Titanium – You can weld it!

By David Hass, Contributing Writer

April 6, 2004 *"Titanium need not be all that hard to weld!"* The American Welding Society (AWS)[1] said it, and I agree. Well-done titanium welds look like frozen mercury: shiny and reflective. A couple of basic factors make titanium different from other metals. These unique characteristics, and a lack of understanding about them, can lead to the commonly held opinion that titanium is just too hard to weld.

Where do you begin to make good gas tungsten arc welds? Titanium is a reactive metal that forms compounds with less than optimum properties. Heated in air, the part surface contains brittle carbides, nitrides, and oxides, each of which can reduce the fatigue resistance and notch toughness of the weld and heat-affected zone (HAZ). Not only do you need to protect the surface being welded, you also need to protect the back side of the weld, which is just as sensitive.

Copper purge fixtures direct the argon over the surface of the part. Copper or aluminum purges that have not been hard-nickel-plated to prevent metal scuffing can allow localized alloying on the surface of titanium parts.

Chlorine from the perspiration on your hands can create localized corrosion. "White-glove" treatments are not just a sign of quality in welding titanium; using lint-free gloves after the final cleaning before welding may be necessary for the highest-quality welds.

Any time the metal reaches a temperature of 900 to 1,000 degrees F, brittle oxygen-stabilized alpha phase (or *α-case*) can form not only on the weld surface and its back side, but also on grinding tools[2]. Frictional heat, especially from aluminum oxide (Al_2O_3) wheels, can create high enough temperatures to embrittle the surface. Carbide-grit wheels are better because they have no aluminum to contaminate the weld. A gentle touch is best, because titanium has a low thermal conductivity and needs to be kept below the 500 degree F mark, where scaling begins.

Weld Preparation

Weld preparation should include removing any oil, grease, dirt, or grinding dust from the surfaces to be joined. Steam cleaning or an alkali dip in a dilute solution of sodium hydroxide can remove most of these contaminants. To remove the last remaining organic compounds just before welding, use a lint-free glove and methyl alcohol, acetone, or other chlorine-free solvent. Because most of these solvents have a low flash point, be sure they have fully evaporated before striking an arc.

On the most critical parts, using a small hot-air blower (hair dryer-style) to warm the part slightly ensures no moisture has condensed on the surface to be welded. Don’t overlook the fact that rubber gloves may contain chlorine as part of a vulcanizing process. Plastic gloves are recommended.

Pure Argon Applied Correctly

The argon must be 99.999 percent pure. Even if the argon is as pure as the 50 parts-per-million (PPM) range (99.995 percent), some yellow-straw discoloration can result. Many shops strive to maintain a 10-PPM contamination level during welding. If the color begins to mottle, or if it exhibits any hint of blue, the argon isn’t pure enough, or you’re not applying it correctly. Start the argon gas flowing for several seconds before using the high-frequency start. If you have enough shielding and the argon is being dispersed evenly over the part, you should see a uniform color.

Mottled or swirl patterns usually indicate too much argon is flowing (see **Figure 1**). Argon’s density is greater than air, so it tends to flow over the surface of a part in the same way water does. Where eddies occur, air can become mixed with the argon cover gas and create swirl patterns.

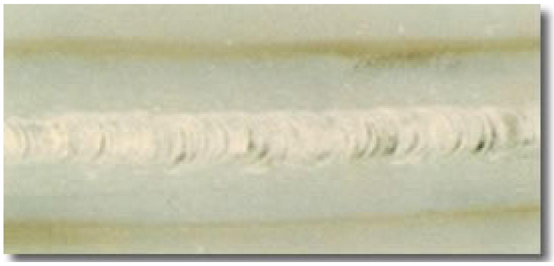

Figure 1

What really separates titanium welding from most other types of GTAW is the need for an argon cover on the weld’s back side. Wherever the titanium is heated, brittle alpha-case can form. For very complex parts with interior passages or parts that require a lot of welding repairs, glove boxes may offer an economical answer. For parts too large to fit through the glove box, special flexible polyethylene plastic bags, complete with attached gloves, can be used. Use a purge monitor to see when the bag contains clean-enough argon, strike an arc, and weld away. Working in airtight gloves, especially for extended periods, can be hot, but doing so is part of the challenge of working with titanium.

Finishing Up

The end of the weld is equally important. The titanium is hot, and the protective argon flow is still needed until the metal has cooled below about 500 degrees F. Color can be your best indicator of sufficient argon use. Some discoloration may occur beyond the HAZ and, depending on the criticalness of the weld, may be acceptable.

Unwelcome Fireworks

Be certain to contain the titanium dust from grinding operations. Titanium flake and powder are used in fireworks and should not be allowed to accumulate. Many times the white sparkling effect in aerial shells or pyrotechnic fountains comes from the burning reaction of titanium. The reaction can be similar to the thermite welding reaction if mixed dust is allowed to react. While fireworks are fun on the Fourth of July, an unexpected release of this kind of energy can be hazardous. Waterfall filters can be effective in controlling titanium dust.

Why use GTAW for welding titanium and not gas metal arc welding? Many times, it's easier to adjust the temperature of the weld pool, ensure there is just enough metal to prevent undercuts, or add a filler metal that is not the same as the base metal or metals with GTAW. By adding the metal separately from the electrode maintaining the weld pool, you have more options and more control.

Blueprint for Success

High-purity argon; clean work areas free of combustible grinding debris; the white-glove treatment after thorough cleaning; well-designed and -maintained purges on both sides of the part to distribute the argon evenly; and the technique of holding the torch in place until the metal has cooled below 500 degrees F should produce a clean, silver-colored titanium weld every time.

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Notes:

1. American Welding Society, The Practical Guide for Welding

Titanium
2. Alpha contamination and Aircraft crashes: NTSB/AAR-SO/06, NTSB/AAR-98/01

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