Mechanical Properties of Titanium Alloy Ti-5111 Welds

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Titanium and its alloys are finding increasing applications on U.S. Naval surface ships and submarines. The physical, mechanical and corrosion properties of titanium favorably impact current U.S. Navy ship design requirements for increased reliability with reduced maintenance and weight. Based on the excellent erosion-corrosion properties of titanium, commercially pure grades are used extensively for seawater pumps, cooling and piping applications on surface ships and for a number of seawater cooling components on nuclear submarines. For high-strength critical applications, the US Navy developed and certified the Ti-6Al-2Cb-1Ta-0.8Mo (Ti-100) alloy. While this alloy was used for pressure hulls on Navy deep submersibles, the high cost of alloying additions and low product yields limited the use of this material. The Naval Surface Warfare Center, in cooperation with Titanium Metals Corporation, developed the Ti-5Al-1Sn-1Zr-1V-0.8Mo (Ti-5111) alloy as a lower cost, more producible alternative alloy. A minimum ultimate tensile strength of 120 ksi, a tensile ductility elongation of 12% (10% in weld) and 1-inch dynamic tear energy of 1500 ft-lb were selected as target properties.

As part of a material characterization program, the objective of this study was to characterize the mechanical properties of Ti-5111 weld metal. Standard titanium joint preparation and shielding techniques were used in the production of 1- and 2-inch thick weldments by the automatic and manual gas tungsten arc welding process. The filler wire was of matching composition. The completed weldments were evaluated by both nondestructive and mechanical property tests. The results of radiographic examination indicated sound weldments with no indications of cracking, porosity or incomplete fusion in the weld or along the sidewalls of the joint. Rockwell C hardness scans indicated uniform hardness across the fusion zone. Longitudinal and transverse tensile tests exceeded the minimum target goals. The Charpy impact energy exceeded 27 ft-lb at 30ºF and 1-inch dynamic tear tests exceeded the goal of 1500 ft-lb. Fracture toughness tests indicated ductile fracture. Stress corrosion cracking resistance exceeded 90 ksi-$\sqrt{in}$ at –1000mV. The results of tensile, fracture toughness and seawater corrosion/stress corrosion resistance tests demonstrated that Ti 5111 welds possess high strength, good fracture toughness and excellent resistance to seawater corrosion.