講演番号	128

On the Fatigue Limit Diagram and Fatigue Life Prediction Models

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KEY WORDS: **Materials, Fatigue, Strength,** Stress concentration, Stress ratio, Stress intensity factor [D3]

The fatigue limit and lifespan vary depending on the loading mode and are also greatly affected by stress concentration. The effect of mean stress has been mathematically expressed using several models, but based on experimental data, the Walker model has been shown to be the most appropriate and to have high predictive accuracy for metallic materials. The same was true for the effect of assembling stress due to welding on the fatigue limit and the threshold stress intensity range. Furthermore, it was shown that it can also be applied to predict multiaxial fatigue.

The effect of mean stress can be expressed mathematically using the Walker model as follows:

$$\sigma_a = \sigma_{a(R=-1)}[(1-\sigma_{min}/\sigma_{max})/2]^{1-\gamma} \quad (1)$$

Here, σ_{min} is the minimum stress, σ_{max} is the maximum stress, σ_m is the mean stress, σ_a is the stress amplitude, $\sigma_{a(R=-1)}$ is the alternating stress amplitude when σ_m is zero, and R is the stress ratio. γ is the Walker exponent as a material constant. If the value of $\sigma_{a(R=-1)}$ is known, σ_a can be estimated from the above formula.

The 10^7 cycle fatigue limit data sets for several materials in the axial tension-compression mode are plotted in Fig. 1. For smooth specimens, i.e., specimens with K_t close to 1, the Walker lines provide the best fit for the regression lines in the plots, with γ values ranging from approximately 0.43 to 0.75 depending on the material. For the notched material, i.e., the specimen with high K_t, the Walker lines also provide the best fit, with γ values of approximately 0.27 to 0.75.

In the out-of-plane bending loading mode, the crack initiation and propagation direction are significantly different from those under axial loading or in-plane bending loading conditions. For example, the fatigue limit data for out-of-plane bending loads of a SUS 436L plate with a V-2 mm notch are plotted in Fig. 2. The best fit is the Walker line with γ = 0.67. Because γ is larger under out-of-plane bending loads than under axial loads, the sensitivity to mean stress is low. In addition, the fit of models other than the Walker line is poor.

Examples of the application of the Walker model to fatigue strength and life prediction, the effect of assembling stresses, the effect of mean stress on stress intensity factor range, and multiaxial fatigue are also presented.

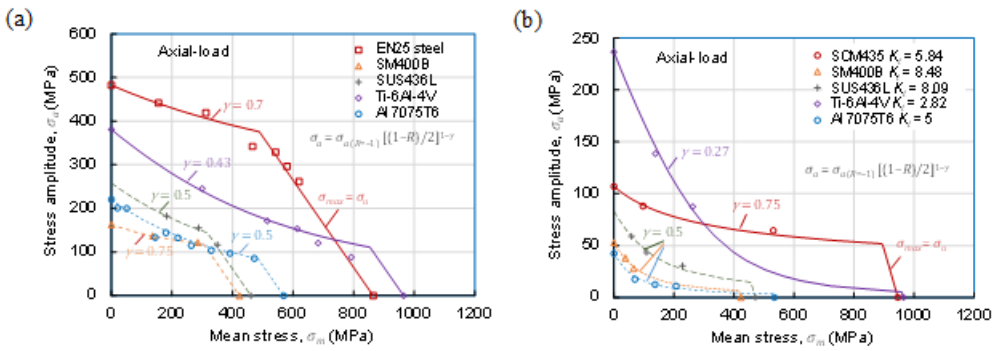

Fig. 1 Fatigue Limit Diagrams for Various Materials under Axial Load

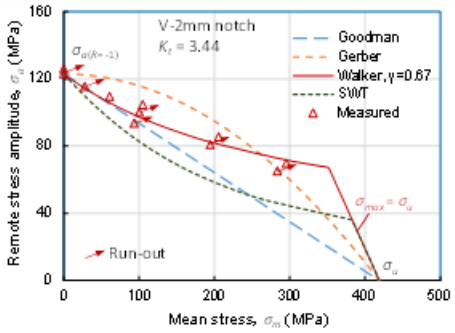

Fig. 2 Fatigue Limit Diagram of a Notched Specimen of SUS436L Plate under Out-of-Plane Bending Load