

## 2. Coating Processes and Surface Treatments

GalvInfoNote

2.2

# The Continuous Electroplating Process for Steel Sheet Products

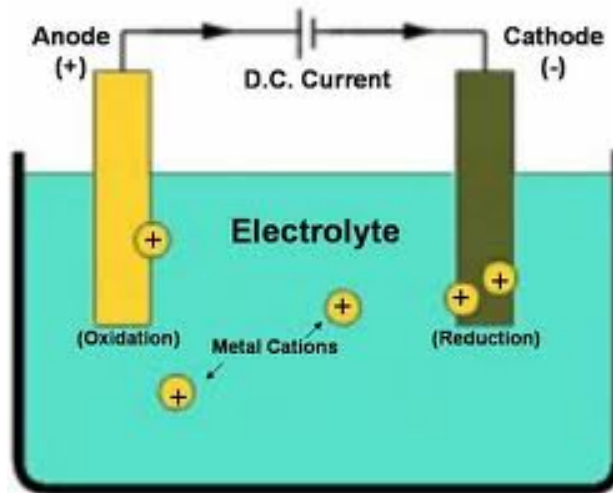
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## Introduction

The steel sheet electroplating process utilizes the same basic principle as that for conventional decorative finish electroplating. However, the steel sheet process differs in that the electroplated coating is applied by passing the strip at high speeds through a series of plating cells, building the coating thickness by a small amount each time the strip passes through an individual cell. This continuous process for electroplating steel strip requires the necessary equipment to transport the strip at high speeds 150-215 mpm [500-700 fpm] and higher through a series of individual plating cells, and is not as simple as it sounds. In this GalvInfoNote, some of the complexities of the process will be covered.

## An Electroplating Cell

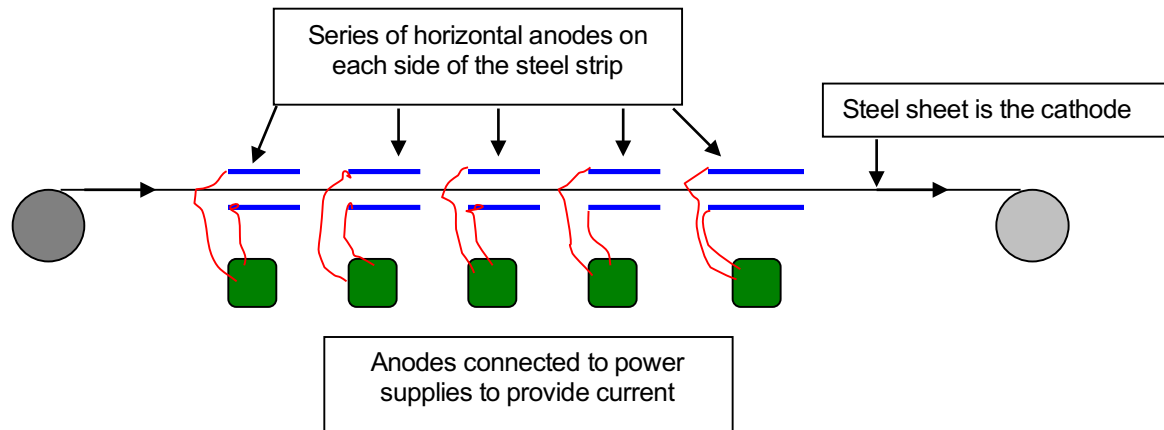
The simplest electroplating cell is shown in this diagram.



This simple plating cell illustrates what occurs during the electroplating process. In the case of the **electrogalvanizing (EG)** process, the **anode** is zinc, the **cathode** is steel, and the **electrolyte** is zinc sulfate (another similar process uses zinc chloride). Electrical power is provided by the DC source. At the anode, zinc is **oxidized** (loses 2 electrons) and dissolves as a **cation** in the electrolyte. At the steel cathode, zinc cations combine with 2 electrons (**reduction**) and form elemental zinc, which deposits onto the steel surface. Back at the anode, water is converted to oxygen and hydrogen ions to maintain electrical balance. The oxygen forms a gas ( $\text{H}_2\text{O} \rightarrow 2\text{H}^+ + \frac{1}{2} \text{O}_2 + 2\text{e}^-$ ), resulting in nothing being deposited on the anode surface. The plating solution (electrolyte) carries the direct current between the cathode and anode.

## Plating of Steel Sheet in a Continuous Process

How is this plating operation extended to the plating of steel sheet as wide as 1800 mm [71 in.] on a continuous basis at high speeds? Imagine a series of cells like the one above, except much larger, aligned in a row. Connect each anode/cathode set to an electrical power source. Add the necessary rolls and motors to transport the sheet between an anode/cathode set in each cell. Use an uncoiler at the entry end of the line to feed the coiled sheet into the processing section, and a recoiler at the exit end of the line to rewind the sheet into a coil.



Of course, many additional pieces of equipment and electrical controls are needed to complete the line. To make the process continuous, an accumulator is needed at the entry end to allow the tail end of one coil to be welded to the head end of the succeeding coil. Alkaline cleaning to remove dirt and oils and a pickling operation to remove the fine film of iron oxide on the steel surface are important operations ahead of the plating cells. The coating is bonded to the steel by inter-atomic attraction; there is no diffusion reaction like that which occurs in the hot-dip process. Thus, the surface of the incoming steel has to be very clean to achieve good adhesion.

There are many types of anode arrangements. Some are horizontal, others are vertical, and one process utilizes a radial cell wherein the strip passes around large diameter rolls inside each plating cell, and the anodes have a radial design to match the diameter of the large rolls submerged into the plating solution. Each type of anode arrangement and design has advantages and disadvantages; thus, it is easy to see why different manufacturers use different methods. Each requires very close control of the anode-to-strip spacing to achieve efficient plating, avoiding arc spots and other defects in the coating.

Maintenance of the large volume of plating solution that is contained in all the cells is a science unto itself. Whether the plating solution for electrogalvanizing is based on zinc sulphate or zinc chloride chemistry, maintenance of the proper ranges of zinc ion concentration and solution pH are important control features. Besides plating zinc, some manufacturers have the ability to deposit alloy coatings. This requires, at a minimum, at least one more level of control of the plating solution. For example, producing a zinc/nickel alloy coating requires close control of the concentrations of both the dissolved zinc and nickel in the solution. Solution control has to be accomplished on a dynamic basis since these lines operate continuously.

The bonding that occurs between an electrogalvanized coating and the steel is different than that for hot-dip coatings. With electrogalvanize the bonding occurs by interatomic attraction. Hot-dip coatings rely on diffusion between the liquid coating metal and the solid steel substrate to achieve the bond. To achieve a good bond, the electrogalvanizing process depends on the steel surface being very clean.

## Power Requirements

The EG process requires a large amount of electric power to deposit zinc coatings. The total power requirement is a direct function of the coating thickness that is needed to meet the customer's specification. For example, the power required to deposit a zinc coating mass of 80 g/m<sup>2</sup> is approximately twice that required to deposit a coating of 40 g/m<sup>2</sup>. A typical line that has the capability to process 70 to 120 tons/hour with a coating mass of 50 g/m<sup>2</sup> per side will consume hundreds of thousands of amperes during this one hour of processing time. It is easy to see why power costs are major cost component for a facility that processes large quantities of electroplated sheet product.

**Note:** This GalvInfoNote uses only coating mass units of g/m<sup>2</sup>. This is so because, even in North America, the coating on EG products is almost always specified in min/max metric (SI) units per surface, a practice that has always been used by the automotive industry – a major consumer of these products. ASTM A879/A879M does contain inch-pound units, but they are rarely specified.

## Product Types

The most common electroplated coating for steel sheet products is **zinc**. Electrogalvanized zinc coatings are used by a number of automotive companies for exposed car-body panels, where the typical coating mass ranges from about 50 to 80 g/m<sup>2</sup> per side. These coatings are considerably thicker than the electrogalvanized coatings typically used for non-automotive applications; so lines built to make products for automotive applications usually have a large number of plating cells. Also, they have the ancillary equipment needed to produce a high quality surface and require a large capital outlay to build. The products are included in ASTM Specification A879/A879M. Also, automotive customers have their own specific coated-product specifications.

Another attribute associated with the use of electrogalvanized coatings for automotive applications is the excellent surface finish that is attainable with the electroplating process. In the 1980s, when automotive companies began using large amounts of galvanized sheet for exposed body panels to improve corrosion protection, one of the few coated sheet products that could meet the demanding surface quality requirements was electrogalvanized. Hot-dip galvanized was, and still is, used for unexposed body parts. As the surface of hot-dip products improved, they replaced electrogalvanized sheet for exposed automotive body panels.

Other zinc electroplating lines have been built through the years to make thinner coatings. Typically, the sheet made on these lines has a coating mass of less than 25 g/m<sup>2</sup>. The applications for these products are often indoors; where the environment is not very corrosive. Many involve a painted product. Some of these coating lines have the ability to apply paint pre-treatment so that the customer can paint directly without additional in-house treating. ASTM Specification A879/A879M also covers these lighter coating weight electrogalvanized sheet products.

A second type of electroplated coated-steel sheet being manufactured today has a coating composed of a **zinc/nickel alloy**. Typically, the nickel content is 10 to 16 percent, with the balance being zinc. The unique feature of this process is that the zinc and nickel ions are co-deposited to make a true alloy coating. It is not composed of alternating layers.

The application for this product has been limited primarily to a few automotive companies. These companies have developed in-house product design and manufacturing processes to take advantage of the unique characteristics of the zinc/nickel coating. For these automotive applications, the metallic coating is often coated with a special corrosion-resistant thin organic coating on top of the zinc/nickel. ASTM Specification A918 covers the zinc/nickel alloy coating.

A third type of electroplated coating is a **zinc/iron alloy** coating. The attributes of this specialized coating are somewhat like those of hot-dip galvanized product. Like the zinc/nickel alloy, the zinc/iron coating is co-deposited as an alloy coating. The iron is uniformly deposited throughout the coating thickness. Also, like the zinc/nickel coating, the zinc/iron coating is used predominantly by the automotive industry.

The attributes of electroplated zinc/iron are that it is relatively easy to weld and paint if the proper electro-priming equipment is available to the automotive manufacturer. Also, the coating is very hard; making it is less susceptible to scratching during stamping and handling. This is an important feature since the zinc/iron alloy coated-sheet product is being used almost exclusively for exposed car-body panels.

## Corrosion Resistance of Electroplated Coatings

Concerning the corrosion behaviour of an electrogalvanized versus a hot-dip galvanized coating, it is important to note that it is essentially equivalent for identical coating masses. A coating mass of  $100 \text{ g/m}^2$  will provide essentially the same amount of corrosion protection whether it is a hot-dip galvanized or electrogalvanized coating. See GalvInfoNote 3.1 for more information on how zinc protects steel.

The reason that the automotive companies can successfully use a coating mass in the  $50$  to  $80 \text{ g/m}^2$  range is because they apply additional treatments on top of the metallic coating, including a zinc phosphate coating, an electro-deposited organic-based coating, a primer, and multiple-layer finishing paint coatings. Clearly, the corrosion resistance needed to protect a car body panel for over 10 years is more than that afforded by the metallic coating alone. Application of the above coatings over the electroplated metallic layer results in a synergistic system, whose corrosion resistance is more than the sum of its individual components.

## Summary

Electroplated zinc- and zinc-alloy coated sheet products are a special type of metallic-coated steel. The applications involve either a coating mass of  $50$  to  $80 \text{ g/m}^2$  (per surface), or a coating mass of less than  $25 \text{ g/m}^2$ . The heavier coatings are used for automotive applications predominantly, while the lighter coating masses are applied for applications (often indoor) that do not require a high degree of corrosion protection.

Remember that the conversion from  $\text{g/m}^2$  to  $\text{oz/ft}^2$  is:  $305 \text{ g/m}^2 = 1.00 \text{ oz/ft}^2$ . Compared with a G90 hot-dip coating, even the heaviest coating masses of electrogalvanized product are considerably less than much of the hot-dip galvanized product in use today for exterior applications. The capital expenditure required to manufacture electroplated zinc coating equal to a G90 coating would be prohibitively expensive, as would operating power costs.

Electroplated coatings on steel sheet have found unique applications in industries using steel sheet products. The high quality surface of the electroplated product, combined with the fact that a coating mass of  $50$  to  $80 \text{ g/m}^2$  is sufficient to meet the corrosion requirements, make electroplated sheet products ideal for exposed panels on a car. Also, the other category of EG coatings, sheet with a coating mass of less than  $25 \text{ g/m}^2$ , is ideal for relatively non-corrosive applications. Production of equally thin hot-dip coatings is not practical.

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