TECHNICAL NOTE
Differing Appearance

Issue 1, April 2017

Preface

This document is intended to inform readers about potential surface conditions resulting from batch hot dip galvanizing through the provision of visual and written guidance. AS/NZS 4680 provides guidance in the area of allowable surface conditions after galvanizing, however identification of a non-conforming surface condition of a galvanized article will depend on the stated end use of the product and the extent and nature of the damage to the coating. This document is not intended to replace guidance provided by an expert, such as a galvanizer or accredited hot dip galvanizing inspector, who may be consulted when issues with the surface condition arise.

Description

Differing appearance describes the variations in the finish of the galvanized coating over different regions of a single article or fabrication, which may include any combination of shiny, dull, mottled, or spangled appearances. Each of these conditions has their own Technical Note detailing the different causes and effects (see *Dull Grey Appearance, Mottled Appearance,* and *Spangle*). This document mainly describes areas of shiny or dull appearance caused by the cooling rate after galvanizing, resulting in differing appearance across a single article.

Cause

Differing appearance is the result of the coating structure at the outer surface of the galvanizing. When the steel is submerged in the molten zinc its temperature rises to match the galvanizing bath temperature (usually around 450°C). A metallurgical reaction occurs between the zinc and steel, which creates zinc-iron alloy layers at the interface between the molten zinc and the steel. During withdrawal, a layer of the molten zinc is drawn out on top of the zinc-iron alloy layers and this forms the eta layer in a typical galvanized coating, as seen in Figure 1. Some steels have a combination of silicon and phosphorous levels which make the galvanizing process continue after withdrawal from the bath and commonly cause the alloy layers to grow, resulting in full consumption of the outer zinc layer and duller grey appearance of the zinc-iron alloy.

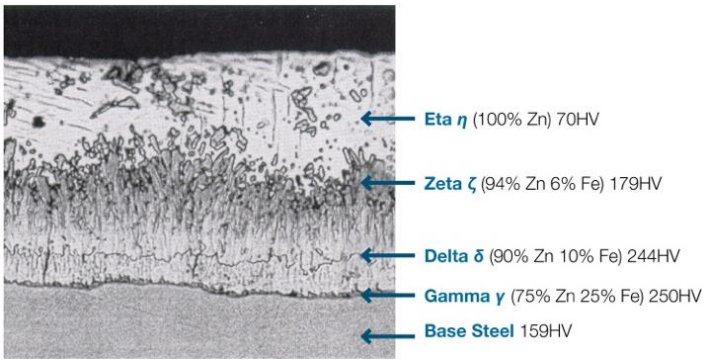

Figure 1: A photomicrograph which shows the alloy layers present in a typical galvanized coating.

The cooling rate after galvanizing also influences alloy layer appearance. When articles have thicker steel areas, they retain heat for longer, which can allow the reaction between the zinc and steel to continue if the temperature stays sufficient. This can cause the alloy layers to grow to the surface in places and develop duller coatings as in Figures 2-3. While the article is being withdrawn, its lower surface may be exposed to radiant heat from the bath or molten zinc draining from the article for a longer period, especially if hung at an angle close to horizontal. This heat at the lower surface can allow the reaction between the zinc and steel to continue and result in a dull appearance. This is the probable cause for the appearance of the coatings seen in Figures 4-7.

During the withdrawal process the top of the article cools quickest, being furthest from the bath and exposed to the lower ambient air temperature first. This can cause the zinc at the top of the article to lose fluidity as it cools, preventing it from running freely down the sides of the article and resulting in a thicker, shiny eta layer on the top surface (see *Lumps and Runs*). This effect can occur in combination with exposure to the bath temperature, with a slower withdrawal speed converting zinc that runs to the lower surface into duller alloy layers.

For a fabricated article, if the steel sections comprising the article have a large variation in steel composition (i.e. different sections use steel from different Categories in Table 9.1 of AS/NZS 2312.2), their differing reactivity will generally result in a varied appearance across the different steel sections, as seen in Figures 8-12.

Prevention

Differing appearance can be minimized by:

- Minimising extreme thickness variations where possible
- Ensuring all steel that comprises a fabricated article has a similar steel composition, e.g. all from the same Category in Table 9.1 of AS/NZS 2312.2
- Ensuring venting and draining holes are adequate to allow more control over immersion and withdrawal times

When cooling effects cause the differing appearance during withdrawal from the bath, preventing the differing appearance can be difficult. The following may need to be considered if changing the withdrawal parameters has not been successful and a uniform appearance is necessary:

- Increasing the fluidity of the zinc to increase the draining rate by either modifying the zinc bath chemistry (e.g. aluminium and nickel levels).
- Hanging non-circular articles with an edge running along the top to promote zinc run off.
- Changing the design of long articles, e.g. using smaller lengths and bolted connections to allow steeper withdrawal angles to be achieved. This allows the part to be withdrawn faster and prevents the bottom of the article from being exposed to the heat of the galvanizing bath for long periods.

Effect

The appearance of the galvanized article can vary significantly over a single article, having:

- Both shiny and dull sections
- A similar colour throughout most of the article with some dull areas (usually where a thickness variation or change in cooling rate occurs)

Differing initial appearance does not affect the corrosion protection properties of the coating and the overall appearance will usually become uniform as the coating weathers with time and exposure.

Acceptability

Differing appearance is acceptable when galvanizing to AS/NZS 4680, if the coating thickness is above the minimum required. AS/NZS 4680 gives the following information on the initial appearance of a galvanized article:

- Special requirements for the surface condition of an article require arrangements with the galvanizer prior to galvanizing (see Note 3 of Clause 7 of AS/NZS 4680).
- Steels of certain compositions or articles that cool slowly after galvanizing can cause a coating partly or wholly grey in colour, which is acceptable provided it has adequate adhesion (see Note 6 of Clause 7 of AS/NZS 4680).

Responsibility

Differing appearance can be caused by the designer/fabricator, when venting and draining holes are inadequate, giving less control over the immersion and withdrawal speed. Large variations in steel thickness during the design phase can also result in differing appearance.

In most cases the initial appearance is outside the control of the galvanizer, as the reaction between the steel and zinc proceeds naturally when immersed in the zinc and while being withdrawn. Articles generally have to be withdrawn within certain rates to allow zinc to drain/run off completely while limiting the exposure of the bottom surface to the temperature of the bath.

Remedy

The initial appearance of the galvanized coating can be modified by:

- Spraying small areas that are aesthetically displeasing with silver spray to provide a **temporary** colour match. Note that most silver sprays do not weather in appearance with the galvanized coating and will remain shiny after the dull grey zinc patina has formed.
- Providing heat treatment to the galvanized coating to cause the shiny pure zinc to convert to dull alloy layers, giving a uniform appearance (damage to the coating may occur if exposed to direct flame).
- Quickly dipping a galvanized article in hydrochloric (pickling) acid or washing with a dilute weak acid solution followed by a thorough rinsing with water may promote faster patina growth and result in a uniform dull grey appearance.

Since the dull grey appearance is the result of alloy layers at the surface from the metallurgical reaction between the zinc and steel, the appearance cannot be changed from a dull finish to a shiny finish. The coating will eventually change to a more uniform grey colour as the zinc naturally weathers in the atmosphere and forms its protective patina.

Examples

Figure 2: The thicker plate has cooled more slowly in the centre, causing a dull grey finish where alloy layers have grown to the surface.

Figure 3: The thick steel behind the beam has caused slower cooling of the web in places, resulting in a duller coating.

Figure 4: The darker section of this beam has likely spent more time over the galvanizing bath while the zinc drains off. The mottled appearance is indicative of the alloy layers growing to the surface in some places.

Figure 5: A well-defined barrier between shiny and dull sections could be a result of prolonged bath temperature exposure or the zinc cooling and losing fluidity during run off.

Figure 6: The duller section of the pipe has been exposed to the bath temperature for longer, with the shiny section consisting of pure zinc.

Figure 7: A small shiny section can be seen in the bottom right of the image, likely caused by the surface cooling at a different rate.

Figure 8: Steels with different chemical compositions on the straight and curved sections have been used, resulting in the straight sections being shiny and the curved sections dull.

Figure 9: Steels of different compositions have been welded together in a straight square hollow section, resulting the differing appearance.

Figure 10: A close up of steel of different compositions being joined in a square hollow section, which is acceptable as long as the coating is sufficiently adherent.

Figure 11: A circular hollow section comprising of steel with different compositions holding up a shade cloth. The colour different is purely aesthetic and has no influence on the corrosion resistance of the part.

Figure 12: The round ball component of a handrail stanchion has been made from less reactive steel, resulting in a shinier appearance.