**High Productivity Welding of HSLA-100 Using the EBW Process**

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With the evolution of the electron beam welding (EBW) process and development of high power Yb-fiber lasers, joining of thicker section steel is now within reach of many fabricators. When welding HSLA-100 it is well recognized that the weld microstructure containing a mixture of acicular ferrite (AF) and low-carbon martensite is required to achieve reasonable toughness. Previous studies have shown that autogenous welding of steel does not produce desirable microstructures due to the low oxygen concentrations. The purpose of this study was to compare the toughness of baseline welds made in HSLA-100 plates and forgings with welds produced using inclusion bearing shim material.

Autogenous welds were produced in 1-in. and 1.5-in. HSLA-100 plate and forgings to establish baseline microstructure, CVN toughness, and hardness profiles. In order to evaluate the effect of oxygen concentration and inclusion distribution on EBW microstructures and properties, EBW shims were fabricated using weld metal deposited using MIL-100S-1 (GMA/SMA), ER70S-6 (GMA, GTA), and E11018 SMA consumables. These electrodes were selected to provide a broad distribution of oxygen and nitrogen concentrations.

Weld soundness was found to depend primarily on weld metal nitrogen concentration. Modification of the beam deflection pattern improved weld soundness in welds with less than 120 ppm nitrogen. Welds produced with higher levels of nitrogen contained unacceptable levels of porosity. Welding of shim material improved the toughness of the weld deposit relative to autogenous weld produced base metal however the toughness of the shim welds were 15-30 J lower than those measured in the original SMA/GMA/SAW deposits. This slight toughness decrease was attributed to the reduced fractions of AF formed during the high solidification rates produced during EBW.

The hardness of the shim welds was primarily related to the carbon content of the shim material (due to large proportions of martensite) and this data suggests that matching/overmatching of the plate and forging material is possible using this technique.

In summary this study indicates that productivity improvements are feasible while maintaining reasonably high strength and toughness in the weld deposit when using inclusion bearing shim material. Additional work is required to optimize the shim material (to reduce nitrogen) and to produce wire that may be used for cold wire feed.