Development of Void Growth Simulation Program for Steam Turbine Casings

Background

Intensive effort has been made by utilities to reduce maintenance cost of high temperature components in aged thermal power plants by extending component life and optimizing inspection under the circumstance of extending deregulation. To reduce maintenance cost while maintaining the reliability, it is necessary to develop quantitative prediction methods of damage accumulation in the high temperature components during operation such as creep voids. In CRIEPI, creep damage mechanism at the heat affected zone in boiler weldment parts under creep-fatigue loading was clarified and a creep void growth model was proposed based on the mechanism[*1]. On the other hand, void initiation and growth in a steam turbine casing due to creep-fatigue loading was reported. Therefore it is an urgent problem to clarify damage mechanism and to develop a quantitative damage prediction method.

Objectives

To clarify creep void growth process under creep-fatigue loading in a steam turbine casing material and to develop a void growth simulation program that can predict void growth behavior quantitatively;

Principal Results

1. Clarification of creep void growth process in a casing material

A creep-fatigue test (Temperature:600°C, Stress:150MPa, Tensile strain hold:10minutes) was performed in a scanning electron microscope and damage process during the test was observed. It was found that spherical shape creep voids with 1μm diameter initiated at 15% (300 cycles) of failure life (crack length 2mm, 2135 cycles), and they continue to grow by changing their shape to crack-like resulting in formation of a grain boundary micro crack at around 70% (about 1400 cycles) of the life (Fig.1). It is an interesting result that void growth rate under the creep-fatigue loading is accelerated by cyclic load compared with static creep loading.

2. Development and verification of a void growth simulation program

A void growth simulation program that can predict void growth behavior within a certain area quantitatively was developed based on the previously proposed void growth model[*2]. It was confirmed that void length predicted by the program agreed with that observed in the experiment shown in Fig.1 (Fig.2(a)), and void growth behavior can be predicted by the simulation (Fig.2(b)).

3. Void growth simulation assuming actual loading condition

Void growth behavior within a certain area was predicted by the program under the assumed start up, steady state and shut down condition at high temperature portion in an actual casing (Fig.3(a)). It was predicted that the voids (initial length of 0.1 μm) grew to a micro crack during 100,000 hours operation (Fig.3(b)).

Future Developments

The developed void growth simulation program will be applied to void growth prediction for heat affected zones in high Cr steel weld joints.

Main Researcher: Takashi Ogata, Ph. D.,
Senior Research Scientist, Structural Material Characterization Sector, Materials Science Laboratory

Reference

T. Ogata, 2006, “Clarification and simulation of void growth behavior of a turbine casing material”, CRIEPI Report (Q05004) (in Japanese)

---

*1 : T. Ogata, Journal of JSME, A, Vol.68, No.665, p.74 (2002).
*2 : T. Kame, Proceeding of Thermal and Nuclear Power Engineering Conference, p.80 (2005).

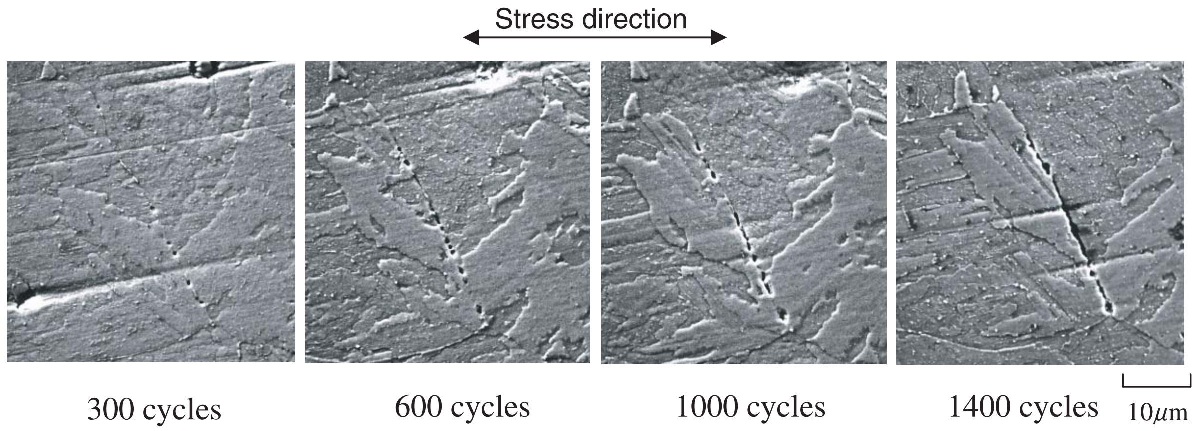
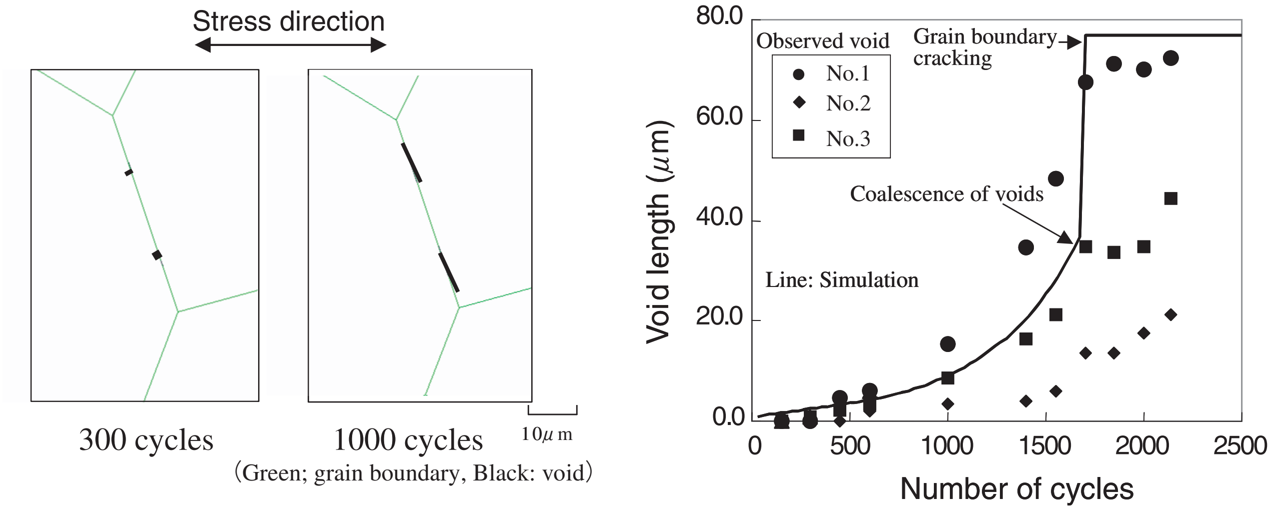


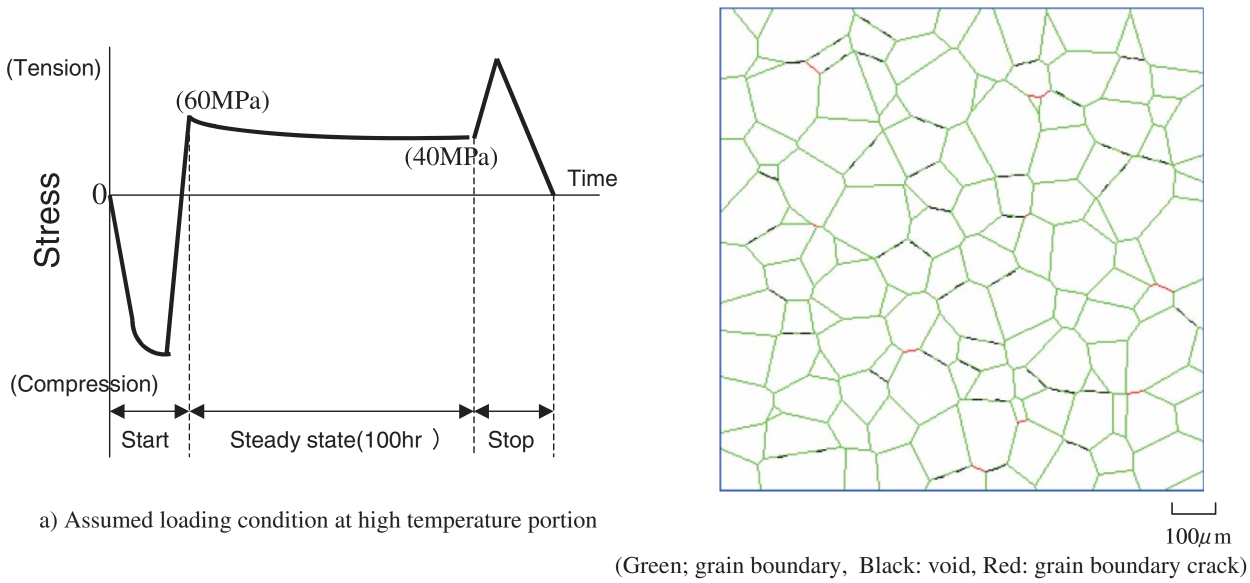
Fig.1 Creep voids observed by a scanning electron microscope during the creep-fatigue test (Life:2135 cycles)



a) Voids at local area (corresponding to Fig.1)

b) Comparison between simulation and observation

Fig.2 Creep voids growth simulation results under the creep-fatigue condition



a) Assumed loading condition at high temperature portion

b) prediction result after 100,000 hours operation

Fig.3 Void growth simulation under assumed loading condition in an actual casing