AluMag Auto Lightweight Procurement Symposium

Aluminum Proves Its Worth in European Automobiles

By Joseph C. Benedyk, Editor

The AluMag® Automotive Lightweight Procurement Symposium was held in Düsseldorf, Germany on October 5-7, 2014 just prior to the biennial ALUMINIUM 2014 World Trade Fair and Conference held nearby at the Messe Düsseldorf. This AluMag symposium was the first of its kind, bringing together the procurement and supply side of automotive lightweight materials (aluminum, high strength steel, carbon composites, magnesium, and plastics) in body-in-white (BIW) and main frame applications, aimed at performance and safety considerations, as well as cost balance and reduction. The AluMag symposium brought together some 150 registrants, mostly from Europe, Asia, and North America, 90% of which represented several OEMS and Tier 1 and Tier 2 suppliers. The agenda of speakers was impressive and included management figures from two OEMs, Audi and Mercedes-Benz, as well as several Tier 1 and Tier 2 suppliers, and automotive industry consultants.

In the competitive materials environment that defines the worldwide automotive industry, driven by the need for cars that use less fuel, run cleaner, are safer, last longer, and are recyclable, automotive aluminum has fared well and has proven its worth—a sentiment that was voiced repeatedly at the symposium. The rule of thumb in the automotive industry generally states that a 10% weight reduction in a hydrocarbon fueled vehicle results in a 5-7% decrease in fuel consumption. The BIW typically accounts for 30% of vehicle curb weight, offering important opportunities for lightweight materials that provide performance at cost guidelines per BIW component. To be sure, high strength steel (HSS), advanced high strength steel (AHSS), composites reinforced with carbon fiber, and magnesium vie with aluminum for automotive market share, each offering lightweighting solutions of their own with unique design concepts, process improvements, and cost reduction efficiencies. Thus, what is evolving in the automotive industry is a holistic multi-material strategy aimed at incorporating selected lightweight materials within a low, medium, or high volume market segment that strengthen brand image while allowing for vehicle cost differentials.

European Automotive Aluminum in BIW Applications

In the symposium introduction, Jost Gaertner, AluMag's managing partner, presented the AluMag aluminum forecast through 2020 for European aluminum demand in main frame applications based on market information obtained from OEMs and suppliers (Scenario I) and assumptions (Scenarios II and III). As shown in Figure 1, Scenario I is the AluMag forecast based on data obtained from European OEMs and suppliers. Scenario II is the forecast beyond 2017 based on market data available today, as well as assumptions with European OEMs using more aluminum in new vehicle generations than anticipated by AluMag, and Scenario III is that middle range cars could use more aluminum than first anticipated by AluMag.

As has been the case for some time, aluminum castings in automotive powertrain applications, typically accounting for 35-40% on average of the aluminum in an automotive vehicle (Ducker Worldwide), are dominant players worldwide, depending on country of manufacture. However, BIW structures already contain significant portions of aluminum castings and will continue to grow in European automotive applications. As an inside example, Gaertner cited the cast aluminum suspension dome or "shock tower" used in European cars, an application that has tripled in size from 2010 to 2015. According to the AluMag follow-up five year forecast, demand will again double by 2020, i.e., an increase from 2,500 tons to 29,000 tons of cast automotive aluminum in ten years. Rheinfelden Alloys GmbH and Co. KG, one of the AluMag symposium exhibitors, supplies three different aluminum alloys for this application (Figure 2) according to their president Dr. Claudio Mus. He spoke at the symposium about Rheinfelden's role in aluminum alloy selection, casting process control, quality control, and production of structural aluminum die castings tailored to automotive end user needs with regard to crash relevant component design, strain rate material sensitivity, and corrosion behavior.

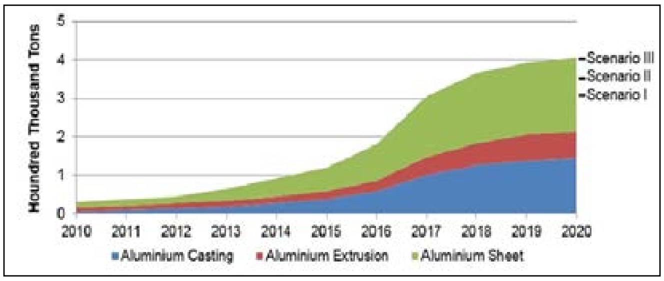

Figure 1. European automotive aluminum demand in BIW main frame applications based on AluMag market research.

Alloy	Silafont-36, AlSi10MnMg	Magsimal-59, AlMg5Si2Mn	Castasil-37, AlSi9MnMoZr	
				
Customer	Mercedez-Benz actual C-class	Porsche Panmera	Jaguar	
Weight	3.1 kg	2.3 kg	3.5 kg	
Dimensions	450 x 420 x 330 mm	590 x 450 x 340 mm	380 x 380 x 340 mm	
State of Casting	two-step heat treatment T6	as-cast state F without HT	as-cast state F without HT	
Foundry	Daimler, Mettingen (Germany)	Georg Fischer, Altenmark (Austria)	JVM, Worchester (England)	
Wall thickness	7 mm at central gate to 2.5 mm	2.5 mm	3 mm	4 mm
Comment	2 cavities die with 3 plates vacuum assisted process forced-air system for HT (T6)	part design has to follow guidelines taking into consideration higher shrinkage, higher casting temperature	properties are WT dependent vaccum assisted process can provide Sigma S value of 120 MPa also in thicker sections	
Die life	100	80	100	
Sigma R	>180 MPa	>290 MPa	>230 MPa	>220 MPa
Sigma S	>120 MPa	>160 MPa	>120 MPa	>105 MPa
A%	>10%	>7%	>10%	>10%

Figure 2. Examples of die cast aluminum suspension domes or shock towers made from Silafont-36, Magsimal-59, and Castasil-37, typically used by Rheinfelden Alloys for automotive structural castings.

Aluminum and Magnesium BIW Castings

Dr. Joachim Gundlach, sales manager from Grunewald GmbH & Co. KG, described the foundry challenge of thin-wall aluminum prototype and small series castings for BIW applications. Grunewald utilizes low pressure sand casting and integrated casting product and process development for prototype and pre-series casting automotive concepts, such as for the Daimler AG SL-Class BIW (Figures 3 and 4) that has a total weight of aluminum castings of 110 kg.

Aluminum and magnesium alloy die castings have resulted in several automotive weight saving applications at

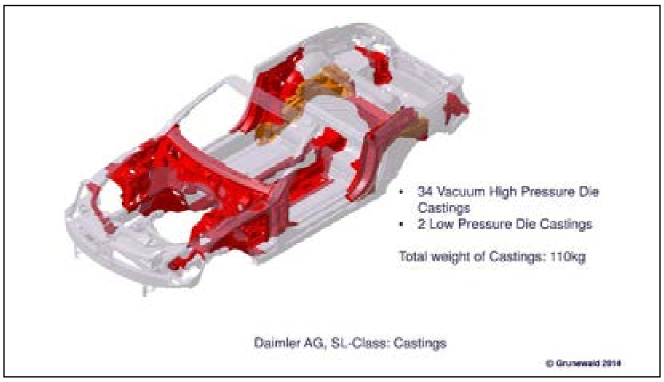

Figure 3. Typical BIW concept for aluminum die casting applications in the Daimler SL-class automobile, for which Grunewald supplied heat treated prototype and pre-series low pressure sand castings to specified wall thicknesses and tolerances and equivalent required mechanical properties.

Figure 4. Example of a pre-series aluminum low pressure sand casting of the roof component for Daimler SL-class automobile supplied by Grunewald to specified high pressure die casting geometry, wall thickness and tolerances, and equivalent mechanical properties required by heat treatment and temper.

Georg Fischer (GF) Automotive AG, another exhibitor at the symposium. In making the comparison of iron, aluminum, magnesium, and carbon composites, Klaus Decking, marketing director at GF Automotive, described how die casting of aluminum and magnesium casting alloys offers high functional integration, design freedom, and a large potential for weight savings, all of which help to make up for the higher cost of the aluminum or magnesium material relative to steel. Figure 5 is one of the several examples he showed, others of which were magnesium alloy die castings.

Although Decking showed average cost estimates per part for aluminum and magnesium castings of 30 and 55% higher, respectively, in comparison to steel sheet assemblies, he pointed out that automakers need to think about many other factors that influence make and buy decisions: weight reduction, energy consumption, repair, and recycling.

Figure 5. Inner door frame for the Maserati Quattroporte die cast from AlMg5Si2Mn aluminum alloy by GF Automotive, saving 40% weight over a steel sheet assembly.

Aluminum BIW Extrusions

Automotive aluminum extrusion applications were represented in various presentations at the symposium, but none more focused than that by Dr. Axel Meyer of Riftec GmbH, who benchmarked an eight chamber hollow extrusion for a structural, crash relevant application. This extrusion (Figure 6) is used in the Audi R8 Spyder as a B-pillar and required a two-extrusion solution utilizing friction stir welding (FSW) to join both top and bottom into a single component along a full length of 650 mm. He also described examples of FSW used in the floor structure of the Mercedes SL made of thin wall extrusions (68,000 panels produced) and tailor welded blanks on the center tunnel of the Mercedes SL and Audi R8 (75,000 blanks produced).

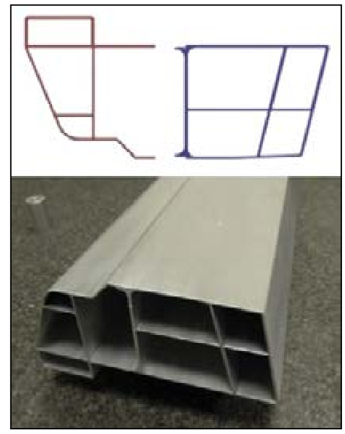

Figure 6. Benchmark on an automotive structural profile for the series production of a B-pillar on the Audi R8 Spyder with optimized extrusion design and processing as two hollow extrusions with three and four chambers joined by FSW to achieve tight tolerances and highly reproducible properties not feasible in a single eight chamber extrusion.

Representatives of Tier 1 supplier F.tech R&D North America Inc., Dr. Bing Liu and Dr. Xin Zhang, presented two technology trends applied to the production of aluminum subframes at their manufacturing sites. The first was hot bulge forming, in which a round aluminum extrusion is quickly heated by induction, expanded by air pressure with axial force to control thickness, crushed to fit into a cross sectional forming die, and formed to shape in the die. Hot bulge forming was successfully used by F.tech to achieve more than a 10% weight reduction in the mass production of welded aluminum subframes compared with previous aluminum subframes (Figure 7). F.tech has expanded automotive applications for hot bulge forming to crash boxes, bumpers, and hanger beams.

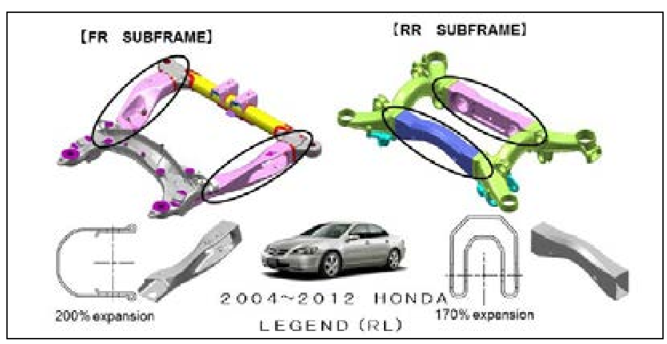

Figure 7. Hot bulge formed sections of aluminum extrusions welded into subframes for the 2004-2012 Honda Legend (RL) produced by F.tech.

Also presented by Liu and Zhang was a newly redesigned engine cradle for the 2013 Honda Accord made with a combination of steel and aluminum joined by FSW (Figure 8). Compared with a conventional steel and aluminum hybrid cradle that was previously bolted together, this new technology reduced the cradle weight by 25%, increased suspension mount rigidity by 20%, and reduced cost by 5%. Honda touted this as the world's first steel and aluminum hybrid structure subframe using FSW.

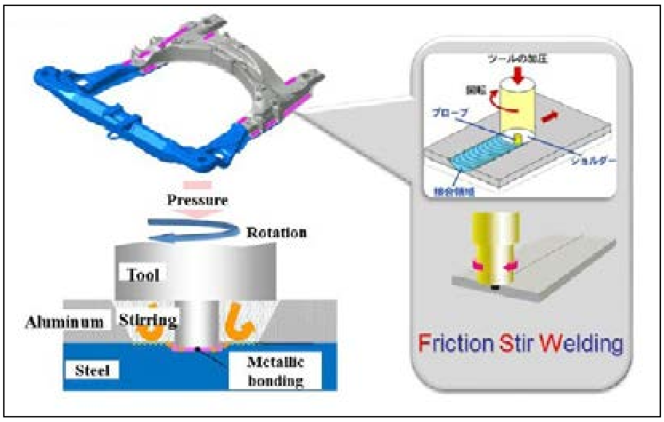

Figure 8. Schematic of FSW to generate an intermetallic bond between the steel and aluminum in the production of a steel and aluminum hybrid engine cradle.

Aluminum BIW Sheet

In regard to automotive body sheet (ABS), Hui Xiong, chief analyst for Beijing Antaike Information Development Co. Ltd., presented an exceptionally optimistic forecast for European demand for ABS at the symposium. She pointed out that, in 2009, China became the world's largest automaker, with China's automobile output in 2013 surpassing 20 million units. Aluminum demand from China's automobile industry has grown at a compounded annual rate of 18.6% between 2008 and 2013 to a level of 3.44 million tons in 2013, with 88% of this aluminum content in the form of castings.

Stressing the interest in China for ABS, Xiong cited Antaike figures for global ABS demand at about 500,000 tons in 2013, with European ABS demand in closure applications reaching 315,000 tons in 2013. Borrowing a forecast from Novelis, she posited that European demand for ABS will reach 780,000 tons in 2016 and will thence grow at an annual rate of 20%. With nine ABS projects under construction, China's ABS annual capacity by 2018 will be close to 950,000 tons (Figure 9). Current ABS consumption in China is low and mainly involves joint venture brands. ABS consumption for one such brand, the Faw Volkswagen, was estimated at 18,000 tons in 2014 and 30,000 tons in 2015. Antaike estimates that, with Chinese passenger vehicle output anticipated at 22.5 million units by 2020, ABS consumption in China could be 385,000 tons if ABS demand reaches 17 kg/vehicle, which was the European level in 2013.

Multi-Material BIW Structures

Balancing the cost of lightweighting automotive vehicles against marketing challenges, such as competition of lightweight body designs, Christian Kleinhans, managing partner of Berylls Strategy Advisors, presented his outlook until 2025, during which time lightweight body design will grow by about 15% annually. He said that China will become the major market for lightweight body design and that, in 2025, combined European and Chinese production will capture a market share of over 50%. Focusing on the European BIW competition among lightweight designs, the choice of materials for present and future BIWs will depend on the positioning, planned quantities, and cost efficiencies demanded of an OEM product portfolio (Figure 10). Kleinhans presented a couple of examples. The steel intensive (~25% HSS and ~35% AHSS) monocoque body structure of the VW Golf VII (~900,000 production units per year, base car price in Germany = €17,175) weighs 245 kg. Meanwhile, the BMW i3 (~30,000 production units per year, base price in Germany = €34,950) has a bi-module BIW concept consisting of a 100% aluminum space frame for the drive module and a 100% carbon fiber reinforced plastic (CFRP) passenger module at a total weight of 150 kg.

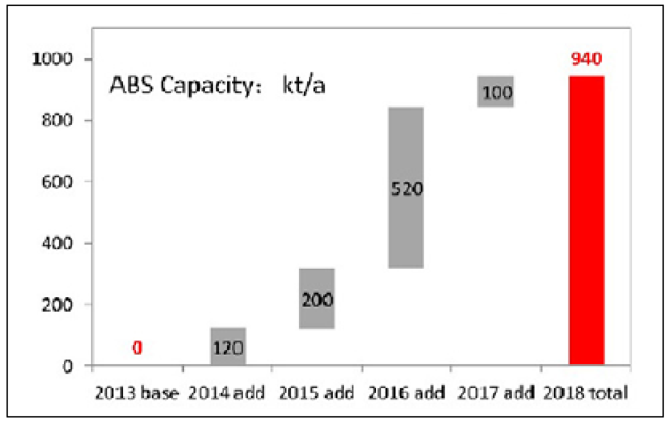

Figure 9. Antaike projections on Chinese ABS production capacity taking account of ABS projects under construction in China.

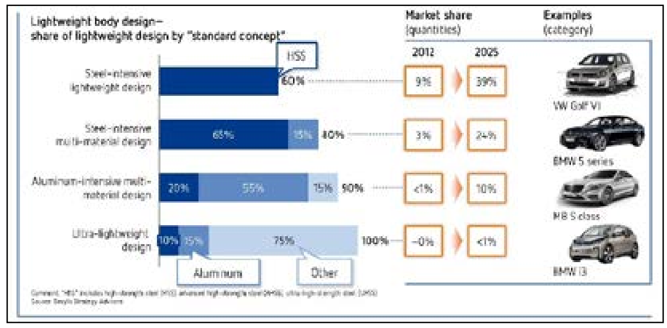

Figure 10. Standard lightweight design concepts for 2012 and the different material mix projected for BIW of various European vehicles.

The seminar presentations by European OEMs Audi (Arne Lakeit, vp manufacturing engineering, and Thomas Heußer, technology development and production) and Mercedes-Benz (Dr. Marcus Hermle, manager interior safety and durability) both pointed to lightweighting of their respective automotive lineup today as dependent on the multi-material design concept. As one of the pioneers in aluminum intensive cars in Europe, Audi's future BIW plans aim at the multi-material automobile (Figure 11), with a percentage mix of steel, aluminum, and fiber reinforced plastic (FRP) in a particular model, dependent on many factors, including lightweight poten-

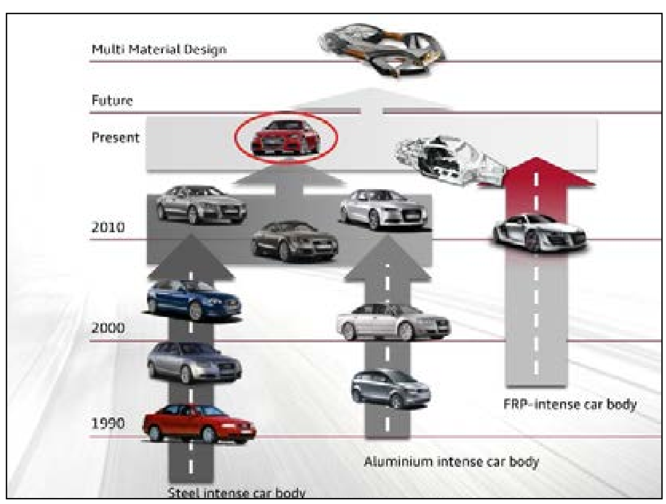

Figure 11. Historical development of BIW materials at Audi evolving into the multi-material design.

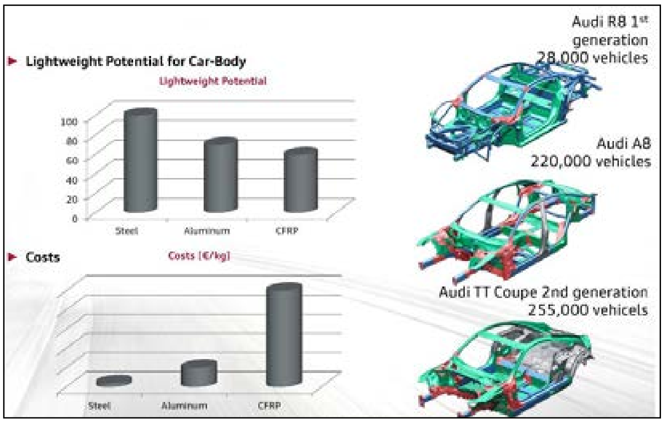

Figure 12. Balancing lightweight potential of steel, aluminum, and carbon fiber reinforced plastic (CFRP) against costs in select Audi vehicles.

tial and costs (Figure 12), all balanced with performance and safety requirements.

Mercedes Benz chooses "the right material in the right place" based on performance and safety requirements in different parts of the vehicle (Figure 13). Thus, in the C-class W205, aluminum usage is primarily selected for the outer skin and detachable parts (14.5% 5000 and 6000 aluminum alloy sheet, 1.2% aluminum die castings, and 1.6% aluminum extrusions), which is a significant increase over 0.5% aluminum (as 5000 and 6000 sheet) used for this purpose in the C-class W204, where aluminum has displaced some of the steel. However, the body structure of the C-class W205 (Figure 14) uses little aluminum compared with the new high strength steels.

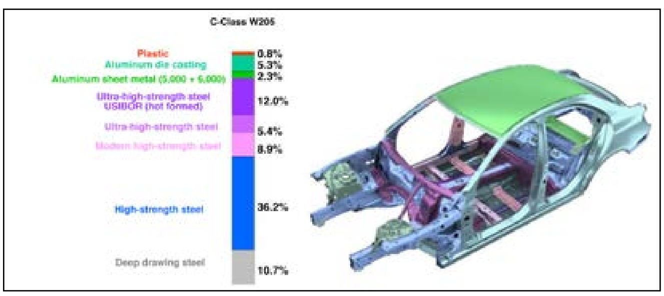

Figure 13. Mercedes-Benz requirements and lightweight design approach for different modules in the automobile in order of selected lightweight material options.

Presentations by the Tier 1 suppliers Thyssen Krupp System Engineering (Dr. Achim Agostini, head of lightweight solutions division) and Magna Steyr Fahrzeugtechnik (Dr. Wolfgang Zitz, vp operations) provided full capabilities for multi-material lightweight BIW design and production. Multi-material BIW production planning must take into account differences in physical and mechanical properties throughout the manufacturing chain. Bonding of dissimilar materials, for example, may involve selection from as much as a dozen different approaches in order to accommodate the differences among steel, aluminum, magnesium, and FRP/CFRP. Both of these Tier 1 suppliers have various multi-material BIW projects currently in-house that showcase the advantages of balancing light weight, performance, and cost with a multi-material mix. The R&D CULT project at Magna Steyr (Figure 15) and the multi-material super light car (SLC) project at Thyssen Krupp (Figure 16) are examples that showcase the light weight and performance advantages of aluminum within the manufacturing requirements of fabrication and joining to itself or competitive materials.

Figure 14. The lightweight material selection for the Mercedes-Benz C-class W205 hybrid body structure.

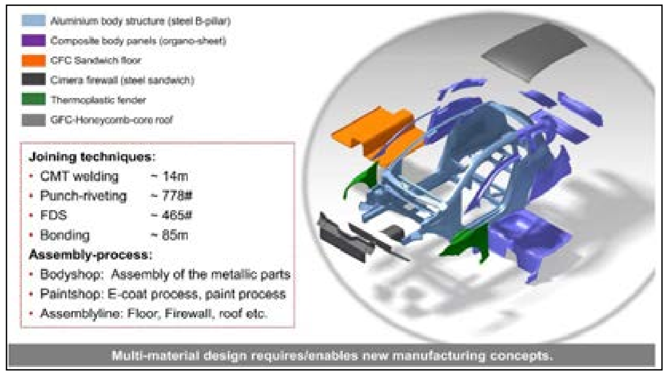

Figure 15. Product and production concept for joining and assembly in the lightweight Magna Steyr R&D CULT BIW project.

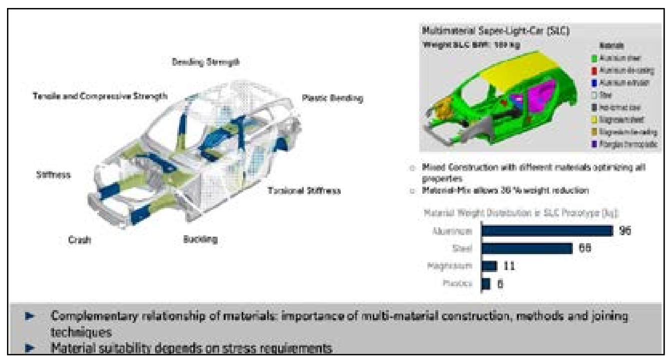

Figure 16. Complimentary relationships of the BIW multi-material mix in the Thyssen Krupp SLC project.

Conclusions

This first symposium by AluMag focusing on lightweight automotive material management was exceptionally informative and transparent. All the presentations by OEMs, suppliers, and automotive market specialists showed aluminum to be a major contributor to the lightweighting of present and future automotive vehicles. Aluminum content in the BIW of future European vehicles was predicted to vary considerably in competition with AHSS and CFRC and with the type and production volume of the vehicles. The BIW of low volume luxury and sport vehicles and mid-volume niche vehicles will contain a higher percentage of aluminum (competition mostly from CFRP) compared with high volume platform vehicles (competition mostly from AHSS). Overall, automakers must balance the costs of aluminum and competitive materials with the benefits for car buyers.

Editor's Note: The complete presentations made at the AluMag Automotive Lightweight Procurement Symposium are available online: www.alumag.cc/europe-2014-symposium/presentation-downloads/. The America Automotive Lightweight Procurement Symposium will take place November 9-11, 2015 in Detroit, MI. See all upcoming events at: www.alumag.de.