GALVANIZING AND MECHANICAL PREPARATION OF STEEL FOR POWDER COATING

K R Evans, Sunstate Coatings Pty Ltd (1997)

INTRODUCTION
This paper, as the title suggests, is to provide a basic understanding of the process of hot dip galvanizing, properties of the galvanized coating and how to prepare this surface mechanically prior to powder coating.

To achieve this I will provide a brief discussion on the following topics.

- History of Galvanizing
- Process of Galvanizing
- Abrasion Resistance of Galvanizing
- Main Advantages of Hot Dip Galvanizing
- Recommended method of Mechanical Preparation Prior to Powder Coating

HISTORY OF GALVANIZING
Hot dip galvanizing is the process of applying a metallic zinc coating to fabricated steel by immersing the material in a bath consisting of molten zinc.

The process goes back as far as the mid 1700's, however the first patented process was by the French chemist Sorel in 1836, and in fact by 1850, British galvanizing industry was using some 10,000 tonnes of zinc per year to protect steel.

This popularity has continued to this day, because galvanizing is a simplistic method of steel protection and provides a zinc coating that is a controlled metallurgical combination of zinc and steel that can provide a corrosion resistance in a wide variety of environments. In fact, its corrosion resistance factor can be some 70 to 80 times greater than the base steel.

In Australia today, over 40 companies use 12,500 tonnes of zinc to galvanize over 200,000 tonnes of steel per year.

Hot dip galvanizing protects steel from corrosion by providing a thick, tough metallic zinc envelope, which completely covers the steel surface and seals it from the corrosive action of its environment. The galvanized coating provides outstanding abrasion resistance. Where there is damage or minor discontinuity in the sealing coat of zinc, protection of the steel is maintained by the cathodic action of the surrounding galvanized coating.

Cathodic protection simply means that in the presence of an electrolyte, the anodic zinc coating on a galvanized article corrodes preferentially to the cathodic steel substrate, preventing corrosion of small areas, which may be exposed through accidental damage.

The cathodic or sacrificial protection continues for as long as the galvanized coating remains.

LET US NOW LOOK AT THE PROCESS OF HOT DIP GALVANIZING
The current process that is most commonly used in Australian galvanizing operations is "dry galvanizing" which is best suited both environmentally and in terms of this paper, for paint and powder applicators.

With galvanizing, the surface preparation contains its own built-in means of quality control in that zinc will not react with the steel surface unless it is perfectly clean.

Any failures or inadequacies in surface preparation will be immediately apparent when the steel is withdrawn from the molten zinc and any uncoated areas remain, and immediate corrective action can be taken.

STEP ONE
Caustic Cleaning - The work is placed on beams or jigs and is manually loaded. This is to allow numerous products to be handled and processed simultaneously and then immersed in hot alkali solution which is generally heated to around 90 degrees Celsius and is used to remove organic contaminants like dirt, paint marking, grease and oil from the metal surfaces.

Epoxies, vinyls, previous powder coating systems must be removed by mechanical cleaning such as shot or sand blasting.

STEP TWO
Pickling - Scale and rust are removed by placing the work in a dilute solution of hydrochloric acid at an ambient temperature. Usually run between 5% to 16% concentration, the strength of acid also governs the speed of pickling.

Surface preparation can also be achieved using abrasive cleaning as alternative or in conjunction with chemical cleaning.

STEP THREE
The work is generally immersed in a static rinse bath or spray rinsed to remove acid and iron salts and prevent these being carried over to the preflux bath.

STEP FOUR
The dry galvanizing process is where the steel is immersed in a bath containing an aqueous solution of zinc ammonium chloride. Concentration is approximately 25%. The bath is also heated to around 65 degrees Celsius.

Flux is the final surface preparation step in the galvanizing process. Fluxing removes oxides that form on the very active steel surface produced from the pickling operation and prevents further oxides from forming on the surface of the metal prior to galvanizing and promotes bonding of the zinc to the steel or iron surface.

STEP FIVE
Galvanizing - This is where the material is completely immersed in a bath consisting of a minimum of 98% pure molten zinc. The bath is chemically analysed on a regular basis to ensure it meets Australian Standards 1650 1989 (now AS/NZS 4680:1999-Hot-dip galvanized (zinc) coatings on fabricated ferrous articles).

The temperature at which galvanizing takes place is around 450 degrees Celsius.

Fabricated items are immersed in the bath long enough to reach bath temperature. The surface of the bath is swept to remove ash and flux decomposition products that have floated to the surface, and any zinc oxide slag that may form on the surface, then the articles are slowly withdrawn from the galvanizing bath and excess zinc is removed by draining, wiping, vibrating or in some instances spinning.

Finally, the articles are quenched in a mild solution of sodium dichromate. This solution is designed to provide a thin zinc chromate layer for the initial protection of zinc surface.

Naturally the galvanized work can be air-cooled and for powder coating we believe this to be essential, as the chromate passivation on the zinc surface interferes with the phosphate reaction with the zinc in the powder coating pretreatment process and in some instances prevent it altogether. The elimination of the chromate passivation stage from the galvanizing process causes problems in that the freshly galvanized surface is very reactive, and if it is wet with atmospheric moisture or precipitation, zinc oxide and zinc hydroxide compounds (commonly called “white rust”) rapidly form. In fact these begin forming immediately.

METALLURGY OF GALVANIZING
When the cleaned and fluxed steel surface contacts the molten zinc in the galvanizing bath the protective flux layer is removed leaving a clean steel surface, which is immediately wetted by the zinc. This results in reaction between zinc and steel with the formation of zinc-iron alloy layers.

The photomicrograph shows a section of a typical galvanized coating, which consists of a progression of zinc-iron alloy layers, bonded metallurgically to the based steel, with the relatively pure outer zinc layer.

The layers in the galvanized coating are as follows:

1. Base Steel
2. Gamma Layer - Thin molecular layer containing 21 to 28% iron.
3. Delta Layer - Zinc-iron alloy containing 7 to 12% iron.
4. Zeta Layer - Zinc-iron alloy containing 5.8 to 6.2% iron.
5. Eta Layer - Relatively pure outer zinc coating.

ABRASION RESISTANCE OF GALVANIZED COATINGS
The photomicrograph shows that the delta and zeta zinc-iron alloy layers are actually harder than the base steel, resulting in galvanizing's outstanding resistance to abrasion and mechanical damage. Abrasive or heavy loading conditions in service may remove the relatively soft eta layer of zinc from a galvanized surface, but the very hard zeta alloy layer is then exposed to resist further abrasion and heavy loading.
The hardness of the relative alloy layers is as follows:

1. Base Steel - 159 DPN hardness
2. Delta Layer - 244 DPN hardness
3. Zeta Layer - 179 DPN hardness
4. Eta Layer - 70 DPN hardness

ADVANTAGES OF HOT DIP GALVANIZING
The advantages of using hot dip galvanizing as a substrate for powder coating are:

1. **COATING STRENGTH**

The metallurgically bonded coating includes hard alloy layers for abrasion resistance and a soft-top layer for ductility. These factors of bonding, hardness and ductility are unmatched by other coatings.

2. **ENVELOPE PROTECTION**

Hot Dip Galvanizing provides a metallurgically bonded full envelope coating on the base steel.

An additional advantage, which is not always promoted, is that the process will deliver coatings at least as thick at the corners and edges as the coating on the rest of the article.

As coating damage is most likely to occur at the edges, this is where added protection is needed most because galvanizing involves total immersion of the material. It is a complete process and all surfaces are coated. Galvanizing provides both outside and inside protection for hollow structures.

3. **ALL WEATHER**

Galvanizing can be done in all weather and humidity conditions.

RECOMMENDED METHOD OF MECHANICAL PREPARATION OF A GALVANIZED SURFACE FOR POWDER COATING
Firstly let me say that to achieve a successful result in blasting a galvanized coating, the blast standards for preparing steel surfaces for painting or powder coating are totally inappropriate, because as we saw in the section of this discussion relating to the "Metallurgy of the Coating", the outer free zinc layer is very soft and ductile and therefore requires very little impact to remove oxides and promote adequate surface roughness.
Due to the lack of any standard relating to sweep blasting the Galvanizers Association of Australia has prepared a data sheet that provides a set of parameters we believe will provide a satisfactory blasted galvanized surface.

The normal conditions used for blasting of steel surfaces involve high air pressures, the nozzle of the blast gun close to the surface and the use of new sharp edged sand.

To sweep blast galvanized coatings we recommend that the operator start with the lowest air pressure possible, the lowest angle of impact possible and the use of old used abrasive, with the nozzle 300-400mm from the surface.

The operator should then slowly increase the air pressure, angle of impact until a satisfactory surface is obtained.

A satisfactory surface finish will be obtained when the gloss or sheen has been removed from the galvanized coating. This should involve the removal of less than 10 microns of surface zinc.

If the blasted surface is to be directly powder coated without any other treatment, care should be taken to ensure the surface is not contaminated with dirt or grease. To assist in this area the people handling the product should wear clean soft gloves.

Copies of the data sheet are freely available from the Galvanizers Association of Australia offices or any galvanizer who is a member of the Galvanizers Association of Australia.

This method of mechanical preparation has been used successfully in many different applications to date, and if the procedure is followed you should achieve a suitably blasted surface for the powder coater to work with.

GALVANIZERS ASSOCIATION OF AUSTRALIA

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T E C H N I C A L   D A T A   S H E E T
SWEEP BLASTING HOT DIP GALVANIZING

This method of surface preparation is normally not required when using good quality and appropriate paint topcoats over galvanizing.

However, in some circumstances where good wet adhesion or semi immersion of the combined system is intended light sweep blasting can provide maximum topcoat adhesion over galvanizing.

To achieve a successful result it must be understood that blast standards for preparing steel are totally inappropriate for galvanizing where the outer free zinc layer requires very little impact or scouring action to promote adequate surface roughness.

The following criteria should be observed.

- Blast pressure 50-60 psi maximum
- Abrasive Grade 0.2 - 0.5mm (clean ilmenite)
- Angle of blasting to surface 45° angle
- Distance from surface 300 - 400mm
- Nozzle type min 9.5mm of venturi type

These controls will ensure that the severity of blasting does not damage the galvanized surface and should remove only 10 um of surface zinc.

If operators with good experience in sweep blasting are unavailable, it is wise to begin with a greater distance between the nozzle and the surface to be sweep blasted until standards for the work have been established.