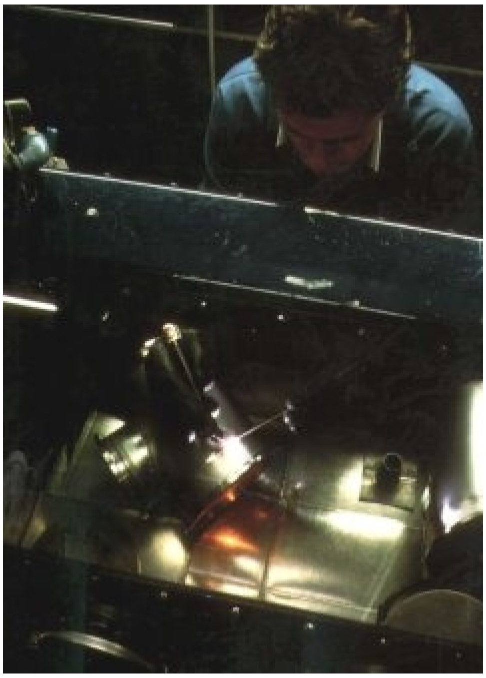
Welding Job Knowledge

Titanium and titanium alloys

Weldability of materials

Job Knowledge



Titanium and its alloys are chosen because of the following properties:

- high strength to weight ratio;
- corrosion resistance;
- mechanical properties at elevated temperatures.

Titanium is a unique material, as strong as steel but half its weight with excellent corrosion resistance. Traditional applications are in the aerospace and chemical industries. More recently, especially as the cost of titanium has fallen significantly, the alloys are finding greater use in other industry sectors, such as offshore.

The various types of titanium alloys are identified and guidance given on welding processes and techniques employed in fabricating components without impairing their corrosion, oxidation and mechanical properties or introducing defects into the weld.

Material types

Alloy groupings

There are basically three types of alloys distinguished by their microstructure:

Titanium - Commercially pure (98 to 99.5% Ti) or strengthened by small additions of oxygen, nitrogen, carbon and iron. The alloys are readily fusion weldable.

Alpha alloys - These are largely single-phase alloys containing up to 7% aluminium and a small amount (< 0.3%) of oxygen, nitrogen and carbon. The alloys are fusion welded in the annealed condition.

Alpha-beta alloys - These have a characteristic two-phase microstructure formed by the addition of up to 6% aluminium and varying amounts of beta forming constituents - vanadium, chromium and molybdenum. The alloys are readily welded in the annealed condition.

Alloys which contain a large amount of the beta phase, stabilised by elements such as chromium, are not easily welded.

Commonly used alloys are listed in Table 1 with the appropriate ASTM grade, the internationally recognised designation.

In industry, the most widely welded titanium alloys are the commercially pure grades and variants of the 6% Al and 4%V alloy.

Table 1: Commonly used titanium alloys and the recommended filler material

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Filler alloys

Titanium and its alloys can be welded using a matching filler composition; compositions are given in The American Welding Society specification AWS A5.16-2004. Recommended filler wires for the commonly used titanium alloys are also given in Table 1.

When welding higher strength titanium alloys, fillers of a lower strength are sometimes used to achieve adequate weld metal ductility. For example, an unalloyed filler ERTi-2 can be used to weld Ti-6Al-4V and Ti-5Al-2.5Sn alloys in order to balance weldability, strength and formability requirements.

Weld imperfections

This material and its alloys are readily fusion welded providing suitable precautions are taken. TIG and plasma processes, with argon or argon-helium shielding gas, are used for welding thin section components, typically <10mm. Autogenous welding can be used for a section thickness of <3mm with TIG, or <6mm with plasma. Pulsed MIG welding using novel coated wires results in very low porosity and spatter.

The most likely imperfections in fusion welds are:

- Weld metal porosity
- Embrittlement
- Contamination cracking

Normally, there is no solidification cracking or hydrogen cracking.

Weld metal porosity

Weld metal porosity is the most frequent weld defect. Porosity arises when gas bubbles are trapped between dendrites during solidification. In titanium, hydrogen from moisture in the arc environment or contamination on the filler and parent metal surface, is the most likely cause of porosity.

It is essential that the joint and surrounding surface areas are cleaned by first degreasing either by steam, solvent, alkaline or vapour degreasing. Any surface oxide should then be removed by pickling (HF-HNO_3solution), light grinding or scratch brushing with a clean, stainless steel wire brush. On no account should an ordinary steel brush be used. After wiping with a lint-free cloth, care should be taken not to touch the surface before welding. When TIG welding thin section components, the joint area should be dry-machined to produce a smooth surface finish.

Embrittlement

Embrittlement can be caused by weld metal contamination by either gas absorption or by dissolving contaminants such as dust (iron particles) on the surface. At temperatures above 500°C, titanium has a very high affinity for oxygen, nitrogen and hydrogen. The weld pool, heat affected zone and cooling weld bead must be protected from oxidation by an inert gas shield (argon or helium).

When oxidation occurs, the thin layer of surface oxide generates an interference colour. The colour can indicate whether the shielding was adequate or an unacceptable degree of contamination has occurred. A silver or straw colour shows satisfactory gas shielding was achieved but for certain service conditions, dark blue may be acceptable. Light blue, grey and white show a higher, usually unacceptable, level of oxygen contamination.

For small components, an efficient gas shield can be achieved by welding in a totally enclosed chamber, filled with the shielding gas. It is recommended that before welding, the arc is struck on a scrap piece of titanium, termed 'titanium-getter', to remove oxygen from the atmosphere; the oxygen level should be reduced to approximately 40ppm before striking the arc on the scrap titanium and <20ppm before welding the actual component.

In tube welding, a fully enclosed head is equally effective in shielding the weld area and is be preferable to orbital welding equipment in which the gas nozzle must be rotated around the tube.

When welding out in the open, the torch is fitted with a trailing shield to protect the hot weld bead whilst cooling. The size and shape of the shield is determined by the joint profile whilst its length will be influenced by welding current and travel speed. It is essential in 'open air' welding that the underside of the joint is protected from oxidation. For straight runs, a grooved bar is used with argon gas blown on to the joint. In tube and pipe welding, normal gas purging techniques are appropriate.

Contamination cracking

If iron particles are present on the component surface, they dissolve in the weld metal reducing corrosion resistance and, at a sufficiently high iron content, causing embrittlement. Iron particles are equally detrimental in the HAZ where local melting of the particles form pockets of titanium - iron eutectic. Microcracking may occur but it is more likely that the iron-rich pockets will become preferential sites for corrosion.

Particular attention should be paid to separating titanium from steel fabrications, preferably by designating a specially reserved clean area. Welders should guard against embedding steel particles into the surface of the material by:

- Avoiding steel fabrication operations near titanium components.
- Covering components to avoid airborne dust particles settling on the surface
- Not using tools, including wire brushes, previously used for steel

- Scratch brushing the joint area immediately before welding
- Not handling the cleaned component with dirty gloves.

To avoid corrosion cracking, and minimise the risk of embrittlement through iron contamination, it is best practice to fabricate titanium in a specially reserved clean area.

Further information

Titanium information and technical support

Welding titanium - a guide to best practice