

Dipl.-Ing. Stefan Schacht, Dipl.-Ing Michale Gummert, Prof. Dr.-Ing. Friedrich-Wilhelm Bach, Institute for Materials Science, Univeristy of Hanover

Compared to pressure die casting components, formed parts made of magnesium alloys exhibit an up to 100% higher strength and an up to 150% higher ductile yield. Despite the relatively poor material exploitation, most magnesium alloy components are currently made by pressure die casting in the automotive and other industries. Apart from problems like deficient knowledge about adapted processing technologies for extruding, rolling and forging Magnesium alloys, supply with semifinished products for forming processes is difficult for magnesium alloys today. Continuous casting is the key technology for cost effective manufacturing of semifinished products. Specific properties of magnesium alloys causing problems in continuous casting process, particularly the fact that the melts tend to burn when exposed to air and the very low strengths at elevated temperatures. Developed in an EC-contributed project, a new continuous casting process was designed exclusively to cast magnesium alloys. The vertically upwards billet discharge direction is the basic feature of this method, allowing a solidification process with no contact to atmosphere and producing high purity cast billets.

“Integrated Process Chain for Automobile Magnesium Sheet Components”

Peter Juchmann, Salzgitter Magnesium-Technologie GmbH

Due to their outstanding property profile Magnesium flat rolled products represent an attractive material for new ultralight constructions. This is especially valid for large thin-walled automobile components as well as for high performance machines or electronic equipment. The growing interest for Magnesium sheet results from continuous quality improvements and a better availability of semi-finished products. The technical and economical competitiveness is closely related with a further optimising of the process chains of Magnesium wrought alloys.

Salzgitter Magnesium-Technologie GmbH in Germany concentrates on the development, production, processing and trading of new, high quality Magnesium flat rolled products. The company offers a complete technology and material partnership ranging from product development to series applications.

The presentation focuses on Mg-sheet products and gives an overview of a joint research project of Salzgitter Magnesium-Technologie GmbH, Volkswagen AG and other partners developing ultralight Mg-sheet components for auto-body structures.

“Alternatives of SF₆ for the Magnesium Processor – A technical, environmental and economic assessment”

Gabriella Tranell, SINTEF Materials and Chemistry

In response to increasing global awareness and legislation regarding green house gas emissions, the International Magnesium Association initiated a research project in the year 2000, aimed at finding alternatives to SF₆ for melt protection in the Magnesium industry. The research project was carried out by SINTEF in Norway and focused both on investigating the fundamental mechanisms of melt protection, as well as industrial scale testing and bench-marking on new and proposed SF₆ replacements. This paper summarizes some of the key technical findings of the industrial scale testing of SF₆ alternatives and subsequently attempts to make an objective comparison of the technical, environmental and economic performances of HFC 134-a, HFE 7100 and Novec 612, as SF₆ replacements.

“Capture & Recycle for Emission Reduction of Sulfur Hexafluoride in Magnesium Casting”

Tom Tripp and Joe Fox, US Magnesium; John Barney, Air Liquide America

A partnership in 2000 between US Magnesium (MagCorp) and Air Liquide was formed to develop and test the potential of reducing sulfur hexafluoride emissions from magnesium casting operations via gas recycling based on membrane technology processes. Air Liquide has developed a Floxal SF₆ Recycle Process, which is capable of capturing dilute SF₆ in the parts per million (ppm) range from the casting system exhaust and recycle it as a concentrated feed gas in percentage levels. This process utilizes proprietary membrane technology to separate the SF₆ from air in four stages: pretreatment, compression, separation and recycle.

“Use of SO₂ as protection gas for Mg-recycling”

Guenter Franke and Dr.-Ing. Juergen Schlimbach, Norske Hydro

Different protection gases are used to protect liquid magnesium metal. Most of them are containing fluoride except sulfur dioxide. Mixing with carrier gases is possible in different concentration of the protection gas, depending on produced alloys and equipment used.

The most used protection gas today is SF₆, unfortunately this gas has a very high global warming potential and the magnesium industry is one of the largest emitter. Due to the high GWP in future production and use will be restricted or forbidden. Alternative cover gases are offered, also containing fluoride but with lower GWP compared to SF₆. Some of them have been tested at different companies with all kind of magnesium alloys. During reaction with the magnesium melt other gases can be generated with a global warming potential. The generation of HF is possible, too.

“The Protection of Molten Magnesium by SO₂ Gas Mixtures”

Karin Renger, ARC LKR; Andreas Bucker, Heinz Schulte Rosier, ASKI Gasetechnik GmbH

Molten magnesium oxidizes rapidly in air and starts to burn. Magnesium oxide formed on the surface of molten magnesium is not able to prevent further oxidation of the magnesium and the vaporization of magnesium. This is due to the fact that the molar volume of magnesium oxide is smaller than the molar volume of magnesium (Pilling-Bedworth ratio [1]). This problem can either be solved by using salt fluxes and/or protective gas atmospheres. The use of salt fluxes can lead to salt contamination and reduce by this the corrosion resistance of the magnesium products. Furthermore use of flux increases the melt loss. Therefore most die casters prefer fluxless protection.

“AM-cover: A production proven SF₆ replacement for the magnesium die casting industry”

Rob Bailey, Australian Magnesium Corp. Ltd.; Nigel Rickets, CSIRO

With the challenge in the late 1990's of developing a replacement cover gas technology which performs as well as SF₆ and substantially reduces greenhouse gas emissions, Australian Magnesium Corporation (AMC) and the CRC for Cast Metals Manufacturing (CAST) have developed AM-cover, which uses HFC-134a as the active gas. Greenhouse gas emissions have been reduced by over 95%, as compared to normal usage of SF₆ cover gas mixtures. This paper summarizes experience with the use of AM-cover in the production of over 1.25 million pounds of magnesium die castings in North America in the 10 month period from April 2003 through to the end of January, 2004