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Comparison of multiaxial fatigue parameters using biaxial tests of Waspaloy[☆]

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Abstract

In laboratories most fatigue testing is uniaxial as many aeronautical components such as wing spars are uniaxially loaded. However important components, such as aero engine disks, operate under multiaxial loading conditions. Hence multiaxial data is desirable to safely design them. This paper describes biaxial fatigue tests carried out under a range of loading conditions with cruciform specimens made of Waspaloy, a nickel based superalloy widely used in the fabrication of aero engine disks. Finite Element modelling of the specimen was performed to set the test conditions and to predict stress-strain fields and failure location. In order to investigate the effect of strain biaxiality, different biaxiality ratios with the same maximum principal stress were considered. Results demonstrate a variation in total life to failure and failure location, confirming the FE predictions. Then the experimental results obtained were used with three groups of multiaxial criteria. Initially, von Mises and elastic strain energy density yield theories were extended to the multiaxial fatigue context. Secondly, the stress invariant based criterion proposed by Crossland was considered, where the maximum shear stress amplitude was calculated through the Minimum Circumscribed Circle and the Maximum Prismatic Hull methods. Lastly, the critical plane approach was investigated by considering the propositions made by Findley and Matake. In general all the criteria probed here gave good predictions. As for the first group, better correlation was obtained with the energy parameter. For the last two groups, Crosslands formulation performed the best, with close agreement with experimental observations. The critical plane criteria gave conservative predictions for uniaxial stress cases and non-conservative for the other assessed conditions. In addition, both criteria misbehaved outside their calibration region, i.e. outside the tension-torsion region, and were unable to properly describe equi-biaxial conditions.

Keywords: Multiaxial Fatigue, Superalloys, Aircraft Engineering
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1. Introduction

Aircraft failure and repair pose potentially costly and serious problems in the airline industry. The safety of mechanical components is strongly related to the dynamic forces acting during their

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