Engineering Failure Analysis 66 (2016) 455–467

Contents lists available at ScienceDirect

Engineering Failure Analysis

journal homepage: www.elsevier.com/locate/engfailanal

Investigation of a surface defect and its elimination in automotive grade galvannealed steels

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ARTICLE INFO

Article history:
Received 21 November 2015
Accepted 5 May 2016
Available online 6 May 2016

Keywords:
Surface coatings
Defects
Abrasive wear
Confocal Laser Scanning Microscopy
Fe–Zn intermetallic

ABSTRACT

The galvannealed coating have gained importance as a potential solution for auto body panels owing to their superior performance like weldability, paintability and after painting corrosion resistance. Efficient production of galvannealed strip through hot dip galvanising and subsequent annealing root is a challenge as occurrence of surface defects results in material downgrading and rejection. The present work deals with one type of surface defect present at the bottom surface of the galvannealed strip with high defect severity. The defect appearance was like a shining spot by naked eye. It was characterised using Optical Microscope, Scanning Electron Microscope coupled with Energy Dispersive Spectroscopy to analyse shape, size, morphology and composition. The defect was further analysed by Confocal Laser Scanning Microscope (CLSM). The features of CLSM like high resolution, high depth of focus, 3D surface topography were useful in determining the relative depth of the defect at different regions. The results indicated that the defect occurrence was due to mechanical abrasion of coating with deposited dust of Fe–Zn intermetallic phases at the galvannealing tower top roll. The production line parameters were modified to maintain the temperature and cleanliness of the top roll and a reduction in defect severity was achieved.

1. Introduction

Galvannealed steels have emerged as an important material for auto body outer and inner panels as well as for fuel tanks. The galvannealed coating which is an alloy coating of iron and zinc provides excellent weldability, formability and corrosion resistance after painting. The automotive outer or skin panels are critical grades to produce industrially. Small compositional variation in coating affects the coating formability adversely and might cause powdering, flaking etc. during panel forming. Furthermore the surface defects hamper the aesthetics, average surface roughness and thereby deteriorate the paintability. Therefore accurate process control, galvanising bath management etc. are essential to produce high quality galvannealed coatings.

However producing defect-free galvannealed (GA) materials from continuous processing line is difficult. Comprehensive literatures are available from researchers and manufacturers on different types of galvanised and galvannealed coating defects [1]. The defects can originate from two sources, firstly defects like sliver, rolled in scale, etc. from the cold rolled strip that further may aggravate post galvanising and galvannealing treatment. It was reported that the presence of defects prior to galvanising bath may result in uncoated spots and improper alloying after galvannealing [2–3]. Secondly the defects originating from the continuous galvanising line. The defects generated during galvanising and galvannealing were reported to originate from different sources such as improper air-knife arrangement [4–6], poor bath management [7–11] and improper alloying of GA [12–13]. Surface appearance was also affected due to defects originating from post galvanising treatment [14].

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http://dx.doi.org/10.1016/j.engfailanal.2016.05.010
1350-6307/

Table 1
Chemical composition of steel substrate (in wt.%).

C	Mn	S	P	Si	Al	Cu	Cr
0.0035	0.38	0.006	0.044	0.013	0.040	0.005	0.044

There was a new type of defect observed in continuous galvanising line #2 of Tata Steel, Jamshedpur, India. The defect looked like bright shining spots under visual inspection. The spots were very high in number. There was no specific pattern of the occurrence of the spots. These defects were randomly spaced only at the bottom surface of the strip. There was no particular pitch of the defects equivalent with any of the rolls in operation. These spots damaged the product quality severely.

In the present study we have examined this defect in detail to understand the origin of the defect. The macro structure as well as the microstructural features of the defect is analysed. The defect was characterised by visual inspection, optical microscopy, confocal laser scanning microscope, scanning electron microscope and energy dispersive spectroscopy. The probable root cause for the defect formation and possible elimination strategies are outlined.

2. Methodology

The galvannealed steel samples were collected from Continuous Galvanising Line #2 of Tata Steel Limited, Jamshedpur, India. The steel composition is given in Table 1. Galvanising and galvannealing process parameters are given in Table 2.

The defect regions looked like bright shining spots as observed in naked eye. The defect areas were marked and observed under Optical Microscope (OM). Samples were analysed using a Scanning Electron Microscope (SEM) coupled with Energy Dispersive Spectrometry (EDS) to examine the morphology and the compositions of the defect and defect-free areas. Point and area analysis and elemental mapping were done for regions of interest. The cross sectional analysis of the defect region was attempted, although, sample preparation was not successful due to extremely small size of the defect and no further information was obtained from the cross sectional images. The defect samples were further studied under Confocal Laser Scanning Microscope (CLSM). The instrument has been extensively used in the field of bio-medical engineering owing to the features like high resolution, high depth of focus, 3D surface topography etc. In the present study we have extended the uses of CLSM for non-destructive defect characterization. 2D along with 3D laser images were recorded from different areas. The relative depths of the defect at various positions were measured. Furthermore the galvannealed coating was stripped off using 10 vol.% sulphuric acid and the underlying steel substrate was exposed to analyse using the LSM.

3. Results and discussion

3.1. Structural analysis of the defect

The as-received sample is shown in Fig. 1. The regular galvannealed surface looked greyish in colour whereas these spots appeared shining bright. The shining spots are marked with arrowheads in Fig. 1. The shiny spots appeared only at the bottom surface of the galvannealed steel strip. There was no specific pattern of occurrence of the defect. The spots were spread throughout the length as well as across the width of the coil. The density of the defect was very high. The defects were present irrespective of the strip sections i.e. for all combinations of thickness and width.

The optical microscopic images of the spots are presented in Fig. 2. The shape of the spots under high magnification was like the English alphabets 'C' and 'J' or the mirror images of these alphabets, 'Ɔ' and 'ɭ'. Each of the spots when magnified under optical microscope revealed the same or similar shape. The width of the defect at different positions within the 'C' shape was marked and it appeared to be an average of 30–60 μm. The depth of the defect was not revealed from optical microscope images. It was interesting to note that all the defects maintained a certain positional relationship with the rolling direction, although there was no preferred positional orientation observed macroscopically.

The defects were further studied under SEM at lower (150×) and higher magnification (750×) as shown in Fig. 3. The surface morphology at defect regions was largely different from that of regular galvannealed coating surface.

The top surface of regular galvannealed coating usually has crystallites that are formed due to annealing treatment given after galvanising. The Fe–Zn crystals, mostly delta and zeta, are present at the top surface of the coating giving rise to desired surface roughness [15]. In the present samples, the defect free areas had Fe–Zn crystallites as well as skin pass marks, whereas both were absent in the defect region. The Fe–Zn intermetallic crystals were not observed from one end of the defect to another; although such crystallites were present surrounding the defect. A smooth surface was observed inside the defect region. The smoother region within the defect and accordingly specular reflection of light from it might be the reason for the shiny appearance of the defect.

Table 2
Operating parameters of the galvanising and galvannealing process.

Strip thickness	Line speed (mpm)	Zinc bath temperature (°C)	Zinc bath aluminium (wt.%)	Galvannealing temperature (°C)
0.8	90	470	0.135	500