High Alloy Weldments for Fatigue Resistance in Structural Carbon Steel

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Introduction:

As the materials science advances, the improvement of the mechanical characteristics of the alloys has led to focus on other technical issues. The fatigue resistance of plain carbon steel weldments is a metallurgical issue of concern that arises because improved service performance and reduced maintenance costs are required to survive in the highly competitive environment of modern industry.

It has long been known that compositional variations made to steel weld metal can alter the martensite start temperature (M_ST) and therefore alter the residual stress state left in the weldment. The resulting compressive stress state has been shown to increase the fatigue limit of plain-carbon steel structural welds by as much as three times that of conventional weldments (1, 2).

The objective of this research was to quantify the influence of nickel and manganese on the development of a martensitic microstructure in weld metals for plain-carbon steel structures. Fixed welding parameters and varied compositions of metal-cored filler wires were employed to obtain a low cost, high performance weldment containing a maximum compressive residual stress state.

Procedure:

For this study, the first step was to determine the influence of the nickel and manganese on the production of martensite. An experimental matrix that assumed no interaction between the two variables and five values (zero to sixteen percent in weight as deposited) was designed. These eleven compositions were made into GMAW-FC wires, then fused to produce all-weld-metal deposits in a water-cooled copper chill mold. The effects of both nickel and manganese on the martensite transformation were clearly defined by dilatometric methods, and by metallographic analysis and hardness determinations.

Following the preliminary assessment, a new experimental matrix, designed to substitute for economic reasons as much manganese as possible for the nickel, was developed. Because manganese is known to produce low-fluidity weld metals, additional compositional variables were needed. Silicon was added to improve the fluidity of the molten metal pool, and the chromium content of the weldment was also modified. This second experimental matrix was of the 4^2 format. In addition to the metallographic and hardness analysis, residual stress, fatigue and fluidity tests will be performed on these latter samples, but these data are not included in this initial study.

Results:

Results from the first experimental matrix showed that there is a limit of the amount of nickel that can produce an all-martensitic microstructure (10Cr10Ni). Once the limit was reached, no additional martensite was produced under conventional welding parameters, and the hardness decreased abruptly values higher than 60RHA to below 40HRA. The solidification behavior also changed to cellular growth. For compositions up to 16 percent, manganese did not show this limit, even when low transformation temperatures (as calculated by the equation developed by J.A. Self, et.al. (3)) were achieved.

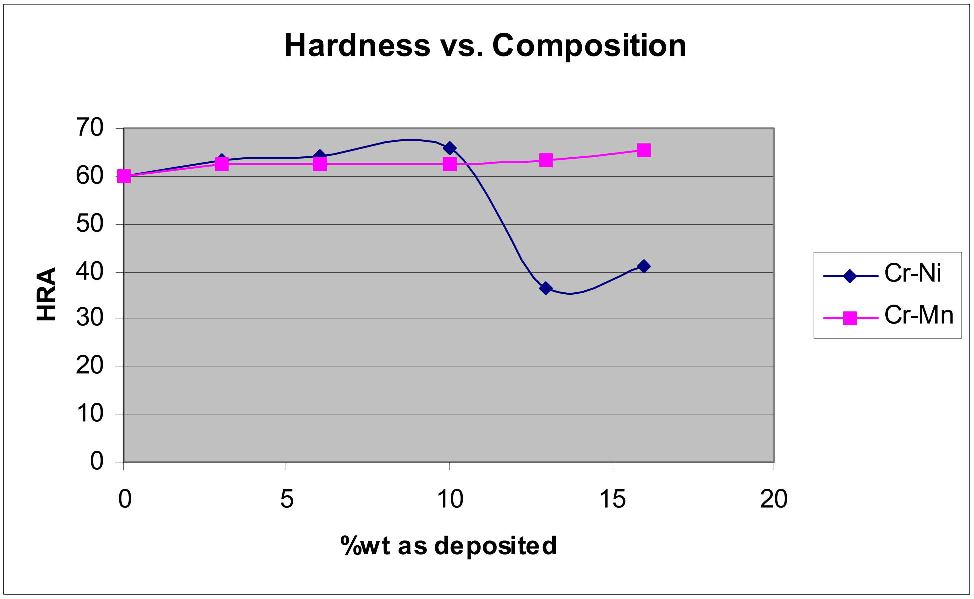

Figure 1. Effects of Nickel and Manganese on Weld Metal Hardness

Dilatometric measurements using the Gleeble 1500 thermo-mechanical simulator revealed that changes in microstructure and hardness were consistant with the martensite start temperatures determined. The addition of Mn decreased the fluidity of the weldments, resulting in poor bead morphology.

Conclusions:

This study showed that systematic changes in composition in metal-cored filler wires can be used to produce conventional GMAW weldments with good bead morphology and relatively low cost. The results obtained were very consistent with predictions made by the Schaeffler and DeLong diagram(4,5). Predictable variations in microstructure and important changes in hardness were recorded at the phase boundaries of the Schaeffler and DeLong diagram. According to the conducted dilatometric analysis, the measured martensite start temperatures were higher than those predicted by any of the commonly used equations for estimating M_s. Methodology that altered weld metal composition for the purpose of creating fatigue-resistant residual compressive stresses in plain-carbon steel structural welds was established.

References:

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