Friction Stir Welding of Structural Materials for Naval Combatants

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Introduction

The most common process for joining combatant structures such as ships and amphibious assault vehicles is arc welding. Because arc welds consist of fused metal and a high peak-temperature heat affected zone, the properties of the weld region may be degraded due to inferior mechanical properties, solidification-induced defects, high residual stresses, and weld shrinkage and distortion. Friction stir welding offers many advantages over arc welding, such as improved joint strength, ductility, and toughness; improved corrosion resistance; reduced residual stresses and distortion; absence of solidification defects; elimination of welding consumables; simplified joint preparation; and elimination of welding fumes and arc radiation. The present paper describes work being performed on several materials applicable to military combatants: Al-Cu-Mg alloy 2519-T87 for the Advanced Amphibious Assault Vehicle, Al-Mg alloy 5083-H131, Al-Cu-Li alloy 2195-T8P4, and high-hardness armor steel for use in Army combat vehicles, and HSLA-65 high-strength low-alloy steel for Navy ships.

Procedure

Using new pin tool materials and new pin designs to optimize travel speed in thick plates, FS welds were made in 1-inch 2519-T87, 1-inch 5083-H131, and 0.725-inch and 1.6-inch 2195-T8P4 flat panels. Corner joints were also made in these materials using both a butt and rabbeted configuration. Transverse tensile and microhardness testing, metallographic examination, and ballistic shock impact testing were conducted on selected weldments. A new pin tool material and tool holder designed for FSW high-temperature metals was used to join 0.25-inch plates of high-hardness armor steel in two passes. For the HSLA-65 steel, single-pass weldments in 0.25-inch plates, and two-pass weldments in 0.50-inch plates were successfully made. Tensile and bend tests, hardness, and Charpy V-notch toughness testing were conducted on the high-hardness armor steel and HSLA-65 weldments and metallographic evaluations performed.

Results and Discussion

Travel speeds up to 4 ipm were attained in the 2519-T87 FS weldments, which exhibited significantly superior mechanical properties relative to conventional gas-metal-arc weldments. Transverse weldment tensile strengths up to 56 ksi (29% higher) with 14% elongation (87% higher) were obtained. The 2519-T87 FS weldments successfully passed the MIL-STD-1946A ballistic shock test.

Conventional fusion butt welds in 2519-T87 have never passed this demanding test. Similar tensile and ballistic results were obtained for the 1-inch 5083-H131 FS weldments, in which travel speeds up to 5.6 ipm were attained. The best mechanical properties were achieved at 5 ipm travel speed, with 47-ksi tensile strength and 23% elongation (88% joint efficiency based on tensile strength). For the 0.725-inch 2195-T8P4, travel speeds up to 3.7 ipm with 60-ksi tensile strength and 9% elongation (66% joint efficiency) were attained. The HSLA-65 weldments exhibited 100% joint efficiency with satisfactory ductility, Charpy V-notch toughness, and hardness. The properties of the high-hardness armor steel weldments will be discussed.

Conclusions

These results illustrate that FSW can be successfully applied to aluminum ballistic armor, high-hardness steel armor, and HSLA steels. The application of this technology to fabricating corner joints and ballistic mine blast test assemblies, and construction of a large FSW facility capable of fabricating full-size combatant vehicle components will also be presented.