Abstract

HAYNES 282, a newly developed γ′ strengthened wrought superalloy, is a potential material for hot gas path components in advanced Ultra Super Critical (A-USC) steam turbine application. In the present study, effect of ageing on microstructure evolution and high temperature mechanical properties under monotonic and cyclic loading were investigated and analyzed in light of underlying deformation mechanisms and failure modes. Through variation in ageing temperature and time a wide variation in microstructure was achieved. There were variations in volume fraction and size distribution of γ′ precipitates and in some cases, formation of nano carbides, which affected mechanical response of the material differently.

In the study of precipitation of γ′, an integrated analysis of evolution of both the aspects of microstructure, i.e., the size of γ′ precipitates as well as the lattice misfit at the interface, in light of elemental partitioning was investigated. Based on kinetic analyses, involving the interface compositions at the γ/γ′ interface, different rate controlling elements were identified separately at the growth (Cr and Ti) and the coarsening (Mo) stages of γ′. The driving force for these two processes being different, such different rate controlling elements for the two stages are justified and reported for the first time. Interface phase compositions were obtained from atom probe tomography (APT).

High temperature (760 °C) monotonic tensile response of the material for different ageing conditions was investigated. Under tensile loading at high temperature, no evidence of shearing of γ′ precipitate was found. Deformation through twinning was observed for the microstructures with γ′ precipitates. Higher flow stress and strain hardening for microstructure aged at higher temperature was explained in terms of resistance of dislocation motion by different size γ′ precipitates, dislocation pinning by nano carbides, formation of forest dislocations, and twin-twin interactions. Ductility variation was explained in terms of variation in growth of twins and presence of brittle carbides and size variation in γ′ (as in absence of shearing, γ′ also acts as a stress raiser).

High temperature (760 °C) low cycle fatigue (HTLCF) response as a function of ageing condition was investigated. A change in deformation mechanism of overcoming γ′ precipitates from shearing (for lower temperature aged microstructure) to Orowan looping (for higher temperature aged microstructure) was observed. Formation of nano-carbides at higher ageing temperature caused its better LCF response. Failure mode was found to change from predominantly intergranular (for lower temperature ageing) to transgranular fracture (for higher temperature ageing). It was explained in terms of presence of larger MC carbides on grain boundaries for lower temperature aged microstructure and absence of it on grain boundaries and presence of very fine nano carbides inside grains in case of higher temperature aged microstructure.

Creep-fatigue (C-F) response (at 760 °C) of the material (760 °C, 9 days ageing condition) as a function of dwell position (tensile, compressive and both peak strains) and time (100 s and 500 s) was investigated. Damage parameter, effective stress relaxation per cycle and strain energy density were found to correlate well with C-F life. A change in deformation mechanism from shearing to Orowan looping explains the difference in damage as a function of dwell position. The present material shows an inherent anisotropy in strain hardening behavior, being higher under compressive loading. This anisotropy causes the material to damage more under compressive dwell compared to tensile dwell.

Keywords: Ni-based superalloy, HAYNES 282, ageing, growth kinetics, coarsening kinetics, atom probe tomography, solute partitioning, tensile, low cycle fatigue, creep-fatigue, deformation mechanism, failure mode.