The effect of selective oxidation on galvanizing and galvannealing reactions of dual-phase steels

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Abstract

Advanced High-strength Steels (AHSS) have high strength and excellent formability, which offer a potential for weight savings in automotive industry. Therefore, AHSS are considered to be one kind of environmental-friendly materials.[1] Adding alloy elements, such as Mn, Mo, Si, and Cr, are expected to enhance the mechanical properties by solid solution hardening and precipitation hardering The coatings to protect AHSS against corrosion become an important issue. For example, zinc and zinc alloy coatings on steel are widely used to protect steel components against corrosion. Zinc coatings effectively provide barrier protection and galvanic protection on steels. Hot-dip galvanizing is an economic method to make a full coating on steels by which, the steel reacts with molten Zn to form a coating with an alloy layer at the Zn/steel interfaceAfter being withdrawn from the Zn bath, the steel is cooled down to form hot-dip galvanized (GI) steel or heated up for growing more Fe-Zn intermetallic compounds (IMCs) like $FeZn_{13}$ (ζ), $FeZn_{10}$ (δ), Fe_5Zn_{21} (Γ_1), and Fe_3Zn_{10} (Γ),[2] which is known as galvannealed (GA) steel. However, the mechanism of the growth of Fe-Zn IMCs is not well understood yet.[3, 4]

The alloy elements not only affect the mechanical properties of the steel substrate, but also play an important role in the following GI and GA process. In this work, the effects of alloy elements on the interaction between the substrate and coating were studied using a laboratory simulated GI and GA on dual-phase steels. The GI process was performed in molten Zn bath containing 0.12 wt% Al at 450℃ for 3 s. After being withdrawn from the Zn bath, the steel was heated to 500℃ to form the GA specimen. Two kinds of dual-phase steels were used and denoted as HDA and HDB. The HDA contained 0.11 wt% C, 1.3 wt% Mn , 0.03 wt% Si, and 0.04 wt % Nb. The HDB contained 0.10 wt% C, 2.1 wt% Mn, 0.12 wt% Si, 0.55 wt % Cr and 0.035% wt% Nb. OM observations on chemically etched cross-sections (Fig. 1) showed that the HDB steel, which has higher Mn, Cr, and Si contents, displayed less interaction between the substrate and the coating after the GA for 0 s (rapidly cooled down after reaching 500 ℃). Further GA treatments resulted in more Fe-Zn IMCs for both the HDA and HDB steels. This retardation in the Fe-Zn alloy reaction can be attributed to the selective oxidation at steel surface during the annealing process prior to hot dipping[5,6]. Those external selective oxides are too small to be observed by the SEM, but can be confirmed by TEM observations.

Besides cross-sectional microstructure characterizations, the oxidation properties can also be confirmed by using the Open Circuit Potential (OCP) test. The OCP test is a simple and quick technique to analyze the complicated layered structure of the GI and GA coatings. Figure 2 shows the OCP test in 7.5 vol% HCl solution. A noticeable hump present in the HDB-GI sample but not in the HDA-GI sample. This hump can be associated with the remnant oxides. Although the aluminothermic reduction has taken place to reduce most oxides, some of them still remained at the interface between the steel substrate and the coating. The oxides apparently block the steel/molten Zn interaction during the following GA process. As a result, the HDB steel exhibits less extents of GA reaction compared to the HDA steel.

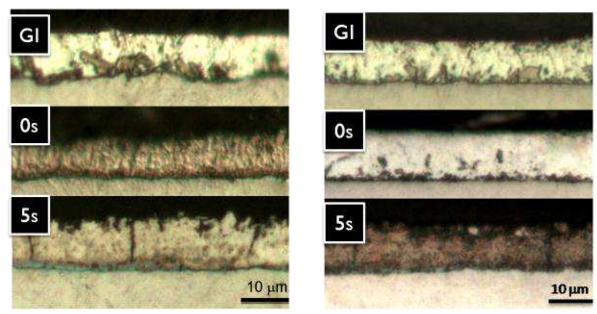

Fig.1 OM micrographs of the chemically-etched crosssections of the HDA (Left) and HDB (Right) samples.

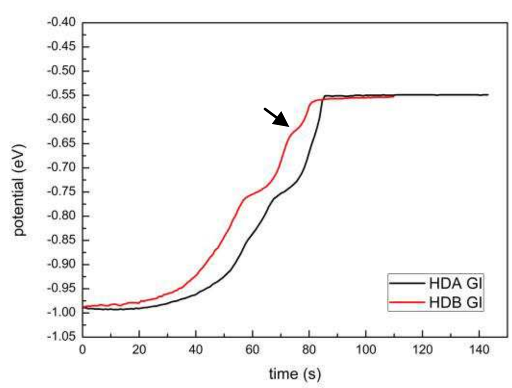

Fig.2 The OCP evolution of HDA-GI and HDB-GI samples in 7.5 vol.% HCl solution.

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