

Role of aluminum in zinc coated Steels

- Steelworld Research Team

Introduction :

For over a century, zinc has enhanced the longevity and performance of steel. Zinc coatings provide the most effective and economical way of protecting steel against corrosion. Zinc-coated (galvanized) steel offers a unique combination of positive features:

- high strength - determined by the steel substrate
- formability - a key feature for roll forming coated steel sheet
- light weight - of steel framing and roofing, as compared to competitive materials
- corrosion resistance - for both long life and the maintenance of esthetic appearance
- recyclability - both for the scrap materials of construction and end-of-life demolition
- low cost - competitive with all construction materials of matching quality

For these reasons, galvanized steel is an ideal material for a multitude of building applications. In the residential construction market, galvanized steel has particular and cost-effective applications in framing, roofing, rainware (gutters and downspouts), ductwork (heating/cooling and venting) and household appliances.

Galvanized steel resists corrosion. In the industrialized nations, at least 4% of GDP is lost to corrosion each year and the trend of the past fifteen years has been for customers and manufacturers to demand better corrosion protection through both higher zinc content and additional applications of zinc-coated steel.

How Zinc Protects :

When left unprotected, steel will corrode in almost any environment. Zinc coatings stop corrosion by providing two types of protection - a physical barrier and cathodic action.

Barrier Protection :

Zinc coatings provide a continuous, impervious metallic barrier that does not allow moisture to contact steel. Without direct moisture contact, there is no corrosion. However, since zinc gradually erodes due to its much slower degradation in the presence of water and atmospheric pollutants in open air applications, barrier life is proportional to coating thickness.

This subject has been researched for many years and the literature is well supplied with reports on zinc's performance in different climates, with different alloy additions to the coating and at different coating thicknesses.

Within the interior of a structure (wall framing and roof trusses) corrosion is not a consideration provided the exterior membrane maintains its integrity.

Barrier coating longevity can be improved a number of ways other than by just increasing coating thickness. The addition of aluminum for alloy coatings such as Galfanâ and Galvalumeâ, or the application of paint, will significantly extend the life of coated steel sheet.

Cathodic Protection :

Another outstanding protection mechanism is zinc's remarkable ability to galvanically protect steel. When bare steel is exposed to moisture, such as at a cut edge or surface scratch, steel is protected by the sacrificial loss of zinc in the vicinity of the exposed steel. In the immediate presence of zinc, steel will not corrode until all the zinc has been sacrificed. This benefit of coated steel sheet is particularly important since corrosion will continually undercut both aluminum or paint barrier coatings.

The presence of zinc is the key to cathodic protection. All zinc-containing metallic coatings, including Galfanâ and Galvalumeâ, share this beneficial characteristic.

Formability and Adhesion :

For residential framing and roofing applications, all zinc coatings are continuously applied by dipping pre-treated, pre-heated sheet steel in a bath of molten zinc or zinc alloy, a process called Continuous Galvanizing.

The bond between the zinc and steel is metallurgical so that a coil of zinc-coated steel can be cut, punched and formed without damaging the zinc coating. There are steel thickness, bending radius and coating weight limitations, but these are well known and respected by the producers of coated steel sheet, framing and roofing products.

Roll of Aluminium in Zinc Coated Steels :

However, the zinc used for coating steel is never in the pure metallic form but in combination with other elements

(metallic and non-metallic). One of the most important and common of the metallic elements is aluminum. Aluminum rich alloys are added for many reasons, from enhancing the application of zinc to steel to improving certain forming and corrosion resistance characteristics of the zinc coating.

The following information relates to only one coating process, continuous hot-dipped, in which a coil of hot-rolled or cold-rolled steel is unwound, cleaned, heated or heat-treated, passed through a liquid bath of a zinc alloy, cooled and rewound.

Galvanized Coatings :

Continuous hot-dipped galvanized coating, by far the most common galvanized steel product, is produced by dipping the steel in a zinc bath containing minor amounts of aluminum (0.1-0.3%) and possibly antimony or lead (0.03-0.1%). At the elevated temperatures of the liquid zinc bath, zinc and iron react to form a brittle intermetallic layer between the base steel and the zinc coating. The function of the aluminum is to inhibit that reaction and reduce the thickness of the intermetallic layer.

The optimum coating structure consists of a layer of zinc on steel, but with that layer separated from the steel by the thin aluminum-rich layer. This coating is economical to produce and provides good all-round corrosion resistant and forming properties.

Galfan® Coatings :

Galfan® is a zinc alloy containing (by weight) 5% aluminum. In production, the only basic difference between Galfan® and galvanized coatings is the alloy mix in the liquid zinc bath.

The structure of this coating is called a eutectic, defined as an alloy mixture that will "freeze" at a specific temperature rather than over a range of temperatures. The eutectic structure is a fine series of alternating zinc-rich and aluminum-rich plates. After the coated steel exits the liquid metal bath, rapid cooling is essential for the development of a fine metallic structure and optimal coating properties.

The fine structure of this coating has excellent formability. Galfan® can be used for severe forming applications such as deep drawing. The aluminum content (higher than that for galvanized coatings) increases the coating's corrosion beyond that of galvanized. However, the inclusion of aluminum increases the cost of the alloy and, by reducing the amount of zinc, also reduces zinc's galvanic protection of steel.

Galvalume® Coatings :

Galvalume® is a zinc alloy containing (by weight) 55% aluminum and 1.5% silicon. As for Galfan®, the only basic production difference with galvanized coatings is the alloy mix in the liquid metal bath. This alloy consists of a complex dendritic structure with interweaving zinc-rich and aluminum-rich phases interspersed with silicon-rich particles. Because of the relatively high aluminum content, it can be said that this alloy behaves like an aluminum coating with zinc whereas the Galfan® alloy behaves like a zinc coating with aluminum.

The result is that Galvalume® has outstanding corrosion and elevated temperature resistant properties, but at the cost of reduced galvanic protection. Production costs also are higher than for galvanized coatings due to increased alloy costs and the need for higher bath temperatures.

General Comments: Galfan® and Galvalume® :

The presence of zinc is the key to cathodic protection. All zinc-containing metallic coatings, including Galfan® and Galvalume®, share this beneficial characteristic. Both Galfan® and Galvalume® are proprietary products and are produced under license from the patent holders.

	Galvanize (Zn)	Galvanneal (Zn-Fe)	Galfan® (Zn-5%Al)	Galvalume® (Zn-55%Al)
Corrosion Resistance	6	5	8	10
Galvanic Protection	10	8	9	5
Formability	8	6	10	6
Paintability	8	10	10	8
Weldability	7	10	6	5

Note – performance scale of 1 (poor) to 10 (best)

Environmental Issues :

Specifying zinc is an environmentally responsible choice. Zinc itself and all types of zinc-coated steel products are fully recyclable. When determining the environmental impact of zinc coatings, local impact as well as macro, long-term effects need to be considered. Zinc is a natural element that is essential to all forms of life, including humans, animals, plants and micro-organisms. While small quantities of zinc will wash off from coatings exposed to outdoor environments, this zinc is usually not bioavailable and has little or no impact on the surrounding ecosystem. On a macro scale, the excellent corrosion protection provided by zinc coatings contributes significantly to the durability and life expectancy of steel products – this in turn helps to conserve natural resources and reduces the cost of maintenance, repair and replacement.

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