TECH

Published by the EPRI Center for Metals Production

Electrogalvanizing:

The electrical way to improve the long-term performance of steel sheet.

Galvanized Steel — A Cost-effective Product

Galvanized steel is one of the most widely known and used coated products. Its popularity results from low cost and effective corrosion resistance in traditional applications for roofing, agricultural equipment, garbage cans, and guard rails. Today, however, it is in great demand by auto makers striving to produce cars that are free of cosmetic corrosion for 10 years. To meet these stringent requirements, automotive fenders and doors require improved quality products that are more easily produced by electrogalvanizing than by the hot-dip coating process.

Galvanized steel has been performing successfully as a corrosion resistant material in automotive applications since the late 1950's when it was used for rocker panels. Use in other automotive applications was limited until 1976 when a one-side-coated electrogalvanized product was developed for fenders and doors. The success of this product led to additional production capacity for both one and two-side coated electrogalvanized steel introduced in the mid-1980s. During this period, the use of galvanized steel for automotive applications grew from 219,000 tons in 1960 to 1,028,000 tons in 1980 and is estimated to be over 4,500,000 tons in 1990, see Figure 1.

The effectiveness of galvanized steel results from a highly successful combination of the bulk properties of steel, the substrate, and the surface properties of zinc, the coating metal. The steel provides a myriad of combinations of strength and formability in

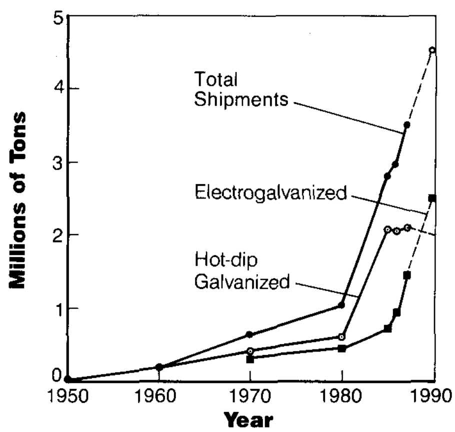

Figure 1 *Use of galvanized steel in automotive applications.*

an inexpensive engineering material whose properties can be tailored as required for specific applications. The zinc coating on the steel surface provides good corrosion resistance, a property ordinary carbon steel lacks. The zinc coating protects the steel in two ways. First, the zinc coating is an overlaying film or "barrier" which shields the steel from exposure to the corrosive environment. The second way zinc protects steel is "sacrificially", or electrochemically. This process becomes effective when the coating is scratched or otherwise damaged exposing bare steel to the atmosphere. Then, the zinc adjacent to any exposed steel sacrifices itself setting up an electrochemical or "galvanic" action which prevents the steel from rusting.

Coating Processes

Steel products can be galvanized by several different methods, but only two of these processes are suitable for the high-volume production of galvanized steel. These methods are continuous hot-dip galvanizing and electrogalvanizing.

Continuous Hot-Dip Galvanizing

This method has grown from the mechanization of the original hand dipping of individual steel sheets in pots of molten zinc and has become the traditional process for producing galvanized steel. In modern lines, a continuous coil of steel is cleaned, annealed, and coated in one operation. The steel is electrolytically cleaned in an alkaline solution by either traditional or high-current density techniques. It is then continuously annealed and passed through either an induction-heated or gas-fired bath of molten zinc. The steel is withdrawn from the bath through a pair of coating control "knives" which direct high-pressure gaseous jets of either air, steam, or nitrogen at the steel. These blow off the excess molten zinc adhering to the surface leaving a film of molten zinc of controlled thickness. This film solidifies as large crystals giving the product the "spangled" or "flowery" appearance which has been the "trademark" of hot-dip galvanized steel.

This product is used extensively for agricultural buildings, construction, and numerous other applications and has firmly established its reputation as an outstanding corrosion-resistant engineering material. Shipments of the hot-dip product grew rapidly in the 1950's reaching 3,060,000 tons in 1960. Its increasing popularity encouraged further significant improvements in surface appearance, smoothness, and coating uniformity. An iron-zinc alloy coated product produced by the in-line post annealing of galvanized steel by induction heating was also developed. This product has improved weldability and paintability. As a result of these improvements, the successful use of this product was extended to pre-engineered building panels and to unexposed automotive applications.

Hot-dip galvanized steel is still ideal for applications requiring the maximum corrosion resistance provided by its relatively thick coatings (0.001 in. or more). Shipments of this product were 4,790,000 tons in 1980 and are estimated to exceed 8,000,000 tons in 1990. Future volume growth for this product is expected in its traditional market areas. New market areas, such as automotive fenders, hoods, and decks are limited because the painted surface is not totally adequate for high visibility areas where undistorted gloss and reflectivity are of prime importance. A further restriction of hot-dip galvanize in automotive applications is the lack of a fully acceptable high-volume production method for a steel having the zinc as a coating on only one surface.

Electrogalvanizing

The principles of the electrodeposition of zinc as a coating process for steel are well known and are illustrated in Figure 2. As shown in the diagram, the deposition process occurs in a "cell" containing an anode and cathode immersed in an aqueous solution of zinc salts, the electrolyte. A low external voltage (10-40V) applied to the anode and cathode causes the zinc ions in the solution to move to the cathode and deposit on it as a film or coating of zinc. The anode may be a bar of zinc called a "soluble anode". Zinc anodes dissolve as a result of the applied voltage at a rate approximately equal to the deposition rate thereby maintaining the zinc concentration of the electrolyte. Alternatively, the anode may be made from a material which does not dissolve (insoluble anode). In this case, zinc dissolved in the electrolyte is plated onto the cathode. The zinc in the electrolyte is then replenished in an off-line regeneration unit.

In a commercial scale electrogalvanizing operation, a continuous strip of steel moves through the cell as the cathode and voltage is applied to the

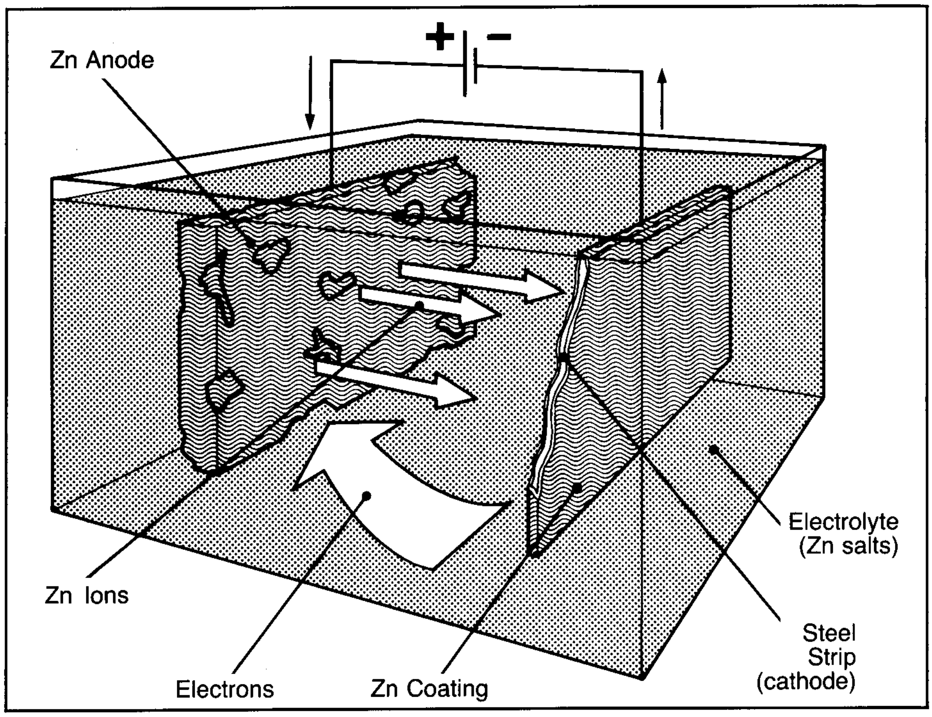

Figure 2 *The zinc electrodeposition process.*

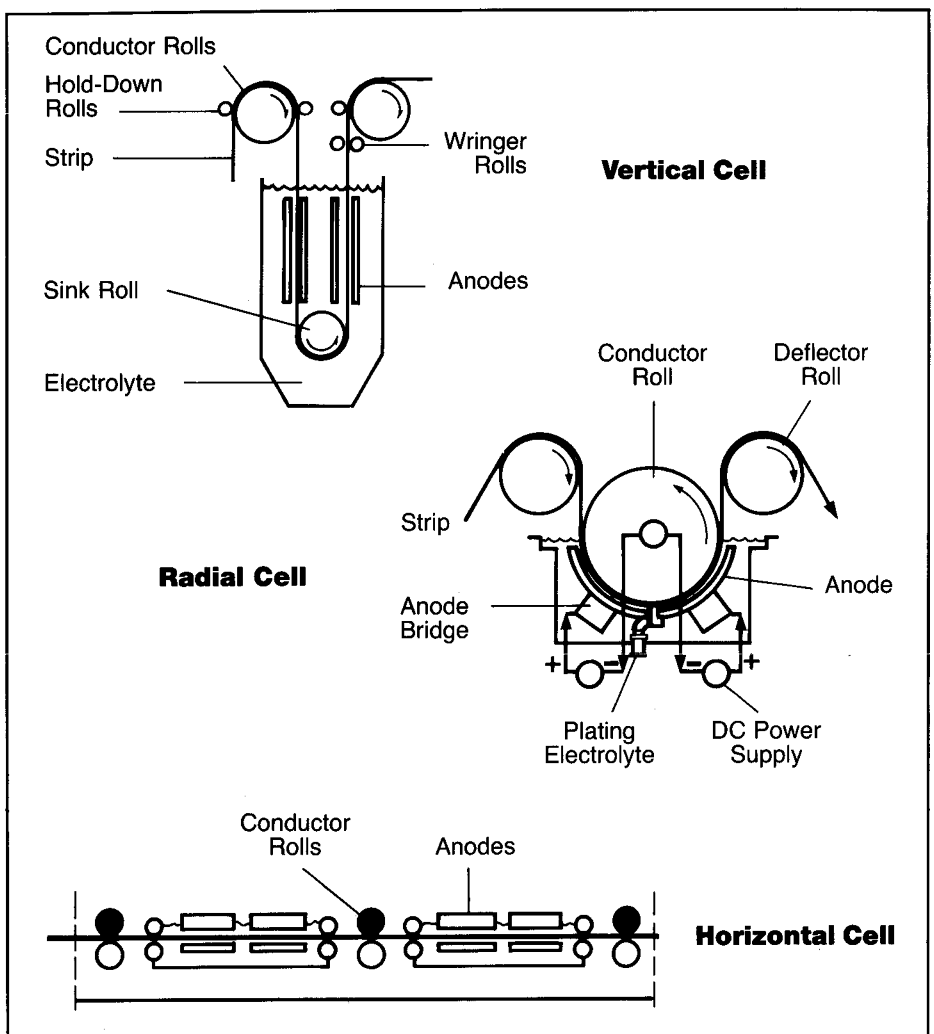

Figure 3 *Alloy plating cells.*

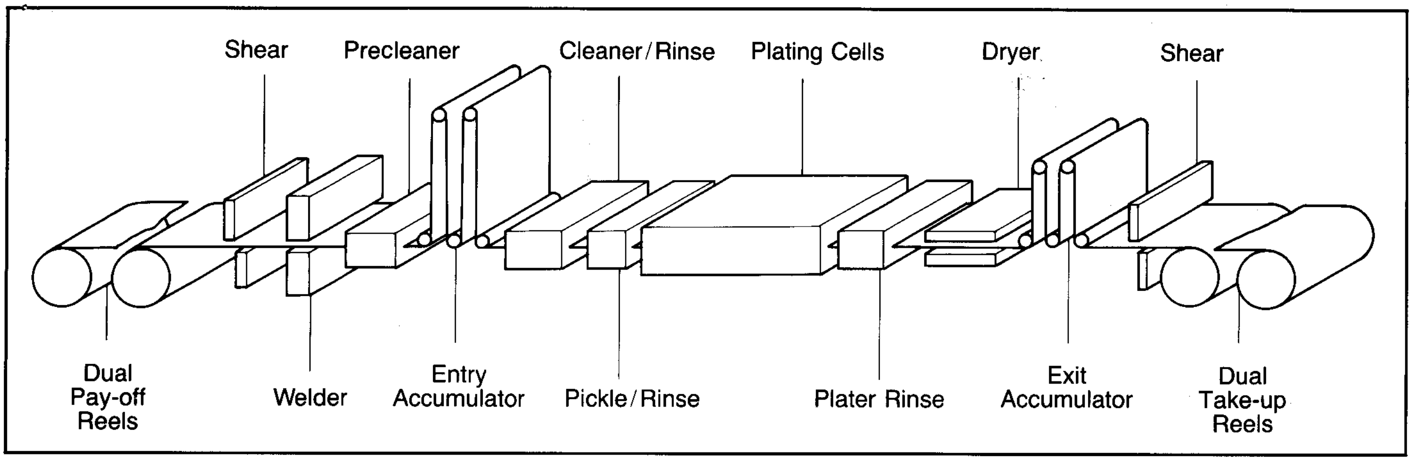

Figure 4 *Modern electrogalvanizing line.*

steel through a rotating roll (conductor roll). The amount of zinc being deposited is directly proportional to the current flow through the cell. Thus the coating thickness can be precisely controlled by controlling the current flow.

The continuous electrogalvanizing of steel has been a commercial process for approximately 50 years. Until recently, the coatings produced were thin, up to 0.20 oz./sq.ft. (or 0.00013 inch per side), because of the low deposition rates and relatively high production costs. These coating thicknesses limited application to products for interior use and those needing improved paintability or temporary corrosion resistance during storage and installation.

Recent improvements in process technology and power efficiencies have made it possible to competitively produce the coating weights (up to 0.90 oz./sq.ft. or 0.00060 inch per side) which are required for the present automotive applications. Other developments include processes for the electrodeposition of iron-zinc alloy and nickel-zinc alloy coatings.

Several different types of plating cells, horizontal, vertical, and radial cells, see Figure 3, have been developed for the modern high-speed lines. Each cell has particular advantages and the choice between them depends upon cost, product mix, production rate, and the type of metal being deposited. The electrogalvanizing process can be designed and operated to produce both one and two-side coatings of different types more easily than by the hot-dip process.

Modern High-Speed Lines - in modern coating lines steel is continuously processed through several operations to produce coils of coated product to exacting customer specifications (Figure 4).

At the entry end of the line, coils are placed on dual pay-off reels which feed the steel to a welder where ends of successive coils are joined to provide continuous feed to the process. After the welder, the steel is cleaned to remove the residual oils and surface contaminants remaining from the prior processing operations. Then the steel enters the entry accumulator where it is stored in an elevator-like unit. This unit provides a surplus of steel to continuously operate the coating section of the line while a new coil is being welded to the one being processed. After the accumulator, the steel receives a final electrolytic cleaning and its surface is activated by pickling before it enters a number of plating cells used in series. Each cell typically operates at about 50,000 to 60,000 amperes. The number of cells in a line is determined by the desired coating weight and production rate. After plating, the steel is rinsed, dried, and coiled for shipment.

TABLE I
Major US Electrogalvanizing Lines

	U.S. Steel	Double Eagle Steel Coating Co.	Armco Steel	Walbridge Coatings	National Steel	L-S Electro-galvanizing Co.
LOCATION	Gary, IN	Dearborn, MI	Middletown, OH	Walbridge, OH	Ecorse, MI	Cleveland, OH
START-UP	4-77	2-86	3-86	4-86	12-85	4-86
PROCESS TECHNOLOGY	U.S. Steel CAROSEL	U.S. Steel CAROSEL	Arus Andritz -Ruthner	Arus Andritz -Ruthner	Nippon Kokan National Steel	Sumitomo
NOMINAL CAPACITY (t/yr)	425,000	700,000	250,000	400,000	400,000	400,000
LINE SPEED (f/m)	400	700	300	700	650	650
WIDTH (in)	64	72	75	72	72	72
PLATING CELLS						
Number	18	37	16	18	20	20
Type	Radial	Radial	Vertical	Vertical	Vertical	Vertical
RECTIFIERS						
Number	36	74	32	36	80	40
Voltage	12	12	30	24	40	42
Current (A)	1,008,000	2,072,000	736,000	900,000	1,000,000	1,320,000

In order to meet the growing demand for electrogalvanized steel for automotive applications, the larger domestic steel producers commissioned five new electrogalvanizing lines during 1985-1986. These lines and an earlier line have a total rated capacity of more than 2,500,000 tons per year and represent four different plating technologies, (Table 1). Electrical power consumption varies with the technology used and the product being made but can be as high as 600 kWh per ton of steel coated.

Related Technologies

In efforts to improve corrosion resistance and to reduce product cost, new zinc-based alloys which can be applied by the same process are being developed. These coatings have improved performance and can be applied as thinner coatings. These efforts are particularly strong in countries where energy costs are high, such as Japan.

Iron-Zinc Alloys

Major developmental efforts are being made to produce an electrogalvanized, 15% iron-zinc alloy coating which is equivalent to that produced by the hot-dip process. This product has improved weldability and paintability and is preferred for some applications.

Nickel-Zinc Alloys

Coatings with 12% nickel-zinc are an excellent base for organic finishes and are used by some auto makers.

Dual-Layer Coatings

Auto makers are evaluating the performance of a roll-coated organic paint over electrogalvanized steel as a means of improving stampability and paintability.

Advantages of Electrogalvanizing:

Smoother - the electrodeposited product has a smooth, matte-gray appearance which does not show through the organic surface finishes used for cars.

Coating thickness - precise control of the process current gives a multitude of easily reproducible coating thicknesses of equal or varying amounts on any steel surface.

Uniformity - electrodepositon produces coatings which are extremely uniform in thickness at any given thickness level.

One-side coating - specially designed cells and equipment have been developed for the high-volume production of steel with a zinc coating on only one surface.

Versatility - the electrodeposition process can produce coatings of different metals on opposite surfaces of the steel sheet or produce coatings of other zinc alloys for further improvement in corrosion resistance .

Mechanical properties - the mechanical properties of the steel are not affected by the temperature of the coating process.

Weldability - the higher purity of the coating provides improved electrode tip life on spot welding operations.

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Applicable SIC Codes 3312,3313,3315,3316

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