American Welding Society

The Practical Reference Guide for

Welding Titanium

THE PRACTICAL REFERENCE GUIDE for WELDING TITANIUM

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Introduction

Titanium need not be all that hard to weld! In industrial sectors the common opinion is that titanium alloys are difficult to weld. While it is true that titanium alloys can be embrittled by careless welding techniques, it is equally true that these materials are much more weldable than their reputation suggests. Difficulties in welding titanium and titanium alloys originate from several basic sources. The high reactivity of titanium with other materials, poor cleaning of parts before joining, and inadequate protection during welding can lead to contamination, porosity and embrittlement of the completed joints.

Titanium is one of the most common metals occurring in the earth's crust. Particularly in North America, there is an abundance of titanium ores available for commercial exploitation. Pure titanium is a silvery-colored metal that melts at approximately 3035°F. It is as strong as steel, but half its weight with excellent corrosion resistance. Traditional applications are in the aerospace and chemical industries.

Titanium and titanium alloys have a number of desirable properties and, when suitability combined, these properties make the metal the best material for a variety of service applications. These properties include:

- Excellent fatigue resistance.
- Good notch toughness.
- Stability over a wide temperature range.
- Low coefficient of thermal expansion.
- Low thermal conductivity.
- Outstanding corrosion characteristics for some of the most troublesome industrial chemicals.
- Excellent resistance to erosion and cavitation from high velocity fluid flow.
- No scaling below 800°F, although discoloration of the metal may occur.
- Inert in electrochemical operations, when charged as an anode in an electrochemical circuit.

Titanium has a strong affinity for oxygen, and it forms a tight microscopic oxide film on freshly prepared surfaces at room temperature. Titanium tends to oxidize rapidly when heated in air above 1200°F. At elevated temperatures it has the propensity for dissolving discrete amounts of its own oxide into solution. For these reasons, the welding of titanium requires the use of protective shielding, such as an inert gas atmosphere, to prevent contamination and embrittlement from oxygen and nitrogen. Titanium reacts with air to form oxides, and at elevated temperatures it will readily oxidize and discolor. The color of the welds can be used as an indication of the effectiveness of the shielding and resulting weld quality. Good shielding and cleaning will produce bright metallic, silvery welds, while the presence of straw, blue, gray, and white surface colors indicate increasing amounts of weld contamination. Weld contamination is usually the result of faulty or inadequate trailing or back up shielding, excessive heat input, or too high a rate of travel when welding.

Titanium's relatively low coefficients of thermal expansion and conductivity minimize the possibility of distortion during welding.

Pure titanium is quite ductile (15 to 25% elongation), and has a relatively low ultimate tensile strength (approximately 30 ksi) at room temperature. Adding limited amounts of oxygen and nitrogen in solid solution will strengthen titanium markedly, but it will also embrittle the metal if present in excessive quantities.

The sensitivity of titanium and titanium alloys to embrittlement imposes limitations on the joining processes that may be used. Small amounts of carbon, oxygen, nitrogen, or hydrogen impair ductility and toughness of titanium joints. As little as 5000 parts per million of these elements will embrittle a weld beyond the point of usefulness. Titanium has a high affinity for these elements at elevated temperatures and must be shielded from normal air atmospheres during joining. Consequently, joining processes and procedures that minimize joint contamination must be used. Dust, dirt, grease, fingerprints, and a wide variety of other contaminants also can lead to embrittlement and porosity when the titanium or filler metal is not properly cleaned prior to joining.

When heated to joining temperatures, titanium and titanium alloys react with air and most elements and compounds, including most refractories. Therefore titanium and titanium alloys are welded with the inert gas shielded processes. See Table 1.

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