Welding of Zinc-Coated Steel

Coating by hot dip galvanizing is usually carried out after fabrication is complete. This provides a continuous corrosion resistant barrier to the component so that a reasonable service life can be achieved.

Modular lengths of components smaller than available bath sizes are recommended since single dipping of the component will generally achieve a better overall coating quality. Components are occasionally double end dipped if joining is appropriate and the available bath size is inadequate for a single dip. Components that have been designed in modular lengths appropriate to the available bath sizes occasionally have to be joined on site. This can be achieved by bolting or welding. When welding is preferred certain precautions are required to achieve quality joints. The most common welding processes with their respective effects on the welded joint are provided below.

14.1 SHIELDED METAL ARC WELDING (SMAW)

Welding conditions are similar to those used on uncoated steel, except that the root opening is increased in certain cases to give full penetration and allow for drainage.

The welding arc should be advanced on to the zinc coating by a weaving action ahead of the molten weld pool to melt and vapourise the coating from the steel.

T-Joints using SMAW
The same basic welding technique used for welding butt joints should be employed; that is, a slower travel speed than normal and a slight whipping action of the electrode. Undercut is the most prevalent defect found in fillet welds deposited in the horizontal and vertical positions with either rutile or basic covered electrodes.

With general galvanizing, the zinc coating is thicker than that deposited on continuously galvanized sheet. This extra zinc may cause trouble in the vertical position, because when it is molten it tends to run down into the weld pool and make the slag difficult to control. This can be minimised, and often prevented, by maintaining as short an arc length as possible.

14.2 GAS METAL ARC WELDING (GMAW)

Conditions for Welding General Hot Dip Galvanized Steel
The short-circuiting transfer mode produces less distortion and damage to the zinc coating than the spray transfer mode.

GMAW Spatter Formation
With the carbon dioxide GMAW process, each short circuit during the transfer of metal causes a momentary rapid rise in current followed by extinguishing the arc. Re-ignition is accompanied by the ejection of small particles of molten metal in the form of spatter. When either carbon dioxide or 80% argon, 20% carbon dioxide shielding gas is used, spatter is increased when welding hot dip galvanized steel compared with uncoated steel.

if the spatter particles adhering to the workpiece are unsightly, the problem can be minimised by spraying an anti-spatter compound on to the workpiece before welding. Available anti-spatter products are based on silicone, petroleum or graphite compounds. Applying one of these products will allow the spatter particles to be brushed off easily.

Spatter formation increases with the thickness of the zinc coating and, is therefore greater on general galvanized steel than continuously galvanized sheet. When general hot dip galvanized steel is welded in a T-joint, in a flat position, spatter particles tend to roll into the corner of the joint causing difficult welding. Spatter formation is also troublesome when welding in the overhead position, as spatter particles are apt to fall into the gas nozzle of the welding gun. Spatter formation is reduced by reducing the diameter of the welding wire.

14.3 GAS TUNGSTEN ARC WELDING (GTAW)

Gas tungsten arc welding of general galvanized steel is *not* recommended unless the zinc coating is first removed. The zinc vapour may contaminate the electrode which in turn will cause erratic arc operation and poor weld quality. If the zinc coating is removed, the bare steel is welded using procedures suitable for uncoated steel. Gas tungsten arc braze welding with its attendant lower temperatures, can be carried out with less joint preparation.

14.4 FLUXED CORED ARC WELDING (FCAW)

Hot dip galvanized steels may be arc welded with flux cored electrodes. Slag systems have been developed for carbon dioxide shielding as well as for gas-free applications. The self-shielded electrodes are favoured for fabricating sheet metal because of the low penetration and high travel speeds that are possible. The recommendations of the electrode manufacturer should be followed and the welding procedure should be qualified by appropriate tests.

14.5 SUBMERGED ARC WELDING (SAW)

Butt Joints
Butt joints can be welded using hot dip galvanized steel using the same edge preparation as for uncoated steel.

Low travel speed can reduce or eliminate porosity. By supporting the plates free from the welding bench, so that zinc vapour can escape from above as well as below the joint, thicker general hot dip galvanized coatings can normally be welded without porosity.

T-Joints
Submerged arc twin-fillet welds, in which both sides of a T-joint are welded simultaneously can be deposited on hot dip galvanized steel.

14.6 OXYFUEL GAS WELDING (OGW)

Hot dip galvanized steel may be oxyfuel gas welded using copper-coated mild steel filler rods. Preparation for welding is similar to that used for welding uncoated steel; jigs and clamps are used to prevent distortion caused by heat buildup and any grease or dirt is removed from the weld area. A neutral flame should be used, and the size of the tip should be the same as that used for welding uncoated steel or similar thickness.

With oxyfuel welding, because of the low travel speed used, the zinc coating is volatilised and completely removed for at least 7mm on each side of the weld. For an additional 7mm or so on each side, partial volatilisation occurs. These changes result in a reduction in corrosion resistance. Beyond this depleted region, for up to 19mm, the appearance of the zinc coating may be degraded; however, this matted region has been observed to have no deterioration in corrosion resistance.

14.7 BRAZING AND BRAZE WELDING

Brazing

High-frequency induction brazing can be performed on general galvanized sheet with very good results using filler alloys of silicon bronze or 60% copper – 40% zinc. Careful control of heating rates can result in sound joints with very little damage to the zinc coating.

Braze Welding

Braze welds are made at a lower temperature than fusion welds. The base metal is not melted and there is less loss of the zinc coating from the steel. Use of suitable brazing alloys produces strong corrosion resistant welds.

14.8 SOLDERING

Hot dip galvanized steel can be soldered using either an acid or an organic flux. Zinc chloride- and ammonium chloride-based fluxes are usually adequate when using tin-lead solders containing 20 to 50% tin. The most popular solder composition is 40% tin – 60% lead. The recommended heat source is a soldering iron. A caustic treatment prior to soldering helps to improve wettability.

Sodium dichromate passivation, used to prevent wet storage staining, may interfere with solder flow. Sodium dichromate should be removed *(see Chemical Cleaning - Chapter 17)* prior to soldering.

Hot dip galvanized coatings that have been phosphated are difficult to solder. The phosphate films must be removed prior to soldering.

14.9 EMBRITTLEMENT OF STEEL BY LIQUID ZINC DURING ARC AND OXYFUEL GAS WELDING

Welding general galvanized steel joints using carbon-steel electrodes can be prone to cracking. This cracking is caused by intergranular penetration of zinc into the weld metal. It occurs most often along the throat of a fillet weld, in the weld root and is also observed in the base metal in the heat-affected zone.

Properly designed welded joints using the procedures which follow can minimise the occurrence of such embrittlement and the residual tensile stresses which exaggerate the problem. Selecting an electrode containing silicon below 0.4% is also advisable.

The likelihood of cracking occuring in fillet welds depends upon several key factors:

- the thickness of the hot dip galvanized coating;
- the method of hot dip galvanizing;
- the thickness of the hot dip galvanized steel;
- the width of the joint root opening;
- the method of joint restraint;
- the welding process; and
- the electrode classification.

Weld cracking is influenced by coating thickness. For this reason, cracking occurs most often when thick coatings are applied by general galvanizing. Cracking may not develop at all with thin, electro-deposited coatings. Cracking tends to be less prevalent with low-penetrating shielded metal arc welding and more prevalent with gas metal arc welding and more prevalent with gas metal arc welding, especially with carbon dioxide shielding gas. The higher heat input and slower welding speed with shielded metal arc welding allows more zinc to volatilise ahead of the molten weld pool.

Methods for minimising fillet weld cracking on hot dip galvanized steel, due to zinc penetration fall into four categories;

- use correct root opening between the plates, about 1,6mm is recommended;
- correct choice of consumable, with the GMAW process low silicon E70S-3 electrodes are better than the high silicon E70S-6 electrodes, also rutile E6012/13 are better than low hydrogen E7015/16 types;
- selection of the galvanized base metal by suitable procedure tests; and
- preparation of the base plate to reduce the available zinc by burning the zinc off by oxy-gas torch, grinding or abrasive blasting.

14.10 RESISTANCE WELDING

Resistance welding or spot welding is commonly used to join steel sections thinner than 5mm thick if the coating is lighter than 300g/m^2 (43µm thick). Coatings up to 450g/m^2 (65µm thick) have been successfully welded, although the life of the copper electrode is much shorter than with lighter coatings. On heavy coatings, it is necessary to frequently redress or replace worn electrodes, due to the build up of zinc on the electrode.

Coating damage by resistance welding is usually of minor significance, requiring very little or no repair. If the galvanized coatings are thick, resistance welding is impractical.

Resistance seam welding is not recommended due to zinc contamination of the electrode wheel but projection welding is possible without serious difficulty.

14.11 SAFE HEALTH PRACTICES

Fumes are always generated during the welding of uncoated steel. They contain varying amounts of iron oxide, ozone, hydrogen, carbon monoxides, nitrous oxides and fluorides. Zinc oxide is generated when welding or cutting zinc coated steel. Zinc oxide is a white compound that is clearly visible in the welding fumes, unlike the gases mentioned above.

Health Effects of Zinc Oxide

The inhalation of newly formed zinc oxide can cause a condition known as zinc fever, or zinc shivers. The symptoms are similar to those of influenza, i.e. fever, fits of shivering, increased salivary secretion, headaches and, in more serious cases, nausea and vomiting.

Zinc is not however, retained in the body in the same way as lead, cadmium, and other heavy metals, but is excreted in urine and faeces. The symptoms of zinc fever usually disappear within a few hours and long term effects are thought to be minimal. Temperature, however, does not seem to exceed 39°C and complete recovery usually occurs within 24 - 28 hours. A suggested Threshold Limit Value (TLV) of 5mg/m^3, has been laid down for American practice. A worker may be exposed to this level for a period of eight hours without harmful effects.

Protection from Welding Fumes

By taking elementary precautions, particularly in confined spaces, the effects of zinc fume can be minimised as follows:

- provide positive ventilation such as a suction hose;
- use suction tube gun nozzles on gas metal arc and flux cored arc welding equipment;
- use face masks and respirators;
- weld out of doors if practicable;
- use copper chill bars if practicable, to absorb the heat of welding;
- welders should position themselves so as not to be overexposed to fume; and
- ensure that areas to be rewelded / repaired are cleaned of remaining zinc. Grinding is considered to be the most effective way of removing such coatings.

Additional technical information on welding of hot dip galvanized steel can be obtained from Hot Dip Galvanizers Association Southern Africa.