34. WELDING GALVANIZED STEEL

Welding techniques for galvanized steel include GMA (gas metal arc), carbon arc, GTA (gas tungsten arc), manual metal arc, and torch welding. Galvanized steels are welded easily and satisfactorily by all commonly practiced welding techniques. Closer control of welding conditions than for uncoated steel is usually necessary but procedures are simple and well established.

GMA (gas metal arc) welding, also known as CO_2 or MIG welding, is a versatile semi-automatic welding process which is convenient and easy to use. It is particularly suited to the welding of thinner materials. In the GMA welding of galvanized steel the presence of the zinc coating has no effect on weld properties although some weld spatter is produced. Arc stability is excellent and is not affected by the galvanized coating. Some reduction in welding speed is required

The GMA welding process
The weld takes place in a protective gas shield. A small diameter consumable wire electrode of 0.8 mm to 1.6 mm is fed automatically to the weld torch. The high current density resulting from the small diameter of the wire is in the region of 200 amperes per square millimetre.

Shielding gas for GMA welding galvanized steel
Galvanized steel is welded satisfactorily using the GMA process and pure carbon dioxide shielding gas that provides excellent weld penetration, but considerable weld spatter. The use of a spatter release compound should be considered for this application.

Alternatively, the more expensive argon/CO_2 or argon/CO_2/ O_2 mixtures provide adequate weld penetration, a superior weld bead, and far less spatter. A 92% Ar/5% CO_2/3% O2 mixture has been found to provide excellent results on galvanized sheet up to 3.0 mm thickness

Welding conditions
GMA welding speeds should be lower than on uncoated steel as specified in the weld conditions tables, to allow the galvanized coating to burn off at the front of the weld pool. The reduction in speed is related to the thickness of the coating, the joint type and the welding position, and is generally of the order of 10 to 20 per cent. Fillet welds in steel with thicker galvanized coatings may be welded more readily if the current is increased by 10 amps.

The increased heat input helps to burn away the extra zinc at the front of the weld pool.
Penetration of the weld in galvanized steel is less than for uncoated steel so that slightly wider gaps must be provided for butt welds. A slight side-to-side movement of the welding torch helps to achieve consistent penetration when making butt welds in the flat position.

Effect of welding position in GMA welding galvanized steel
To achieve complete penetration in the overhead position on galvanized steel with 600 g/m^2 coatings, weld current should be increased by 10 amps, and voltage by 1 volt. Welds in the vertical downwards and overhead positions may require a speed reduction of 25 to 30 per cent by comparison with uncoated steel, depending on joint type and coating thickness, to prevent rising zinc vapor from interfering with arc stability. Butt welds in the horizontal-vertical positions require less reduction in speed because the zinc vaporises away from the weld area.

Appearance of GMA welds in galvanized steel

Surface appearance of GMA welds in galvanized steel is satisfactory although a certain amount of weld spatter is generated, regardless of whether CO_2 shielding gas or an argon/CO_2 mixture is used.

Adhesion of weld spatter to the gun nozzle, and to the workpiece with resulting marring can be prevented by application before welding of an aerosol spray petroleum base or silicone base spatter release compound available from welding consumables suppliers. Any adhering spatter particles can then easily be brushed off. Silicone-based compounds may interfere with the application of subsequent coatings.

GMA braze welding

An extension of the GMA process, GMA braze welding utilises a filler metal with a lower melting point than the parent metal. The joint relies neither on capillary action nor on intentional melting of the parent metal. Shielding gases of the argon/oxygen type are the most suitable, the low oxygen level being sufficient to permit excellent edge wash and a flat weld without causing surface oxidation.

The low heat input minimises damage to the coating on the underside of the parent plate, enables the corrosion resistant bronze filler to cover any of the coating damaged by the arc, and minimises the level of distortion when welding sheet metal components.

Finishing costs of thin tubular or sheet metal components such as automotive panels can therefore be reduced substantially.

Manual metal arc welding galvanized steel

Manual metal arc welding is recommended only for galvanized steel of 1.6 mm thickness or thicker, as difficulies may occur with burning through on light gauges. GMA, GTA, or carbon arc welding are recommended for sheet lighter than 1.6 mm. In general, manual metal arc welding procedure for galvanized steel sheet is the same as for uncoated steel although the following points should be noted:

1 The welding electrode should be applied a little more slowly than usual with a whipping action which moves the electrode forward along the seam in the direction of progression and then back into the molten pool. All volatilisation of the galvanized coating should be complete before bead progress, after which welding is the same as for uncoated steel.

2 A short arc length is recommended for welding in all positions to give better control of the weld pool and to prevent either intermittent excess penetration or undercutting.

3 Slightly wider gaps up to 2.5 mm are required in butt joints in order to give complete penetration.

4 For operator comfort adequate ventilation should be provided and the use of a respirator is recommended in confined space.

5 Grinding of edges prior to welding will reduce fuming from the galvanized coating. Welding schedules will then be the same as for uncoated steel.

6 Repairs to the coating should be carried out.

Electrodes for manual metal arc welding galvanized steel

Electrodes to Australian Standard 1553.1 classifications E4112 and E4113 are recommended as suitable for all positions. In butt and tee-joint welds in the flat and horizontal-vertical positions the E4818 basic coated electrode is highly suitable, giving fast, easy welding, improved bead shape, and easier slag removal.

Both rutile and basic coated iron powder electrodes perform satisfactorily on galvanized steel, giving a good weld profile with freedom from undercutting, and easy slag removal. In butt joints in plate with vee edge preparation, an electrode should be chosen which limits the tendency to produce a peaky or convex deposit run since this can cause slag entrapment which will not be removed by subsequent weld runs.

Physical properties of arc welds in galvanized steel
Extensive tensile, bend, radiographic and fatigue testing at the Welding Institute* Cambridge, UK, for International Lead Zinc Research Organisation has shown the properties of sound GMA welds and manual metal arc welds in galvanized steel to be equivalent to those of sound welds in uncoated steel. Test welds were made without removing the galvanized coating from edges to be welded. The presence of any weld porosity due to volatilisation of the galvanized coating during welding has no effect on joint properties except in loss of fatigue strength.

Properties of sound welds in galvanized steel

General properties
When welding conditions are chosen to give sound welds in galvanized steel, the tensile, bend and charpy impact properties are equivalent to those of welds in uncoated steel. Tests showed that the presence of zinc at the levels occurring in the weld metal does not affect tensile, bend or impact properties.

Fracture toughness
Crack opening displacement (COD) measurements and drop weight tests established that fracture toughness properties of welds are unaffected by the presence of galvanized coatings.

Fatigue strength
The fatigue strength of arc welds in galvanized steel is equivalent to welds in uncoated steel. Fatigue tests were carried out on fillet welded cruciform joints made by CO_2 GMA welding with low silicon filler metal of the AWS Classification E60S-3.

PROPERTIES OF WELDS CONTAINING POROSITY

General effects
Porosity will occur in certain weld joint designs in galvanized steel, depending on coating thickness, due to volatilisation of the zinc coating and entrapment of gas in the weld.

The type of joint affects pore formation since gases cannot readily escape from tee joints and lap joints or from butt joints in thick materials. In the case of butt joints, a vee edge preparation or provision of a gap between square edges facilitates the escape of gases, minimising porosity. Pore formation is also influenced by the thickness of the galvanized coating relative to the steel base. Close attention to welding conditions will reduce the extent of porosity but complete elimination is not always possible and it is important to consider the effect of porosity on static strength, fatigue strength and cracking of the weld joint.

Effect of porosity on fatigue strength
The extent of weld porosity is a function of heat input and the solidification rate of the weld metal. Not always possible to eliminate, porosity affects the fatigue strength and cracking tendencies of welds. When welds are subject to fatigue loading, welds on galvanized steel should be made oversized to reduce the influence of any weld metal porosity. When evaluating the effect of porosity on the fatigue strength of a fillet weld, it is necessary to consider both the function of the joint and the weld size. When a fillet weld on galvanized steel is large enough relative to plate thickness to fail by fatigue from the toe of the weld in the same manner as in uncoated steel, the presence of porosity in the weld does not reduce the fatigue strength of the joint. Where the dimensions of the weld are just large enough to cause fatigue failure from the toe in a sound weld, a weld containing porosity at the root may fail preferentially through the throat of the weld.

Cracking
Intergranular cracking of fillet welds containing porosity, sometimes referred to as zinc penetrator cracking, does not significantly affect the strength of non-critical joints. For more critical stressed applications however, it is advisable to carry out procedural tests on material and samples.

GTA brazing galvanized steel
GTA (gas tungsten arc) process, also known as argon arc, provides an excellent heat source for braze welding. In GTA brazing, the weld area is shielded from the atmosphere by a protective flow of inert argon gas. A non-consumable tungsten electrode is employed with a separate 'Cusilman' (96%Cu, 3% Si, 1% Mn) filler wire, as used for carbon arc welding. The argon barrier prevents oxidation of the electrode or the weld pool and welds of excellent appearance result.
The process allows continuous welding at very high speeds, particularly with mechanised arrangements.

In the GTA brazing of galvanized steel the arc should be played on the filler wire rather than on the weld area to prevent undue coating damage. The following variations in welding technique are also recommended to minimise contamination of the tungsten electrode by traces of zinc oxide fume:

1 Hold the weld torch at a 70° angle rather than the 80° angle normally used for uncoated steel
2 Increase shielding gas flow from 6 to 12 p/min to flush zinc oxide fume from the electrode area.

Corrosion resistance of GTA brazed joints made in galvanized steel is excellent. During the welding operation the corrosion resistant brazed metal tends to wet and flow out over the small area from which the galvanized coating has been volatilized. GTA welding is recommended only as a heat source for brazing galvanized steel, not as a fusion welding technique. When used for fusion welding the tungsten electrode is fouled rapidly by zinc oxide fume.

Torch welding galvanized steel
Torch welding of galvanized sheet steel either with or without a filler rod is generally carried out on the lighter gauges. Because zinc volatilises at about 900°C while steel melts at about 1500°C, the necessary welding temperature usually results in coating damage and the need for subsequent treatment of damaged areas.

Brazing
Coating damage may be overcome by brazing. Brazing employs much lower temperatures (900°C), producing very little coating damage in the area adjacent to the weld. The weld metal itself is corrosion resistant and tends to wet and cover all bare steel in the weld area so that joints are normally acceptable without further treatment. The suggested filler rod is a copper-zinc-silicon alloy, such as Austral Tobin Bronze (63% Cu, 37% Zn, 0.3% Si, 0.15%Sn). Prior to brazing, the edges of components should be painted for about 6 mm back with a flux such as Comweld Copper and Brass Flux or Liquid Air 130 Flux. The lowest practical heat input is desirable and flame adjustment must be oxidising, as this helps to reduce local loss of zinc in the weld zone.

Butt welds are preferred to lap joints and the gap in such welds should be equal to half the thickness of the sheet.

Cutting galvanized steel
Cutting of galvanized steel is commonly done with oxy-acetylene cutting torches. Thinned galvanized sections may also be cut using abrasive cut-off saws. Each of these processes generates sufficient heat to volatilise the galvanized coating.

Some coating burn-back will occur when oxy-cutting galvanized steel, although this is usually less than 10 mm from the affected area, and dependent on steel thickness.

In both these processes, fume management should be implemented as for welding galvanized steel, and remediation of the cut edges and areas affected by burn-back should also be done. The heat affected area of thinner galvanized sections (under 3 mm thick) cut by abrasive saw is very small, and the cut edges of such thin sections may not require repair because of the cathodic protection of the exposed steel provided by the galvanized coating on the adjacent surfaces.

RECONDITIONING WELD-DAMAGED SURFACES

Weld damage

When damage to the galvanized coating has occurred during welding or when the weld area will be exposed to corrosive service conditions, the damaged area should be repaired. Width of the weld-damaged zone will depend on heat input during welding, being greater with a slow process such as torch welding than with high speed arc welding. In the manual metal arc welding and torch welding of galvanized steel, the weld metal itself will corrode in most atmospheres and the application of a protective coating is essential. Suitable materials for coating the weld metal and adjacent damaged areas of the coating are zinc rich paints, and in some circumstances, zinc metal spraying.

Repair methods

The methods described are in accordance with Australian/New Zealand Standard 4860:2006 Appendix E ‘Renovation of damaged or uncoated areas’. In the case of weld repairs, surface preparation consists of removal of any welding slag with a chipping hammer followed by vigorous wire brushing.

Welding fumes

All welding processes generate fumes. Hazardous Substances regulations have been introduced in all Australian states and territories. The National Occupational Health and Safety Commission (NOHSC) has set standards for allowable exposure for atmospheric contaminants in the occupational environment (NOHC: 1003 – 1995).

The Welding technology Institute of Australia (WTIA) has published guidelines for fume minimisation and control.

Zinc volatilizes at welding temperatures to form white zinc oxide, so its presence is easily detected. Various fume extraction options are listed in the WTIA Fume Minimisation Guidelines – Guideline 2.

All materials of construction may contain potentially hazardous components that can be released in the welding process. In addition to zinc coatings such as galvanizing, other coatings in steel including paints, plastics and other metallic coatings can give rise to a wide range of prescribed hazardous compounds.

Good welding practice in keeping with these OH&S industry guidelines will define the operational requirements for welding galvanized steel.

INGAL
SPECIFIERS MANUAL

01 - SPECIFIERS MANUAL — THIRD EDITION

Industrial Galvanizers Australian Galvanizing Division (IGAG) operates nine galvanizing plants around Australia, ranging in size from large structural galvanizing facilities to specialised small plants designed to process small parts.

The Australian Galvanizing Division has galvanized in excess of 2 million tonnes of steel products in Australia since its first plant was commissioned in 1965 and is recognized for its ability to handle complex and difficult projects, as well as routine contracts.

This experience has been collated in the Specifiers Design Manual, to assist those involved in the design of steel products and projects to better understanding the galvanizing process and allow the most durable and cost-effective solutions to be delivered to these products and projects. All sections of this Third Edition have been completely updated and additional sections have been included to provide additional technical information related to the use of hot dip galvanized steel.

In addition to its Australian Galvanizing operations, Industrial Galvanizers Corporation has a network of manufacturing operations in Australia, as well as galvanizing and manufacturing businesses throughout Asia and in the USA.

The company's staff in all these locations will be pleased to assist with advice on design and performance of hot dip galvanized coatings and products. Contact details for each of these locations are located elsewhere in this manual.

This edition of the Industrial Galvanizers Specifiers Manual has been produced in both html and .pdf formats for ease of access and distribution and all documents in the Manual are in .pdf format and can be printed if paper documents are required.

The Specifiers Manual is also accessible in its entirety on the company's web site at www.ingal.com.au.

Additional copies of the Specifiers Manual are available on CD on request.

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