Zinc Plating

Steve Schneider

Applications

Zinc plating is widely employed for providing sacrificial protection to steel. Zinc is preferential to cadmium in industrial environments and is deposited in thicknesses ranging from 0.1 mil to over 1.0 mil, depending upon the intended application and the corrosion protection required. The bulk of commercially plated zinc is 0.1 to 0.3 mil thick.

The relatively low cost, protective nature and attractive appearance of zinc make it a popular coating for nuts, bolts, washers, metal stampings and automotive parts, such as certain interior components and gas filters. In addition, zinc serves as an effective undercoat for paints.

Processes

Zinc coatings are commonly applied by mechanical plating and electroplating. Mechanical plating is achieved without electrical current, and is utilized where hydrogen embrittlement of plated parts cannot be tolerated. Hydrogen embrittlement reduces the fatigue strength of steel. Steel with a hardness of over Rc 35 is susceptible to this type of failure from any plating operation where current is used to deposit metal.

Electroplating is by far the most available and common method of applying zinc coatings. Zinc electroplated coatings are generally applied using one of the three major types of plating solutions: Cyanide, alkaline non-cyanide, and chloride.

Cyanide zinc solutions employ zinc metal (0.8 to 5.0 oz/gal), sodium cyanide (l to 14 oz/gal), sodium hydroxide (8 to 12 oz/gal), and organic additives in a variety of ratios and concentrations. These solutions are generally easy to control, have wide operating parameters, excellent covering power, and relatively low operating cost. Due to the cyanide content, they are extremely toxic and have relatively high effluent treatment costs. They exhibit low current efficiency, which exists in an inverse relationship to cathode current density, a characteristic that is beneficial for more uniform metal distribution on large parts requiring coverage in low-current-density areas. This low efficiency is less beneficial for plating heat treated and carbonitrided parts.

Alkaline noncyanide zinc solutions eliminate cyanide as a constituent and utilize zinc metal (0.8 to 1.6 oz/gal), sodium hydroxide (l0 to 18 oz/gal), and organic brightener systems. Effluent treatment is less extensive and these solutions exhibit good plate distribution. These solutions do require closer control, with special attention given to the metal content, which rises when the solution is idle unless the anodes are removed during this period. Both cyanide and alkaline noncyanide solutions can be operated in unlined steel tanks, although lined tanks may be preferred.

Chloride zinc solutions employ zinc metal (2.0 to 5.0 oz/gal), chloride (15 to 20 oz/gal), and organic brighteners. These solutions produce exceptionally bright deposits with high current efficiency, good covering power and easy effluent treatment. The high current efficiency is beneficial for plating carbonitrited steel and cast iron parts. The high efficiency results in more variation in plate distribution as the bath maintains in excess of 95 percent cathode current efficiency over its entire current density range. The plating tank must be lined and the solutions must be continuously filtered.

Development in all three categories of zinc plating solutions has been continuous primarily with regard to the proprietary brightener systems. The choice of solution is dependent upon effluent treatment requirements, the type or variety of parts to be plated, and the design of the existing plating equipment.

Corrosion Protection of Chromate Coatings

Type of chromate	Time to white salts on zinc plate (salt spray test)
Clear (bright blue)	12-24 hr
Iridescent yellow	100-200 hr
Olive drab	100-300 hr
Black	12-125 hr

Post-plating

Due to the active nature of zinc, plated coatings are generally passivated through chromate treatment. Chromate coatings are classified by color, which reflects the film thickness and chromate content. Colors include clear to blue, yellow, olive drab and black. Slight variations in thickness of light film coatings create color interferences, giving the iridescence typical of these coatings. The table outlines the approximate salt spray resistance provided by each color. These figures show the protection to "white corrosion salts," which indicate that the chromate has failed and that the zinc plate is beginning to corrode. For most applications, the chromate is chosen to provide protection through the useful life of the part being plated.

Good rinsing following zinc plating is important in order to achieve an acceptable chromate color with good adhesion and corrosion resistance.

A typical processing cycle for zinc electroplating of steel parts is as follows: (1) soak clean; (2) electroclean; (3) double rinse; (4) acid pickle; (5) double rinse; (6) zinc electroplate; (7) double rinse; (8) chromate; (9) double rinse; (10) warm rinse; (II) dry. Other functional post treatments of zinc plated parts have included dyeing of the chromate films with a variety of pastel colors, water phase lacquering, post dipping in wax or oil, and proprietary corrosion resistant dips or leaching solutions.

On electroplated parts, the possibility of hydrogen embrittlement can be mitigated by baking at 350 to 400 °F for 3 to 24 hr soon after plating.

Health Impact

All components of zinc plating solutions should be considered toxic and handled with care, with particular attention given to Material Safety Data Sheets and operating instructions. Acids and cyanides should never come in contact with one another, nor should they be stored together, since deadly hydrogen cyanide gas would be liberated. Goggles, gloves, aprons and boots should be worn whenever working with plating solution components and operating solutions.

The threshold limit value (TLV) for zinc in the workplace is 5 mg/mL for fumes and 10 mg/m^3 for dust.

Environmental Status

Wastewater zinc limits under EPA Metal Finishing Regulations are 2.61 mg/L for any single day and 1.48 mg/L as a 30 day average. Cyanide effluent must be oxidized with chlorine and the zinc metal precipitated through pH adjustment of 9.0 to 10.5 in a clarifier. Sludge must be disposed of in accordance with federal EPA, state and local regulations.

Trends

Zinc will continue to be a popular and widely available corrosion-resistant coating. The trend in recent years has been away from the cyanide type of plating solution due to effluent treatment and disposal costs. Current developments in zinc plating technology involve alloyed coatings, primarily incorporating zinc-cobalt and zinc-nickel. These alloys provide extended corrosion resistance and are of emerging interest, especially for automotive applications.