Abstract

Creep behavior of the Inconel 617 alloy has been investigated through tests carried out in the temperature range of 650 - 800 ºC under 95 - 350 MPa. Creep curves obtained from tests on the alloy have exhibited non-classical nature, with the primary creep rate decreasing to a minimum value, followed by a typical increase, which is either continuous at temperatures ≤ 700 ºC or has an intermediate steady-state regime at 750 °C or 800 °C. The variation of minimum creep rate ($\dot{\varepsilon}_{min}$) with stress (σ) obeys a power law relationship ($\dot{\varepsilon}_{min}$= $A\sigma^n$) with the stress exponent, n increasing with temperature to a peak value at ~700 ºC, and decreasing with further increase in temperature. The values of $n > 5$ has been rationalized by considering the existence of threshold stress, which like n has been found to decrease sharply with temperature beyond 700 °C. The Monkman-Grant and modified Monkman-Grant constants derived from the aforementioned test results have indicated microstructural instability. Investigation of the post-creep microstructures by transmission electron microscope has revealed the formation of γ' and $M_{23}C_6$ precipitates, which obstruct dislocation motion during the primary stage. Microstructures of the samples creep-tested at ≥750 °C have exhibited relatively smaller amounts of γ'. The existence of threshold stress and steady state regime in tertiary creep stage has been ascribed to obstruction of dislocation motion by $M_{23}C_6$ and γ' precipitates.

The ample presence of intragranular secondary γ' precipitates has led to significantly higher strength of grain bodies than their corresponding grain boundaries, which is found to be scantily populated with secondary $(Cr,Mo)_{23}C_6$ precipitates in the temperature range of 650 - 750 ºC, and this has led to the formation of creep cavities resulting in intergranular fracture. The creep damage tolerance factor, λ value found as ~ 2.5 is in tune with the predominance of creep cavitation in the temperature range of 650 - 750 ºC. In contrast, as suggested by both the λ value of ~10.51 obtained from empirical damage analysis and mixed mode nature of the fracture surface, substantial plastic deformation manifested as necking has been found in the alloy creep-tested at 800 ºC, primarily because of the reduction of strength of the matrix due to the absence of γ' precipitates and restriction of grain boundary sliding by the abundant presence of discrete secondary $(Cr,Mo)_{23}C_6$ precipitates along the grain boundary. Based on the plot of applied stress against Larson-Miller parameter, it is possible to predict that the Inconel 617 alloy would withstand the steam pressure of 30 MPa at 750 ºC for a design life of 10^5 h experienced in a typical AUSC boiler tube.

A thorough investigation of the ‘non-classical creep behavior’ of the IN617 alloy has been carried out through interrupted creep tests at 700 ºC/275 MPa and 800 ºC/95 MPa, having nearly similar time to rupture (~3500 h) to understand the role of microstructural evolution. A steady state tertiary creep region present at 800 °C/95 MPa, is found to be absent at 700 °C/275 MPa. The microstructural changes including formation of γ' and fine secondary carbide precipitates, and twin boundary generation in the microstructure observed on interrupting the creep tests at both the aforementioned conditions after varying durations, have been investigated using optical, scanning and transmission electron microscopy, electron back scattered diffraction (EBSD) and thermal analysis. The formation of ample fine γ' precipitates along with the fine secondary carbides in the samples subjected to creep tests at 700 °C with interruptions after varying fractions of time to rupture lead to increase in hardness, which is found to be lower for similar tests at 800 °C due to the absence of γ' precipitates. Moreover, the EBSD analysis has confirmed a higher length fraction ratio of twin boundary (TB) to high angle grain boundary (HAGB) in the samples exposed to the steady state tertiary creep regime (almost 95% of total rupture time) at 800 °C. The increased TB to HAGB length fraction ratio is considered as responsible for improving the creep resistance by restricting the damage accumulation, as the TBs are typical coincident site lattice boundaries with lower energy and greater packing density.

Keywords: *Inconel 617 alloy; Non-classical creep behavior; stress exponent; threshold stress; Rupture behavior; Creep damage analysis; post-creep microstructure.*