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Thermo-mechanical fatigue behaviour of the near-γ-titanium aluminide alloy TNB-V5 under uniaxial and multiaxial loading
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With increasing environmental awareness and the general need to economise on the use of fossil fuels, there is growing pressure for industry to produce lighter, more efficient, gas turbine engines. One such material that will help to achieve these improvements is the intermetallic gamma titanium aluminide (γ-TiAl) alloy. At only half the density of current nickel-based superalloys its weight saving capability is highly desirable, however, its mechanical properties have not yet been fully explored especially, when it is to be considered for structural components in aeronautical gas turbine engines. Critical components in these engines typically experience large variations in temperatures and multiaxial states of stress under non-isothermal conditions. These stress states are known as tri-axial thermo-mechanical fatigue (TMF).

The work presented here investigates the effects these multi-axial stresses, have on a γ-TiAl, (Ti-45Al-5Nb-0.2B-0.2C) alloy under TMF conditions. The uniaxial, torsional and xialtorsional TMF behaviour of this γ-TiAl alloy have been examined at 400 – 800oC with strain amplitudes ranging from 0.15% to 0.7%. The tests were conducted at both thermomechanical in-phase (IP) and out-of-phase (OP). Selected tests additionally contained a 180 seconds hold period.

Fatigue lifetimes are strongly influenced by the strain amplitude, a small increase in amplitude reduces the lifetime considerably. The uniaxial IP tests showed significantly longer fatigue lifetimes than of all the tests performed. Torsional loading although have shorter fatigue lifetimes than the uniaxial IP loading they have longer fatigue lifetimes than the uniaxial OP loading. The non-proportional axial-torsional 90 degree OP test is most damaging which resulted in a shorter lifetime than the uniaxial OP test with the same Mises equivalent mechanical strain amplitude. A hold period at maximum temperatures reduced the lifetime for all tests regardless of the temperature-strain history. The effects of TMF on the microstructure were also investigated. For all types of tests intergranular fracture is predominant. Failure is strongly influenced by environmental conditions.

This study compares TMF results of TiAl with previous TMF investigations on the nickelbased alloys IN 738 and Nimonic 90. IN 738 shows similar TMF behaviour to γ-TiAl in that uniaxial IP loading has the longest fatigue lifetimes. Nimonic 90 shows the opposite behaviour to both of these alloys.

A lifetime model developed for this near-γ-TiAl alloy, successfully describes all temperaturestrain TMF loading conditions over the test temperature range, with the use of a single loading parameter. The loading parameter is based on the plastic work per cycle, and is not only dependant on the mean tensile stress but also on the maximum principal stress. The loading parameter responds to various strain-temperature-paths differently. It describes the lifetime relation between uniaxial IP and OP loading, axial and torsional loading and the hold period effect.