CREEP FATIGUE LIFE PREDICTION FOR ENGINE HOT SECTION MATERIALS (ISOTROPIC)*

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The presentation will summarize the activities performed during the first year of the NASA HOST Program, "Creep Fatigue Life Prediction for Engine Hot Section Materials (Isotropic)", being conducted by Pratt & Whitney Aircraft. The program is a 5-year, two part effort aimed at improving the high temperature crack initiation prediction technology for gas turbine hot section components. The two-year base program comprises the following tasks:

Task I - Material/Coating/Component Selection and Acquisition
Task II - Screen Candidate Life Prediction Approaches
Task III - Evaluate Best Candidate Life Prediction Approach
Task IV - Reporting

Significant results of the program produced thus far are listed below.

Task I - Material/Coating/Component Selection and Acquisition

1. Cast B1900 + Hf and wrought IN 718 were selected as the base and alternate materials, respectively.

2. A single heat of B1900 + Hf was obtained and test specimens fabricated.

3. The material was characterized with respect to grain size, γ' size, carbide distribution, and dislocation density.

4. Monotonic tensile and creep testing has shown engineering properties within anticipated scatter for this material.
5. Examination of the tensile tests has shown a transition from inhomogeneous "planar" slip within the grains at lower temperatures to more homogeneous matrix deformation.

6. Examination of the creep tests has shown a transgranular failure mode at 1400°F and an intergranular failure mode at 1600°F and 1800°F.

* NASA Contract NAS3-23288

Task II - Screen Candidate Life Prediction Approaches

1. A study was conducted to investigate the effects of test specimen geometry and fabrication process on fatigue life. As a result, axial strain controlled specimens were designed with a smooth (no extensometer ridges) gage section and fabricated using centerless grinding followed by light electropolishing.

2. A fatigue test matrix was established to provide baseline data to define crack initiation life as a function of major variables and for life prediction model evaluation. A total of 43 fully reversed strain controlled fatigue tests have been completed. Major variables investigated were temperature [871°C(1600°F) vs 538°C(1000°F)], strain range and strain rate.

3. Examination of specimens during testing indicated that measurable 76mm((.030 in.) surface cracks appear early in the specimen life i.e., 15% of total life at 871°C(1600°F) and 50% of life at 538°C(1000°F). This has been used as the definition of crack initiation for the initial model evaluation work.

4. Observed crack initiation sites are all surface initiated and associated with either grain boundary carbides or local porosity. The initiation life is not significantly affected by the character of the site.

5. Transgrannular cracking is observed at the initiation site for all conditions tested.

6. Grain dislocation structure is significantly less than that observed in monotonic tensile or creep tests.

7. A ranking procedure for evaluation of the prediction models has been established. The procedure assigns a numerical score based on the amount of data required, the predictive capability and the adaptability to engine relevant loading conditions for each model considered.

Task III - Evaluate Best Candidate Life Prediction Approach

1. Life prediction models representative of macroscopic (Coffin-Manson) and microscopic (Damage-Rate) approaches were selected for preliminary evaluation using the model ranking procedure developed in Task II.

2. Using limited data obtained at 871°C(1600°F)-(2 strain rates) and 538°C(1000°F)-(1 strain rate), the macroscopic approach obtained a higher overall score on the basis of data requirements and predictive capability.