

Development of Corrosion Testing Protocols for Magnesium Alloys and Magnesium-Intensive Subassemblies

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ABSTRACT

Corrosion tendency is one of the major inhibitors for increased use of magnesium alloys in automotive structural applications. Moreover, systematic or standardized methods for evaluation of both general and galvanic corrosion of magnesium alloys, either as individual components or eventually as entire subassemblies, remains elusive, and receives little attention from professional and standardization bodies. This work reports outcomes from an effort underway within the U.S. Automotive Materials Partnership - 'USAMP' (Chrysler, Ford and GM) directed toward enabling technologies and knowledge base for the design and fabrication of magnesium-intensive subassemblies intended for automotive "front end" applications. In particular, subassemblies consisting of three different grades of magnesium (die cast, sheet and extrusion) and receiving a typical corrosion protective coating were subjected to cyclic corrosion tests as employed by each OEM in the consortium. Results of these tests are compared.

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INTRODUCTION

Since 2006, the U.S. Automotive Materials Partnership (USAMP), through efforts of participants from partner companies - Chrysler Group LLC, Ford Motor Company and General Motors Company, has engaged in an extensive project known as "Magnesium Front End Research and Development" (MFERD). The project, now in its third phase, has been supported by the Vehicle Technologies Program in the Office of Energy Efficiency and Renewable Energy (EERE) of the U.S. Department of Energy, and by numerous supplier companies and universities. The project further engages international collaborators from Canada and the People's Republic of China. The overarching objective of the project is the development of enabling technologies and engineering knowledge base to permit increased deployment

of magnesium alloys in automotive body substructures, in support of vehicle weight reduction with accompanying benefits in both improved fuel economy and reduced greenhouse gas emissions. An overview of this project has recently been published [1].

The technical and engineering benefits of magnesium alloys as a material of choice for vehicle lightweighting have often been reviewed and are not elaborated upon here. An industry report projecting both applications and challenges for increased use of magnesium alloys in vehicles was prepared in 2006 with support of the USAMP [2].

Corrosion studies of magnesium alloys and assemblies within the "MFERD" project framework have focused on the following:

1). Assessment of performance for commercial and developmental treatments to surfaces of die-cast, extruded and sheet-formed magnesium alloys, either as single components or joined assemblies.

2). Establishment of common measurement techniques for corrosion resistance of the various magnesium alloys as provided by different coating systems.

3). Assessment of current status for commercial and developmental coatings to steel fasteners to resist galvanic attack when used in magnesium assemblies.

4). Establishment of pilot scale capabilities for coating magnesium-intensive “demonstration” structures.

The physical objective of the latter phases of MFERD has been the design and fabrication of multiple copies of a “demonstration” structure which embodies the various types of magnesium alloys envisioned for specific functions within the front-end substructure - e.g. shock tower (die casting), upper and lower crush rails (wrought magnesium). These structures are intended for study of joining methods, strength, durability and corrosion. [Figure 1](#) illustrates a “demonstration” structure as configured for these studies, employing friction stir linear welding (FSLW) as the primary joining technique. The upper rail structure is formed by joining two “half box” pieces and the lower rail is a magnesium AM30 or AZ31 extrusion. A similar set of structures was also manufactured using self-piercing rivets (SPR) as the primary joining method.

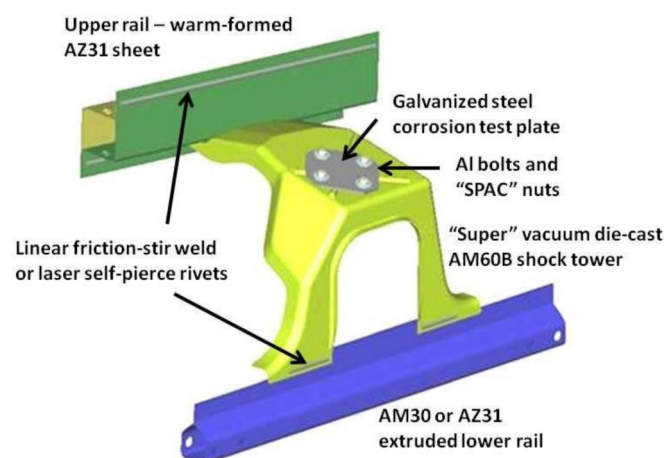


Figure 1. Friction-stir welded version of the magnesium-intensive front-end ‘demonstration’ structure.

Self-pierce riveted structures differed as well, inasmuch as chemical pretreatment of the magnesium components was employed in order to permit adhesive bonding, which was used in some structures as a supplement to the riveting process.

The work reported here details experiments conducted by the USAMP OEM participant companies using their individual cyclic test protocols to evaluate both baseline

structure corrosion indicative of the rate of attack of the underlying magnesium alloys, as well as performance of structures coated by a commercial pretreatment process. In principle, the former measurement may give some indication of the relative severity of attack for the alloys of interest as exposed to each of the cyclic environments.

EXPERIMENTAL DETAILS

Materials and Structures

The magnesium “front end” demonstration structure, illustrated in [Figure 1](#) was implemented either by friction-stir welding or by self-piercing rivets, (both with and without supplemental adhesive bonding). The self-piercing riveted structures employed a pretreatment step of Henkel Alodine® 5200 for the component pieces prior to assembly. This process was necessary to permit adhesive bonding on some structures. A laser *in-situ* heating process was employed to enable riveting into multiple layers of magnesium as employed in this design. Only the friction stir welded assemblies were used in comparison of the intrinsic corrosion rates for the various magnesium alloys exposed to the different OEM test cycles. Structures pretreated for the riveting and adhesive bonding assembly were also exposed to the various corrosion test cycles, and that comparison is included.



Figure 2. Actual friction-stir welded version of the magnesium-intensive front-end ‘demonstration’ structure less the steel corrosion test plate shown in [Fig. 1](#).

For all structures, the central cast shock tower piece shown in [Figure 1](#) was AM60B magnesium cast by a super-vacuum die casting (SVDC) [3] process. In all instances, the upper rail structure was formed by joining of two warm-formed, angled sheets of AZ31-H24 (supplied by Magnesium Elektron, N.A.). For the friction-stir welded assemblies, the lower rail was implemented in AM30 extruded magnesium.