A Comparison of Postweld Heat Treatment Cracking Susceptibility in Two Nickel-base Alloys

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Introduction

The purpose of this work was to employ a thermo-mechanical simulator to develop a simple test that could be used to create time-temperature C-curves to predict susceptibility to postweld heat treatment cracking for alloys strengthened by precipitation reactions. The test developed uses in-situ strengthening due to precipitation, rather than constant strain or constant load, to cause failure or cracking during post weld heat treatment. Two Ni-base superalloys (Waspaloy and IN 718) were tested and their cracking susceptibility compared.

Procedure

Bars of the sample alloys were heated to a peak temperature, held at the peak temperature, and cooled to room temperature. The cooling rate was controlled to ensure uniformity between samples. A slight tensile load prior to HAZ simulation allowed constant monitoring of stresses in the samples. The application of a tensile load was used to augment the residual stress on cooling. Application of the tensile load while cooling did not begin until the sample cooled below its nil ductility temperature (NDT) to ensure no liquation cracks were created. After reaching room temperature the sample was heated to a simulate PWHT. Upon reaching the PWHT temperature no further loading took place. Load was monitored at the PWHT temperature for test durations of up to 8 hours. At the end of the PWHT cycle samples were strained to failure. Following testing, samples were evaluated for cracking and characterized using both optical and electron microscopy techniques.

Results and Discussion

Stroke control of the hydraulic jaws on the Gleeble^{TM} provided a means of producing repeatable residual stress. Acquisition of tensile force data during PWHT showed relaxation of stresses, followed by a rise in stress as precipitation strengthening occurred. The change from stress relaxation to in-situ hardening provided a time-temperature relationship for precipitation. Changing the peak temperature in the HAZ thermal cycle shows the relation between different areas of the HAZ (partially melted zone, coarse grained heat affected zone) and their susceptibility to PWHT cracking. Calculating the reduction in area of failed samples after different PWHT times showed a minimum ductility at an elevated temperature after 2 to 4 hours. Grain size in the alloy with lowest ductility was very large compared to the initial grain size.

Conclusions

The test developed is simple and repeatable. Careful control and timing of both thermal and mechanical loading ensure only PWHT cracks will develop in the sample. The loads and thermal cycles limited the cracking phenomena to the solid state. The results show C-type curves for the alloys tested. The time-temperature relationship and ductility measurement allows ranking of the alloys by susceptibility to cracking. Microstructural evaluation suggests grain size has a large part to play in PWHT cracking susceptibility.