Development of Analytical Life Evaluation Method for 1300˚C Class Gas Turbine Blades

Background

It is an important subject for utilities to reduce maintenance costs of gas turbines (GT) based on appropriate operation and maintenance. Especially, there is a strong need for development of life evaluation method for first row blades. So far CRIEPI conducted temperature and stress analyses of a 1100˚C class GT blade, and proposed a crack initiation life evaluation method under multiaxial thermo mechanical fatigue (TMF) loading conditions. Recently, operation time of 1300 class GT are increasing and first row blades of the 1300˚C class GT are subjected to sever temperature and stress conditions. Therefore development of a life evaluation method for first row blades made from an Ni base directionally solidified (DS) super alloy, becomes more important.

Objectives

To develop a crack initiation life evaluation method under biaxial TMF loading conditions and 1300˚C class GT life assessment analysis system by incorporating the developed method.

Principal Results

1. Development of TMF life evaluation method of a DS super alloy

(1) It was found that biaxial TMF life of the DS super alloy was not correlated with Mises equivalent strain range, which correlated with the biaxial TMF life of the IN738LC, due to the biaxial TMF life depending on not only the maximum shear strain but also normal strain on the maximum shear strain (Fig.1(a)). An equivalent shear strain range, which is function of the maximum shear strain and normal strain on the maximum shear strain was derived based on the Γ-plane theory *1. The biaxial TMF life was well correlated by the equivalent shear strain range (Fig.1(b)). The biaxial TMF life of coated specimen with similar coating to actual blades reduced to 1/2 from that of the substrate.

(2) A biaxial TMF life evaluation procedure for the 1300˚C GT blades was developed by incorporating the “equivalent shear strain range” to previously proposed procedure for the 1100˚C class GT blades (Fig.2(a)). The biaxial TMF life obtained from simulated actual blade temperature and strain conditions could be predicted by the life evaluation model within factor of 1.5 (Fig.2(b)).

2. Development of crack initiation life assessment system for 1300˚C class GT blades

A crack initiation life assessment system based on a finite element analysis for 1300˚C class GT blades was developed by composing an inelastic constitutive equation, which describes stress-strain behavior of the DS super alloy precisely, and the above mentioned TMF life evaluation method. Temperature and stress distributions within first row blades were analyzed by using the system (Fig.3). From the temperature and stress analysis results, TMF life at mid height portion of the blade was predicted. It was found that convex side near leading edge had the maximum value of a damage ratio, which was defined as reversed number of the TMF life, and those values at the leading edge and at mid height in concave side were approximately 0.6 to 0.4 times of the maximum value (Fig.4).

Future Developments

1300˚C class GT blade life assessment system developed in this study will be applied to life assessment of actual 1300˚C class GT blades. Crack propagation property of the DS super alloy will be studied and crack propagation analysis function will be added to the developed system.

Main Researchers:

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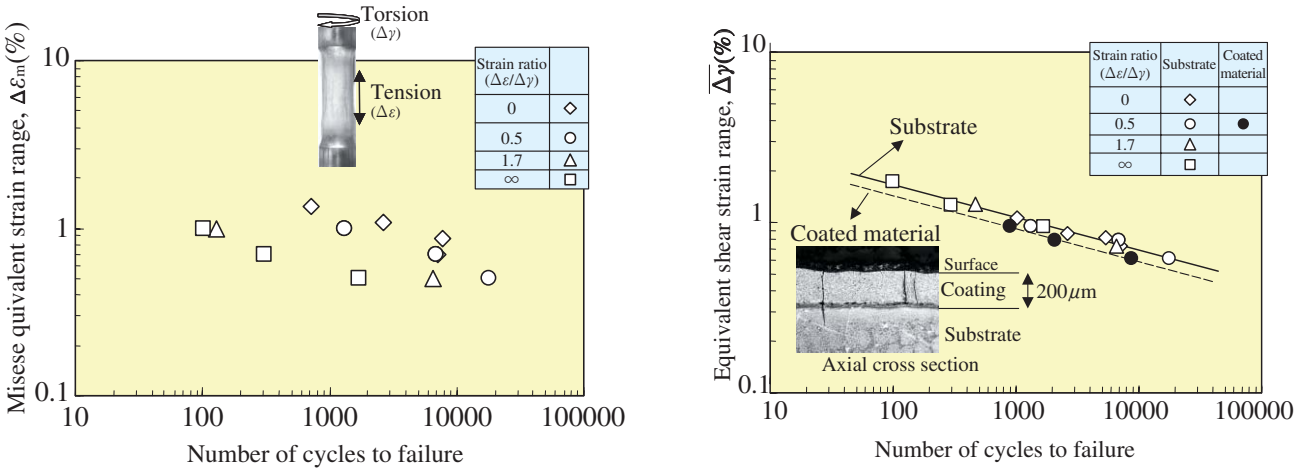
Reference

T. Ogata, et al., 2005, “Development of high temperature strength evaluation methods for Ni base directionally solidified super alloys, Vol.5”, Technical Report Q04008 (in Japanese)

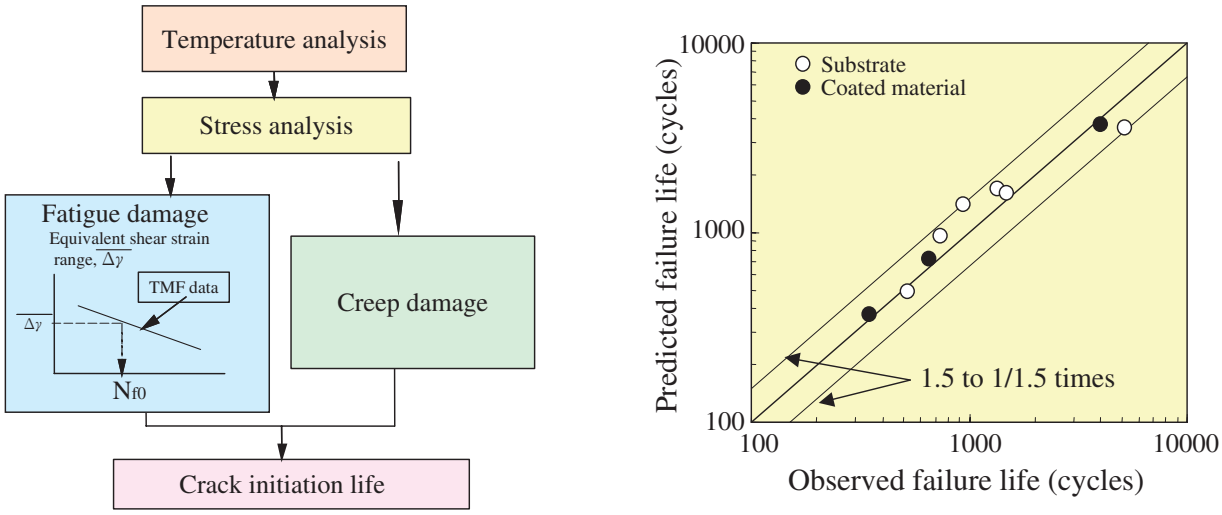
*1 : Theory that both the maximum shear strain and normal strain on the maximum shear strain plane control crack initiation under multiaxial stress condition.



(a) Mises equivalent strain range

(b) Equivalent shear strain range

Fig.1 Correlation of TMF life with strain based parameters



(a) TMF life evaluation flow

(b) Comparison between predicted and observed life

Fig.2 Thermo mechanical fatigue life evaluation method of 1300˚C class GT and a life prediction result

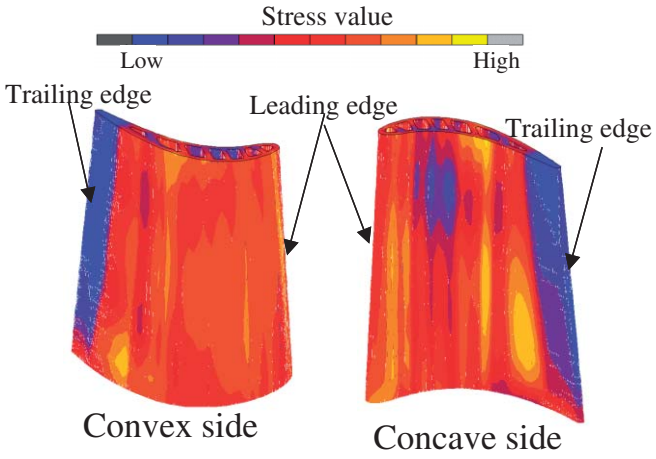


Fig.3 A stress analysis result of the blade

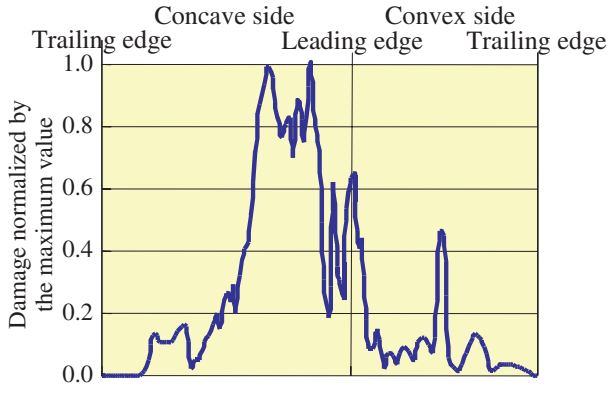


Fig.4 Damage distribution at mid height of the blade