Mechanism of undercreep corrosion of Zn, ZnMgAl alloy and ZnMg PVD layers under E-coating for automotive applications

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Steel for automotive applications is typically coated with a zinc (GI or EZ) or a Zn/Al/Mg based layer (Magizinc®), which in turn is coated with a phosphate layer and a subsequent organic E-coating. The latter functions as a primer for subsequent coatings to provide colour, UV resistance etc. A novel development is to apply a ZnMg layer with PVD. In this study PVD produced ZnMg samples are benchmarked against hot-dipped produced coatings. In all cases the zinc-based coating provides galvanic corrosion protection of the steel substrate, together with a barrier protection by deposited corrosion products.

A crucial criterion is the rate of corrosion in the lateral direction from a scratch or a cut edge, which should be as low as possible. Corrosion was invoked on scratched samples by exposure to a cyclic humidity/saltspray test (VDA 233-112). The corrosion mechanism is studied post mortem using SEM-EDX mapping of the fracture plane (where the E-coating is removed) and cross sectioning with PECS sputtering.

A zinc coating provides sacrificial protection, where the corrosion front is marked by the presence of chlorides. Magnesium influences the corrosion mechanism in two ways. The first is the precipitation of insoluble salts onto steel, a mechanism well documented in literature. However, we found another distinct effect of magnesium: magnesium oxidises well in advance of the zinc oxidation. This oxidised magnesium accumulates at the metal/phosphate interface and is hygroscopic. As such it increases the water content in the E-coating. The additional water does not compromise the adhesion, if fact the adhesion appears to increase: the fracture plane is no longer located at the phosphate/E-coating interface but within the E-coating. Chloride plays no role in this part of the corrosion mechanism. The pre-oxidation of magnesium does not result in an overall increase in the corrosion rate: the corrosion rate decreases proportionally to the percentage of magnesium in the layer.

The change in fracture pattern is observed both for (hot-dipped) Magizinc® and ZnMg PVD coatings, demonstrating that the method of producing the layer has less effect than the magnesium percentage.