Effect of Boron and Zirconium on the Resistance of Alloy N07214 to Strain Age Cracking

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Introduction

HAYNES® 214™ alloy[1] (UNS N07214) is a nickel-chromium alloy containing 4.5 wt% aluminum. Aluminum imparts excellent resistance to high temperature oxidation, but introduces the potential for strain age cracking. During development of the alloy, it was recognized that boron and zirconium improved resistance to strain age cracking, but increased the susceptibility to solidification cracking. The influence of boron and zirconium on the solidification cracking resistance of N07214 alloy was investigated by Cieslak et al. (Ref. 1). The objective of this investigation was to find a test method capable of measuring resistance to strain age cracking and characterize the associated microstructure.

Procedure

Two 50 lb laboratory heats were melted: with and without addition of boron and zirconium. The Gleeble®[2]-based test procedure was modeled after Nakao (Ref. 2), using a notched sheet tensile specimen. The solution annealed specimen was heated to the test temperature at a selected heating rate in air, then pulled to failure. Ductility was measured by comparing the notch dimensions before and after the test. Heating rates were 15, 30, 60, and 100 °F/min. (0.14, 0.28, 0.56, and 0.93 °C/s). Test temperatures were 1400, 1500, and 1600 °F (760, 816, and 871 °C). Microstructural characterization and fractography were conducted after testing.

Results and Discussion

Measured ductility was increased by a factor of 2 to 3 through addition of boron and zirconium. Heating rate to the test temperature had no measurable effect on ductility. Both alloys exhibited ductility at 1600 °F (871 °C) that was 2 to 3 times the value at 1400 and 1500 °F (760 and 816 °C). Gamma prime forming alloys exhibiting greater intermediate temperature ductility have been shown to possess greater resistance to strain age cracking, as measured by the restrained circular patch test. (Ref. 3)

Both alloys exhibited an intergranular fracture surface near the edges of the specimen and a ductile rupture fracture morphology near the center. Intergranular crack initiation at the surface has been attributed to the embrittling influence of an oxidizing atmosphere on gamma prime forming alloys (Ref. 3). The grain facets of the intergranular fracture surface displayed ductile dimpling, similar to that observed by

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Norton and Lippold (Ref. 4). Zirconium was detected by energy dispersive x-ray spectroscopy on the intergranular fracture surface of the alloy with zirconium addition, even though it was only present at 0.038 wt % in the bulk alloy. Widely scattered zirconium-rich particles were present on the fracture surface.

Conclusion

Addition of boron and zirconium to alloy N07214 increased the ductility of the alloy over the 1400 to 1600 °F (760 to 871 °C) temperature range, which is believed to indicate an increased resistance to strain age cracking. The Gleeble based test method effectively discriminated between the two alloys. No influence of heating rate was detected.

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