

Development of a Test Technique For Evaluating Ductility-Dip Cracking Susceptibility in Austenitic Alloys

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Introduction

Ductility Dip Cracking (DDC) is a solid-state phenomenon that plagues a number of engineering materials, including austenitic stainless steels, Ni-base alloys, Cu-base alloys, and Ti alloys. Under the right conditions these materials exhibit a loss of ductility over a narrow temperature range below the solidus temperature. In the weld metal it occurs preferentially along migrated grain boundaries. The mechanism for DDC is unclear and tests to determine susceptibility to DDC are often inconclusive. This presentation will examine new work completed on the strain-to-fracture test technique.

Procedures

Susceptibility to DDC was evaluated using a Gleeble®-based test technique to isolate the desired temperature range over which cracking occurs and to determine the threshold stress and/or strain required for cracking. Samples were machined out of plate stock and a pre-weld was made in the center of the sample. This favorably orientated the microstructure in the area of the weld and allowed for the formation of a reproducible microstructure. The samples are then heated in the Gleeble® using optimized heating cycles and strained to desired extents. Three materials have been evaluated: Alloy 690 and Type 310, and AL-6XN. Optical and electron microscopy were used to evaluate the microstructure and fracture surfaces, respectively.

Results and Discussion

Results showed a difference in susceptibility between the base material and the pre-weld within the same sample. A critical strain to fracture parameter has been developed that provides quantification of material susceptibility. This critical strain has been found to be sensitive to variables such as temperature, grain size, stroke rate, and grain boundary orientation. This testing method provided several advantages over the double-spot vareststraint technique that had been developed previously at OSU and EWI. The primary advantages of this technique is that it eliminates liquation and solidification cracking and allows a uniform strain to be applied at a given test temperature. Optical and electron microscopy have been performed at low, medium and high cracking temperatures. Optical microscopy results revealed the importance of migrated grain boundaries and the effects of precipitates and eutectic formation have on their mobility and subsequent cracking susceptibility. Electron microscopy revealed an intergranular cracking morphology with evidence of microvoid coalescence at a very fine scale along the grain boundaries. Temperature-strain envelopes have been developed for Alloy 690, Type 310, and AL-6XN. In addition, many of the tests variables have been evaluated including repeatability, heating rate, peak temperature, stroke rate, time at temperature, and the effect multiple thermal cycles have on cracking.

Conclusions

The strain-to-fracture test technique has been demonstrated as an effective tool in predicting a material's susceptibility to DDC. It has proven to be much more discriminating than the double-spot vareststraint test. Both the critical strain for cracking and the temperature range over which cracking occurs has been identified for all three materials. The test was also found to be an effective means of evaluating the effect of welding conditions on DDC susceptibility. Additional alloys are being tested in order to develop a better assessment of the efficacy of the technique.