GalvInfoNote	Galvanneal – Differences from Galvanize
1.3	Rev 0 Jan-07

Introduction

This GalvInfoNote explains how hot-dip galvanneal differs from hot-dip galvanize. The hot-dip galvanizing process is explained in GalvInfoNote 2.1. In manufacturing galvanneal, the main differences in the process are that a lower level of aluminum (typically from 0.11% to 0.14%) is used in the zinc bath, and the moving, zinc-coated strip is reheated immediately after it passes the air wiping step above the zinc bath. By heating the strip to between 935 - 1050°F (500 - 565°C), and holding at this temperature for a few seconds, the zinc coating, by way of diffusion, alloys with the iron in the steel. The end result is that the coating is composed of layers of intermetallic compounds averaging approximately 90% zinc and 10% iron. This is an average, as the iron amount varies throughout the coating thickness, from as low as ~7% at the surface, to as high as ~23% at the steel interface. Galvannealed coatings have no free zinc present and have a low-lustre matte appearance, versus the metallic sheen of galvanized coatings. The final bulk iron concentration depends primarily on the heating cycle, since the rate of diffusion is a function of time and temperature. The zinc and steel chemistries can also affect the alloying behavior, but they are secondary to the heating cycle. A schematic representation of the galvannealing process is shown in Figure 1. Micrographs of galvannealed coatings are shown in Figures 2 & 3.

The differences in characteristics and performance between a galvannealed coating and a galvanized coating are explained below.

Coating Composition

A galvanized coating is essentially pure zinc, with between 0.20 and 0.50% aluminum. The aluminum is added, not to affect the corrosion performance, but to improve the adhesion between the coating and the steel substrate during forming operations by the user.

As stated above, a galvannealed coating contains approximately 10% iron. It, too, contains a small amount of aluminum similar to galvanize.

See GalvInfoNote 2.4 for an explanation of the role of aluminum in continuous hot-dip galvanizing.

Coating Weldability, Paintability, Formability and Adherence

Two primary benefits of using galvanneal rather than galvanize are:

- Improved spot-weldability
- Ease of painting and improved coating adhesion

Zinc-iron alloy coatings generally have better spot welding characteristics than pure zinc coatings[1]. The coating's higher electrical resistance, along with its higher hardness and higher melting point, allow good welds to be obtained at lower currents with longer electrode life.

Performance of galvanneal under paint is synergistically improved because of the excellent bond formed between the paint and the surface of the coating. The reason for the good bond is evident in Figure 3 – the paint can "mechanically lock" with the zinc-iron crystals on the surface. Compared with a galvanized product, galvanneal generally exhibits less undercutting corrosion beneath paint at exposed edges, scratches, or other defects in the paint.

A galvanized coating is quite soft, and easily scratched. A galvannealed coating is very hard, and thus not as easily scratched when handling. The harder zinc-iron alloy powders on deformation, unlike pure zinc coatings which flake[1].

The good frictional behaviour and ductility of zinc, combined with the excellent adhesion achieved between the coating and the steel, allows galvanized sheet to be formed into many intricate shapes without any loss in coating adhesion. In fact, because the coating is soft, care needs to be exercised to prevent flaking resulting from galling.

With galvanneal, the alloying reaction results in a hard, relatively brittle coating. Even so, the coating can be bent, stretched and drawn when correct sheet manufacturing and part forming procedures are used. Many parts made from galvannealed sheet require a deep drawing operation. When deep drawn, galvannealed sheet typically exhibits some "powdering" of the coating as a result of high compressive strain that can occur during the forming operation. By proper control of the steel-manufacturers' processing practices, combined with the proper setup of the drawing dies, the amount of powdering can be minimized and excellent performance can be achieved.

The powdering of a galvannealed coating during forming is a function of many parameters, mostly relating to the steel manufacturing practices. Also, the stamping/forming practices used by the customer influence the powdering performance. Perhaps the most important characteristic of the coating that affects the powdering tendency is the coating thickness (weight or mass). The amount of powdering rises directly as the coating thickness increases. For this reason, the maximum coating weight for galvannealed product is restricted to A60 (0.60 oz/ft^2) [ZF180 (180 g/m^2)]. For many applications, an A60 coating weight is too thick to provide acceptable powdering performance, and many users specify A40 (0.40 oz/ft^2) [ZF120 (120 g/m^2)] or less. In fact, most automobile applications of galvanneal use the equivalent of about an A30 [ZF90] coating. The tendency for A60 to powder should be considered when selecting a coating weight.

Generally, there are no significant differences in the properties of the steel substrate whether it is galvanize or galvanneal. Any differences in forming behaviour (splits, etc.) are usually related to the different nature of the two metallic coatings. For example, the substantial difference in coating hardness can necessitate changes to the stamping parameters, i.e., die type, die clearances, hold-down forces, lubrication type, etc.

Corrosion Performance

The thickness of a galvanized coating has a direct influence on the corrosion performance and life of the product, i.e., the thicker the coating, the longer its life. See GalvInfoNote 3.1 – "How Zinc Protects Steel" for more information.

The corrosion performance of a galvannealed coating is more complicated than its galvanized counterpart. Almost all applications of galvannealed sheet involve painting after fabricating. The primary reason is that, when unpainted, the presence of 10% iron in the coating can lead to a "reddish-colored" corrosion product. The color is related to corrosion of the iron within the coating and does not necessarily signify that corrosion of the steel substrate is occurring. This discoloration due to the iron in the coating is purely a cosmetic effect.

Nevertheless many users find this staining unacceptable, thereby requiring most applications for galvanneal be painted after fabrication. For this reason, most corrosion studies of galvanneal relate to painted sheet. Since the primer and the topcoat have a direct influence on product life, the corrosion performance of galvanneal is generally not compared with bare (unpainted) galvanize. The importance of the galvannealed coating thickness is often revealed at sheared edges or scratches, etc, i.e., places where the steel and metallic coating are directly exposed to the corroding environment. At such discontinuities, a thicker coating can improve resistance to "undercutting" the paint film, i.e., a thicker galvannealed coating can slow down degradation of the paint, as evidenced by edge "creep back" corrosion and eventual total loss of paint adhesion.

Considering the relative corrosion rates:

- A pure zinc coating (galvanize) provides a high degree of galvanic protection to exposed steel such as at sheared edges and scratches.
- A galvannealed coating is about 10% less galvanically active in most environments because it contains 10% iron.
- The more galvanically active galvanized coatings could be more quickly consumed when acting as a galvanic protector. The less galvanically active galvannealed coatings do not offer as much galvanic protection, and therefore are not as rapidly consumed during the corrosion process. In both cases, the coating thickness determines how long the coating will be available to provide galvanic protection. Keep in mind that the thickest coating available on galvanneal is equivalent to a G60 galvanize coating.
- The specific needs of the application and the corrosion performance requirements dictate which coating will perform best. Other requirements for the application, such as weldability and the specific capabilities of each product manufacturers' paint shop need to be considered when deciding which product is best for the situation.

Which Product to Use

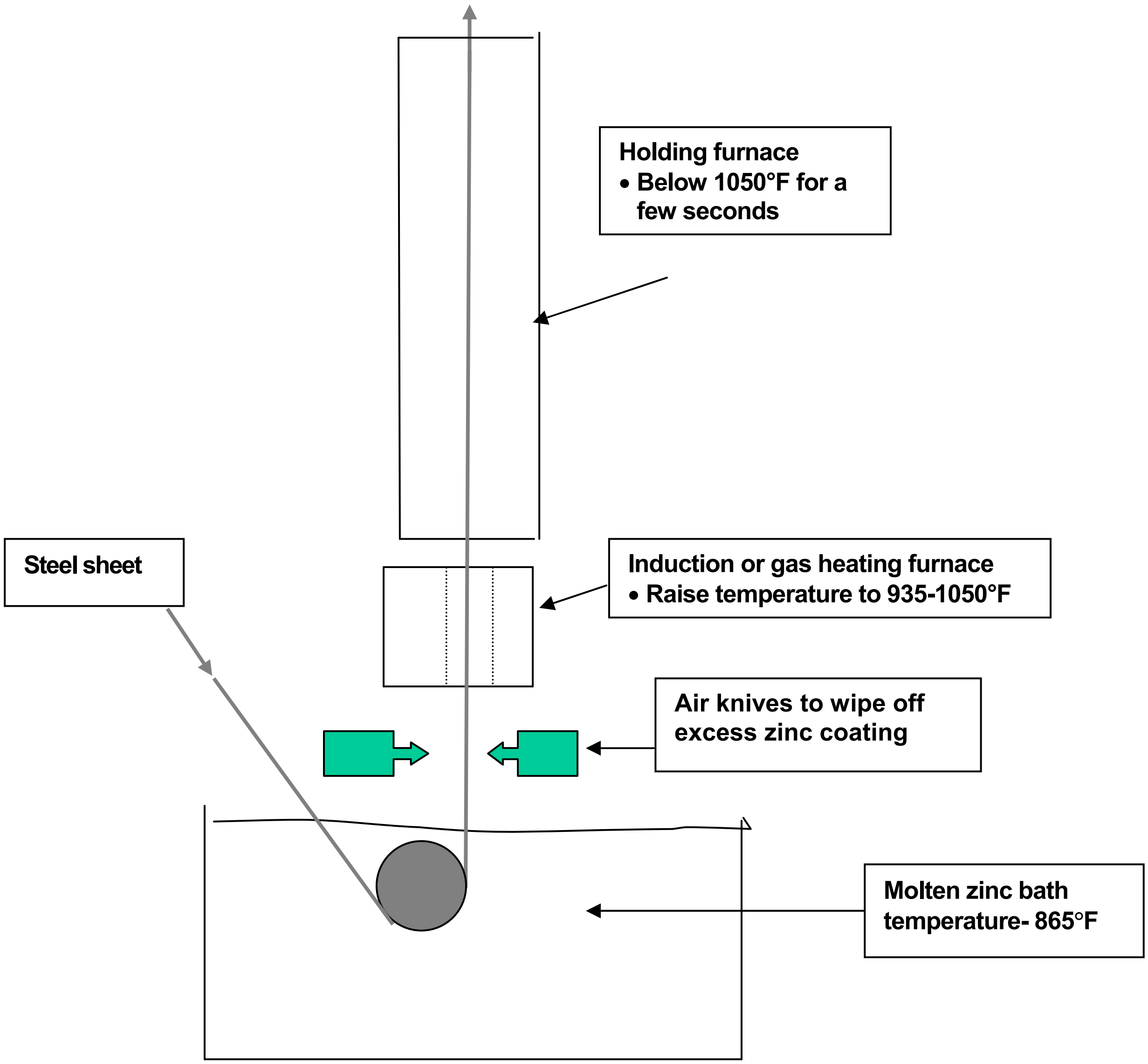
When considering which product to use for a specific application, consider issues such as:

- What are the corrosion demands of the end use and the environment? Coating thickness is the primary consideration.
- Is spot welding involved? Galvanneal might perform better.
- Is the product going to be used unpainted? In most cases, galvanize is preferred.
- Is deep drawing involved? Before applying galvanneal, stamping trials need to be conducted in order to assure that the amount of powdering is acceptable.

In almost all applications, there is more than one issue involved. The proper choice of product requires in-depth consideration of all processing steps included in manufacturing, plus knowledge of end-use requirements.

Reference:
1) J. P. Landriault, F.W. Harrison: CIM Bulletin, August 1987, pp. 71-78

Figure 1: The Galvannealing Process



1. Moving steel sheet is immersed into the zinc bath.
2. In the bath, a thin alloy layer forms between the zinc and the iron in the steel sheet.
3. As the strip emerges, it drags excess zinc with it.
4. The air knives wipe off excess zinc to get the desired coating thickness.
5. The sheet with the molten zinc coating passes through a heating furnace to heat it to 935 -1050°F.
6. The sheet then travels through a "holding" furnace to hold it below 1050 °F for a few seconds.
7. During this time, the molten zinc becomes fully alloyed with the iron from the sheet to form a "galvannealed" coating; an alloy of zinc with an average 10% iron.

Figure 2: The Stages of Alloying Between the Steel Sheet and the Molten Zinc Coating to Produce "Galvanneal"

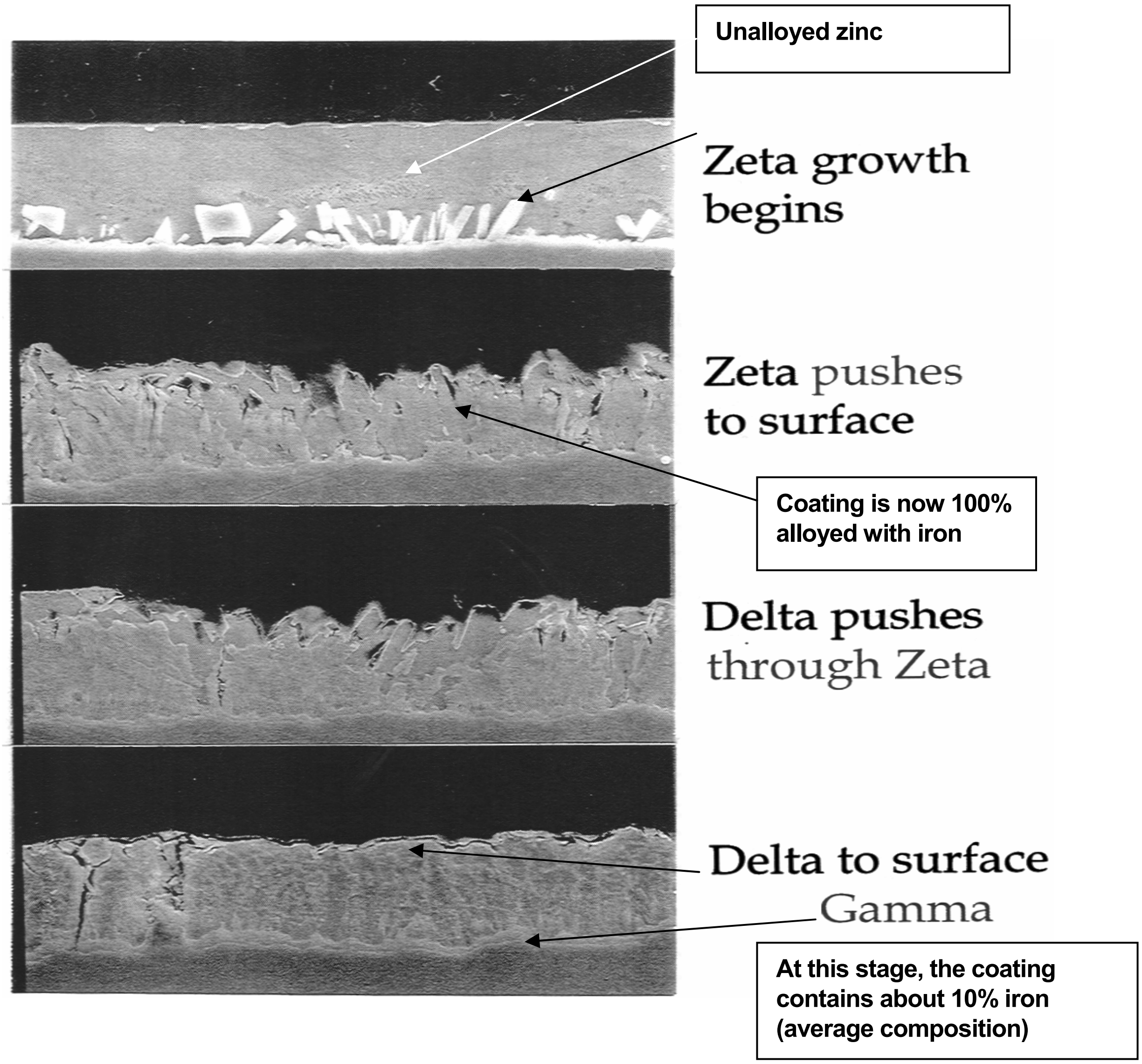
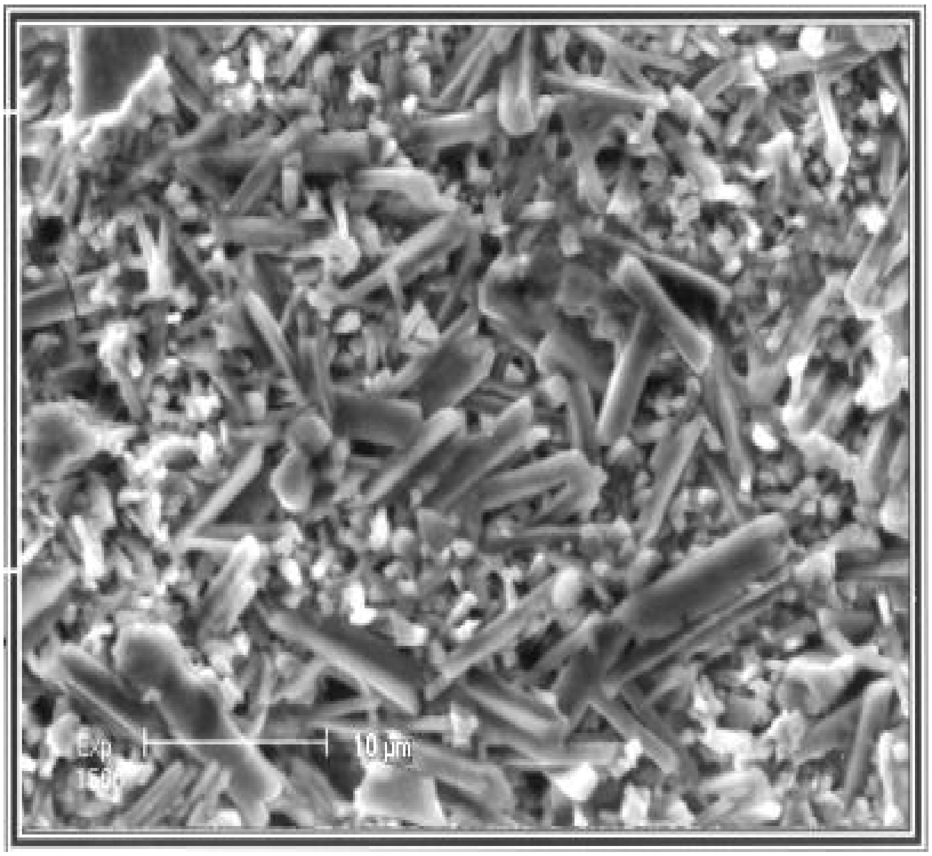


Figure 3: **Surface of Galvanneal – Showing Zinc-Iron Alloy Crystals**



Magnification: Approx. 2700 X