Case study for various fatigue curve using fatigue simulation

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1. Introduction

Products are often subjected to cyclic loads with fatigue failure. Representative fatigue curve can be divided two methods, broadly. These are stress-cycle(S-N) curve (Eq. (1)) and strain-cycle(ε-N) curve (Eq. (2)). The equation of these curves are given by

$$\sigma_a = \sigma_f^{`} \times N^b \text{ (stress-cycle curve)}^{2)} \quad (1)$$

$$\frac{\varepsilon_a}{2} = \frac{\sigma_f^{`}}{E} \times N^b + \varepsilon_f^{`} N^c \text{ (strain-cycle curve)}^{2)} \quad (2)$$

Where $\sigma_f^{`}$ is fatigue strength coefficient, b is fatigue strength exponent, $\varepsilon_f^{`}$ is fatigue ductility coefficient and c is fatigue ductility exponent. In case of strain curve, it can cover elastic and plastic region.

Also, it is known that the mean stress has a significant influence on the fatigue life[1)]. Various methods were studied to model mean stress effects on the fatigue behavior of metals. In case of S-N methods (Eq. (3)), Goodman relation is representative method.

$$\frac{\sigma_a}{\sigma_{ar}} + \frac{\sigma_m}{\sigma_u} = 1 \text{ (Goodman relation)}^{2)} \quad (3)$$

$$\frac{\sigma_a}{\sigma_{ar}} + (\frac{\sigma_m}{\sigma_u})^2 = 1 \text{ (Gerber relation)}^{2)} \quad (4)$$

However, this method is not proper to use in ductile material[2)]. In case of Gerber relation (Eq. (4)), it can compensate weakness of the Goodman relation. By defining non-linear relation, it can represent ductile materials more correctly.

Also, there are many methods regarding ε-N. Morrow (Eq. (5)), and Smith Watson Topper are representative methods. Morrow is effective for non-uniform load condition. However, this cannot cover higher loading condition. In case of SWT, it is effective for higher loading condition by multiplying $\sigma_{n,max}$ in both sides.

$$\frac{\Delta\varepsilon}{2} = \frac{\sigma_f^{`} - \sigma_m}{E}(2N_f)^{2b} + \epsilon_f^{`}(2N_f)^c \quad (5)$$

$$\sigma_{n,max}\frac{\Delta\varepsilon_1}{2} = \frac{\sigma_f^{`2}}{E}(2N_f)^{2b} + \sigma_f^{`}\epsilon_f^{`}(2N_f)^{b+c} \quad (6)$$

To determine proper method, we should consider various condition such as material or loading condition. In case of 4007A, this is not well defined yet. In this study, we will investigate which is proper method for aluminum, through finite element program, Optistruct.

2. Finite element method

To perform fatigue finite element method analysis, this study utilized scroll compressor. The material what we used is 4007A, and information is in table.1. By comparing with experiment and FEM results, it can decide proper method. In addition, various mean stress effects were considered.

Table 1 FEM information

FEM information		
Material Information	Young`s Modulus	70GPa
	Yield Strength	340MPa
	Tensile Strength	405MPa
FEM Condition	Load Type	Point Load
	Element Type	Hexa
	Element size	0.5 mm
	R-ratio=$\frac{\sigma_{max}}{\sigma_{min}}$	0.125
Fatigue Curve	S-N	Goodman
		Gerber
	ε-N	Morrow
		SWT

3. Results of FEM

In case of S-N curve, Fig. (a) is results of Goodman and Gerber. Gerber relation is more similar with experiment than Goodman relation. This is because 4007A has ductility and Goodman relation did not depict non-linear property.

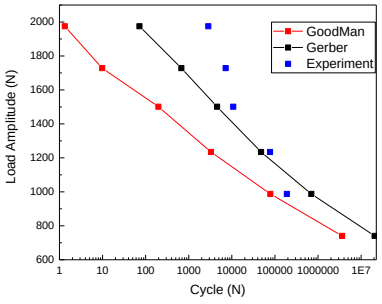

Fig. (a) FEM and experiment results for S-N curve adoption in FEM

In case of ε-N (Fig. (b)), SWT is well matched with

experiment. However, there gap is much smaller than that of S-N methods. However, it is obvious that in case of low-cycle (high loading region), SWT is more similar to experiment than Morrow. Especially, at cycle 10E4, the difference is meaningful. This is because SWT can reflect maximum load.

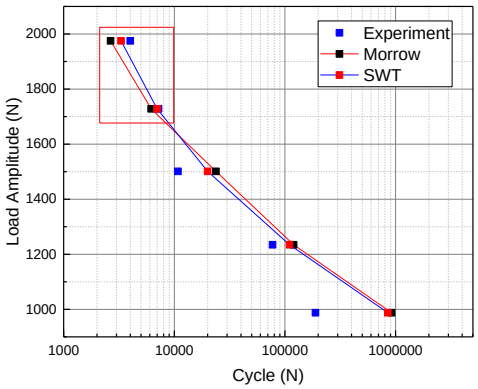

Fig. (b) FEM and experiment results for ε-N curve adoption in FEM

4. Conclusion

In this study, we investigate proper method for Aluminum 4007A. This study focused on mean stress effect, by using various mean stress effects in FEM. In case of S-N, Goodman and Gerber were compared with experiments. Morrow and SWT were adopted for ε-N.

Because of it`s ductility and stiffness, it was well matched with Gerber relation rather than Goodman relation. In case of Morrow and SWT, the difference between them is smaller than that of S-N. However, it is obvious that SWT can reflect loading condition effectively. Therefore, considering 4007A for FEM, Gerber and SWT are effective.

References

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