Development of the Temperature Prediction Method for Hot Gas Path Parts of 1300℃ Class Gas Turbines

Background

Electric power companies are working to extend the remaining life of gas turbine (GT) hot gas path parts to reduce maintenance costs in Japan. But there are few effective methods to evaluate the remaining life of GT hot gas path parts quantitatively, so it is important to develop the temperature prediction method of GT hot gas path parts to realize the evaluation of them correctly. CRIEPI is developing the NDE (non-destructive evaluation) method to evaluate the thermal barrier performance and the degradation property of the TBC (Thermal Barrier Coating) which is coated over GT hot gas path parts, and the numerical method based on CFD (Computational Fluid Dynamics), which analyzes flow and thermal field in a gas turbine. Development of NDE method for the performance of the TBC, temperature analysis and analytical life evaluation of a first stage rotor blade of a 1100℃ class gas turbine have been conducted.

Objectives

The prediction methods of temperature distributions of the combustion liner and the first stage rotor blade for the operating 1300℃ class gas turbine. The developed methods shall be verified by comparison between the predicted temperature and actual conditions of ex-service parts.

Principal Results

1. Development of NDE prediction method for temperature distribution of the TBC coated over the combustion liner

CRIEPI developed the prediction method for the average temperature of TBC (TBC temperature) and the temperature of the substrate over the operation term by means of NDE method [*1] and degradation prediction method [*2] for the TBC thermal barrier performance (Fig.1). The predicted temperature distribution on the whole inner surface of the TBC which was used about 15,000h in thermal power plant is shown in Fig.2 by our developed method and NDE apparatus. It is possible to confirm from the result of the predicted TBC temperature distribution that the TBC temperature becomes higher from the center of the combustion liner to the downstream, and some parts show high temperature locally due to the effect of non-uniform cooling of the film cooling air. Using this method of predicting TBC temperature makes it possible to predict substrate temperature and to evaluate the remaining life of GT hot gas path parts more correctly.

2. Numerical prediction procedure of temperature profile for a first stage rotor blade

The three-dimensional steady-state numerical analysis was conducted by thermal conjugation of inside and outside fields of the blade, which consists of convection heat transfer around the blade, thermal conduction in the blade material and internal blade cooling. In the present analytical method, cooling structure of the blade was conscientiously modeled and correlations of heat transfer and friction in the rib-roughened internal cooling passage derived from Large Eddy Simulation were applied. The predicted temperature profile on the blade wall is in agreement with estimation based on the material of ex-service blades [*6](Fig.3), and the hot spot predicted by the numerical analysis coincides with the distinctive damages due to oxidation on ex-blades (Fig.4). Accordingly, capability of the present analysis to utilize for the life evaluation of the blade has been verified.

Future Development

On the NDE prediction method for temperature distribution of the TBC coated over the combustion liner, we will hope to measure the many actual combustion liners in order to raise its reliability. And with regard to the numerical analysis, transient variations of the blade temperature in start-up and shut-down will be predicted in order to contribute to the life evaluation.

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※Estimation by means of thickness of the aluminum diffusion layer at the boundary between the coating and the substrate

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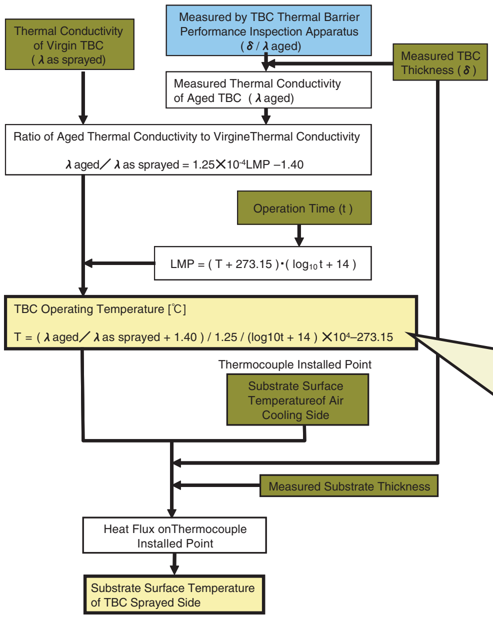

Fig.1 Calculating Flow of the TBC Temperature

NDE method and degradation prediction method for thermal barrier performance of TBC enable to predict the TBC and the Substrate temperature under operation

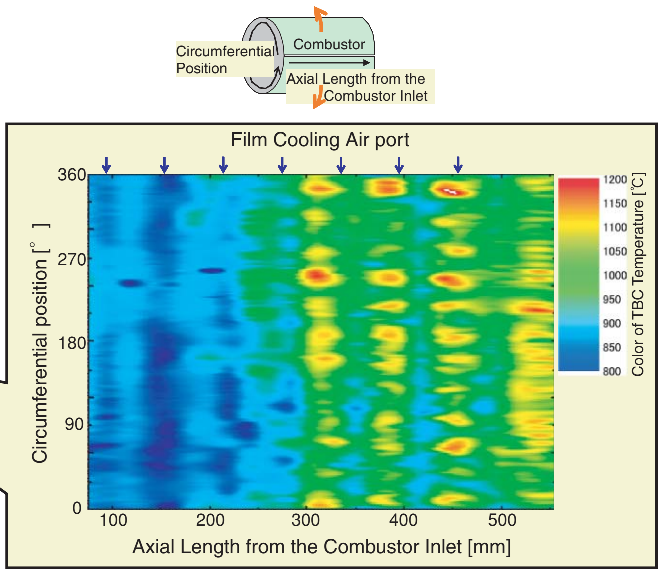

Fig.2 Predicted result of TBC Temperature

TBC temperature becomes higher from the center of the combustion liner to the downstream, and some parts show high temperature locally due to the effect of non-uniform film cooling.

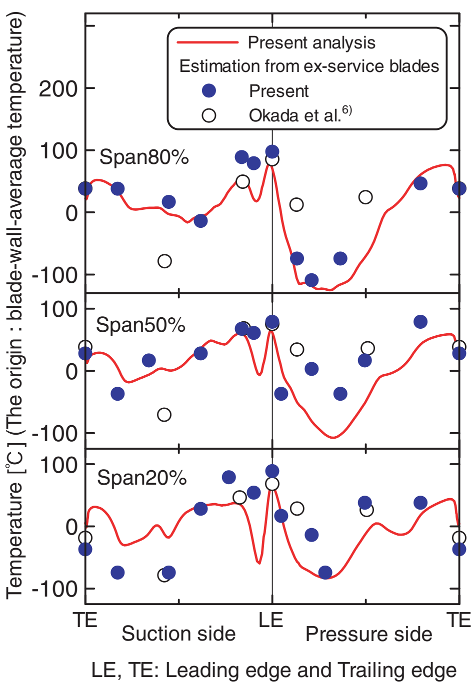

Fig.3 Predicted temperature profile on the blade wall, compared with estimation based on ex-service blades

Predicted temperature profile is in agreement with estimation based on ex-service blade

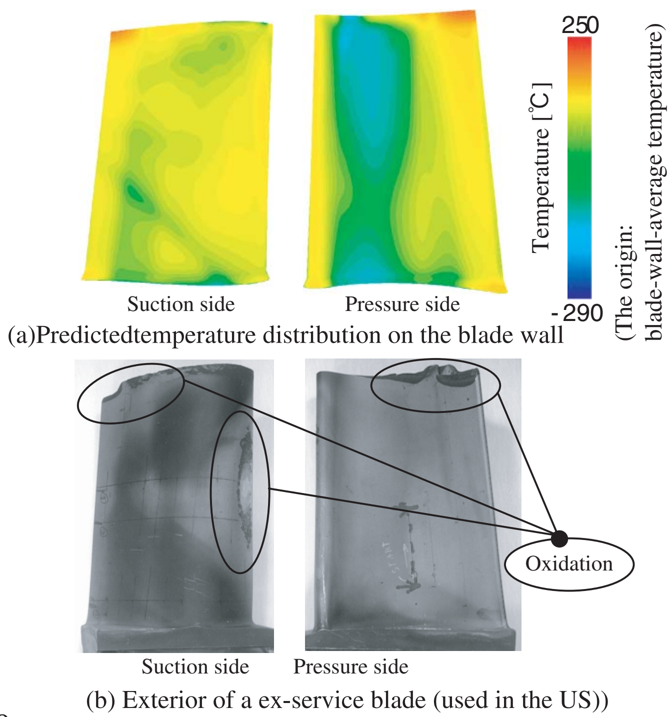

Fig.4 Predicted temperature distribution on the blade wall and Exterior of an ex-service blade

Hot spots predicted by numerical analysis coincides with the distinctive damages on an ex-service blade