ANALYSIS OF DEFECTS IN HOT DIP GALVANIZING IN STEEL STRUCTURES

[1]Amir, [2]Harpreet Singh, [3]Mohd Zahid Saifi
[1]M.Tech-student, [2]Assistant Professor, [3]M.Tech-student
[1]Mechanical Engineering Department
[1]Subharti Institute of Technology & Engineering, Meerut-250005, India

Abstract: As continuous up gradation and advancement in continuous galvanizing technology which is resulting improvements in quality of surface of hot dip galvanized and galvanized coatings, producing entirely blemish-free coatings which still stand out with challenging task. An in-depth study of these defects helps in identifying and employing prompt remedial measures to eliminate there occurrences. This paper researched by me reviews the commonly visible defects in continuously galvanized pipes products with their characteristics as studied by metallographic techniques and the means of eliminating them. Although almost every tiny defect in a galvanized coating may look like a grey spot, Less coating , ash, Black spots, peel off, lumps, Dross dimples,&Excess zincare only a small portion of the defects found in hot dip galvanized coatings. The normal size of intermetallic particles dipped in a bath < 15 µm. Such small particles are often found buried in the coating, patches of oxide skin taken up mostly on the corner of the coated strip so are not visible and distinguishable. As a matter of fact, most defects occur because of a rough or mechanically damaged substrate surface, insufficient cleaning of the substrate, poor maintenance of bath and poor handling of bath.. Thus, galvanizers producing coated products must improve quality of the incoming steel strip, the batch equipment, the batch line heat treatment zone and the coating bath in order to meet the stringent quality requirements for exposed automotive body panel applications. For batch producing both galvannealed as well as galvanized products, the additional challenges are to improve quality of chemistry of bath and to control galvannealingbatch to batch from bottom-dross formation, develop a galvannealing to galvanizing formation procedure to clear up or minimize the disturbance deposit bottom dross.

1. INTRODUCTION

In centralised steel plants where both hot and cold-rolled flat products or pipes, a significant proportion of cold rolled pipesproducts are galvanized for use in construction and automotive sectors. Continuous hot dip galvanizing operation entails joining, cleaning, annealing and cooling of cold-rolled steel strip to 455-460 oC before hot dipping in molten zinc (Zn) bath at 455-460 oC followed by post-treatment processes involving air wiping, chromate passivation, temper-rolling and, finally, coiling. The quality requirements of galvanized sheet products encompass a prescribed uniform coating grey spot, Less coating , ash, Black spots, peel off, lumps, Dross dimples, & Excess zinc with the steel substrate. Typically, hot dip galvanization baths make use of about 0.18-0.20% aluminium (Al), 0.10-0.20% lead (Pb) while restricting iron (Fe) to a level of 0.30-0.40% maximum for achieving high-quality coatings [1]. Al enhances the fluidity as well as the wettability of the zinc melt and also, aids in suppression of brittle Fe-Zn intermetallics at coating-steel interface by forming an “inhibition” or “barrier” layer of Fe2Al5 between the steel and the coating, thereby promoting the coating adhesion. Al is also known to improve the lustre and brightness of hot dip coatings and minimises the dross generation, to an extent, by forming an oxide (Al2O3) skin on the surface of molten zinc. Pb also lowers the surface tension and promotes the fluidity of molten zinc in much the same way as Al besides promoting the formation of “spangles” on the galvanized steel surface. Excess bath Fe, on the other hand, adversely affects the fluidity of molten Zn and leads to dull-appearing coatings with a poor peel-off resistance and adherence .

Although the surface quality of continuously hot-dip galvanized coatings has witnessed significant improvements in the recent years, it still remains a challenge to produce defect and blemish-free coatings for an exposed automotive body panel application. Continuous galvanizing of steel sheets basically involves chemical reactions between Fe, Zn and Al at temperatures above 450oC. As a consequence of bath-metal reactions, intermetallic particles constantly form in the bath, while Zn-Al oxide skin forms on the bath surface. Besides, the Fe-Zn intermetallics, which constitute the bottom dross, are in a continuous state of levitation due to the turbulence created by strip movement through the molten Zn bath. During continuous hot dip galvanizing, these intermetallic particles and surface skimmings can be easily dragged onto the coating. Intermetallic compounds can also grow on the surface of submerged hardware operating inside the bath. It is not uncommon for deteriorated surface quality of the submerged hardware to result in interior coating quality. Undesirable contaminants and pick-ups can be transferred from the hardware surfaces to the coatings The quality of the steel substrate can also strongly affect coating quality. Defects on the substrate surface, such as marks and indentations caused by mechanical damage, can be easily highlighted through the coating. Surface contaminants of the substrate, if not properly removed, can inevitably intervene with the coating process and result in bare spots. Most surface defects in galvanized steel sheets occur due to rough or mechanically damaged substrate surface, insufficient cleaning of the substrate or poor bath management and line equipment maintenance. Surface defects can be large or small. But in order to be considered noticeable and rejectable, they must be large enough to be seen with the naked eye (The resolution limit of human eye is 0.1 mm). Consequently, an objectionable defect is larger than 100 µm. When viewed under an optical microscope at high magnifications, such a defect can extend to more than one view field. Based on their origin, the surface defects encountered in galvanized and galvannealed sheet products can be broadly classified into six categories .

1. Defects originating from steel substrate

2. Defects associated with chemical cleaning

3. Defects originating from annealing furnace

4. Defects related to zinc bath

5. Defects originating from air jet wiping

6. Defects related to temper rolling

2. DEFECTS ORIGINATING FROM STEEL SUBSTRATE

Steel substrate defects, no matter how minute, do not get hidden by the zinc coating overlay in hot dip galvanized sheets. In fact, zinc magnifies those defects by reacting with the substrate, especially when the steel sheet is in full hard condition. Imperfections on the incoming steel sheet such as steel-making slivers, hot strip mill mechanical defects, scratches, surface damage during cold rolling, etc. cause Zn-Fe alloy outbursts at the steel-coating interface and/ or different dendritic zinc crystal orientation. Temper rolling makes these areas more prominent as a result of light reflectivity differences. Even tiny pimples in the substrate stand out and are mistakenly identified as dross. Some examples of commonly encountered defects relating to poor surface quality of steel sheet are discussed below .

Bare spots are uncoated areas caused by incomplete wetting during dipping. Good wetting requires that all mill scale, rusts and oxides, oils and cleaning solutions be removed, exposing clean steel surface. Galvanizers commonly produce exposed-quality galvanized coatings in baths containing Al in excess of 0.2%. Coatings produced in such baths appear shinier and are preferred by users. However, at high levels of bath Al, the requirement of substrate surface cleanliness becomes much more critical for a good wetting. Frequently, tiny uncoated areas can be found in such coatings, as shown in Figs.1(a) and (b). Also, high-strength steels such as dual phase and TRIP steels contain alloying elements such as Si, Mn, Cr and Al, which can segregate to the steel surface and get converted to oxides during in-line heat treatment. As a result, wetting frequently becomes a problem. Exfoliation or peel-off refers to the delamination of galvanized coating under application of external stress, as in bending, and is usually the result of poor adhesion between the coating and the substrate. One of the main reasons for the occurrences of above surface defects in hot dip galvanized sheets is

the poor surface cleanliness of the incoming cold rolled steel strip. Surface contaminants and cold rolling defects such as carry-over of cold rolling oil, emulsion, grease and oxidized rolling debris in the form of iron fines and particulates can leave residues on the strip inspite of in-line cleaning and annealing; leading to bare spots, on one hand, and poor adhesion at the coated areas on a galvanized steel sheet leading to coating exfoliation and peel-off, on the other hand.

Fig1. Bare spots in hot dip galvanized coatings [a] SEM micrograph, [b] Optical micrograph Figs.2(a), 2(b) and 2(c) depict the carry-over of cold rolling oil on a cold rolled strip sample and the typical appearance of bare spots encountered, as a consequence, in a hot dip galvanized steel sheet, manifesting as small and massive streaks respectively, with intermittently-dispersed thin zinc ribbons adhering to bare steel surface. Fig.2(d) shows a bare spot along with coating exfoliation and peel-off. Electron probe microanalysis (EPMA) in a through-thickness direction by back-scattered electron (BSE) imaging, X-ray elemental mapping and line profiling at the coated areas, as shown in Figs.3(a), (b) and (c), revealed delamination and presence of carbon at the steel-coating interface; indicative of carbonaceous residues resulting from burning of carry-over oil over the strip surface during annealing. Figs.4(a), (b) and (c) show a typical scanning electron micrograph taken along with energy-dispersive X-ray spectrometric (SEM-EDS) analyses of the surface features observed in a bare spot. The micrograph reveals random white patches on a dark-appearing uncoated and rough steel undersurface. Both dark and light areas reveal significant levels of carbon, suggestive of carbonaceous residues. The analysis confirms the white areas to be oxidized rolling debris consisting of iron fines from cold rolling. Figs.5(a), (b), (c), (d), (e) and (f) show SEM micrographs depicting both rolling debris at a bare spots as well as those entrapped at steel-coating interfaces, Zn-Fe intermetallic formation/ outbursts at coating-steel interface and the hemispherical appearance of the zinc ribbons on a bare spot with entrapped rolling debris and delamination between the steel and the coating.

Frequently, the remnants of iron fines generated during cold rolling and subsequently carried-over on the strip surface get partly converted into intermetallic compounds and can be found in coatings. An example is shown in Fig.6.

For a number of reasons, the reactivity of the substrate in molten galvanizing bath differs from one location to the other. Surface roughness and mechanical damage to the substrate during rolling processes, such as scratches, are the most common causes. Although galvanizing provides some levelling action to this unevenness on the substrate, surface roughness can still show through the coating, resulting in uneven coating thickness. In such cases, the resulting high spots associated with a thick coating are abraded in temper tolling. These areas are flatter than the surrounding coating and appear brighter. Fig.7 shows a cross-sectional view through a shiny spot. The coating was thicker than the surrounding coating and flattened by temper-rolling.

As is the case with iron fines, mechanical damage to the substrate can also induce Zn-Fe alloy growth (outbursts) in galvanizing. If the alloys grow through the coating thickness, gray or black spots will appear on the coating surface, as shown in Fig.8. High spots or bumps can also result from dross particle entrapment.

2.1 Substrate Scratches and Gouges

finished of Pickling - washing - plus help the bath - drying - hanging plating - cooling - Pharmaceutical - cleaning - polishing - completion of the hot-dip galvanizing, hot dip galvanized by the ancient method of hot-dipped development come since 1836, France had been used in industrial hot dip galvanized, has a history of 140 years. However, the hot-dip galvanizing industry the past three decades along with the rapid development and large-scale development of the cold-rolled steel strip.

With the discovery of the industrial, hot dip galvanized products have been applied to many areas, hot-dip galvanized advantage of the anti-corrosion service life for a long time, to adapt to the the antiseptic treatment method widely been very popular. Been widely used in power tower, communication tower, railway, road protection, light poles, marine components, construction steel structure components, substation ancillary facilities, light industry.

2.2 UN-GALVANISED WELD AREAS

Coating misses on weld areas are caused by the presence of welding slag on the welds. All welding slag must be removed by the fabricator prior to despatch to the galvaniser.

Fig-1

2.3 DARK STAINING ADJACENT TO WELDS

Fig-2

Preparation chemicals entering unsealed overlaps or through poor quality welds boil out of the connection during galvanising and cause surface contamination and coating misses during galvanising. Also, anhydrous fluxing salts left in the connection will absorb atmospheric moisture and leach out onto the adjacent galvanised surface. Leaching of these salts will eventually reach equilibrium. Affected areas should be washed clean to remove slightly corrosive leachate.

2.4 DROSS PIMPLES/INCLUSIONS

Dross is formed in the galvanising process in the form of zinc-iron crystals (approx 95% zinc – 5% iron) with a higher melting point than the metal in the zinc bath. Dross trapped in the galvanised coating may give the coating a rough or gritty appearance. The presence of dross inclusions in the coatings is not detrimental to the coating's performance as the corrosion resistance of zinc dross is identical to that of the galvanising coating.

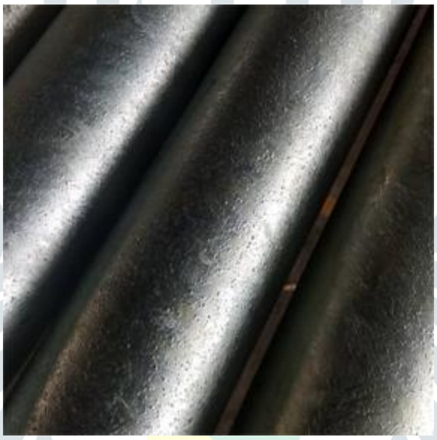

Fig-3

2.5 WET STORAGE STAIN OR BULKY WHITE DEPOSIT

A bulky white or grey deposit, known as wet storage stain may form on the surface of closely stacked freshly galvanised articles which become damp under poorly ventilated conditions during storage or transit. As such, wet storage stain on new galvanised surfaces is readily prevented by attention to conditions of storage and transport. Heavier deposits can be removed by brushing with a 5% solution of sodium or potassium dichromate with 0.1% by volume of concentrate sulphuric acid.

3. SPANGLED COATINGS

Some hot-dip galvanised coatings exhibit a high level of 'spangling' caused by zinc crystal patterns on the surface. This phenomenon arises with galvanising alloys produced in particular smelting processes and these alloys are commonly used for hot-dip galvanising. There is no difference in coating performance.

Fig-4

4. BARE SPOTS

Small localised flaws up to about 3mm wide in a galvanised coating are usually self-healing because of the cathodic protection provided by the surrounding coating. They have little effect on the life span of the coating. Bare spots may be caused by inadequate pretreatment, the presence of residual welding slags, rolling defects such as laps, field and laminations, and non-metallic impurities rolled onto the steel surface.

5. DULL GREY COATING

Grey coatings may appear as localised dull patches or lacework patterns on an otherwise normal galvanised coating or may extend over the entire surface. Dull grey coatings usually occur on steels with relatively high silicon content (>0.24%) which are highly reactive to molten zinc. Welds made with steel filler rods containing silicon may also produce localised grey dull patches. As such, it is rarely possible for the galvaniser to minimise or control the development of dull grey coatings which is dependent basically on the silicon content of the steel.

Fig-5

6. ASH STAINING

Zinc ash is formed in the galvanising process as the work is immersed in the zinc. The ash formed is skimmed off the surface of the molten zinc prior to withdrawing the work from the galvanising bath. Sometimes, ash is trapped inside inaccessible areas and sticks to the outside of the coating as the work exits the bath. Ash may leave a dull surface appearance or a light brown stain after removal. It does not affect the performance of the galvanising coating.

Fig-6

7. RUNS, DRAINAGE SPIKES AND PUDDLING

These defects are unavoidable in the hot-dip galvanising of general items and are acceptable as long as they do not interfere with the assembly of the function of the item or present a safety hazard in handling r service.

Fig-7

8. RUST STAINS

Rust staining on the surface of galvanised coatings is usually due to contact with or drainage from other corroded steel surfaces. Staining arises from corrosion of the iron content of zinc-iron alloy coating and is therefore outside the control of galvaniser. It has no effect on the corrosion resistance of the coating.

9. DELAMINATION

Heavily galvanised coatings (over 250 microns thick) may be brittle and delaminate from the surface under impact and requite more careful handling in transport and erection. Thin, cold rolled items with very smooth surface finish and manufactured from reactive steel may also give rise to coating delamination.

9.1 Principle

hot dip galvanized iron pieces cleaned, and then the solvent treatment, drying after immersion in liquid zinc, iron, and the reaction of molten zinc alloyed zinc layer, its processes: the skim - washing - pickling - the fluxing - drying - hot-dip galvanized - separation - cooling passivation.

Galvanizing alloy layer mainly depends on the thickness of the silicon content of the steel chemical composition, the rough degree of the size of the cross-sectional area of the steel surface of the steel, the temperature of the zinc pot, the zinc immersion time, the cooling speed, and the cold deformation.

9.1.1 Hot-galvanized advantages

low-cost processing: hot-dip galvanized anti-rust lower cost than the cost of other paint coating; Durable: standard hot dip galvanized rust thickness can be kept for 50 years or more in the rural environment, without having to patch; standard hot dip galvanized rust layer can be maintained for 20 years in the urban areas or offshore area, without having to patch; good reliability: galvanized layer with steel is metallurgically bonded to become a part of the surface of the steel, and therefore more reliable coating persistent;the toughness of the coating: zinc coating to form a special metallurgical structure, this structure can withstand transportation and use of mechanical damage; full protective: plated parts each part can be plated with zinc, even in the recesses, sharp corners and hiding places can be fully protected; saving time and effort: the the galvanizing process faster than other coating construction method, and can avoid the the brushing time required on site after installation.

9.1.2 Specification

A hot-dip galvanized coating is relatively easier and cheaper to specify than an organic paint coating of equivalent corrosion protection performance. The British, European and International standard for hot-dip galvanizing is BS EN ISO 1461 which specifies a minimum coating thickness to be applied to steel in relation to the steels section thickness e.g. a steel fabrication with a section size thicker than 6 mm shall have a minimum galvanized coating thickness of 85 µm.

10. DEFECTS RELATED TO TEMPER-ROLLING

Due to the sliding friction between the hard work roll surface and soft zinc coating on the strip, zinc pickup on the work roll and consequent imprint on strip surface during rolling, especially on stand-alone temper mills even with wet rolling, is a frequent problem. Although work roll polishing and wet rolling solution practices have been developed to combat this problem, a practical solution to totally prevent pickup has yet to be developed.

11. CONCLUSIONS

It is technically difficult to produce entirely defect and blemish-free galvanized and galvannealed coatings for applications such as exposed automotive body panels. Coating defects are tiny, and instruments to identify their nature are not readily available to line operators. Consequently, most of the defects are believed to be dross pick-up. However, studies indicate that dross entrapment in coatings constitutes only a small portion of all the defects encountered in continuously galvanized sheets. Most defects are the result of poor substrate surface quality, insufficient strip surface cleaning, poor bath chemistry management and inadequate line equipment maintenance. The entrapment of dross particles large enough to be spotted by unaided eyes may occur during galvannealing to galvanizing transitions when bottom-dross particles are floated up following a significant increase in the bath effective Al level. Such dross particles are accumulated at the bottom of a bath during the galvannealing campaign and grow to a large size (>100μm). If the line solely produces galvanized products and the bath surface is constantly skimmed, it is not likely that dross particle entrapment in coatings will occur frequently. Studies have also shown that top-dross particles could be entrapped in coatings if bath surface oxide film is caught on the strip. Top-dross particles always segregate to the bath surface and co-exist with the oxide film. This finding points to the importance of maintaining a clean bath surface, free of oxide film. Dross particles in coatings may also come from the following sources: They grow in-situ at the coating-substrate interface because the effective Al level in the bath is relatively low and the strip entry temperature is relatively high. Under normal circumstances, the formation of discrete Zn-Fe crystallites in a coating is not detectable without sectioning the coating. Nor would they noticeably affect the adhesion and ductility of the coating.

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