High Temperature Fatigue of a Directionally Solidified Ni-base Superalloy

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Introduction

The blades used in the hot sections of land based gas turbine engines are often made of directionally solidified Ni-base superalloys. These components have to be replaced periodically due to crack damage and mechanical property degeneration. The high cost of inspection, service, and replacement has inspired interest in predicting the life of the blades. Directionally solidified Ni-base alloys are a relatively new material and therefore have interesting properties that make the material useful for turbine blades.

The goal of the experiment is to develop an experimental approach to predict the life of materials used in the hot sections of gas turbines by simulating the elevated temperatures and high stresses experienced in the turbines. Both orientation of the material and the thermal properties of the material are taken into consideration as it is subjected to low cycle fatigue. The data acquired from the tests will help supplement data provided by our sponsor as well as verify an analytical fatigue life model.

Procedure

Using a uniaxial MTS® test system, several load controlled isothermal low cycle fatigue tests were done on a directionally solidified Ni-base superalloy. Two notched specimens in longitudinal and transverse orientations were subject to several different fully reversed continuous cycle fatigue tests. All experiments were performed at either 750°C or 950°C using an induction heater.

Cylindrical specimen pieces were sectioned from either a longitudinal or transverse axis of a rectangular slab of the directionally solidified Ni-based alloy. The strain was recorded with a high temperature extensometer. A set of K-type thermocouples was spot welded to the gage section of the specimen to monitor temperature.

Results and Discussion

An experimental procedure and data analysis methodology was developed and refined to analyze the mechanical properties of the material.

Data from longitudinal specimens at 750°C was combined with our sponsor's data of the same orientation and temperature to produce the S-N curves in figure 1. This plot represents only one of three S-N plots.

Our sponsor's data is represented in yellow, while our data is in blue. The outlined points are predicted points for the future. The plots show that our data not only fits well with our sponsor's data, but it also shows the expected decrease in fatigue life with the increase of notched severity.

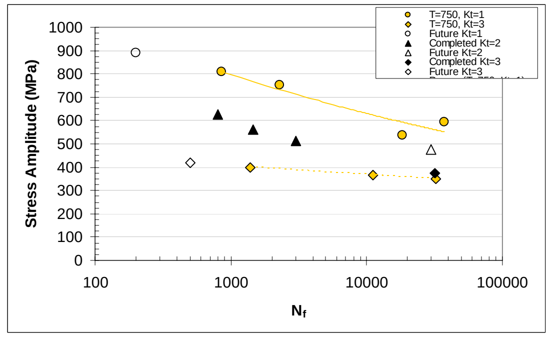

Figure 1: S-N Curve for Longitudinal at 750˚C

The crack initiation was also analyzed for each test. Figure 2 shows the stress-strain curves for five different cycles of a longitudinal specimen at 750˚C. As the specimen fatigues, the tensile loading curve deforms. The increase in tension-compression asymmetry suggests crack growth, as the tensile stiffness decreases in the presence of a crack. This trend was similar in every test, and therefore the crack initiation criterion was established.

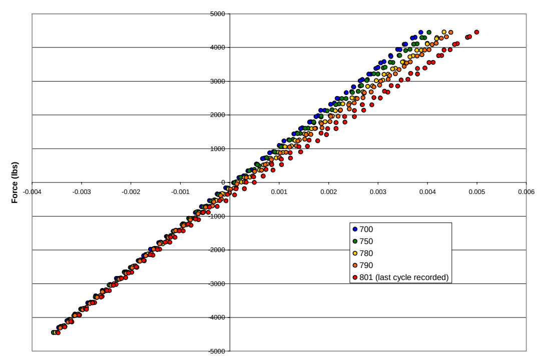

Figure 2: Crack Initiation of K_t=2 Longitudinal Specimen at 750˚C

Conclusions

The data acquired from the tensile tests fits with the data provided by our sponsor. The results will help to predict the life of future specimens. Crack initiation criteria was developed using elastic modulus asymmetry. An experimental procedure was developed that will allow for future fatigue life analysis and further verification of the analytic fatigue life model.

References

1. Gordan, Ali. "Crack Initiation Modeling of a Directionally-Solidified Nickel-Base Superally." Ph.D. diss., Georgia Institute of Technology, 2006.