Development of creep damage evaluation method of Mod.9Cr-1Mo steel weld joint for USC boiler steam piping

Background

In Japan, more than half of the electricity from thermal power plants is generated by ultra super critical (USC) power plants in which steam temperature is over 593°C and steam pressure is over 24.1MPa. Modified 9Cr steels (9Cr), which have temper martesitic microstructure with higher creep strength than low alloy ferritic steels, are being used for high temperature boiler components in the USC plants. Study on high temperature strength and damage assessment methods have been conducted for base metals of the 9Cr. On the other hand, limited studies on creep damage assessment methods have been made for 9Cr welded joints. Recently, damage incidents of 9Cr boiler welded piping in USC plants have been reported [*1], and it was pointed out that creep rupture strength of the welded joint is significantly reduced in comparison with the base metal. Thus development of a remaining life assessment method for 9Cr welded components in USC plants is an urgently required task in Japan.

Objectives

To clarify creep rupture strength and micro damage evolution process, and to develop a quantitative creep damage assessment procedure of a modified 9 Cr welded joint

Principal Results

1. Creep rupture strength of modified 9Cr welded joint

(1) Welded joint specimens tested at 650°C and 700°C failed at heat affected zone (HAZ), so called Type IV failure, as has occurred in actual welded components in USC plants. It is found that the creep rupture strength of the welded joint falls to approximately 1/5 of the base metal due to Type IV failure (Fig.1(a)). Therefore appropriate remaining life method should be applied to welded piping because damage evolution in the welded piping is much faster than that in the base metal.

(2) Creep analysis of the welded joint specimen has been conducted by using a finite element model consisting of a base metal, a weld metal and a HAZ. As a result, it was found that creep rupture life reduction in the welded joint is mainly caused by accumulation of larger amount of creep strain in the HAZ than that in the base metal (Fig.1(b)).

2. Micro damage evolution process and damage assessment method of the welded joint

(1) It was found that spherical shape creep voids grow up to 5 μm of diameter at the 20% creep damage material from microstructure observation. The maximum void length and the void area fraction rate increase with increasing creep damage. This suggests that the creep damage of the welded joints can be predicted by the void parameters like the area fraction rate if appropriate void observation can be made for components (Fig.2, Fig.3).

(2) The previously proposed void growth simulation program [*2] was modified to be able to handle probabilistic factor related to the void initiation and was applied to void growth prediction in the HAZ of the welded joint. As a result, it was demonstrated that void growth behavior simulated by the program agreed with that observed in the creep damage materials qualitatively, and that changes in the maximum void length and the area fraction rate with creep damage were predicted by the simulation with high accuracy (Fig.2, Fig.3). Thus creep damage evolution process featured by the void growth of the 9Cr welded joints can be predicted by the void growth simulation. This contributes to increase of maintenance reliability of the 9 Cr welded joints.

Future Developments

Modified void growth simulation program in this study, which can simulate void growth behavior in HAZ precisely, will be applied to remaining life assessment of actual boiler welded piping.

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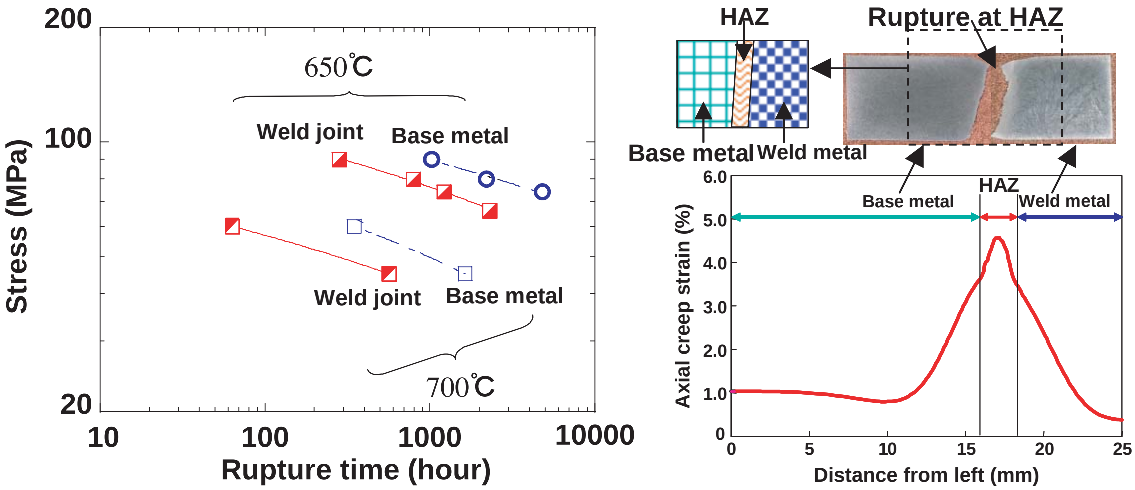
Reference

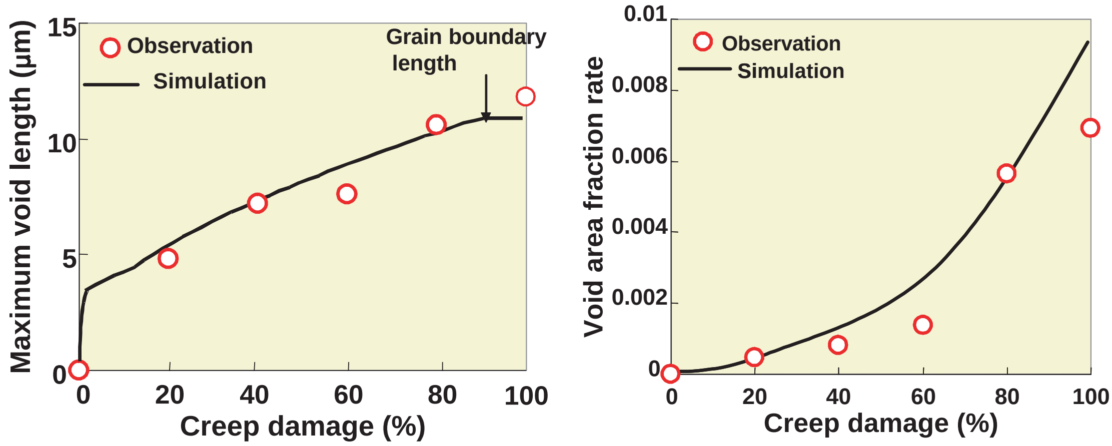
T. Ogata, 2006, "Development of damage assessment method of Mod. 9Cr-1Mo steel weld joints," CPIEPI Report Q06002 (in Japanese)

＊1：S. J. Brett et. al., "In-Service Type IV Cracking in a Modified 9Cr Header", Proceeding of ECCC Creep Conference, London, 2005, pp.563-572
＊2：T. Ogata, CPIEPI Report Q05004, 2006



(a) Creep rupture property of weld joint (b) Creep strain distribution in weld joint

Fig.1 Creep rupture property and creep strain distribution using three materials FE model



(a) Maximum void length – creep damage (b) Void area fraction rate – creep damage

Fig.2 Relationship between maximum void length, void area fraction rate and creep damage in HAZ

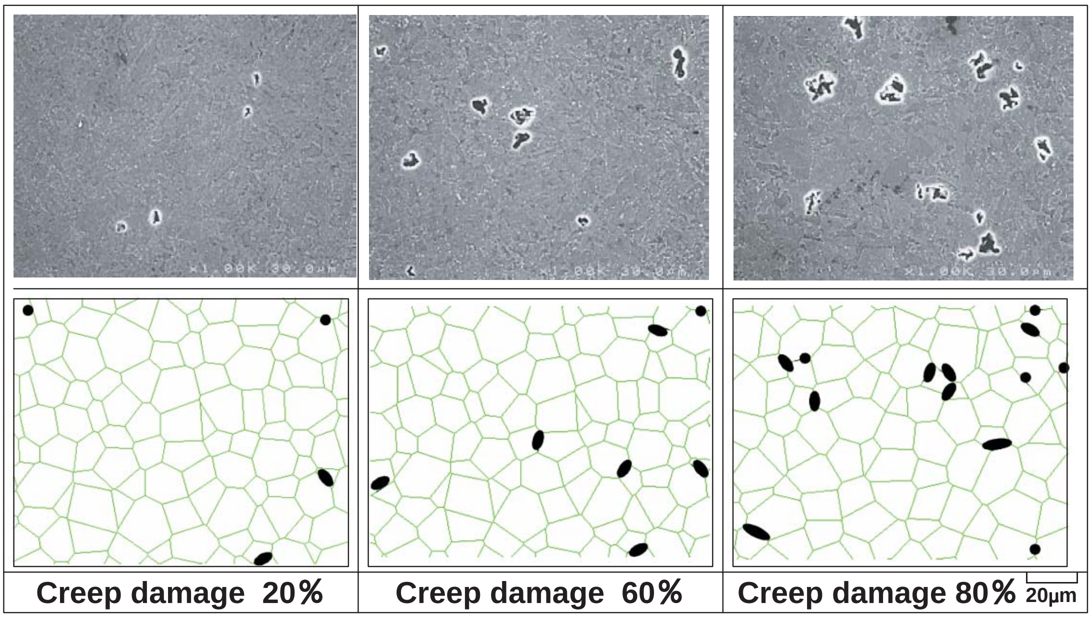


Fig.3 Comparison between void observation (upper) and void growth simulation results (lower)