GalvInfoNote 1.9

Zinc-5% Aluminum Alloy-Coated Steel Sheet

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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 coating that was successfully developed is zinc-5% aluminum (Zn-5% Al) alloy-coated steel sheet, the most popular version of which is known throughout the world as **GALFAN**. It is a registered trademark of the Galfan Technology Center, Inc. (GTC) http://galfan.com/home.html. This website lists all the active producing Galfan® licensees.

The GTC website summarizes the history of Galfan® as follows:

> "Galfan® as a trademark has been around since the International Lead Zinc Research Organization (ILZRO) obtained worldwide patents on this new alloy for anti-corrosion coating in 1981. This grew from an ILZRO-organized project co-sponsored by Arbed, Cockerill Sambre, Usinor and Sacilor (now all part of ArcelorMittal), British Steel, Fabrique de Fer de Maubeuge (now all part of Corus), New Zealand Steel (now part of Bluescope), and Stelco (now U.S. Steel Canada) at the Centre de Recherches Metallurgiques (CRM) in Belgium. This project showed that an alloy combining 95% zinc, nearly 5% aluminum, plus specific quantities of rare earth mischmetal, could be reliably used in the hot-dip coating process, and conferred substantially improved performance to the end-product. Licenses to use the revolutionary Galfan® technology have been granted to manufacturers worldwide.
>
> "The name Galfan® was given to the new alloy product during a business meeting one evening after the first large-scale production campaign at Sacilor's, Ziegler S.A. works in Mouzon, France on July 8-10, 1981. Upon reviewing the success of this campaign, in which 150 tonnes of coils were coated, with high quality product obtained after running the first 250 meters of strip through the continuous coating line, J-L. Pagniez, head of the French Coated Steel Information Center (CITAG), christened the product "galvanisation fantastique". This was shortened to Galfan®, and this name was then trademarked by ILZRO."

The ASTM steel sheet product specification for Zn-5% Al alloy-coated sheet is A875/A875M. The coating is available in two types: Type I alloy coating contains small additions of rare earth mischmetal (Zn-5Al-MM) and is what is used to produce sheet under the trade name Galfan®. Type II contains 0.1% magnesium (Zn-5Al-Mg). Zinc-5% Al alloy-coated sheet is also manufactured and sold under other trade names.

Both Type I and Type II can be used for prepainted sheet as specified in A755/A755M.

Specifications EN 10214 and ISO 14788 are other documents that can be used to specify Zn-5% Al coated sheet.

Manufacture

In the 1970s, research in America, Europe, and Japan experimented with zinc coatings containing up to 15% aluminum. This research found that zinc with 5% aluminum provided the best corrosion resistance but the problem of small, unwetted bare spots stymied commercialization of the alloy as a coating[1].

Research that ILZRO later commissioned CRM to conduct on the Zn-5% Al system determined that the addition of small amounts of rare earth mischmetal[1] containing cerium and lanthanum improved fluidity, wettability, coating ductility, and inhibited intergranular corrosion. This mischmetal formulation is what later became known as Galfan®.

Composition of the mischmetal-bearing alloy used to produce GALFAN is specified in ASTM B750. The technology used to manufacture this alloy is *licensed technology*[1]. Also, see GalvInfoNote 5.2 for the specified chemistry limits.

Galfan® 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 some cases, production lines that produce Zn-5% Al coatings are dedicated to this product, although most lines that produce GALFAN also produce galvanize through the use of dual, interchangeable coating pots.

Coating Metallurgy and Microstructure

Zinc with 5% aluminum is a *eutectic alloy*. A *eutectic composition* is that ratio of elements having the lowest melting temperature, and is located at the intersection of the elements' liquidus curves in a *phase diagram* (a representation of what occurs when elements are mixed together). The *eutectic* is a unique temperature-composition *point* for two or more elements. Lowering the temperature to just below the *eutectic temperature* results in a reaction where the all of the liquid mixture freezes to a complete solid at that temperature. In non-eutectic mixtures, freezing occurs over a range of temperatures, and elements can segregate into phases. For more information on this phenomena refer to literature about the zinc-aluminum phase diagram, as a more detailed explanation here is beyond the scope of this GalvInfoNote.

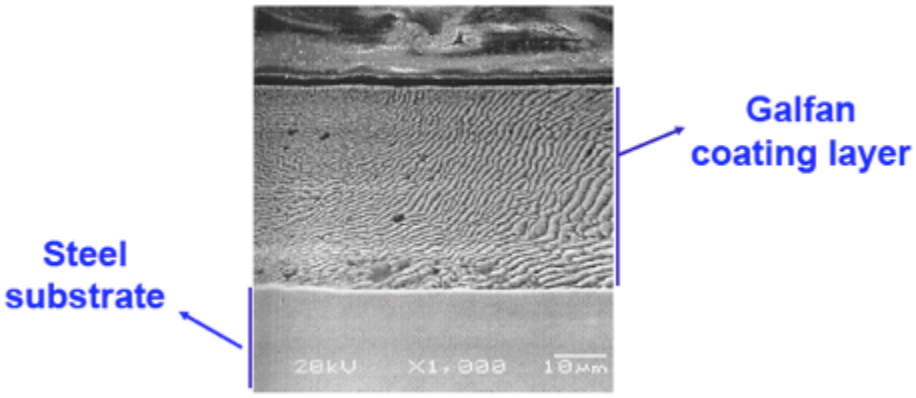

Figure 1 Microstructure of Zn-5% Al Coating (note the lamellar plate-like structure) [1]

Regular zinc galvanizing alloys freeze into a single-phase microstructure. Al-Zn alloys such as Galvalume® form two-phase microstructures in which aluminum phases are surrounded by the lower freezing temperature zinc phase (see GalvInfoNote 1.4). Galfan®, however, forms a *hypoeutectic* microstructure in which the high zinc phase and high aluminum phase freeze into very thin, alternating parallel plates called lamellae, as shown in Figure 1. Control of the cooling rate is necessary to ensure that the entire microstructure is lamellar.

The intermetallic alloy layer that forms between the Galfan® coating and the steel substrate is a very thin (1 μm) ternary Al-Fe-Zn compound. This layer is thinner than a similar layer that forms on galvanized sheet, and is the reason for the extremely good formability of Galfan®.

[1] The mischmetal used in GALFAN is a mixture of cerium (Ce), lanthanum (La), two of the 15 elements between atomic numbers 57 and 71, sometimes called rare earths. Their percentage in the alloy is extremely small but their effect in improving wettability is very significant.

Corrosion Resistance

Aluminum corrodes more slowly than zinc in most atmospheres because of its surface barrier layer of very passive aluminum oxide. However, this passive layer prevents aluminum from adequately contributing towards cathodic (sacrificial) protection. Cathodic protection is the strong point of zinc coatings, in that if the coating is cut or scratched, the zinc near the exposed steel will corrode first. Galfan® combines the strengths of both zinc and aluminum, giving better passive barrier protection than regular galvanize, and better sacrificial protection than alloy coatings with lower zinc compositions.

Regular galvanized coatings corrode in the atmosphere by the zinc being continually converted to zinc oxide and zinc carbonate. The lamellar eutectic microstructure of Galfan®, shown in Figure 1, interferes with this mechanism, as corrosion must follow the direction of the thin lamellae. Also, the dense, more passive, aluminum-rich corrosion products that are left behind lower the reactivity of the surface. Naturally, corrosion will be slowest when the lamellae are parallel to the sheet, but even the random orientation that the lamellae usually take greatly reduces the corrosion rate.

Galvanize exhibits a linear corrosion rate. ILZRO research has shown that the corrosion rate of Galfan® is parabolic rather than linear. Galfan's weight loss during the first two or three years is slightly less than galvanize, but as its surface passivates, it's rate of weight loss decreases parabolically. This is illustrated in Figure 2.

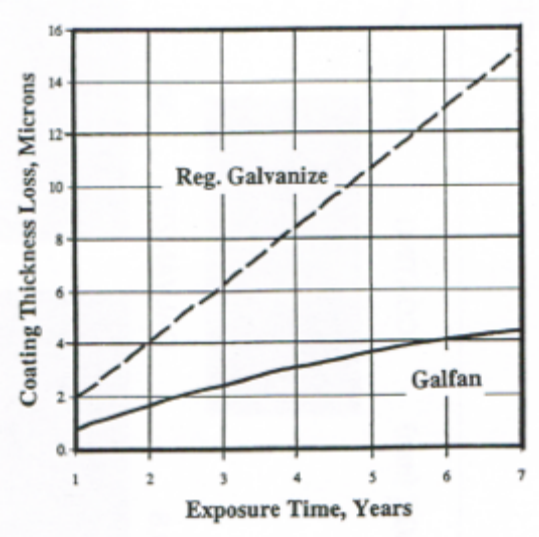

Figure 2 Coating Thickness Loss in Marine Environment from New Zealand Steel Study[1]

The results of field studies have shown that Galfan® has a minimum of two times better outdoor corrosion resistance than conventional galvanize of the same coating weight. This is the case in rural, industrial, and marine environments.

The issue of whether to use galvanize or Galfan® for a particular end use therefore becomes one of overall value versus initial cost. If the objective is to have products last over 2 times longer than those made with galvanize, then the same coating weight as used with galvanize can be specified. If lower initial cost is paramount, then the same service life can be obtained by specifying one-half the normal galvanize coating weight.

Summary

Years of testing and evaluation have allowed the comparison chart shown in Figure 3 to be compiled. It shows that Galfan® is equal to or better than galvanize in all the important coated sheet attributes.

Compare Galfan to Other Coatings

	Galfan	Hot-dipped Galvanized	Electro-galvanized	Galvanneal	Galvalume
Formability	5	3	5	3	3
Corrosion Resistance (bare)	4	3	3	2	5
Sacrificial Protection	5	5	5	5	3
Corrosion Resistance (formed)	5	3	3	3	3
Paint Adhesion	5	4	5	5	4
Corrosion Resistance (painted)	5	4	4	5	3
Weldability	4	4	5	5	2
Heat Resistance / Reflectivity	3	3	3	2	4

Note• 5 • Best 1• Worst

Source: Galfan Technical Resource Centre

Figure 3 Galfan® Compared to Other Metallic Coatings

Zinc-5% aluminum hot-dip coated sheet has corrosion resistance at least twice as good as galvanize. It has been in use for 25 years and has application in many markets, including construction, agriculture, appliance, automotive, highway, and utility.

More information on this product can be found at: http://galfan.com/home.html

References:

[1] GALFAN Product Manual, ILZRO, June 1993