Transactions of the Korean Nuclear Society Spring Meeting
Chuncheon, Korea, May 25-26 2006

Variations of Induced Strain Range in Low Cycle Fatigue Test

Ho-Jin Lee, Dae-Whan Kim, Bong-Sang Lee, and Woo-Seog Ryu
Nuclear Material Research Team, Korea Atomic Energy Research Institute, P.O.Box105, Yuseong, Daejeon, Korea, 305-600, hjlee1@kaeri.re.

1. Introduction

Monotonic stress-strain curves have been used to obtain design parameters for limiting stresses on engineering structures subjected to static loading. Similarly, cyclic stress-strain curves are useful for assessing the durability of structures subjected to repeated loading. At the beginning of fatigue loading irreversible plastic deformation causes fatigue hardening or softening, depending on the initial state of the material and loading parameters like stress amplitude, mean stress, temperature and deformation rate. The typical material response in case of strain controlled cycling is seen in Fig. 1. [1] In order to obtain just fatigue properties of material during the test, the test specimen and test method should be prepared to maintain the control parameters constantly.

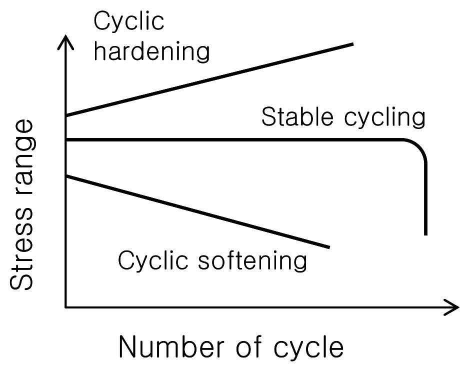

Fig. 1 Typical material responses in fatigue tests.

In this study, the stress and strain analysis in the specimen during the fatigue test was performed by using commercial calculation code. Because any theory for softening or hardening behavior of the materials is not used in simulation, the softening or hardening behavior, which is the material intrinsic property, should not be occurred during the calculation. If the variation of stress range at each cycle is occurred in this calculation, it can be expected to be resulted from the variation of strain range at each cycle in the specimen during the test.

2. Simulation of fatigue test

Figure 2 shows the specimen drawing and the axi-symmetric calculation domain which is a quarter of full domain considering the symmetry of the specimen. The gage length is 8mm, and the thickness between inner diameter and outer diameter is 1.5 mm. The modeling material is type 316 stainless steel.[2]

The temperature in the gage length region of the specimen is controlled to maintain its range and distribution at each cycle. The specimen is cooled by the air flow through the inside of specimen, and heated by the induction coil located outside the gage length region. The element heat generation was used to simulate the induction heating, and the film thermal convection was used to simulate the inside air cooling. Initial temperature was selected as a mid value between maximum and minimum temperatures.

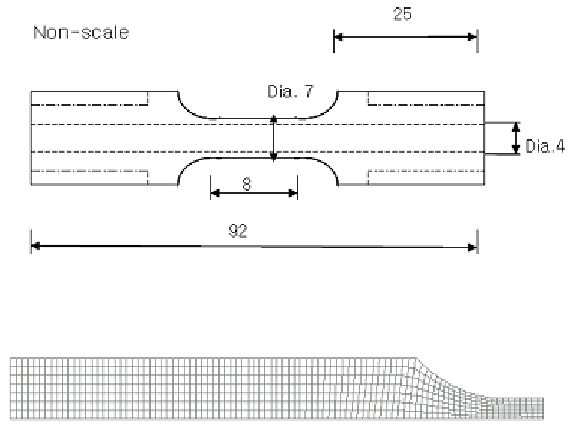

Fig. 2 Schematic drawings of the fatigue test specimen and the meshed calculation domain.

3. Results and discussion

3.1 Occurrence of variation of strain range

As the cyclic constant deformation was applied at the ends of specimen without thermal cyclic loading in the state of uniform temperature of 600 ^{o}C, the change of stress range at the center of the specimen was calculated at each cycle. This modeling was performed to investigate the occurrences of non-uniformity of strain in the specimen and variation of strain at each cycle, when the location of controlling deformation was far from the gage length region. As shown in Fig.3 the calculated logarithmic strain at the center of specimen is changed at each cycle, which results in the increase of stress range during the test. It is expected that the variation of strain range may be occurred because the test condition could not maintain the control parameter of strain range at the center of the specimen.

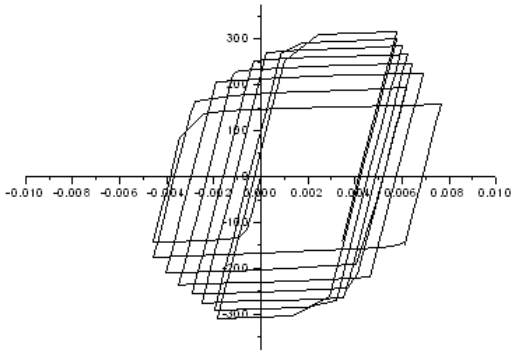

Fig. 3 Variation of calculated logarithmic strain at the center of specimen.

The thermal cyclic loading in the range between 300 °C and 600 °C was simulated to be applied in the gage length region as constraining the deformation at the ends of the specimen. The non-uniformity in the specimen and the variation of strain range at each cycle were also occurred in this case.

3.2 Simulation of Low Cycle Fatigue Test

The thermal loading cycle in the range between 300 °C and 600 °C was applied as constraining the deformation at the ends of gage length of 8 mm to simulate the low cycle thermal fatigue test. As shown in Fig. 4 the calculated stress range at the center of gage length increases with increasing number of cycle. Though this behavior looks like a transient region of the low fatigue response, this behavior is due to the effect of variation of strain range during the test because the any theory about low cycle fatigue is not considered in this analysis.[3]

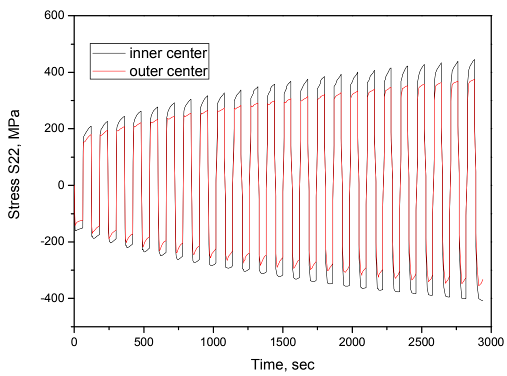

Fig. 4 Stress range vs. number of cycle.

As shown in Fig. 5, the calculated strain range at the center of specimen is varied at each cycle, though the cyclic constant temperature range is applied in the gage length region. Consequently, if the control parameter within the gage length cannot be maintained constantly at each cycle, the intrinsic low cycle fatigue properties of the material cannot be measured by the unexpected variations of parameters. The stress range calculated inner side of the specimen is higher than that of outer side. This means that inner side of specimen may be a location of initiating fatigue crack.

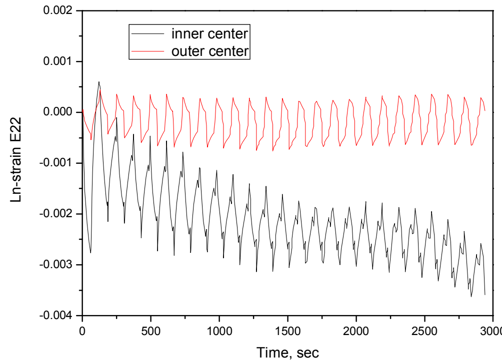

Fig. 5 Variation of logarithmic strain with increasing time.

4. Conclusion

If the test condition could not maintain the control parameter such as strain at the center of the specimen during fatigue test, the variation of strain range may be occurred at each cycle. The calculated stress range at the center of gage length increases with increasing number of cycle. Though this behavior looks like a transient region of the low fatigue test, this behavior may be resulted from the non-uniformity of strain in the specimen and the variation of strain range at each cycle.

ACKNOWLEDGMENT

This research was supported by the Nuclear R&D Program funded by MOST in Korea.

REFERENCES

[1] Julie A. Bannantine et al., Fundamentals of Metal Fatigue Analysis, Prentice Hall, p. 46-73, 1990.
[2] Dae-Whan Kim et al., Influence of Nitrogen on Thermal Fatigue Properties of 316(LN) Stainless Steel, J. Kor. Inst. Met. & Mater. Vol.43, p.382-388, 2005
[3] Y.H He et al., Low-cycle fatigue behavior of HAYNES HR-120 alloy, International Journal of Fatigue, 24, p.931-942, 2002