TECH SPOTLIGHT

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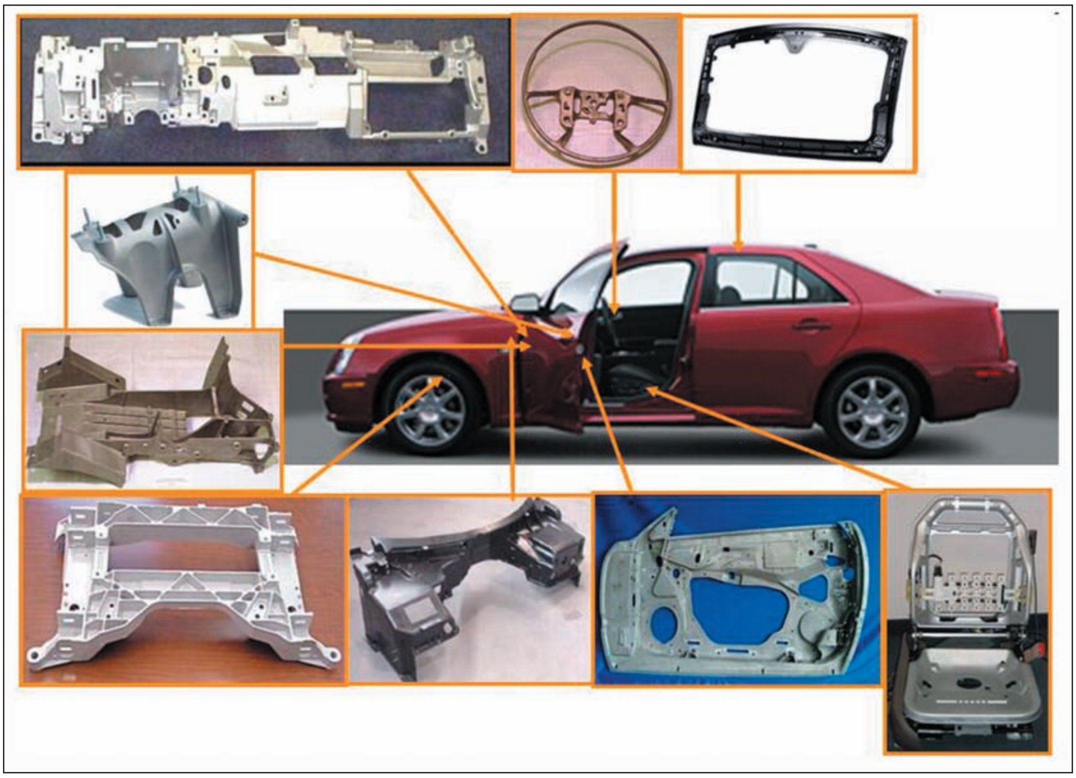

Fig. 1 — Although corrosion rates of modern high-grade magnesium alloys are quite acceptable for interior applications, automotive exterior environments are extremely harsh for bare and even coated magnesium parts. Cold-spray application of an aluminum coating may provide enough protection to enable the exterior application of magnesium alloy parts. Image courtesy Alan A. Luo, General Motors.

Corrosion Protection of Magnesium Alloys by Cold Spray

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Corrosion protection by cold spray is a revolutionary method by which thick aluminum coatings can be directly and locally applied to magnesium alloys to reduce or eliminate general or galvanic corrosion. This method promises to address many of the shortcomings associated with classical methods for corrosion protection of magnesium alloys, and may enable the application of magnesium to exterior automotive components. (Fig. 1)

Cold spray is an emerging solid-state process in which the kinetic energy of supersonically accelerated solid particles is converted into interfacial heat upon impact with the substrate, producing metallurgical bonding. The technology is based on the fact that every metal displays a temperature-dependent critical particle velocity above which the particles bond to the substrate.

In conventional thermal spraying, both coating and substrate materials are subjected to oxidation, metallurgical transformations, and tensile residual stresses due to the elevated process temperature. In contrast, cold spray is capable of producing thick coatings that exhibit extremely low porosity (<0.5%), while avoiding oxidation, phase transformations, and tensile residual stresses for a wide selection of metals, cermets, and other material combinations.

In high-pressure cold spraying, pressurized helium or nitrogen (350 to 450 psi) serves as a carrier gas to accelerate spray material to supersonic speeds. The gas is heated and then forced through a converging-diverging nozzle (de Laval), where it can be accelerated to supersonic speeds (over 1000 m/s). Spray powder is axially injected upstream of the nozzle.

In low-pressure cold spraying, nitrogen or air is pressurized to 70 to 145 psi, and the spray powder is radially injected downstream of the diverging section of the nozzle. Low-pressure systems are portable and more economical to operate, while particle velocities can be as high as 800 m/s. These portable systems (Fig. 2) are capable of spraying aluminum, copper, zinc, and other metal combinations. Portability makes low-pressure cold spraying ideal for field maintenance and repairs.

Cold spray represents an effective way to deposit thick metallic aluminum coatings on magnesium alloy surfaces with minimum surface preparation and without mechanically or thermally compromising the substrate properties. The presence of aluminum on the surface has been shown to reduce the general and galvanic corrosion tendency of magnesium components. In many cases, only areas surrounding steel fasteners require protection against galvanic corrosion, for which cold spray offers an innovative method to locally protect exposed magnesium surfaces. (Fig. 3).

However, more research is required to understand and optimize the cold spray process. In particular, many

Figure 2 — Low-pressure portable cold spray machine. Image courtesy of SST, a Division of CenterLine (Windsor) Ltd.

Magnesium and corrosion

Magnesium is the lightest of all structural metals, 35% lighter than aluminum and 78% lighter than steel. As a constituent of many minerals, it represents about 2% of the mass of rocks, and 0.13% of seawater. The lightweight characteristics and wide availability make magnesium alloys ideal for components in cars and light trucks. However, the percentage of magnesium alloys in automobiles has traditionally been low, with an average of about ten pounds in a typical domestic model. The reasons are associated with its low resistance to creep and corrosion.

However, increasingly demanding applications in aerospace and the military have resulted in the development of creep- and corrosion-resistant magnesium alloys. Some examples include housings for helicopter transmissions, compressors, and engines, as well as forgings for critical gearbox components.

Over the past few years, the demand for lighter, more fuel-efficient vehicles has spurred increased interest in applying magnesium to more critical components such as engine blocks, engine cradles, and transmission housings. Therefore, in addition to developing alloys with improved corrosion resistance, finding cost-effective ways to protect magnesium alloys from corrosion has become paramount.

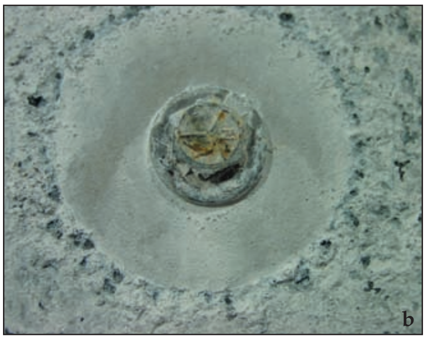

Fig. 3 — (a) The central area of this magnesium casting alloy AE44 plate was selectively cold sprayed with aluminum. It is shown after 100 hours of salt-spray exposure, as per ASTM B117. Note that the cold-sprayed area between the three washers is free of corrosion attack. (Courtesy Natural Resources Canada-CANMET, Ottawa, Ontario) (b) Magnesium alloy AM60 plate is shown after 1000 hours of corrosion testing, as per ASTM B117. The circular area surrounding the fastener hole was selectively cold sprayed with aluminum. (Courtesy NRC Integrated Manufacturing Technologies Institute, London, Ontario)

material combinations and cold spray procedures are yet to be developed in the endless pursuit of innovative and better ways to utilize the materials of the future.

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