**AN ANALYIS OF MICROSTRUCTURE AND CORROSION RESISTANCE OF UNDERWATER FRICTION STIR PROCESSED 304L STAINLESS STEEL**

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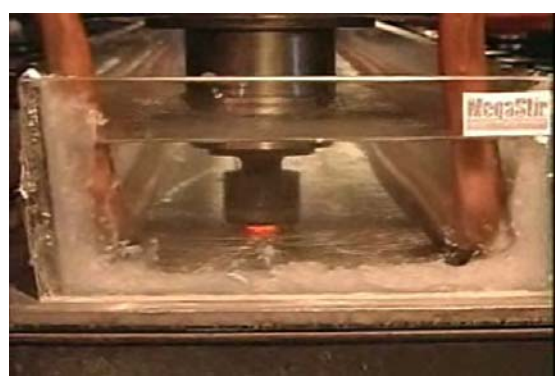
**Objective:**
A process window varying key parameters: travel speed, rotation speed, and vertical force, is being developed, in conjunction with a metallography analysis of each set of weld parameters, to help ensure sound underwater welds in stainless steel 304L. The various weld regions: Parent Material, HAZ, TMAZ, and Weld Nugget are being examined to determine the quality of weld obtained from each set of parameters. The strength of the welds will be determined through tensile testing of transversely cut weld specimens. The corrosion resistance of the welds will also be analyzed through sensitization and Stress Corrosion Cracking (SCC) testing. The results will be contrasted to comparable friction stir welds performed out of water as well as arc welds.

**Background:**
Until recently, suitable tool materials for joining steels and stainless steels have not been available. Polycrystalline Cubic Boron Nitride (PCBN) tools have been utilized to perform successful underwater welds in 304L stainless steel. As a new welding process, very little, if anything, has been known about the behavior of friction stir welding underwater in stainless steels. Underwater friction stir welding offers several potential improvements in welding microstructure that would prove to be very beneficial to many different applications and industries.

**Experimental approach:**
A process window varying key parameters: travel speed, rotation speed, and vertical force, is being developed, in conjunction with a metallography analysis of each set of weld parameters, to help ensure sound underwater welds in stainless steel. The welding process is being performed on the BYU FSW adapted mill with a special tank adhered to the 304L steel plate that is then filled with water. The welds are welded under approximately 2 inches of water. A flow rate of about 2.5 gal/min is maintained through the welding process in order to approximate the temperature effects of a large body of water. Weld strengths will be determined by pulling transverse weld specimens in a MTS tensile testing machine. Electrochemical Potentiokinetic Reactivation (EPR) testing will be used to determine the degree of sensitization (chromium carbide formation) in the underwater FSW welds.



Transverse weld U-bend test specimens will be machined and tested on a corrosion wheel. The ferris wheel type contraption will run on a one hour cycle where the U-bends are dipped in a 3.5% NaCl solution as defined by ASTM Standard G44 for 10 minutes and allowed to dry for the remaining 50 minutes of the cycle. This cycle will be carried out for 1000 hours and then the microstructure of the samples will be re-examined to determine the degree that Stress Corrosion Cracking (SCC) has occurred.

**Results/Discussion of Results:**
A process window (seen below) is currently being developed. Not as many fully consolidated welds are being obtained at this point as was initially expected. A similar process window when performed out of water yielded a larger number of consolidated welds. The grain sizes in the various weld regions are being refined compared to the parent material. This should result in higher strengths in the 304L. The tool temperatures seen in the underwater welds of 400-500 $^{o}$C are relatively low compared to similar weld parameters friction stir welded out of water which generally result in weld temperatures of 800-900 $^{o}$C. This is also much less than the liquid forming temperatures that are seen in arc welds. The lower temperatures allow less sigma phase to form relative to both friction stir welds performed out of water and arc welds. This phenomenon is being observed as metallography is being performed on the different welds. Other interesting results that are being seen at this point include the high degree of variability that is being seen in the flash of the welds. Peculiar surfaces such as steel wool type structures are being formed in several of the sets of weld parameters. The surface of the welds are generally quite dark in color as well due most likely from the oxidizing effects of the oxygen in the water and the fact that no shielding gases are being used.