Material Dependence of Multiaxial Low Cycle Fatigue Damage under Non-proportional Loading

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INTRODUCTION

This study describes the evaluation of material dependence of multiaxial low cycle fatigue (LCF) to develop a suitable strain parameter for life estimation under non-proportional loading. The relationship between additional hardening and reduction in life is discussed and a simple method of evaluation of α which is employed in non-proportional strain range is proposed on the basis of material constants obtained by monotonic tension test.

RESULTS AND DISCUSSION

Total strain controlled multiaxial LCF tests were carried out under push-pull and circular straining tests. The circular straining is non-proportional loading and has 90° sinusoidal phase difference between axial and shear strains. The non-proportional strain range in which material constant α is replaced by $(\sigma_B - \sigma_{0.2})/\sigma_B$ is equated as,

$$\Delta\varepsilon'_{NP} = \left(1 + K \, \frac{\sigma_B - \sigma_{0.2}}{\sigma_B} \, f_{NP} \right) \Delta\varepsilon_I \tag{1}$$

where σ_B and $\sigma_{0.2}$ are strength and 0.2% proof stress. $\Delta\varepsilon_I$ is the maximum principal strain range. Coefficient K indicates the difference of relationship between the degree of reduction in life (α^*) and additional hardening (α) for FCC and BCC materials and has a relationship as $\alpha^* = K\alpha$. Here, K takes K=1 for FCC and K=2 for BCC as shown in Fig. 1. f_{NP} is the parameter expressing the intensity of non-proportional loading. Figure 2 shows the comparison of failure lives between experiment and calculation by Eq. 1. A good correlation was obtained.
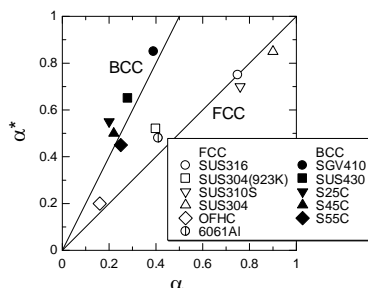

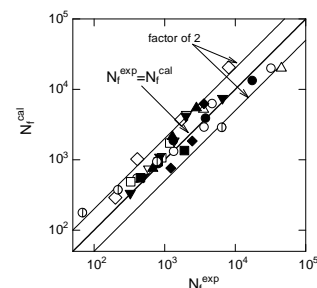Figure 1. Relationship between α and α^*.

Figure 2. Comparison of N_f between calculation and experiment.

CONCLUSION

Reduction in life has closely relationship with additional hardening under non-proportional loading which depends on crystal structure of tested materials.