MEASUREMENT METHOD OF CYCLE SEQUENTIAL CHARACTERISTICS OF STRESS REDUCTION UNDER STRAIN-CONTROLLED CREEP-FATIGUE CONDITIONS USING CIRCULAR SHARP NOTCHED ROUND BAR SPECIMEN

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Abstract

Concerning strain-controlled creep-fatigue conditions of a notched specimen, since cycle sequential characteristics of stress reduction are affected not only by materials and test conditions but also by a dimension of notch, estimation of experimental result by conventional method is not feasible. In order to establish a unified measurement method of the cycle sequential characteristics of the stress reduction for a notched specimen under strain-controlled creep-fatigue condition, the stress range $\Delta\sigma$ ($=\sigma_{max}-\sigma_{min}$) and its reduction ratio η has been proposed. In this study, strain-controlled creep-fatigue crack growth tests were conducted for the CNS (Circular sharp Notched round bar Specimen) using two types of the extensometers which has different gauge lengths, and the effect of gauge length on cycle sequential characteristics of the stress reduction and failure life was investigated in relation to the crack length. In addition, the optimum gauge length was discussed using FEM.

1. Introduction

As a material test method considering the operating conditions of boiler piping, ASTM E2714-13 which is conducted under strain-controlled creep-fatigue conditions has been proposed. According to this method, the failure criterion is expressed as a specified percentage reduction ratio in the maximum stress from the cycles. However, since cycle sequential characteristics of the maximum stress σ_{max} shows various behaviors depending on the test conditions and materials, it is difficult to estimate the failure life uniformly using σ_{max}. Therefore, it has been reported that the cycle sequential characteristics of the stress range $\Delta\sigma$($=\sigma_{max}-\sigma_{min}$) and its reduction ratio η ($=(\Delta\sigma_0-\Delta\sigma)/\Delta\sigma_0$) are useful for life estimation of notched specimen instead of σ_{max}. In previous study, crack initiation and failure lives of the notched specimen have been defined as η=10% and 25%, respectively. On the other hand, the cycle sequential characteristics of the stress may be affected by the the notch depending on the gauge length. In this study, strain-controlled creep-fatigue crack growth tests were conducted for the CNS using two types of the extensometers which has different gauge lengths, and the effect of gauge length *GL* on cycle sequential characteristics of the stress reduction and failure life was investigated in relation to the crack length. In addition, the optimum gauge length was discussed using FEM.

2. Results

The material used in this study is Ni-base alloy, Alloy 617. Strain-controlled creep-fatigue crack growth tests were conducted under the conditions of T=750°C, $\Delta\varepsilon$=0.4%, t_H=600sec using CNS for Alloy 617. The cycle sequential characteristics of the stress range $\Delta\sigma$ are shown in Fig. 1. In Fig. 1, the cycle sequential characteristics of $\Delta\sigma$ using specimens of diameter D=6mm (GL/D=2.0, 2.8) decreased monotonously regardless of the gauge length. For the specimens of D=10mm (GL/D=1.2), $\Delta\sigma$ showed work-hardening behavior from 0 to 20 cycles, after that decreased monotonously with increase in cycles. The absolute value of stress was lower than that of D=6mm. On the other hand, the crack growth curves showed similar characteristics regardless of the specimen and the gauge length, as shown in Fig. 2. From these results, it was found that the crack length reached almost 200μm at η=10% under all conditions. The time when the crack length reaches 200μm is defined as the crack initiation life in ASTM E1457-19e1. At η=25% which is proposed as the criterion for failure life, stable crack growth was observed. Therefore, even if different gauge lengths and specimens are used, $\Delta\sigma$ can be used to estimate the crack initiation and failure lives of CNS uniformly under the condition of GL/D>1.2.

In addition, FEM analysis was conducted to discuss about the difference in stress as shown in Fig. 1. Fig. 3 shows the relationship between *GL/D* and the maximum hydrostatic stress in the notch tip direction. In Fig. 3, the peak value of hydrostatic stress increased with increase in the value of *GL/D* and tends to saturate at *GL/D* is more than 1.0. The same result was also obtained about the equivalent stress. From the view point of FEM analysis, when notched specimen is used, it is considered that the gauge length is necessary to be ensured longer than the diameter of the specimen, that is *GL/D*>1.0. This result approximately corresponds to the standard of smooth specimen.

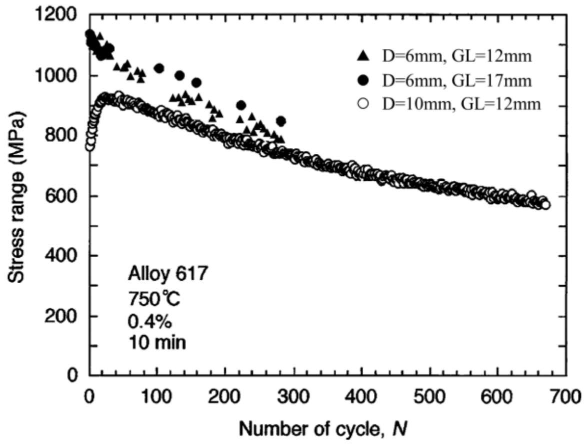

Fig. 1 Cycle sequential characteristics of $\Delta\sigma$ under strain-controlled creep-fatigue conditions.

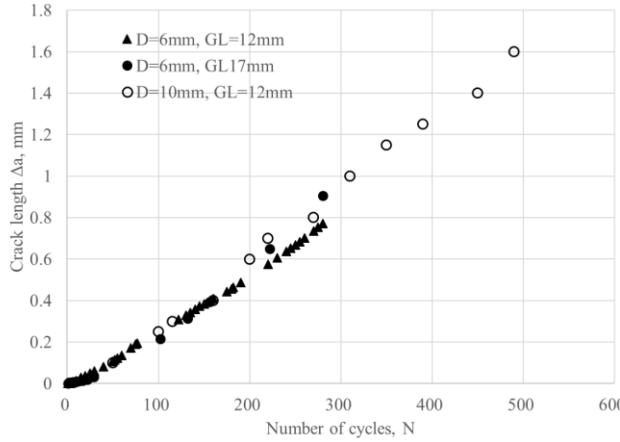

Fig. 2 Crack growth curve.

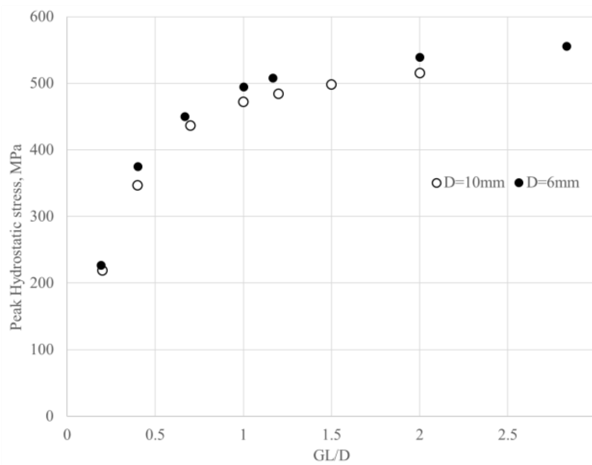

Fig. 3 Relationship between *GL/D* and peak hydrostatic stress in the notch tip direction.

3. Conclusions

(1) Although the absolute value of the stress changes depending on the gauge lengths and the specimens, $\Delta\sigma$ can estimate the failure life of CNS under strain-controlled creep-fatigue conditions uniformly.

(2) When notched specimen is used, it is considered that the gauge length is necessary to be ensured longer than the diameter of the specimen.

Acknowledgements

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