GalvInfoNote 1.4	55% Aluminum-Zinc Alloy-Coated Steel Sheet REV 1.2 DEC 2017

Introduction

The most widely used metallic coating for the corrosion protection of steel is zinc (galvanize). It offers a very good combination of galvanic and barrier protection. Its excellent performance for many applications is well documented. However, in the desire to improve, there is always a quest to find even better products. Researchers continually attempt to develop superior steel coatings that can be commercially applied. Often, the target is to find better products for specific end uses or environments, e.g. ones having superior corrosion resistance, or better coating formability. These attempts meet with little success most of the time, due either to an undesirable product attribute, or because manufacturing is too expensive or difficult, but every so often a breakthrough coating is discovered.

One hot-dip product that was successfully developed is 55% aluminum-zinc alloy-coated steel sheet. This product is known by many different trade names throughout the world. **Galvalume®** is the most widely used name. It is a registered trademark of BIEC International Inc., and is used by many of its licensed producers, including ArcelorMittal Dofasco Inc. Steelcscape Inc. uses the trademark **ZINCALUME®** for this product, while Ternium brands it as **Cincalum-Galval®**. Following its introduction in 1972, Galvalume® was well received in the marketplace, particularly for metal building roofing. The cumulative worldwide production now exceeds 70 million tons[1], with an annual production level currently approaching 7 million tons. Steel sheet with this coating has proven to be an excellent product for long-life building cladding, especially low slope roofing on industrial buildings. It has been widely applied as bare (unpainted) sheet with the coating being directly exposed to the atmosphere. The product is also used as a substrate for prepainted sheet and this use has also grown significantly. The ASTM product specification for 55% Al-Zn coated sheet is A792/A792M, and the prepainted sheet version is specified in A755/A755M.

Galvalume® alloy-coated sheet has performed extremely well for over 35 years, particularly in the case of unpainted, low-slope roofing.

In this GalvInfoNote, the basis for the excellent corrosion performance of 55% aluminum-zinc alloy-coated steel sheet is explained. More information can be obtained at www.galvalume.com/

Manufacture

The exact composition of the 55% Al-Zn alloy is more precisely 55% aluminum, 43.5% zinc and 1.5% silicon. Although the corrosion performance is primarily related to the composition and microstructure of the aluminum-zinc alloy coating, the addition of approximately 1.5% silicon is vital. The purpose of the silicon is to control the growth of a brittle intermetallic layer that would otherwise form during manufacture of the product. (*Refer to GalvInfoNote 2.4 for a discussion of a similar, but thinner, intermetallic layer that forms when steel is zinc-coated using the hot-dip process)*.

As with hot-dip galvanized sheet, controlling the interaction between the steel sheet and the molten coating during the manufacturing process is vital to achieve good adhesion of the coating during eventual forming operations by the customer. Even so, the intermetallic alloy layer is hard and brittle and it is therefore important for this layer to be kept as thin as possible. This is the role of silicon in a 55% Al-Zn bath. It dramatically restricts growth of the alloy layer, allowing the product to be readily formed after manufacture. The silicon is not added to enhance the corrosion performance.

In some applications, especially those that involve deep drawing, the coating adhesion of the as-produced product is not as good as that of a galvanized coating. The inhibition of the alloy layer growth is not as effective with the addition of silicon to a 55% Al-Zn bath as it is when aluminum is used in a

galvanizing bath. For this reason, and also for reduced galling behavior, galvanized sheet is often the preferred product when deep drawing, bi-axial deformation is involved. However, advancements in coating technology, in particular the use of clear resin coatings (usually designated as “55% Al-Zn Plus”), permit it to be used for some deep drawing applications.

Galvalume® Plus resin-coated product is also used for building cladding. This clear coating prevents black scuff marks from the roll forming operation, and from construction activities. Without it, contact with the forming rolls in roofing sheet lines can leave permanent black abrasion lines on the sheet surface. Workers constructing roofs can leave handprints and boot marks that turn dark and remain visible for years.

Galvalume® sheet products are coated on processing lines that are almost identical to those used to produce galvanized sheet, and which are described in GalvInfoNote 2.1. In many cases, production lines that produce 55% Al-Zn coatings are dedicated to this product, although there are lines that can produce two coatings by using dual interchangeable coating pots.

Coating Microstructure

The microstructure of the 55% Al-Zn coating is shown in Figure 1. The coating has two principal phases in its microstructure. One phase is the primary aluminum-rich dendritic phase that begins to grow initially during solidification. The other is an interdendritic zinc-rich region that forms when the zinc concentration in the solidifying liquid reaches a high level. The origin of these phases is explained by reference to the aluminum-zinc phase diagram, and is beyond the scope of this GalvInfoNote. This microstructure; aluminum-rich dendrites plus a network of zinc-rich interdendritic areas, is essential to obtain the desired corrosion resistance. Other phases in the microstructure of the coating include small discrete needles of elemental silicon, and the intermetallic layer at the steel-coating interface.

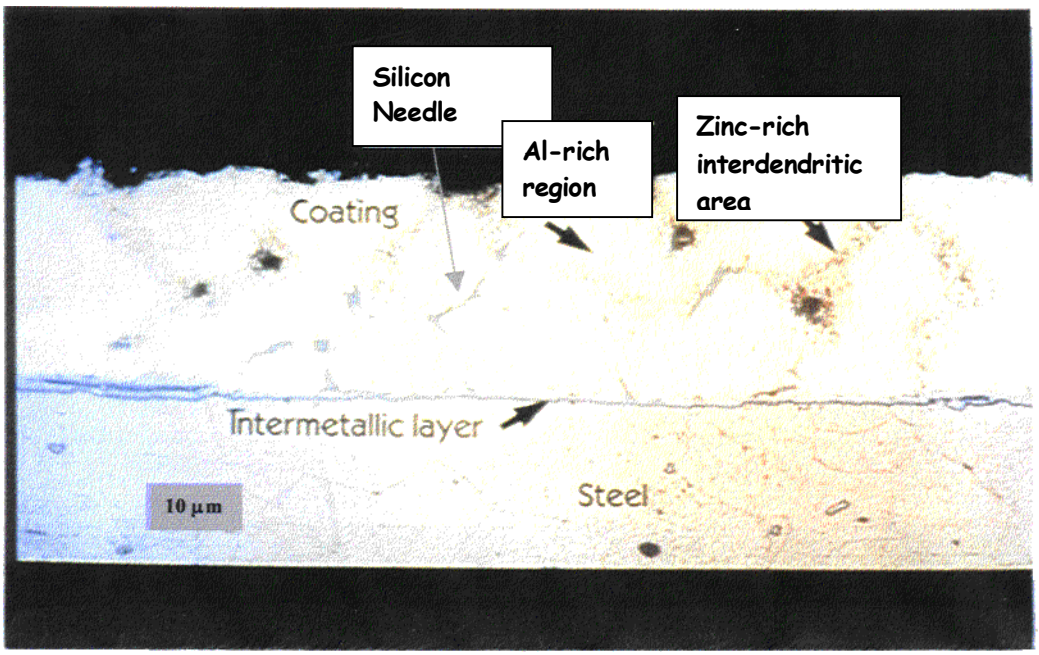

Figure 1: Microstructure of 55% Al-Zn Coating (note the interdendritic zinc-rich areas)

The coating relies on an extensive labyrinth of zinc-rich regions throughout the microstructure to optimize the anti-corrosion performance. This labyrinth forms during the post dip cooling section.

Corrosion Resistance

Table 1 contains corrosion performance data comparing the performance of 55% Al-Zn with galvanized coatings. The data[2] indicate that the performance is superior versus galvanize coatings in all three types of environments – marine, industrial and rural.

Table 1: Ratios of Average Corrosion Rates of 55% Al-Zn and Galvanize Coatings[3]

Location	Ratio of Average Corrosion Rates 55% Al-Zn: Galvanized*
Kure Beach, NC 25-meters (Severe Marine)	3.8
Kure Beach, NC 250-meters (Moderate Marine)	8.2
Bethlehem, PA (Industrial)	6.4
Saylorsburg, PA (Rural)	18.7

*Ratio gives the relative improvement of the 55% Al-Zn coating versus galvanize for coatings of approximately the same thickness (G90 [Z275] galvanize and AZ50 [AZM150] Galvalume®). Note: since the density of the 55% Al-Zn coating is much lower than for the galvanize coating, coatings with the same thickness (20 μm) are much lighter for 55% Al-Zn (150 g/m^2) than for galvanize (275 g/m^2).

The unique dendritic structure of the alloy coating is now widely recognized as the primary reason for the improved corrosion resistance of the 55% Al-Zn coating. When it is exposed to the environment, the zinc-rich areas corrode first. Since these areas are located in a labyrinth of interdendritic regions in the coating, the products of corrosion tend to fill the interdendritic interstices and the corrosion rate decreases[4]. This leads to a flattening, parabolic corrosion rate curve in most environments. This contrasts with the linear behavior typical of galvanize.

Corrosion of a 55% Al-Zn coating is therefore not the uniform thinning process of a galvanized coating. During the early stages of the product life, the aluminum-rich dendrites are largely unaffected by most environments. In a sense, the aluminum-rich dendrites perform like a barrier coating, while the zinc-rich areas provide the galvanic protection that is needed to minimize the tendency for rust staining at sheared edges and other areas of exposed steel.

The most common coating designations for 55% Al-Zn product to be used in outdoor environments are AZ50 [AZM150], AZ55 [AZM165], and AZ60 [AZM180], as described in ASTM Specification A792/A792M. The AZ50 [AZM150] coating is approximately as thick as a G90 [Z275] galvanize coating. The product is also used for corrugated steel pipe with a coating of AZ70 [AZM210] as described in A929/A929M. Furthermore, it is specified for use as cold-formed steel framing in A1003/A1003M with a coating designation of AZ50 [AZM150].

Refer to GalvInfoNote 1.1, pages 6 & 7, for a full explanation of these coating designations and how they are related to coating thickness.

There are two notable exceptions to the improved corrosion performance of 55% Al-Zn coated sheet versus galvanized sheet.

1. The most important exception is its performance in animal confinement buildings for swine, cattle, and poultry. Buildings that house these intensive farming activities present problems for 55% Al-Zn alloy-coated sheet. They buildings can produce waste decomposition by-products, which can be extremely aggressive towards this coating, creating significant corrosion problems[5]. Some producers[5, 6] neither recommend nor warrant the use of 55% Al-Zn alloy-coated sheet (bare, for animal confinement buildings.
2. Bare 55% Al-Zn alloy-coated sheet should not come in contact with wet concrete. Concrete's high alkalinity quickly attacks the aluminum, causing the coating to become porous and prone to corrosion[6, 7]. The product should not even be used in contact with dry, fully cured concrete in applications such as bottom tracks of exterior steel-framed walls. If they get wet, the resulting alkaline pH can be aggressive to 55% Al-Zn, and even to a lesser degree with Plus coated material.

High Temperature Resistance

Due to the high aluminum content of the 55% Al-Zn coating the sheet can withstand surface temperatures of up to 750°F [400°C] without discoloration, and up to 1200°F [650°C] without heavy oxidation and scaling.

Summary

The composition of the aluminum-zinc alloy used in 55% Al-Zn coatings has been proven to outlast galvanized steel by two to four times, depending on the environment. Building panels fabricated from 55% Al-Zn alloy-coated steel sheet will provide many years of trouble-free service when properly designed, installed and maintained.

References:

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