MICROSTRUCTURE AND LOW-CYCLE FATIGUE BEHAVIOR OF INCONEL 718

P. C. S. WU
Westinghouse Electric Corporation, Advanced Reactors Division, P.O. Box 158, Madison, Pennsylvania 15663, U.S.A.

SUMMARY

The development of a new generation of advanced nuclear reactors imposes severe demands on materials of construction. Such is the case with the advent of the LMFBR where high operating temperatures and high neutron fluxes may cause rapid degradation of material properties. Inconel 718 with its excellent high temperature strength is an attractive structural material for many LMFBR components. In the present investigation, the low-cycle fatigue properties of this alloy are investigated at 538 °C in air. The purpose is to provide information which will supplement the in-sodium test results which are being generated under similar conditions for the same material.

The effect of pre-test annealing and hold-time in compression on the fatigue strength of this material in the double aged condition was studied. Smooth specimens of Inconel 718 were tested in air under conditions of fully reversed axial strain control with various hold-times (0-60 minutes) in compression. In general, specimens solution annealed at 940 °C followed by double aging (AMS-5596C) show strain softening while those solutions annealed at 1038 °C then double aged to AMS-5597A show strain hardening. In addition, results show that some increase in fatigue life, particularly at lower strain ranges, is observed for specimens vacuum annealed at 538 °C for 2000 hours before testing. However, hold-time in compression slightly decreases the fatigue life and the amount of decrease in fatigue life increases with increasing hold-time. Coffin-Manson type equations are derived to describe this dependence of the low-cycle fatigue life of the test material on the plastic strain range.

Microstructural characterization of the as-received and post-tested specimens shows that fine grains (ASTM No. 8-9) and heavy precipitation of carbides and other phases along the grain boundaries occurred after the *first* double aging procedure (AMS-5596C). In contrast, coarse grains (ASTM No. 3-4) and very little precipitate except carbide along the grain boundaries resulted from the *second* annealing procedure (AMS-5597A). Fractography of the post-test fatigue specimen is characterized by optical and electron microscope. Transgranular cracks prevail in all specimens including those tested with hold-time in compression. Scanning Electron Microscopy (SEM) micrographs and the Electron Dispersive Analysis of X-Rays (EDAX) reveal the microcracking of the (Nb, Ti) C type carbides presumably due to stress concentration. Transmission Electron Microscope (TEM) micrographs show fatigue striations in the brittle as well as ductile failure regions. In addition, the substructure including the precipitation morphology of the major strengthening phase (γ'') in double aged Inconel 718 and its fracture mode under the present test conditions were also characterized by TEM.

In the present material which contains the dispersed γ'' and γ' phases, the resistance to deformation appears to be by the pinning of dislocations until the applied stress overcomes pinning by cutting through the precipitates. The massive cutting of γ'' particles revealed in the present investigation further substantiate the massive planar slip deformation mode suggested for this alloy.