

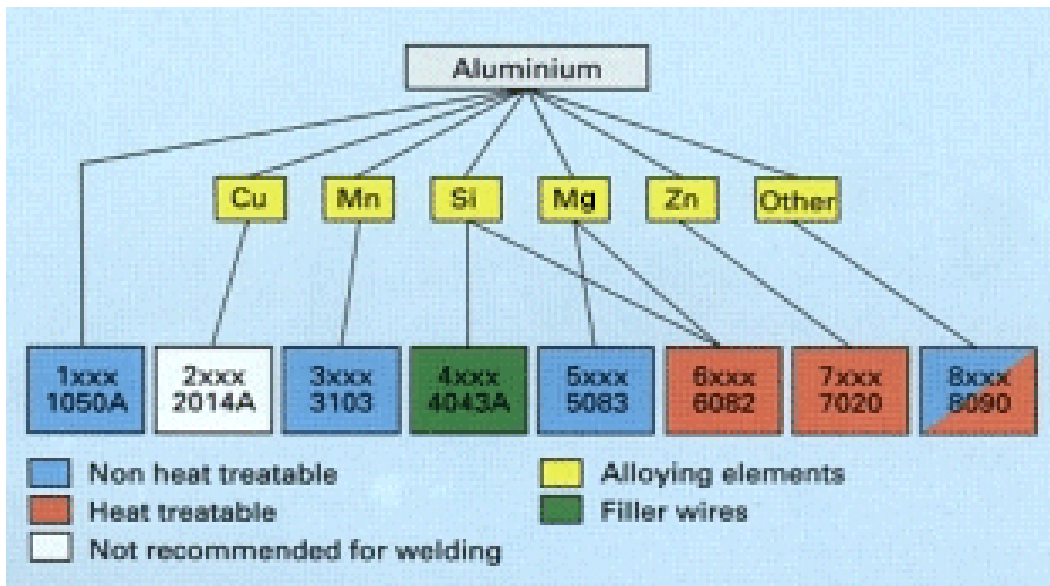
Aluminium alloys

Weldability of materials

Job Knowledge

Aluminium and its alloys are used in fabrications because of their low weight, good corrosion resistance and weldability. Although normally low strength, some of the more complex alloys can have mechanical properties equivalent to steels. The various types of aluminium alloy are identified and guidance is given on fabricating components without impairing corrosion and mechanical properties of the material or introducing imperfections into the weld.

Material types



As pure aluminium is relatively soft, small amounts of alloying elements are added to produce a range of mechanical properties. The alloys are grouped according to the principal alloying elements, specific commercial alloys have a four-digit designation according to the international specifications for wrought alloys or the ISO alpha - numeric system. The alloys can be further classified according to the means by which the alloying elements develop mechanical properties, non-heat-treatable or heat-treatable alloys.

Non-heat-treatable alloys

Material strength depends on the effect of work hardening and solid solution hardening of alloy elements such as magnesium, and manganese; the alloying elements are mainly found in the 1xxx, 3xxx and 5xxx series of alloys. When welded, these alloys may lose the effects of work hardening which results in softening of the HAZ adjacent to the weld.

Heat-treatable alloys



Welding Job Knowledge



Material hardness and strength depend on alloy composition and heat treatment (solution heat treatment and quenching followed by either natural or artificial ageing produces a fine dispersion of the alloying constituents). Principal alloying elements are defined in the 2xxx, 6xxx and 7xxx series. Fusion welding redistributes the hardening constituents in the HAZ which locally reduces material strength.

Processes

Most of the wrought grades in the 1xxx, 3xxx, 5xxx, 6xxx and medium strength 7xxx (e.g. 7020) series can be fusion welded using TIG, MIG and oxyfuel processes. The 5xxx series alloys, in particular, have excellent weldability. High strength alloys (e.g. 7010 and 7050) and most of the 2xxx series are not recommended for fusion welding because they are prone to liquation and solidification cracking.

The technique of Friction Stir Welding is particularly suited to aluminium alloys. It is capable of producing sound welds in many alloys, including those heat treatable alloys which are prone to hot cracking during fusion welding.

Filler alloys

Filler metal composition is determined by:

- weldability of the parent metal
- minimum mechanical properties of the weld metal
- corrosion resistance
- anodic coating requirements

Nominally matching filler metals are often employed for non-heat-treatable alloys. However, for alloy-lean materials and heat-treatable alloys, non-matching fillers are used to prevent solidification cracking.

The choice of filler metal composition for the various weldable alloys is specified in BS EN 1011 Pt 4:2000 for TIG and MIG welding; recommended filler metal compositions for the more commonly used alloys are given in the *Table*.

Principal Designation	Application
1Al 99.8(A)	Al plant
3Al Mn1	s, heat exchange
4Al Si5(A)	re/rod
5Al Mg4.5	ail wagons, bridge
5Al Mg2M	hicles, marine
5Al Mg5C	re/rod

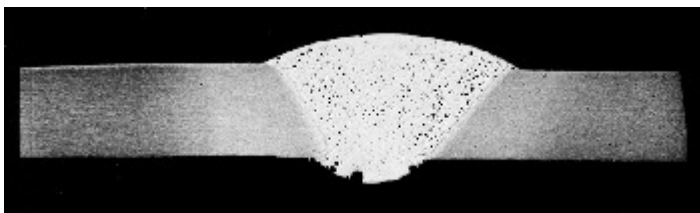
5Al Mg5M	e/rod
6Al Mg1Si	al, pipes
7Al Zn4.5I	al, transport
at treatable, NHT = Non He	

Imperfections in welds

Aluminium and its alloys can be readily welded providing appropriate precautions are taken. The most likely imperfections in fusion welds are:

- porosity
- cracking
- poor weld bead profile

Porosity



Porosity is often regarded as an inherent feature of MIG welds; typical appearance of finely distributed porosity in a TIG weld is shown in the photograph. The main cause of porosity is absorption of hydrogen in the weld pool which forms discrete pores in the solidifying weld metal. The most common sources of hydrogen are hydrocarbons and moisture from contaminants on the parent material and filler wire surfaces, and water vapour from the shielding gas atmosphere. Even trace levels of hydrogen may exceed the threshold concentration required to nucleate bubbles in the weld pool, aluminium being one of the metals most susceptible to porosity.

To minimise the risk, rigorous cleaning of material surface and filler wire should be carried out. Three cleaning techniques are suitable; mechanical cleaning, solvent degreasing and chemical etch cleaning.

In gas shielded welding, air entrainment should be avoided by making sure there is an efficient gas shield and the arc is protected from draughts. Precautions should also be taken to avoid water vapour pickup from gas lines and welding equipment; it is recommended that the welding system is purged for about an hour before use.

Mechanical cleaning

Wire brushing (stainless steel bristles), scraping or filing can be used to remove surface oxide and contaminants. Degreasing should be carried out before mechanical cleaning.

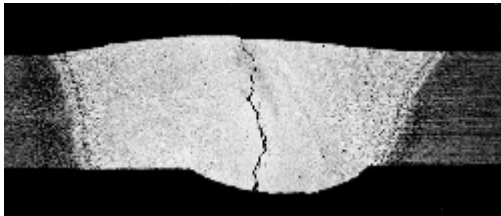
Solvents

Dipping, spraying or wiping with organic solvents can be used to remove grease, oil, dirt and loose particles.

Chemical etching

A solution of 5% sodium hydroxide can be used for batch cleaning but this should be followed by rinsing in HNO₃ and water to remove reaction products on the surface.

Solidification cracks



Cracking occurs in aluminium alloys because of high stresses generated across the weld due to the high thermal expansion (twice that of steel) and the substantial contraction on solidification - typically 5 % more than in equivalent steel welds.

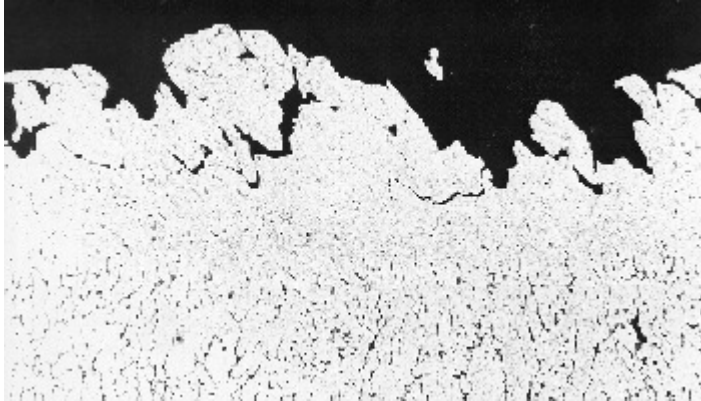
Solidification cracks form in the centre of the weld, usually extending along the centreline during solidification.

Solidification cracks also occur in the weld crater at the end of the welding operation. The main causes of solidification cracks are as follows:

- incorrect filler wire/parent metal combination
- incorrect weld geometry
- welding under high restraint conditions

The cracking risk can be reduced by using a non-matching, crack-resistant filler (usually from the 4xxx and 5xxx series alloys). The disadvantage is that the resulting weld metal may have a lower strength than the parent metal and not respond to a subsequent heat treatment. The weld bead must be thick enough to withstand contraction stresses. Also, the degree of restraint on the weld can be minimised by using correct edge preparation, accurate joint set up and correct weld sequence.

Liquation cracking



Liquation cracking occurs in the HAZ, when low melting point films are formed at the grain boundaries. These cannot withstand the contraction stresses generated when the weld metal solidifies and cools. Heat treatable alloys, particularly 6xxx and 7xxx series alloys, are more susceptible to this type of cracking.

The risk can be reduced by using a filler metal with a lower melting temperature than the parent metal, for example the 6xxx series alloys are welded with a 4xxx filler metal. However, 4xxx filler metal should not be used to weld high magnesium alloys (such as 5083) as excessive magnesium-silicide may form at the fusion boundary decreasing ductility and increasing crack sensitivity.

Poor weld bead profile

Incorrect welding parameter settings or poor welder technique can introduce weld profile imperfections such as lack of fusion, lack of penetration and undercut. The high thermal conductivity of aluminium and the rapidly solidifying weld pool make these alloys particularly susceptible to profile imperfections.