

## 2008 Abstracts

### **China's Magnesium Industry Development Status in 2007**

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This article will release the output of primary magnesium, with magnesium alloys and powders/chips/granules included, and the domestic consumption in China in 2007. Insisting on its own innovative way, the China's magnesium industry has adopted clean energy resources and high-temperature heat-storage air combustion technology, which help it to save energy up to 40%. A part of smelters in China has increased their competence with the aid of the mode of circular economy.

In China, the flourishing development of deep-processing magnesium products is promoting the whole industry to optimize its structure. In 2007, the domestic consumption in China breaks through 263 kt and China will continue its efforts to expand the magnesium applications. The domestic consumption is set to rise quickly and the exports of primary magnesium & alloys will be reduced further.

### **Status, Potential & Challenges for Automotive Magnesium Applications from the Point of View of an OEM**

*Hans-Helmut Becker, Volkswagen AG, Werk Kassel*

The reduction of CO<sub>2</sub> emission caused by car traffic is a significant and important aim for all car manufactures. The CO<sub>2</sub> emission is directly correlated to the consumption of fossil fuels. Therefore cars must be developed which need less fuel. One way to reduce the fuel consumption consists in reduction of the car weight by the means of lightweight design and the use of light metals. Magnesium alloys with the low density of about 1.8 kg/dm<sup>3</sup> offer a high level of weight reduction in comparison with conventional construction materials.

There are several methods to produce magnesium or magnesium composite parts. In addition to the application of extrusion and sheet metal processes die casting is an established method. Some usual parts are gearbox housing, cylinder block or thin-walled and highly integrative vehicle structure components.

This paper discusses the different kinds of production and magnesium products in automotive applications from the Volkswagen point of view starting in history with the beetle till his day. Furthermore a foresight will be given.

### **Accelerated corrosion tests for magnesium alloys: Do they really simulate field conditions?**

*Martin Jönsson and Dan Persson*

Magnesium is a very un-noble metal, therefore corrosion properties are an important issue which has to be considered when magnesium alloys are used in corrosive environments. To evaluate and compare magnesium alloys accelerated corrosion tests, such as salt spray tests, is commonly use by the industry to simulate real conditions.

However, the corrosion rates after different types of accelerated corrosion tests often show a wide scatter, and the corrosion behaviour is poorly correlated with the results obtained in the field. In the present study magnesium alloy AZ91D was exposed in three different types of atmospheric environment, viz. urban, rural and marine exposure sites. Corrosion rates, corrosion products formed, and the influence of the microstructure on the corrosion behaviour of the alloy were investigated. The results were compared with the behaviour observed previously in laboratory exposure. The differences between the laboratory and the field are considered and the implications for the design of accelerated corrosion tests of magnesium alloys are discussed.

### **Development of new low-cost Mg-Al-Zn based casting magnesium alloys with high strength and high ductility**

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Magnesium based alloys with excellent properties as well as low cost have great potential for substituting their heavier aluminum and steel based counterparts. This investigation focused on the effects of carbon inoculation by adding magnesite particles, antimony element, and heat treatment on the microstructure and room temperature mechanical properties of Mg-Al-Zn alloys with compositions within the high zinc castable domain. Thus, a system study for improving both strength and ductility of Mg-Al-Zn based magnesium alloys was carried out and series of low-cost casting magnesium based alloys possessing mechanical properties superior to AZ91 were obtained. For example, excellent tensile properties (Y.T.S.≈160MPa, U.T.S.≈313MPa and Elongation≈6.0%) were obtained in AZ64-0.1Sb-C magnesium based alloy under T6 condition. These excellent tensile properties are higher than those of existing Mg-Al-Zn series casting magnesium alloys and promising for the application to automotive load-bearing parts.

### **Improved magnesium alloys for automotive powertrain applications and extrusion: AM-SC1™, AM-HP2plus™ and AM-EX1™**

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In order to be truly competitive in critical automotive applications, magnesium alloys need to have properties that are similar to, or better than, their aluminium alloy counterparts and they need to be readily manufacturable. For high temperature powertrain applications, AM-SC1 is an excellent alloy for sand casting and permanent mould casting with properties that have been proven in engine applications. AM-HP2plus has been tailored specifically to provide good castability for high pressure diecasting while delivering similar high temperature mechanical properties. These two magnesium alloys have similar creep strengths to aluminium alloys used in powertrain components. The newly developed extrusion alloy, AM-EX1, can be extruded at rates similar to 6xxx series aluminium alloys and has mechanical properties that are also comparable to aluminium alloys.

### **Development of a new AZ based secondary magnesium alloy**

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The increasing use of magnesium in various sectors will result in a rising quantity of scrap and there is a clear trend towards recycling of magnesium alloys visible. However, so far post consumer scrap has not been used for magnesium alloy production. Two major problems in this regard are on the one hand the entry of impurities and on the other hand the use of feedstock from mixed alloys. Removal of the impurities by melt cleaning is difficult, expensive or even impossible. To address this problem new secondary magnesium alloys are required with a much higher tolerance limit against impurities and variations of concentrations compared to the available conventional magnesium alloys.

Such a new AZ based secondary magnesium alloy with a high tolerance limit against impurities and similar corrosion properties as AZ91D was successfully developed. The various development steps included the alloy development combined with a microstructural characterisation and casting from lab scale gravity die casting to final industrial high pressure die casting of real components. Microstructure, mechanical and corrosion properties were determined and compared to the standard AZ91D alloy, revealing quite similar property profiles. The major drawback of the secondary alloy is the reduced ductility.

### **Magnesium Rudder Pedal Assembly for passenger jet aircraft.**

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Today the majority of all parts in aircrafts are made of aluminum alloys. Replacement of Al by Mg would therefore reduce the weight of parts up to 35%. The mechanical properties of magnesium, high specific strength, castability and energy absorption properties makes the magnesium a preferred material for weight saving applications, especially in the aviation industry.

The subject of this work is replacement of 7075 aluminium alloy rudder pedal assembly produce by machining with an AZ91D magnesium alloy die-cast assembly. The 3 parts magnesium assembly was developed by Ortal in cooperation with the customer. The complicated development involved stress analyses under static and dynamic loads, casting simulations, designing and producing dies and improving and upgrading these dies.

All the 3 parts of the magnesium assembly underwent strict mechanical, corrosion and quality tests, required by the aviation standards and passed these tests successfully.

This innovative design, utilizing magnesium for pedal assembly for the aviation industry will lead to development of additional parts for this field.

### **Mobile with Magnesium Sheet**

*Peter Juchmann, Sébastien Wolff , Salzgitter Magnesium-Technologie GmbH, Salzgitter, Germany*

In Europe several R&D-activities concentrate on the development of new Magnesium wrought materials and process chains especially for automotive applications. Salzgitter Magnesium-Technologie GmbH is heading an ongoing joint research project in Germany called “**Mobil mit Magnesium**”, in which among other partners leading automotive companies like Daimler and Porsche are involved. The following presentation shall give a brief overview of current material-, process and application developments.

### **Cost attractive lightweight solutions through new Mg-concepts for the vehicle structure**

*Prof. Dr. Horst E. Friedrich , DLR; Dipl. Ing. Gundolf Kopp, DLR; Dipl.Ing. Elmar Beeh, DLR; Tony Lawson, Meridian Technologies; Luca Zaffaina, Meridian Technologies*

The reduction of the vehicle mass is an important point in order to reach new milestones in reducing fuel consumption and emissions. Today's and future steel structure concepts still shows lightweight potential. But even more attractive potential for lightweight body in white structures could be realised by new multi material design concepts. The DLR (German Aerospace Center) Institute of Vehicle Concepts and Meridian Technologies Inc. are working on innovative and cost attractive magnesium A-pillar solutions. By using the topology optimisation a new design idea for the A-pillar area was found. This new design concept offers the possibility to integrate additional functions. The new design shows expedient crash behaviour. A developed solution has a weight benefit of more than 50% compared to a steel reference structure. Because of functional integration the magnesium part is very cost attractive. To achieve the requirements of corrosion prevention Magnesium parts need to be proper designed. Within the example of a serial production Front End Carrier (FEC) possible solutions will be shown.

### **Comparative Review of Primary Magnesium Production Technologies as Related to Global Climate Change**

*Eli Aghion, Ben-Gurion University of the Negev; Scott C. Bartos, U.S. EPA, Climate Change Division*

While primary magnesium has been commercially produced for more than 50 years for applications in the transportation industry, its relative global climate impact is still uncertain. Regular lifecycle assessments of magnesium components for automotive applications indicate the greenhouse gas emission performance (GHGEP) of magnesium has a relative advantage compared to alternative structural materials such as aluminum and steel. However this GHGEP advantage is highly dependent on the production technology of magnesium and can be significantly reduced if the production process is not environmentally friendly.

The present study introduces and compares the principle characteristics of electrolytic production technologies and thermal reduction processes used for the production of primary magnesium. The differences between the two leading primary production technologies in terms of global climate impact (GCI) highlight the current challenge facing producers and users of magnesium, especially when one considers the dominant role of thermal reduction based processes. To simplify this comparative analysis, the authors assume the industry has achieved its 2010 climate protection goal and has eliminated emissions of sulfur hexafluoride (SF6) in both electrolytic and thermal reduction processes. SF6 is an extremely strong and persistent greenhouse gas. The industry will be well served by eliminating SF6 emissions as rapidly as possible, thus allowing magnesium to meet the rapidly growing demand for climate-friendly materials in transportation applications.

**Status and potentials of magnesium production in China:  
Life cycle analysis focussing on CO<sub>2</sub>eq emissions**

*Simone I. Ehrenberger, Stephan A. Schmid, Shaobo Song, Horst E. Friedrich, German Aerospace Center (DLR)*

Worldwide, production technologies for magnesium differ depending on geographical situation. China produces about three quarter of primary magnesium, but the Pidgeon process as used there in the past was shown to have high CO<sub>2</sub>eq emissions per kg pure Magnesium. Now, production processes in China have changed significantly in the last years, and the phase out of SF6 is well on its way worldwide.

We analyse the present situation based on recent data for the use of producer gas/coke gas and improvements in process parameters in China and give an outlook on further improvements for the Mg production technology chains. Changing the energy carriers for heating from coal to gas can reduce the greenhouse gas emissions up to 45 %. We conclude on the break-even distance from the comparison of an A-pillar strut mounting made from Mg with a steel component.

**Financial benefits from SF6 emission reductions**

*Ms. Adi Dishon, CEO, EcoTraders LTD.*

The Magnesium sector has been granted a golden opportunity to both participate in the global attempt to mitigate climate change and gain substantial financial benefits. Primary producers or die casters can now receive financial incentives to replace the use of SF6 with several alternate cover gases.

A CDM baseline methodology has just recently been approved by the UN.

EcoTraders as the developer of the methodology quantifying the emission reductions in the magnesium sector and Dead Sea Magnesium as developer of the first CDM project in primary production will provide valuable information regarding this new opportunity.

**Superplastic Forming of Magnesium Alloys**

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Intensive investigations have been carried out at the Institute for Metal Forming Technology (IFU) Stuttgart especially with the aluminium alloy AA5083 for superplastic forming particularly with regard to the required pressure curve, pore formation, maximum attainable part height and feasibility of superplastic manufactured real components. The experience gained is presently finding application in similar investigations with magnesium alloys AZ31B and ZE10hp. The focus of these investigations is the identification of important physical characteristics for superplastic forming using high temperature uniaxial tensile tests and high temperature pneumatic bulge tests. These parameters will be further used to facilitate the robust manufacturing of complex magnesium sheet metal parts using superplastic forming.

Extensive studies on warm forming of magnesium sheets and tubes are also being carried out. Some of these investigations have shown that otherwise difficult-to-manufacture automotive magnesium alloy (AZ31) components can be manufactured by pneumatic bulging in the temperature range of 300 to 400 °C. It has been noticed that the pressure curve over forming

time is dependent on the part geometry. It is therefore suggested to investigate the superplastic behaviour of magnesium alloys in more detail. Circumferential strains up to 116 % were achieved in investigations on expansion of magnesium alloy ZM21 tubes using internal high pressure forming with axial feeding.

### **Development of the Magnesium Die-Cast Motorcycle Chassis**

*Takaharu Suzuki, Junichi Inami, Toshikatsu Koike, Yamaha Motor Co., Ltd.*

The large, thin-walled magnesium die-casting technology has been developed for the purpose of motorcycle chassis production. The vacuum assisted die casting process improves not only the soundness but also the mechanical properties of the cast parts. Fatigue strength ( $R = -1$ ) of the cast pieces has been proven to have a minimum of 70MPa. The cast's minimized impurities in combination with undercoating and painting have it possible to attain a sufficient level of corrosion resistance required for use as exterior parts. The magnesium cast features a 20% weight reduction with the same stiffness compared to aluminum cast parts. Magnesium die-cast parts produced by this newly developed technology have been utilized in the rear frame of the mass produced supersport model '08 YZF-R6.

### **Recycling of Post-Consumer Mg Scrap**

*Dr. Adam J. Gesing, Gesing Consultants Inc; Dr. Alain Dubreuil, Natural Resources Canada*

Mg is coming into its own as a structural parent metal. Annually, primary Mg metal production is quickly approaching one million tonnes (T), new scrap recycling and remelting 300 thousand T, and the potential availability of old post-consumer scrap is approaching 100 thousand T.

Since the EU waste directive mandates the recycling of end-of-life vehicles (ELVs), the recyclability of materials in the ELV is becoming a significant consideration that affects the penetration of magnesium-based alloys into the vehicular market.

In North America, there is still almost no recycling of post-consumer Mg. USGS statistics show a decreasing trend in the recycling of post-consumer Mg scrap with only 800 tons consumed in the US in 2005, as compared to the 10,000-20,000 tons of old Mg-alloy diecastings one already expects from shredded ELVs in the US. The Mg in the portion of the scrap that is sold directly by the shredders to the secondary smelters as Al concentrate product ends up chlorinated out of the Al foundry melt and lost in Al dross.

We explore the true global picture of Mg metal recycling, show where and how it is actually taking place, and highlight areas of current and potential use for Mg-based scrap. We describe technologies that are currently used for separation of old Mg from other scrap and waste and that may help improve Mg recovery the future. Areas where Mg losses occur in the current recycling system are described and strategies for minimization of these losses are proposed.

### **Heat Treatment of Magnesium Alloys – Opportunities and Limitations**

*Frank Czerwinski, Husky Injection Molding Systems Ltd.*

Fundamental aspects of heat treatment of cast and wrought magnesium alloys are presented along with the role of chemical composition and specific elements. The strengthening mechanisms and key precipitates are described, explaining crystallographic limitations of their role within the hcp magnesium matrix. Examples of properties change are given for conventional alloys with trends in alloy design to magnify this effect. A particular emphasis is paid to magnesium structures produced by semisolid processing routes where a new approach to heat treatment is required. In addition, some elements of the heat treatment technology are included with the hardware and protective atmospheres against surface oxidation and ignition