

Effects of Manganese and Nickel on the Phase Stability of High Alloy Weld Metals

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Introduction

The chromium, manganese, and nickel concentrations determine the solidification mode of high alloy weld metals. The balance between the austenite and ferrite forming elements define the initial solidification phase and subsequently, the final microstructural components.

This work utilizes prior studies of the solidification mode in austenitic stainless steel weld metals and is aimed at the design of special weld metals for fatigue-resistant fillet welds in carbon steel structures.

As shown in other studies ⁽⁵⁾, the martensitic transformation can be used to create a compressive residual stress state. So it is the focus of this work to evaluate the effects of the chemical composition on both the solidification mode and the final mechanical properties of the welds metals, and thereby specify a range of alloys that can produce a high-martensitic fraction without retained ferrite.

Procedure

Weld samples of 14 different alloys were prepared (GMAW-FC 32V, 10ipm, 300-350A, 90Ar10O₂@45cfh, welded over a copper chill mold) with the compositions ranging from two to sixteen percent manganese or from three to twelve percent nickel. Chromium concentration was fixed at ten weight percent.

Hardness tests were conducted on the samples as well as metallographic analyses to reveal the solidification structure and the solid-state transformation products. X-Ray diffraction analysis (XRD) quantified the phase fractions of each weld metal.

Results

Results from hardness testing (Figure 1) and the microstructural analyses quantified the limit of nickel or manganese that can produce an all-martensitic microstructure (10Cr10Ni or 10Cr14Mn). Once the limit was reached, no additional martensite was produced under conventional welding parameters, and the hardness decreased abruptly.

X-Ray diffraction analysis revealed that changes in microstructure and hardness were consistent with prior studies^(1,2,3) performed at higher alloy contents, and clearly showed that the previously defined ratio between chromium and nickel concentrations correctly define the solidification mode as either primary ferrite or austenite.

Manganese was found to be a stronger austenite stabilizer than previously stated by other studies^(2,3). The effect of manganese was evaluated as 0.66 times that of nickel, *i.e.* $Ni_{eq}=0.66Mn$.

The results indicate that for gas metal arc welds made under typical conditions with compositions in the range of $3.4 \geq Cr_{eq}/Ni_{eq} \geq 1.55$ solidify as primary ferrite. For Cr_{eq}/Ni_{eq} ratios less than 1.55, the primary solidification mode is austenite (Figures 2a and 2b).

These results complement previous studies^(1,2,3) aimed at predicting the solidification mode of stainless steel weld metals.

Conclusions

Primary austenite results for Cr_{eq}/Ni_{eq} ratios of less than 1.55 and primary ferrite will form when higher ratios are applied. Within the range of compositions of this study, the final microstructures observed were adequately predicted by an extension of the Suutala line⁽³⁾ to leaner compositions, with a modification for the manganese effect from 0.5Mn to 0.66Mn.

These results can be used to maximize the fraction of low-carbon martensite in weld metals by defining compositional limits, thereby maximizing the compressive residual stress to improve fatigue resistance.

References

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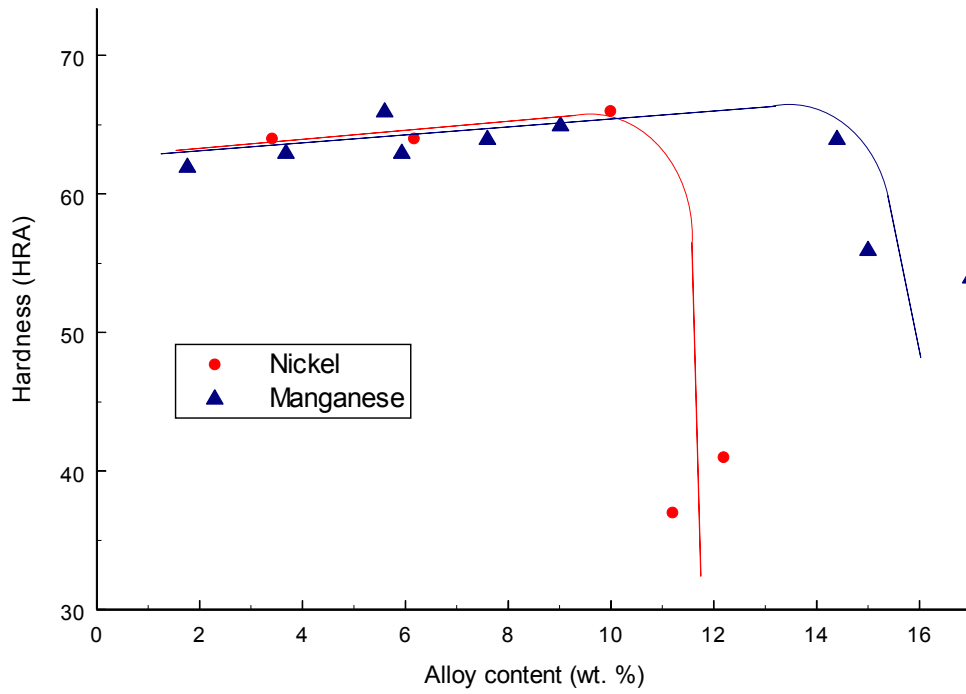
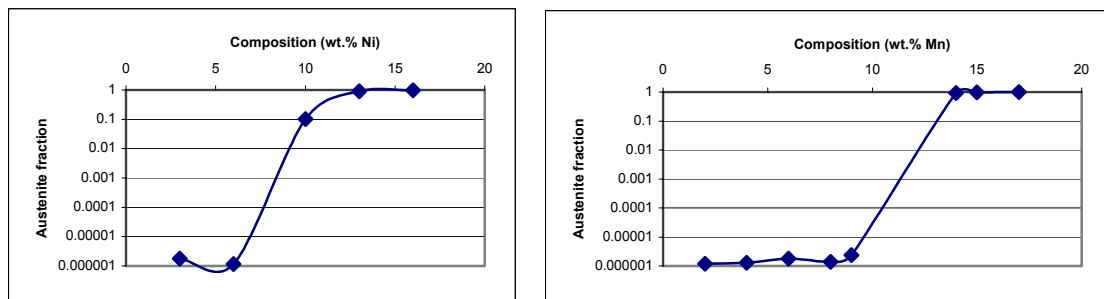


Figure 1. Measured hardness in the analyzed weld metals



a)

b)

Figure 2. Austenite fraction versus nickel (a) and manganese (b) contents of the analyzed weld metals. Chromium content remained constant at 10 wt. pct.