CHAPTER 5

Welding Galvanized Steel

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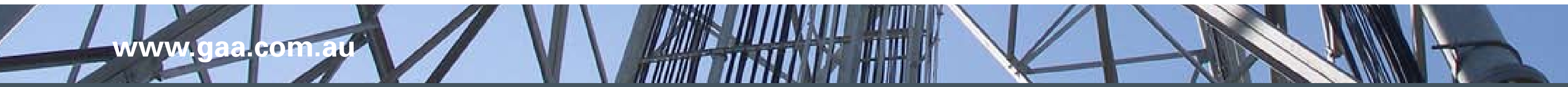
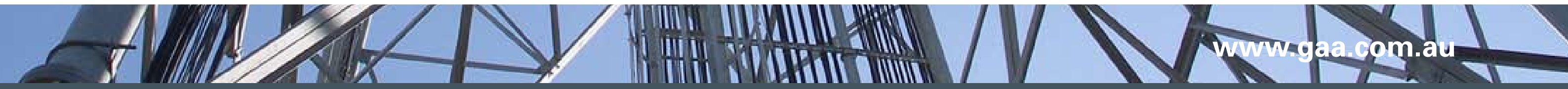


Welding Galvanized Steel

Galvanized steels are welded easily and satisfactorily by all commonly practised welding techniques. Closer control of welding conditions than for uncoated steel is usually necessary but procedures are simple and well established. This chapter details procedures for all suitable welding techniques for galvanized steel including GMA (gas metal arc), carbon arc, GTA (gas tungsten arc), manual arc, and oxyacetylene welding. The welding of galvanized reinforcement for concrete is discussed in 'Galvanized steel reinforcement for concrete'.

Work sponsored by International Lead Zinc Research Organization, New York and carried out by E N Gregory of The Welding Institute, Cambridge, England, has been used in recommendations on GMA welding and manual metal arc welding. Recommendations are based on Australian practice and terminology. Information has also been supplied by Liquid Air Australia Limited and Welding Industries of Australia.



GMA welding galvanized steel

GMA (gas metal arc) welding, also known as CO_2 - or MIG/MAG 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.

Welding galvanized steel vaporizes the zinc near the arc (zinc boils before steel melts). The zinc oxidises in the air to a fine white powder. Prolonged breathing of these fumes can cause side effects which lasts about 24 hours. As with all welding proper ventilation and fume exhaust is of first priority (please see Chapter 13 of WTIA Technical Note 7).

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 as discussed under '**Appearance of GMA welds in galvanized steel**'. Arc stability is excellent and is not affected by the galvanized coating. Some reduction in welding speed is required, see 'Welding conditions' at top right.

The GMA welding process

The weld takes place in a protective gas shield. A small diameter consumable wire electrode of 0.8mm to 1.6mm 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.

The constant voltage type power sources employed offer instantaneous self adjustment of the arc so that the arc length remains constant even when the operator varies the distance between the electrode and the work piece – power sources are designed to increase welding current as the arc length shortens and the wire burns off at a higher rate to maintain the original arc length. When the arc is lengthened, current is reduced and the wire is consumed at a lower rate, again maintaining the original pre-set arc length.

Welding parameters provide for two different types of metal transfer in GMA welding:

1. Spray transfer, in which globules of metal are detached magnetically from the wire and propelled across the arc. This is the high current/high voltage form of the process which is used in the flat position on plate thick enough to prevent burn-through.
2. Short circuiting transfer sometimes known as 'dip transfer', in which lower currents and voltages are used. The end of the wire dips into the molten weld pool while a globule of metal is being transferred. Short circuiting transfer occurs about 100 times per second producing a characteristic buzzing sound. The process is used for welding thin sheet and for positional welding of all thicknesses.

Shielding gas for GMA welding galvanized steel

Galvanized steel is welded satisfactorily using the GMA process and pure carbon dioxide shielding gas which provides excellent weld penetration, but considerable weld spatter. The use of a spatter release compound as discussed under "**Appearance of GMA welds in galvanized steel**", may be worthwhile.

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

Conditions for GMA welding galvanized steel using a short circuiting arc and both Ar/CO_2 and CO_2 shielding gases are given below.

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.

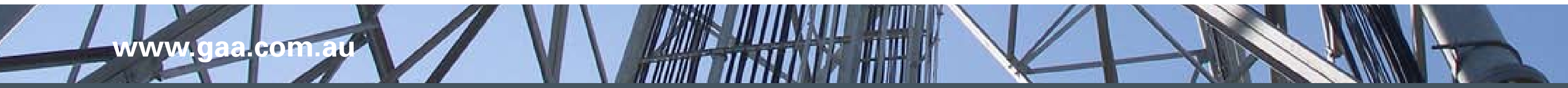
Penetration of the weld in galvanized steel is less than for uncoated steel so that slightly wider gaps must be provided for butt welds. A slight side to side movement of the welding torch helps to achieve consistent penetration when making butt welds in the flat position.

Effect of welding positions in GMA welding galvanized steel

To achieve complete penetration in the overhead position on sheet with 600g/m^2 coatings, weld current should be increased by 10 amps and voltage by 1 volt.

Welds in the vertical downwards position may require a speed reduction of 25 to 30 percent by comparison with uncoated steel, depending on joint type and coating thickness, to prevent rising zinc vapour from interfering with arc stability.

Butt welds in the overhead and horizontal-vertical positions require little reduction in speed because the zinc vapour rises 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.

Minor coating damage occurs and repairs to the weld area should be carried out as detailed in **Reconditioning weld-damaged surfaces**.

Adhesion of weld spatter to the gun nozzle, and to the work piece 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 paintability.

Spatter may also build up in the nozzle of the torch interrupting the flow of shielding gas, in extreme cases causing weld porosity and erratic feeding of filler wire. The application of a spatter release compound to the welding torch nozzle reduces the adherence of spatter particles and with the help of a small wire which can be rubbed inside the nozzle.

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 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 sheetmetal components.

Finishing costs of sheetmetal 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 1.6mm thickness or thicker, as difficulty may occur with burning through on light gauges. GMA, GTA, or carbon arc welding are recommended for sheet lighter than 1.6mm.

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 2.5mm 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 spaces (See '**Welding fumes**')
5. Grinding of edges prior to welding will satisfactorily reduce fuming from the galvanized coating. Welding schedules will then be the same for uncoated steel.
6. Repairs to the coating should be carried out. See '**Reconditioning weld-damaged surfaces**'.

Electrodes for manual metal arc welding galvanized steel

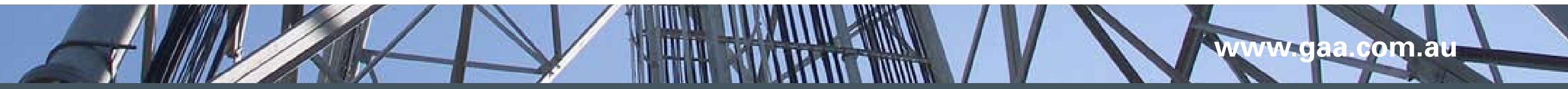
In general, electrodes to Australian Standard 1553.1 classifications E4112 and E4113 are recommended as suitable for all positions. In butt and tee-joint welds in the flat and horizontal-vertical positions the E4818 basic coated electrode is highly suitable, giving fast, easy welding, improved bead shape,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

With metal recovery rates of between 110 and 130 per cent, 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.

Undercutting in fillet welds is reduced if rutile coated electrodes with a less fluid slag are used since these produce a concave weld profile. Electrodes with very fluid slags tend to produce concave weld profiles with more prevalent undercutting, which is difficult for the welder to rectify.

Different brands of electrodes complying with the same specification may behave differently when used in welding galvanized steel and it may be advisable to carry out simple procedure tests before commencing production welding.



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 which can be avoided as discussed under 'Effect of porosity on fatigue strength', below.

Properties of sound welds in galvanized steel

General properties

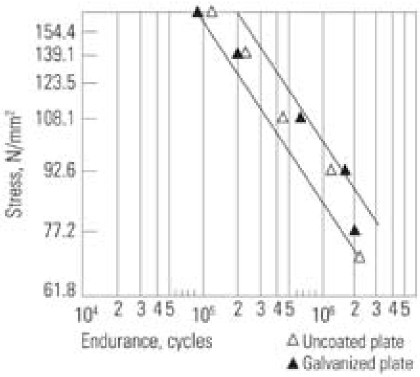
When welding conditions are chosen to give sound welds in galvanized steel, the tensile, bend and charpy impact properties are equivalent to those of welds in uncoated steel. Tests showed that the presence of zinc at the levels occurring in the weld metal does not affect tensile, bend or impact properties.

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 as shown by the test results below. 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 AWS A5.18:ER70S-2



SN curves showing results of fatigue tests on cruciform joints. CO_2 short circuiting GMA welds on 13mm uncoated and galvanized Lloyds Grade A steel, AWS A5.18:ER70S-2 filler metal. EN Gregory, 'The mechanical properties of welds in zinc coated steel'

Properties of welds containing porosity

General effects

Porosity will occur in certain 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.

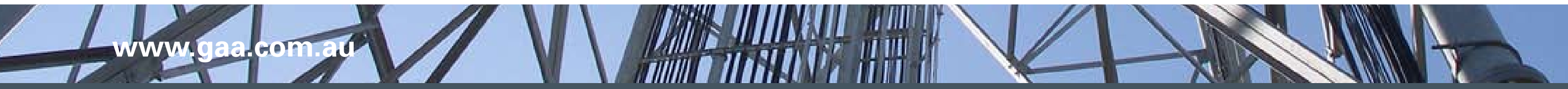
Effect of porosity on fatigue strength

When joints are subject to fatigue loading, welds in galvanized steel should be made oversize to reduce the influence of any porosity in the weld metal.

When a fillet weld in 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 a 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.

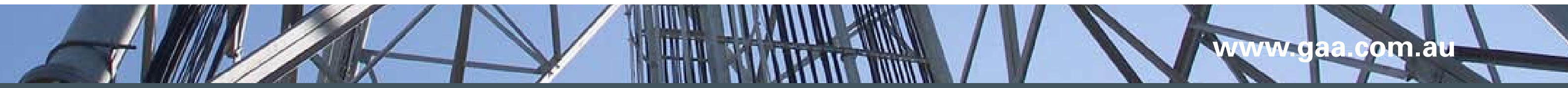
In the GTA brazing of galvanized steel the arc should be played on the filler wire rather than on the weld area to prevent undue coating damage.

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 form 6 to 12 L/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 volatilised, so 'healing' the coating.

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.



Oxyacetylene welding galvanized steel

Oxyacetylene welding galvanized steel sheet 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 damage areas. (See below)

Brazing

Coating damage may be overcome by adopting brazing techniques. 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 6mm 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.

Some welding fume will be given off during brazing and forced ventilation or fume extraction must be provided in confined spaces. (See '**Welding fumes**')

Reconditioning weld-damaged surfaces

Weld damage

When severe damage to the galvanized coating has occurred during welding or when the weld area will be exposed to corrosive service conditions, protection must be restored. Width of the weld-damaged zone will depend on heat input during welding, being greater with a slow process such as oxyacetylene welding than with high speed arc welding.

In the manual metal arc welding and oxyacetylene 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 as discussed above right and in 'Reconditioning damaged surfaces in galvanized steel'.

Coating damage due to rough handling or abrasion

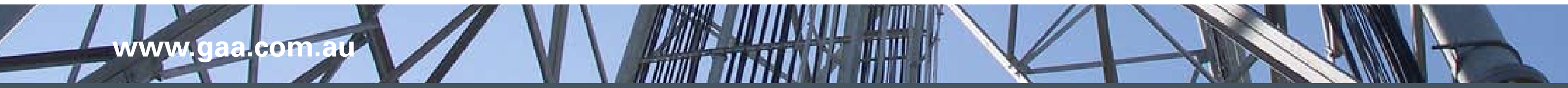
Small areas of the basis steel exposed through mechanical damage to galvanized coatings are protected from corrosion cathodically by the surrounding coating and may not need repair, depending on the nature of the product and the environment to which it is exposed. Small exposed areas normally have little effect on the life of the coating as discussed under 'Bare spots' and 'Cathodic protection'.

Larger damaged areas require coating repair.

Repair methods

Appropriate coating repair methods are detailed in 'Reconditioning damaged surfaces in galvanized steel'. The methods described are in accordance with Australian/New Zealand Standard 4860 - Part 8 'Repair After Galvanizing'.

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

Arc and oxyacetylene welding

In the arc welding or oxyacetylene welding of galvanized steel, provision must be made for control of welding fumes when planning procedures. Due to the relatively low melting point of zinc a proportion of the coating is volatilised and given off as a white zinc oxide fume. The presence of any fume evolved is obvious and this permits simple observation of the efficiency of the ventilation or extraction system.

When welding is carried out in accordance with normal industrial practice with provision for adequate ventilation and air circulation, the non-toxic zinc fumes will cause no inconvenience. If adequate ventilation is not available, supplementary ventilation using air extraction equipment or forced air circulating equipment, should be provided.

Although welding fumes from galvanized steel are not toxic, operators welding in a confined space should always be provided with suitable respirators to minimise possible discomfort. Fume development and consequent coating damage may often be minimized with certain joint designs in flat sheet by the use of copper chill bars. The chill bars are used as a backing strip or clamped on the weld side of the joint to absorb some of the heat generated during welding.

GMA welding

Welding fume extraction guns for GMA welding galvanized steel are available from major welding equipment suppliers. These guns are very effective in removing weld fumes and have negligible effect on weld quality.

GMA welding tests were conducted by the Welding Institute, Cambridge, England for International Lead Zinc Research Organisation Inc. Using CO_2 shielding gas at a flow rate of 15 L/min, a horizontal-vertical fillet weld in 6 mm thick batch galvanized steel was free from porosity. Tests with the same CO_2 flow rate and the fume extractor in operation produced a fillet field on the same plate sample containing only two small pores in 150 mm of weld, showing that disturbance of the shielding gas is extremely small.

Plasma cutting of galvanized steel

Plasma cutting using compressed air as the cutting gas allows high speed cutting of galvanized steels in thicknesses from 0.5 to 10 mm, with reduced distortion. The high cutting speed and concentrated arc results in very limited coating damage and minimal fume generation.