Targeting High Impact R&D for Automotive Magnesium Alloys

William J. Joost

Extended Abstract

Reducing vehicle weight improves the fuel efficiency, driving dynamics, and performance of vehicles ranging from traditional internal combustion engine (ICE) powered to battery electric vehicles (BEVs), fuel cell vehicles (FCVs), and the full range of hybrids [1]. However, along with tremendous opportunities, introduction of novel lightweight materials and architectures presents numerous engineering and commercial challenges. For the case of magnesium (Mg) the weight reduction potential, which exceeds 50% for some components, is offset by manufacturing, mechanical property, corrosion, and material cost hurdles, among others. While the vision of an all-Mg vehicle is laudable in its ambition, a more practical reality features Mg playing an important role in a multi-material vehicle architecture. In order to pursue the most promising and relevant Mg research and development, we need to assess several important questions: for which parts (or kinds of parts) is Mg best suited? What are the predominant engineering challenges preventing use of Mg for these parts? Where do we, as a materials science and engineering community, start in pursuing solutions to these challenges?

As vehicle manufacturers have transitioned from steel dominated architectures to mixed steel-Al structures, automotive engineers have faced a familiar list of barriers such as lower formability in wrought products, higher material cost, issues of compatibility with existing manufacturing infrastructure, and reduced corrosion and coating performance. Conversely, the substantial weight savings potential, implementation of compatible infrastructure, and the capability of Al die-castings to replace multi-part welded steel assemblies supports continued momentum for Al. This same balance of advantages and disadvantages is encountered in the step from steel-Al to steel-Al–Mg vehicles. Early non-powertrain applications of Al thereby provide a clue for likely early applications of Mg. First, the die-castability of Mg exceeds even Al, with excellent flexibility to produce complex shapes with thin walls [2]. Second, the low density and limited formability of Mg make hoods and outer panels attractive weight savings opportunities, surface finish and corrosion performance notwithstanding. Although safety cage and other strength-limited systems are attractive mass saving opportunities, the structural applications where Al first replaced steel should receive the most emphasis for early use of Mg.

For many of the early applications of Mg, the entire range of mechanical properties would benefit from improvement. However, particular emphasis on ductility is essential. In the case of formed sheet outer panels, ductility and formability are necessary to achieve styling and aesthetic details. Formed sheet inner panels and body-in-white components often require more dramatic geometries to meet structural and packaging requirements. Extruded Mg beams can exhibit very exciting properties and enable efficient designs, if ductility requirements are met. Even Mg die-castings, which can in principle compete directly with Al die-castings, are limited significantly by reduced ductility. Pursuing manufacturing processes and alloys to improve ductility is a critical element in Mg R&D.

Corrosion performance and durability remain immense barriers to wider adoption of Mg in automotive structures. As one of the most anodic structural materials, Mg introduces part of potentially problematic galvanic couples with other structural materials. Recent research has provided new insight into the underlying mechanisms for Mg corrosion [3], but substantial runway remains for continued development. In particular, although "stainless" Mg is desirable, durable coating systems and joint designs able to protect in automotive environments must be established.

Finally, many of the development challenges for automotive Mg are intertwined. Alloying affects formability and also corrosion. Manufacturing process parameters affect texture and strength, and also cost. The large search space

W.J. Joost (✉)
Vehicle Technologies Office, U.S. Department of Energy, Washington, USA
e-mail: william.joost@ee.doe.gov

K.N. Solanki et al. (eds.), *Magnesium Technology 2017*,
The Minerals, Metals & Materials Series, DOI 10.1007/978-3-319-52392-7_2

and complicated relationships suggest that application of integrated computational materials engineering (ICME) techniques would provide enormous benefit for Mg development. An ICME approach requires continued development of experimental and computational tools capable of capturing the complex anisotropic and chemical properties of Mg alloys. Examples of successful integration and accelerated engineering development are needed (and underway), and will provide motivation for future approaches.

The low density and weight savings potential of Mg will always provide an appealing opportunity for automotive engineers. However, without consistent pursuit of new technologies in alloying, formability, corrosion protection, material cost, and ICME, Mg will always be on the horizon of vehicle use. Identifying the most promising applications provides a guide for future development, improved Mg alloys, and fuel-efficient lightweight vehicles.

References

1. W. Joost, JOM **64**(9), 1032–1038 (2012)
2. A.A. Luo, J. Magnes. Alloy. **1**, 2–22 (2013)
3. K.A. Unocic et al., J. Electrochem. Soc. **161**(6), C302–C311 (2014)