

Design of low aluminum ZAM coating and research on inhibiting mechanism of liquid metal induced embrittlement

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Abstract The liquid metal embrittlement (LME) cracks that form during the hot stamping process of zinc-based coatings significantly reduce the toughness of the coated sheets, representing one of the bottlenecks for the application of zinc-based coatings in automotive panels [1, 2].

In this work, based on the Zn-Al-Mg database, the liquid phase projection diagram enriched with zinc was calculated, and the coating alloys were designed to be located at the Zn/Al eutectic line, the Al/MgZn₂ eutectic line, and the Zn/Al/Mg₂Zn₁₁ eutectic point. Among these, the Zn-4.5Al-3.0Mg coating possesses the highest content of ternary Zn/Al/Mg₂Zn₁₁ eutectics, exhibits the finest microstructure, and shows the most uniform distribution of elements [3]. In the eutectic region of the alloy, both Mg₂Zn₁₁ and MgZn₂ phases precipitate simultaneously, with the Mg₂Zn₁₁ phase growing and precipitating on the matrix of the MgZn₂ phase [4]. The corrosion resistance of the coating improves with the addition of Mg, Al, or Sn elements.

Then, during the austenitization process under no-strain conditions, for the same coated sheet, as the austenitization temperature increases, the microstructure of the Zn-Al-Mg coated sheet transforms from a coarse layered structure to a fine, dense monolithic structure, with a more uniform distribution of Zn and Al elements. Under the same austenitization temperature, as the content of Al and Mg elements in the coating alloy increases, the coating microstructure becomes progressively finer and denser.

Finally, the LME sensitivity of the coated sheets was evaluated through the relative loss of fracture energy [5, 6]. The relative loss of fracture energy increases and then decreases with the rise in testing temperature and decreases with the increased uniformity of element distribution after austenitization. At a testing temperature of 920 °C, the Zn^xAl^yMg coated sheet exhibits the lowest LME sensitivity, with a relative loss of fracture energy below 10%.

Keywords Zn-Al-Mg Coating; Hot-Dip Galvanizing; Liquid Metal Embrittlement; Phase Diagram Calculations

Reference

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