Clarification of Creep Void Growth Behavior on Steam Turbine Rotor Material and Development of Creep Void Growth Simulation Program

Background

Utilities are making a lot of efforts to reduce maintenance cost by life extension and efficient inspection of high temperature components in aged thermal power plants against a background of advancing deregulation of the electric power industry. In order to maintain reliable operation and reduce maintenance cost of these components, it is necessary to develop a quantitative damage evaluation method which gives accurate prediction of damage status from creep void growth to micro crack initiation and propagation that occur in the high temperature components during operation. This necessity is especially high for steam turbine rotors which rotate with high speed and are not allowed to have macro cracks during operation. However, it is difficult to predict damage extension process quantitatively by existing methods that predict macro crack initiation life based on temperature and stress analysis results.

Objectives

To clarify void growth behavior of a turbine rotor material under creep-fatigue loading condition, and to develop void growth simulation program that can predict damage extension process of actual rotors quantitatively.

Principal Results

1. A creep-fatigue test (temperature:600C, stress 180MPa) was conducted in a scanning electron microscope on a turbine rotor material (Cr-Mo-V forging steel), and damage evolution process was observed by the SEM continuously. As a result, it was found that spherical voids initiated at around 20% of failure life (the maximum crack length is 2mm, 1800 cycles) and these voids grew by changing their shape from spherical to crack-like. Micro cracks in length of 10 μm formed at 50% - 70% of the life (Fig.1). It suggests that void growth mechanism changes from diffusion control at initial stage to combination of diffusion and power law creep by surrounding grains. Also this observation indicates that the turbine rotor material had enough remaining life after initiating creep voids.

2. In order to predict creep void growth behavior quantitatively, a “void growth simulation program” was developed by incorporating previously proposed creep void growth model [*2](Fig.2). The program can simulate void and micro crack growth process at certain temperature and stress using simulated micro structures generated by the program. It enables us to predict void growth process at certain portion of the actual rotor quantitatively and easily.

3. It was indicated that the maximum void and micro crack length observed by above tests coincide with void growth behavior calculated by the void growth simulation program (Fig.3). Void and micro crack growth simulation results within certain area (0.5mm x 0.5mm) agreed well with their growth behavior observed by the SEM during the test (Fig.4).

Future Developments

Developed program in this study will be improved by considering irregularity of void growth process, and applicability of the program to turbine casings and boiler weldment parts will be discussed.

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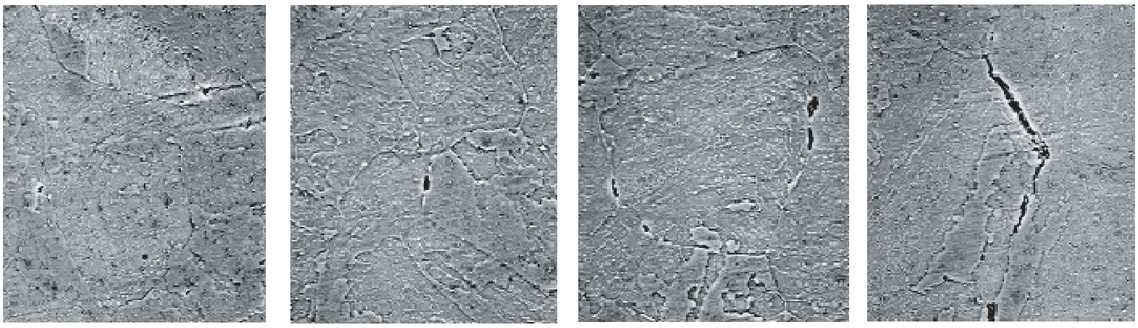
Reference

Takashi Ogata, 2003, “Clarification of creep void growth mechanism on turbine rotor materials and development of void growth simulation program.” Denchuken houkoku T3007

＊1：Equal to or less than 10μm in length was defined as void, and longer than that was defined as micro crack
＊2：T. Ogata, Journal of JSME A-68, 665, pp.74(2002).



300 cycles 700 cycles 1000 cycles 1300 cycles

10 μm

(Failure life was defined as cycles where crack length reaches 2mm. (Life is 1800cycles))

Fig.1 Creep voids observed by a scanning microscope during the creep-fatigue test.

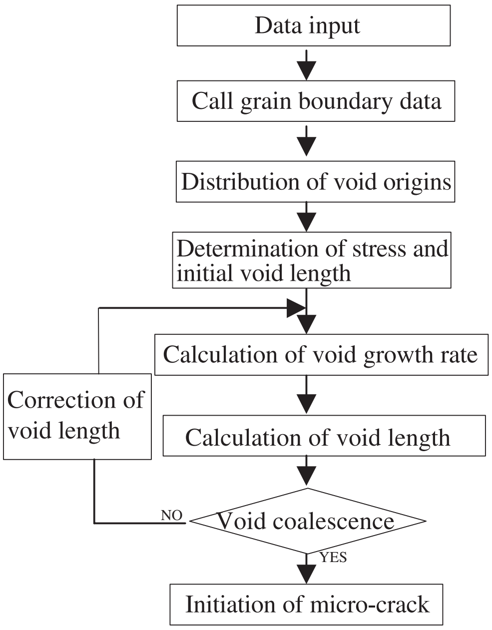


Fig.2 Void growth simulation flow

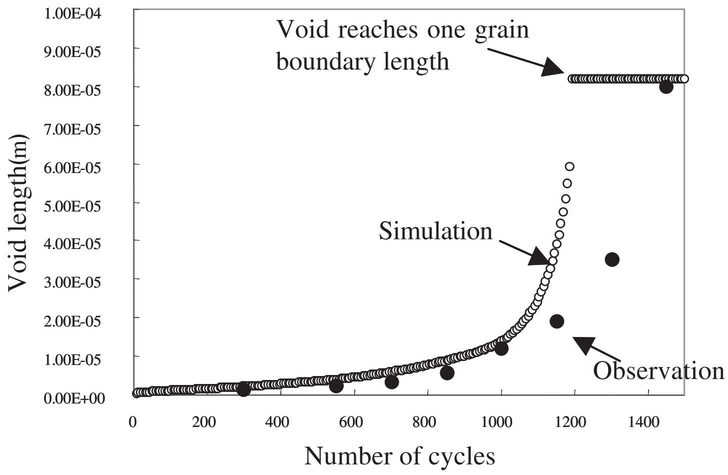
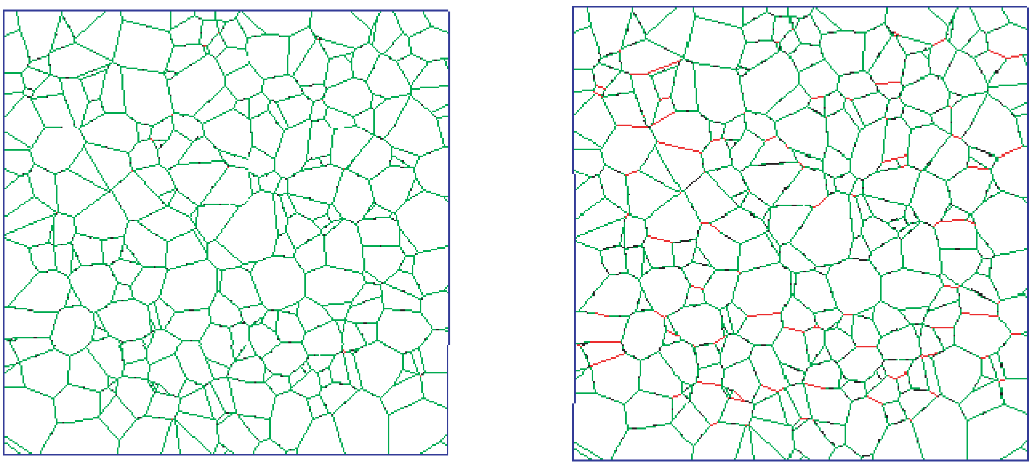


Fig.3 Comparison of maximum void growth between observation and simulation.



700 cycles 1300cycles

50 μm

(Green: grain boundary, Black: creep void, Red: one grain boundary crack)

Fig.4 Void growth simulation results under the creep-fatigue loading (Life: 1800 cycles)