

**D. Feasibility Study of Submerged arc welding a 827 to 1102 MPa Yield Strength 10 Nickel Steel**

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**Introduction**

The Navy is developing a new high strength ballistic steel (yield strength 827 to 1102 MPa) to help reduce the weight in protection systems. The new steel is a low carbon, 10 percent Nickel alloy steel that is not yet in commercial production. Consequently, welding consumables have not been specifically developed for this steel.

A welding feasibility study was initiated to determine if specific weld metal properties could be achieved by currently available welding consumables. The initial target yield strength of the weld metal was 861 MPa, which would represent a 14 percent undermatching strength weld metal for a 999 MPa yield strength plate system. The target dynamic tear toughness of the weld metal was 675 J at — 29 C.

**Technical Approach**

A MIL-I 40S type solid wire electrode was used with a low hydrogen submerged arc welding flux to evaluate if submerged arc weldments meeting these target goals could be achieved. Initial weldments were produced using HY-130 base plate due to lack of available 10 Ni steel plate. A 1.4, 2.4 and 2.9 kJ/mm welding heat input was employed to evaluate the effects of weld metal cooling rate on weld metal strength and toughness. Additional welds were produced using the experimental 10 Ni steel to determine if base plate dilution effects may affect any of the trends identified in the early part of this study.

Weld metal diffusible hydrogen measurements were performed for this wire / flux combination. Non-destructive evaluation was performed on the completed welds. Microhardness and metallographic examination was performed on transverse sections removed from the weldments. Longitudinal all weld metal tensile specimens were tested at room temperature. Transverse Charpy V-notch specimens were removed from the weld metal and tested at several temperatures ranging from room temperature to - 84 C.

**Results and Discussion**

The weld metal diffusible hydrogen content was determined to be 1.7-ml/100 g for this wire and flux combination. There were no indications of hydrogen cracks from radiography or visual inspection. The tensile specimens exhibits yield strength ranging from 875 to 994 ksi and elongation of 17 to 20 percent. There were no indications of hydrogen embrittlement in the tensile specimens. The yield strength was found to increase with increasing cooling rate. The Charpy V-notch specimens exhibited a gradual reduction in energy with a decrease in test temperature. The dynamic tear toughness of the weld metal tested at - 29 C was found to be over 675 J.

Additional welds were produced using the same welding conditions in experimental 10 Ni steel plate. The results of mechanical property tests were similar to those obtained using the FIY-130 plate material.

**Conclusions**

The results of this investigation indicate that it was feasible to produce SAW weld metal in 10 Ni steel that exhibited a yield strength over 896 MPa and a dynamic tear toughness of 675 J at - 20 C when using the submerged arc welding process. No indications of hydrogen embrittlement or cracking were observed in the weldments.