

Enhancing Corrosion Resistance and Prediction of Corrosion Performance in Multimaterial Joints for Automotive Lightweighting Applications

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The growing use of lightweight magnesium (Mg) and aluminum (Al) alloys in automotive structures increases susceptibility to localized galvanic and crevice corrosion, particularly in multi-material joints. Our corrosion-mitigation strategy integrates surface and bulk microstructural processing routes that improve corrosion performance without adding extra manufacturing steps. We combine this design philosophy with COMSOL Multiphysics simulations, mathematical modeling, and corrosion testing (electrochemical testing, immersion and salt fog/spray) to identify and rank the dominant drivers of galvanic corrosion. Across multi-material joining methods, our modeling and experiments demonstrate that cathode-to-anode area ratio emerges as the most critical geometric variable guiding corrosion severity. Where feasible, rivet-less High Velocity (HiVe) clinching provides the most effective mitigation due to the elimination of galvanic corrosion. We extend the same framework to friction stir welded multi-material joints by coupling localized electrochemical measurements with region-specific polarization inputs to build time-dependent corrosion models, and we scale these predictions by simulating corrosion rate and current distribution to full components.

Building directly on these mechanistic, location-specific insights, we translate our philosophy of mitigation-by-design into protection-by-design through selectively applied cold-spray Zn coatings as pre-treatment coatings for HPDC AZ91 Mg in vulnerable regions such as fastener sites and parting lines. Optimized Zn cold spray produces dense, well-adhered coatings with less than 0.5 percent porosity, up to 35 MPa adhesion strength and reduces wear rate by ~50 percent versus uncoated AZ91. It also enables corrosion benefits including a ~400 mV nobler corrosion potential and a greater than 99.3 percent reduction in corrosion rate as quantified by evolved hydrogen with substantially lower hydrogen generation than both bare AZ91 and AZ91 with current state-of-the-art industrial pre-treatments. Overall, our work establishes a scalable, model-guided workflow that links joint geometry and

microstructure across joining methods, and targeted surface protection to corrosion initiation and progression.