1999

SOUVENIR PROGRAMME

EIGHTH SCIENTIFIC CONFERENCE

ELECTRON MICROSCOPY SOCIETY MALAYSIA

PERSATUAN MIKROSKOPI ELEKTRON MALAYSIA

2 - 4 December 1999
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PROCEEDINGS

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ISBN 983-9319-78-7

Perpustakaan Negara Malaysia Cataloguing-in-Publication Data

Scientific Conference (8th : 1999 : Awana Genting)
8th Scientific Conference, 2nd-4th December 1999, Awana Genting : proceedings/editors M.K. Vidyadaran, Tengku Azam Shah Tengku Mohamad,
ISBN 983-9319-78-7
1. Microscopy--Malaysia--Congresses. 2. Electron microscopes--Malaysia--Congresses. 3. Confocal microscopy--Malaysia--Congresses. I. M.K. Vidyadaran (Madamparath Kaiparath Vidyadaran). II. Tengku Azam Shah Tengku Mohamad. III. Title
502.82

Printed by:
Malindo Printers Sdn. Bhd.
Lot. 3, Jalan Ragum,
Seksyen 15/17,
40000 Shah Alam,
Selangor Darul Ehsan.

MATERIAL SCIENCE *(POSTER)*

BIOLOGICAL SCIENCE *(ORAL)*

BIOLOGICAL SCIENCE *(POSTER)*

Crack Mechanism in Creep -Thermal Fatigue of Low Alloy Steel Superheater Tube

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ABSTRACT

The application of superheater boiler tube includes a sequence of events such as fluctuating stress levels at constant temperature, fluctuating temperature levels at constant stress and periods during which both stress and temperature are simultaneously fluctuating. Furthermore, there is evidence to indicate that the thermal fatigue and creep processes interact to produce a synergistic response. Creep-thermal fatigue was generated by constant stress during hold periods at maximum temperature 550°C and at minimum temperature 420°C. Optical microscope and Scanning Electron Microscope (SEM) are the two most useful tools for the study of crack mechanism in creep-thermal fatigue testing and also to identify the mode of crack. Fractographic studies of fracture surface features and metallographic studies of microstructure are information needed for the analysis to aid in determining the initiation and propagation of cracks. Observations suggest that crack nucleation may become predominantly a grain boundary process when creep-thermal fatigue test is performed.

KEYWORD: crack mechanism, creep-thermal fatigue, fractography, metallography, superheater boiler tube.

INTRODUCTION

There are several important high-performance application of current interest in which conditions persist that lead to combined creep and fatigue. For example, components in steam generating service are subjected to long periods of steady operation, interrupted by temperature and load cycles. Creep-fatigue test was generated by using hold periods during, which the strain was maintained constant. In this type of creep-fatigue test, the material is subjected to repeated cycles of stress relaxation. In other tests, the stress was maintained constant during the hold periods. In this type of test, the material is subjected to repeated cycles of creep deformation. The results of both types of test show marked reduction in fatigue life with the increased in hold period[1].

MATERIALS AND METHODS

Creep-thermal fatigue of low alloy steel superheater tube was tested at maximum temperature 550°C and minimum temperature 420°C at constant stress 33.33 kg/mm^2. During the testing the specimen were interrupted at various stages of the holding time (4 and 10 minutes) at maximum temperature and the frequency (3 and 7 cycles) in the thermal cyclic before holding minimum temperature in the furnace. One specimen was tested to rupture without holding at maximum temperature with frequency of 13 cycles. Optical microscope and Scanning Electron Microscope (SEM) were used for surface observation.

RESULTS AND DISCUSSION

Fractography

The results from electron fractographic studies generally supported the

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observation made from the microstructural analysis. Typical SEM fractographs of specimens creep-thermal fatigue tested at maximum temperature 550^{0}C and minimum temperature 420^{0}C at constant stress 33.33 kg/mm^2 are shown in Fig.1a. The fracture surface can be classified as a ductile fracture. This fracture revealed the dimple appearance and less striation on the side of dimple wall. This striation was representing a feature of thermal cyclic which represent local growth increment per cycle.

Metallography

A surface layer was removed by metallographic grinding techniques from creep-thermal fatigue specimens, followed by mechanical polishing. Examination of the repolished surface under the microscope established that the early formation of transverse intergranular cracks is a near-surface phenomenon (Fig.2). The exist of small intergranular cavities could be detected readily by SEM (Fig.1b). The crack morphologies of the specimens of creep-thermal cyclic tests were observed wedge and as cavity intergranular type of crack (Fig.3). The cracks the site of nucleation, growth cavity and coalescence voids occurred on the triple point and grain boundary near edge of specimen. Sklenicka et.al.[2] and Samuel et al.[3] had observed embryonic cracks initiated at the outer surface and the final intergranular fracture path is formed by cavity interlink.

William [4] and Evans [5] who carried out investigation on the formation of W-type intergranular cracks, assumed that grain-boundary sliding is blocked at triple points and a large stress concentration is built up. An alternative mechanism for formation of a wedge crack, do not nucleate as a separate entity but begin as isolated cavities in the triple point region by the same mechanism of high stresses arising from boundary sliding. They subsequently grow vary rapidly and link together into a wedge crack to form the concentrations of stress. Additional evidence for this rapid evolution by growth and linking is visible in Fig.2b, which shows a triple point region of grain junction revealed by the intergranular separation technique. Fig.3b shows specific feature of individual cavities and their distribution. Thus, it can be expected that the final stage of specimen life will be associated with the critical decrease of grain boundary cohesion caused by the accumulation of cavitational damage. Cracking at grain boundary particles is particularly dangerous if the grain boundary cohesion is already weakened by segregation, as a continuous weak path exists to link up the various cracks at the particle boundaries [6,7].

These observations strongly suggest that in low alloy steel intergranular fracture in creep-thermal fatigue, favour wedge intergranular crack type as the frequency is decreased. This type of crack propagates more rapidly than the cracks formed by coalescence of void. The endurance of creep-thermal fatigue tests decreases with increasing hold periods. Eszteragar and Ellis [1] also pointed out that the marked reduction in fatigue life with increases in hold period.

CONCLUSION

The fracture surface can be classified as ductile fracture. The crack morphology of the specimens of creep-thermal fatigue tested were wedge and cavity intergranular crack type, where the site of nucleation, growth cavity, coalescence voids, occurred on the triple and grain boundary near edge of specimen. The decreased in frequency favoured wedge intergranular type of crack. Time to rupture in the creep-thermal fatigue tests was strongly affected by hold periods.

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