GalvInfoNote	The Continuous Electroplating Process for Steel Sheet Products
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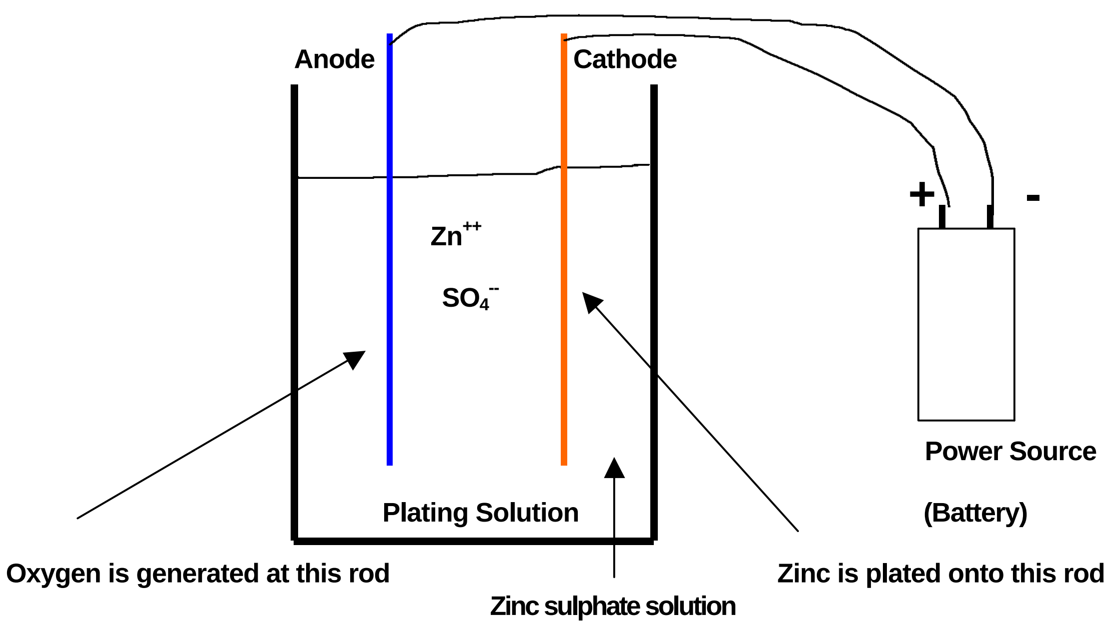
Introduction

The electroplating process for steel sheet involves the same electroplating principle that is associated with the conventional electroplating process used for many decorative finishes. However, the overall process used for steel sheet is very different 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. The continuous electroplating process for steel strip involves the necessary equipment to transport the strip at high speeds (500 to 700 feet per minute 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

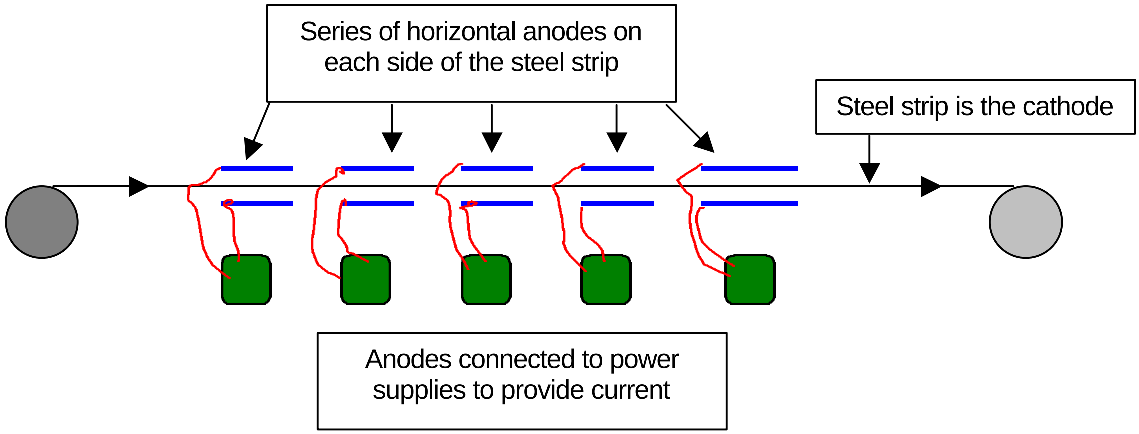
The simplest electroplating cell is shown in this sketch. For this illustration, the plating solution is a zinc sulphate bath.



This simple plating cell illustrates the actions during the plating process. At the cathode (steel, for example), zinc ions dissolved in the zinc sulphate solution combine with 2 electrons and form elemental zinc. The zinc deposits onto the cathode surface. At the anode, water is converted to oxygen and hydrogen ions to maintain electrical balance. The oxygen forms as a gas; thus, nothing is deposited on the anode surface. The plating solution carries the current between the cathode and anode.

Plating of Steel Sheet in a Continuous Process

How does one extend this plating operation to the plating of steel sheet as wide as 1800 mm (70+ inches) 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 strip between an anode/cathode set in each cell. Use an uncoiler at the entry end of the line to feed the coiled strip into the processing section, and a recoiler at the exit end of the line to rewind the strip 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. Remember, the coating is bonded to the steel by inter-atomic bonding; 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 and avoid 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, a zinc/nickel alloy coating is commercially manufactured today. In this case, control of both the dissolved zinc and dissolved nickel concentrations in the solution are important. Solution control has to be accomplished on a dynamic basis since these lines operate continuously.

Power Requirements

The electroplating process requires a high amount of electric power to deposit a metallic coating. 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^2 is approximately twice that required to deposit a coating of 40 g/m^2. A typical line that has the capability to process 70 to 120 tons/hour with a coating mass of 50 g/m^2 will consume hundreds of thousands of amperes during this one hour of processing time. It is easy to see why power costs are very vital to a facility that processes large quantities of electroplated sheet product.

Product Types

The most commonly used 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^2. These coatings are considerably thicker than the coatings typically used for other non-automotive applications; thus the coating lines that were built to make coated-steel sheet products for automotive applications usually have a high number of plating cells. Also, they have all the ancillary equipment needed to make a high quality surface. These lines require a large capital outlay to build. The products are covered by ASTM Specification A 879/A 879M. Also, each automotive customer has their own specific coated-product specification.

Another attribute associated with the use of electrogalvanized coatings for automotive applications is the excellent surface finish that is attainable with the electroplating process. Thus, during the past 10 to 15 years, the automotive companies that use galvanized coatings for corrosion protection have tended to use electrogalvanized for exterior body panels, and hot-dip galvanized for unexposed body parts. This has begun to change, however, as the surface of hot-dip products continues to improve.

Other zinc electroplating lines have been built through the years to make thinner coatings. Typically, the product that is made on these lines has a coating mass of less than 25 g/m^2. The applications for this product are often indoors; applications where the environment is not very corrosive. Almost all applications involve a painted product. Thus, the coating lines often have the ability to apply paint pre-treatment so that the customer can apply paint directly without additional in-house treating. The coated products made on these lines are covered by ASTM Specification A 591/A 591M.

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 several 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. The zinc/nickel alloy coating is covered by ASTM Specification A 918.

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 galvannealed 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 this product 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; thus, 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.

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 g/m^2 (per side), or a coating mass of less than 25 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 g/m^2 to oz/ft^2 is approximately: 305 g/m^2 = 1 oz/ft^2. Thus, 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 the power costs during production.

Concerning the corrosion behaviour of an electrogalvanized versus a hot-dip galvanized coating, it is important to note that they are essentially equivalent for identical coating masses. That is, a coating mass of 100 g/m^2 will provide essentially the same amount of corrosion protection whether it is a hot-dip galvanized or electrogalvanized coating. See GalvInfoNote #6 for more information on how zinc protects steel.

The primary reason that the automotive companies can successfully use a coating mass in the 50 to 100 g/m^2 range is that they apply additional treatment, primer and paint films on top of the metallic coating. Clearly, the corrosion resistance needed to protect a car body panel for 10 years or more is more than that afforded by the metallic coating alone.

In summary, it is apparent that electroplated coatings on steel sheet have found unique applications in the 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 g/m^2 is sufficient to meet the corrosion requirement, make electroplated sheet products ideal for exposed panels on a car. Also, the other category of electrogalvanized coating, sheet with a coating mass of less than 25 g/m^2, is ideal for relatively non-corrosive applications. Production of an equally thin hot-dip coating is not practical.