Evaluation of Hot Cracking in Austenitic Stainless Steel Welds

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A number of criteria such as crack lengths, brittleness temperature range (BTR), critical strain and critical strain rate for initiation of cracking are used for evaluation of solidification cracking susceptibility of austenitic stainless steel welds. The strain response of the material during welding is commonly described [1] as a temperature range using temperature-strain co-ordinates, called the brittleness temperature range. However, total crack length (TCL) has been reported to lead to errors in evaluation material susceptibility to cracking [2]. A major objective of this work was to relate solidification cracking behavior to chemical composition of austenitic stainless steel weld metals. In the process, it was necessary to examine the suitability of various criteria for cracking evaluation. Several stainless steels including AISI 316L, 304L, 347 and 321 were evaluated for solidification cracking using longitudinal and transverse Varestraint tests using 3 mm thick specimens. Two heats of 316L with enhanced nitrogen addition through the shielding gas were also tested. The results were evaluated in terms of crack lengths and brittleness temperature range and correlated to microstructure and composition.

A comparison of cracking evaluation criteria in these tests showed that while BTR was more a function of metallurgical variables influencing cracking, TCL was also influenced by welding parameters and bead geometry. In particular, TCL was influenced by changes in weld bead characteristics caused by S and N without a significant change in BTR. The ratio of TCL normalised by the BTR also revealed the deleterious influence of Ti and Nb on cracking in stabilized stainless steels. Excellent correlation was found between WRC Cr_{eq}/Ni_{eq} ratio and BTR in both unstabilized and stabilized steels. Microstructural examination of type 321 steel weld metal revealed that large (3-5 μm) primary titanium carbonitrides provide nuclei for delta-ferrite during solidification. This indicated that a low energy interface exists between the two phases, which explains the poor resistance to solidification cracking of Ti-stabilized stainless steels even when a primary ferritic solidification mode is ensured. This study has provided valuable information on the relative suitability of evaluation criteria for solidification cracking in austenitic stainless steels. Further, interesting results have been obtained that throw light on cracking mechanisms in stabilized stainless steels.

References

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