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Root cause analysis of an uncommon surface defect on galvannealed steel sheet

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A R T I C L E I N F O

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A B S T R A C T

The galvannealed coating has been extensively used in automotive industries because of its superior performance for weldability, paintability and corrosion resistance. However, surface defect of the galvannealed coating is a major concern for the steel manufacturers and the automotive industries. The galvannealing coating process comprises several process steps and each process step may incorporate different types of defects on the coated surface. In the present study, an uncommon surface defect which looks like an indentation mark on the coating surface has been investigated. Scanning Electron Microscopy (SEM) coupled Energy Dispersive X-ray Spectroscopy (EDS) has been used to analyse the morphology and the chemical compositions. Confocal Laser Scanning Microscopy (CLSM) has been used to measure the depth and the morphology of the defect. It was found that the defect was developed on the steel sheet at the end section of the annealing furnace because of mechanical abrasion with rolls. In-depth analysis suggested that zinc vapour from zinc bath were forming zinc oxide particles in the snout region. Zinc oxide particles were able to travel to the end section of the annealing furnace due to improper snout operation. These particles were getting entrapped in-between the roll surface and the steel strip and forming the surface defect on the galvannealed steel surface.

1. Introduction

Surface appearance of a galvannealed steel sheet is of prime importance for automotive outer panel applications. However, different types of surface defects are found on the galvannealed steel sheet because of the inherent difficulty of the galvannealing coating process. Typically a galvannealed steel sheet goes through different operations such as alkali cleaning, acid pickling, annealing, hot dipping in Zn bath, galvannealing and finally skin passing. Each step in the continuous galvanizing line may impart different types of surface defects and has been investigated by several researchers [1–5]. Defect such as wrinkle bands was reported due to improper arrangement of air-knife [6,7]. Uncoated spot defect and entrapment of dross particle in coating were found to generate because of inappropriate bath management [8–10]. Improper alloying in the coating was found to form because of uncontrolled alloying in the galvannealing process [9,11].

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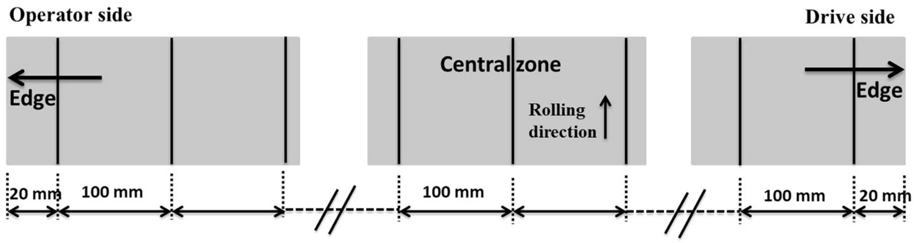

Fig. 1. Method of sampling along the width of the steel sheet.

In the present study, an uncommon defect has been investigated in detail. Previously Shankar et al. [4] has reported defects of similar morphology as the present defect under consideration. They reported the defect might be forming before the zinc coating. However, the researchers were unable to report direct evidence of the generation of the defect and the probable root cause. In the present study, direct evidence of the formation of the defect and probable root cause has been investigated. The defect was characterised with Confocal Laser Scanning Microscope (CLSM) and Scanning Electron Microscope (SEM). The chemical analysis was performed by Energy Dispersive X-ray Spectroscopic technique (EDS). The texture analysis of the steel substrate was performed by Electron Backscattered Diffraction (EBSD) technique.

2. Experimental procedures

Interstitial free steel (IF steel) with ultra-low carbon was used for the study. The chemical composition of the steel is (wt%) s C: 0.003, Mn: 0.5, Al: 0.047, Ti: 0.034, Nb: 0.024, Si: 0.106, S: 0.006, P: 0.028, B: 0.001, and N: 0.0028.

The galvannealing operation was performed in the continuous galvanizing line in Tata Steel Ltd., Jamshedpur, India. The bath temperature was maintained at 460 ± 3 °C and the dissolved aluminum content of the bath was kept at a constant level of 0.134 wt %. Galvannealing temperature was maintained at around 500 ± 10 °C. Around 0.8% skin pass elongation was applied on the galvannealed coated surface.

The defect was randomly distributed on the steel sheet along the width and found almost on every steel strip at the last 10 days of every galvannealing campaign. Under visual inspection the defect looked like an indentation mark. However, it was difficult to resolve because of their microscopic nature. So, the strip was divided into number of small sections along the width and samples from every section were collected for further analysis. Due to the presence of more defects at the edges a smaller section of 20 mm was taken at the edges and the rest of the width was divided into 100 mm sections as shown in Fig. 1. Samples were collected from every section and further analysed. Several samples were collected and analysed using this methodology.

The galvannealed samples were cut in to 2 × 2 cm, pieces from the defect and defect-free areas and the cross section samples were prepared following common metallographic procedures and analysed by Optical Microscopy (OM). The coating was stripped off with 10% H_2SO_4 to analyse the substrate surface. The cross sections of stripped off samples were also analysed using Electron Backscatter Diffraction technique (EBSD). The sample preparation for EBSD includes colloidal silica polishing for about 15–20 min. Methanol was used in place of water as wetting agent. Once the desired microstructural features were obtained, ultrasonic cleaning of the sample was done in ethanol for 3–5 min to make the sample completely dirt-free. The sample was cleaned in ethanol and dried before loading under the electron microscope. The top surfaces of the bare as well as coated specimens were analysed by CLSM, Field Emission Gun - Scanning Electron Microscopy (FEG-SEM) coupled with Energy Dispersive X-ray Spectroscopy (EDS). Samples from the inside wall of the annealing furnace were collected and characterised using FEG-SEM and EDS.

3. Results and discussion

3.1. General observations

The defect was tiny and appeared as an indentation mark on the galvannealed sheet with naked eye although, it was difficult to resolve. There was no pattern in the occurrence; rather it was randomly distributed throughout the full length of the galvannealed steel sheet. The defect density was highest at the edges and reduced along the width towards the centre of the sheet. The defect density was measured for each section for 20 numbers of samples in the scale of zero to five where zero corresponded to no defect and five being the highest. The average defect density map is shown in Fig. 2. The defect was observed on both top and bottom surfaces of the sheet with similar morphology.

3.2. Characterisation of the defect

The cross section of the defect was characterised with SEM as shown in Fig. 3. The average defect depth was about 35 µm and the width was about 100 µm. However, the depth at different defect locations varied from 10 µm to as high as 40 µm. The galvannealed coating at the defect location was found to be uniform and having similar thickness as that of the defect free location. Deformation of the steel surface was observed at the defect location (Fig. 3).