GalvInfoNote	Galvalume® Coated Steel Sheet
12	Galvalume® is a trademark of BIEC, International, Inc. Rev 2.1 Aug-03

Introduction

The most common metallic coating for corrosion protection of steel is a zinc (galvanized) coating. It offers a very good combination of galvanic and barrier protection. Its excellent performance for many applications is well-documented. However, there are applications where a "longer product life" is desired. As a result, researchers have through the years tried to develop improved coatings for steel sheet that can be applied commercially. Often, the target was to develop an improved product for specific end uses through improved corrosion resistance, improved formability, etc. Most often, these attempts met with difficulties, either with respect to an important ancillary product attribute or because it was too expensive or difficult to manufacture.

A hot-dip product that has been developed commercially is known most familiarly in North America as Galvalume® coated-steel sheet. It has been successfully received in the marketplace, especially for metal-building roofing. The coating on Galvalume is comprised of approximately 55% aluminum, 43.5% zinc, and 1.5% silicon. In the construction trade, Galvalume is known as an excellent product for long-life roofing sheets, especially low-slope roofing on industrial buildings. For low-slope roofing, the product is applied mostly as a bare (unpainted) roofing sheet; the coating is directly exposed to the atmosphere. Galvalume steel sheet is also used as a prepainted sheet when a more decorative finish is desired.

When used for low-slope roofing, Galvalume has been shown to perform well for over 20 years, and in many cases over 25 years, without failure. Often, the roof retains its bright metallic finish after 25 years in areas where the atmosphere does not contain too much particulate matter.

In this GalvInfoNote, the basis for the excellent corrosion performance of Galvalume will be explained. Since the product is known by many different trade names throughout the world, the term **55Al-Zn** will be used in the following text. Essentially, all 55Al-Zn coated steel sheet exhibits similar performance.

Manufacture

Throughout this discussion, remember the true composition of the 55Al-Zn coating is more precisely 55% aluminum, 43.5% zinc and 1.5% silicon. Although the corrosion performance is mostly related to the aluminum-zinc alloy, the inclusion of approximately 1.5% silicon is vital. The primary purpose for adding silicon is to minimize the growth of the brittle intermetallic layer that forms when the product is being manufactured. *Refer to GalvInfoNote #10 for a discussion of the alloy layer that forms when steel is zinc-coated using the hot-dip process*. Silicon is a very essential addition; without it the 55Al-Zn product could not be made using the hot-dip process.

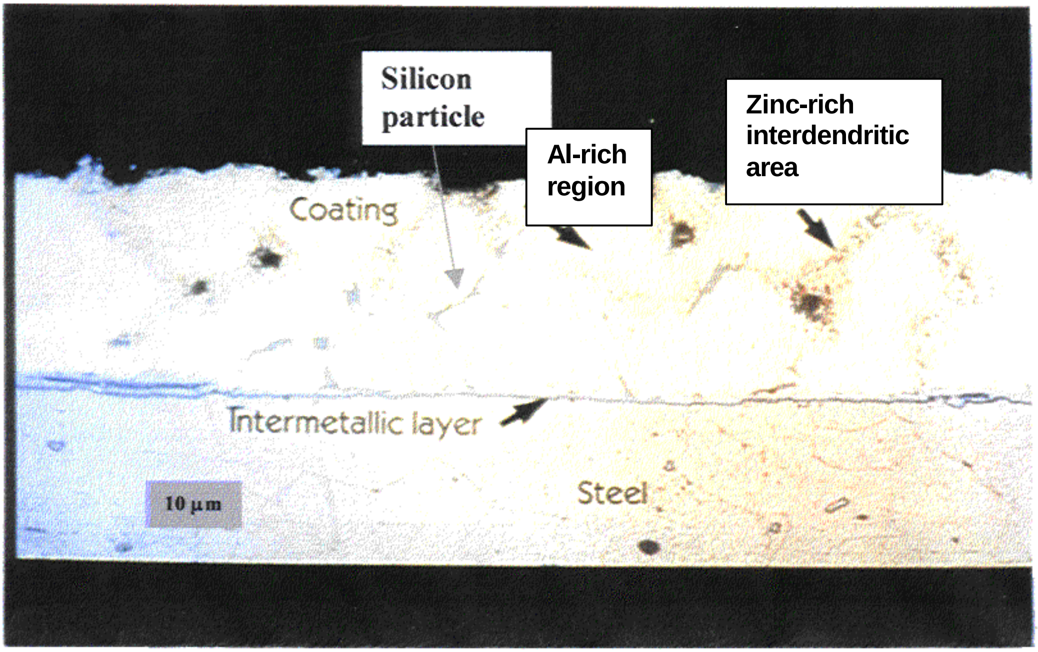
As with hot-dip galvanized sheet, the interaction between the steel sheet and the molten coating during the manufacturing process is very important to achieve good adhesion of the coating during eventual forming operations by the customer; however, the intermetallic-alloy layer is hard and brittle. It is important, therefore, for the alloy layer to be kept as thin as possible. This is the role of silicon in a 55Al-Zn bath. It dramatically restricts growth of the alloy layer, which allows 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 is not as good as that for a galvanized coating. The inhibition of the alloy-layer growth is not as effective with the addition of silicon to a 55Al-Zn bath as that when aluminum is used in a galvanizing bath. For this reason, and also for reduced galling behaviour, galvanized sheet is often the preferred product when deep drawing is involved.

There are some differences in the production practices needed to make 55Al-Zn coated sheet compared with the manufacture of galvanized sheet. These differences are not dramatic, but they are significant for the attainment of a well-coated steel sheet.

Coating Microstructure

The microstructure of the 55Al-Zn coating is shown in the photograph below. 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 layer include small discrete particles of elemental silicon, and an iron-rich phase which results because the coating bath becomes saturated with iron during the production process.



Microstructure of 55 Al-Zn coated sheet.
Note the interdendritic zinc-rich areas.

Because the coating has to have the extensive labyrinth of zinc-rich regions throughout the microstructure, the cooling rate during the solidification step (freezing of the coating) has to be controlled by the producing mill. This is one aspect of the production process where the process needs to be more rigorously controlled than during the manufacture of hot-dip galvanized sheet.

Corrosion Resistance

The following table contains corrosion performance data comparing the performance of 55Al-Zn with galvanized coatings. The data indicate that the performance is superior versus galvanized in all three types of environments, marine, industrial and rural.

Ratios of Average Corrosion Rates of 55Al-Zn and Galvanized Coatings

Location	Ratio of Average Corrosion Rates 55Al-Zn: Galvanized*
Kure Beach, NC 25-meters (Severe Marine)	4.2
Kure Beach, NC 250-meters (Moderate Marine)	2.3
Bethlehem, PA (Industrial)	6.2
Saylorsburg, PA (Rural)	3.4

*Ratio gives the relative improvement of the 55Al-Zn coating versus galvanized

Source: A. Humayun, *The Basics of 55% Al-Zn Coated Sheet's Legendary Performance*, National Conference on Coil Coating and Continuous Sheet Galvanizing, New Delhi, India, Sept. 10-11, 1997

The unique dendritic structure of the coating is given as the primary reason for the improved corrosion resistance. When the coating is exposed to the environment, the zinc-rich areas are corroded 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.[1] This leads to a parabolic corrosion rate in most environments. This contrasts with the linear behaviour typical for galvanized.

Corrosion of the coating for the 55Al-Zn product is therefore not the uniform-thinning process as it is for a galvanized coating. During the early stages of the product life, the aluminum-rich dendrites stay fairly much unaffected in 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.

Because the corrosion resistance depends very much on the microstructural features of the coating, it is more important to have the right microstructure than a thick coating. It has been found that in order to achieve the desired microstructure during production, the coating thickness must not be too thin. For this reason, the most common coating designations for product to be used outdoors in the environment are AZ50, AZ55, and AZ60, as described in ASTM A792/A 792M Specification. The AZ50 coating is approximately as thick as a G90 galvanized coating.

[1]This aspect of corrosion of Galvalume is explained more fully in a paper by H.J. Cleary entitled *The Microstructure and Corrosion Resistance of 55% Al-Zn Coatings on Steel Sheet*, 16th Annual Technical Meeting of the International Metallographic Society, July, 1983.

There are several notable exceptions to the improved corrosion performance of 55Al-Zn-coated sheet versus galvanized. Perhaps, the most important one is the performance in closed animal-confinement structures in cold climates, especially structures housing cattle and hogs. The 55Al-Zn coating is not recommended for concentrated confinement of cattle and hogs[2] in cold climates; regions where overnight condensation is a usual condition. In these types of applications, the coating is susceptible to pitting corrosion. For poultry buildings, the product has been observed to perform well.

[2]Reference: *Performance of Galvalume Sheet in Animal Confinement Applications,* Bethlehem Steel Technical Bulletin, May, 1990