I-127

FRACTURE MECHANICS ANALYSIS ON FATIGUE LIFE OF WELDED CRUCIFORM JOINTS

NAGOYA UNIVERSITY ○ Xiaohua CHENG
Kentaro YAMADA

1. Introduction

It is said that fatigue behavior under Variable Amplitude (V.A.) loading is obviously different from that under Constant Amplitude (C.A.) loading in longer life region. The fatigue test of cruciform joints (Fig. 1) carried out in the U.S. shows this tendency. Based on the test data[1], the analysis on fatigue life under C.A. and V.A. loading were carried out by using fracture mechanics approach with consideration of parameters of initial crack size a_o and crack shape a/b. The stress range spectra of V.A. obtained from actual truck load investigation are shown in Fig. 2. The long-tail spectrum presents actual spectrum. Short-tail spectrum was obtained by truncating the long-tail at 50% stress range ratio with keeping the total frequency unity.

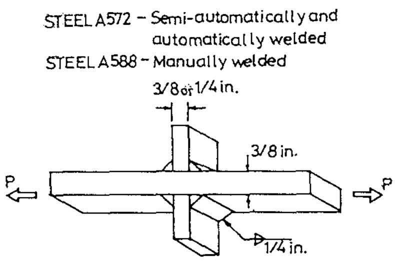

Fig. 1 Test Specimen

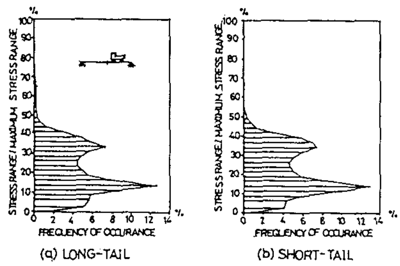

Fig. 2 Stress Range Spectrum Used in the Test

2. Fracture Mechanics Approach

The stress distribution near weld toe of the joint detail was obtained by FEM analysis. The stress intensity factor range can be shown as $\Delta K = F_E \cdot F_S \cdot F_W \cdot F_T \cdot \Delta\sigma \cdot \sqrt{\pi a}$. The empirical formula $da/dN=C(\Delta K^m - \Delta K_{th}^m)$ was used to express the fatigue crack growth rates. For C.A. load, crack propagation life N_p can be obtained by integrating for crack size a. In case of V.A. load, the first order differential equation was solved by using Runge-Kutta method.

3. Analytical Results and Comparison with Test data

(1) Initial crack size a_o: The value of a_o affects on analytical result in longer life region. The curve of C.A. with a_o=0.05mm is the closest to the mean value of test data of automatically welded joints and a_o=0.1mm to the test data of manually welded joints if a/b=1/2 is assumed (Fig. 3).

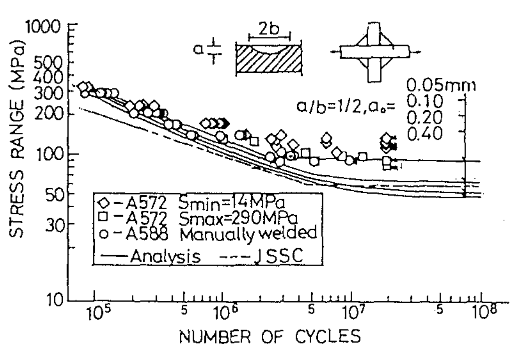

Fig. 3 Effect of a_o

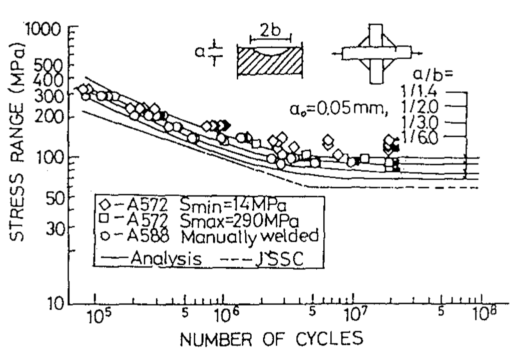

Fig. 4 Effect of a/b

(2) Crack shape a/b: The estimated life is sensitive to a/b. If a_o=0.05mm is assumed, the analytical life with a/b=1/2 and 1/3 are closer to the mean value of test data than the other values of a/b (Fig. 4).

(3) Result of V.A. analysis: For C.A. analysis, a_o and a/b were determined and will be used for V.A. analysis. Equivalent stress range (RMC) is used to express the stress range for V.A. In shorter life region less than $5x10^5$ cycles, the analysis predicts well, as shown in Fig. 5. In the longer life region, for example over 10^6 cycles, the test result shows longer fatigue life than analysis (Fig. 5). It may be because some parameters are not adequate or some other factors, such as neglecting crack initiation life or neglecting crack retardation effect in analysis.

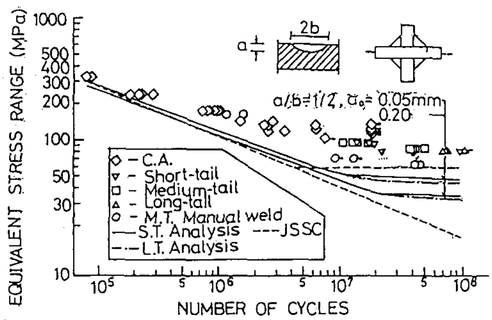

Fig. 5 Analysis of V.A.

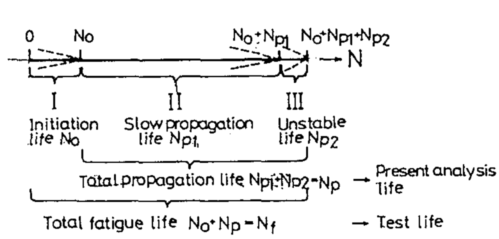

Fig. 6 Relation between Test Life and analytical Life

(4) For the difference between analysis and test result, it is large at lower stress range level. At this level, many cycles seems exhaused for crack initiation, which is neglected in analysis (Fig. 6). For the stress range below 170 MPa, the difference between N_T and N_P is factor 2 or 3, and the larger the a_o is assumed the more the difference is (Fig. 7).

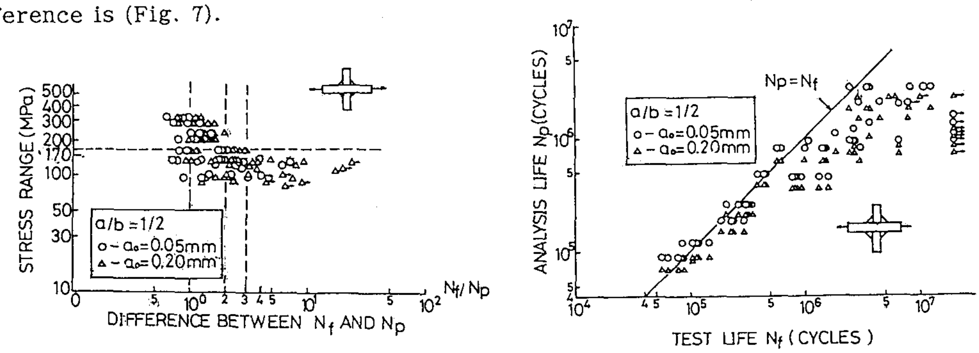

Fig. 7 Difference between test life and analysis life

4. Conclusions

(1)The result of F.M. analysis of C.A. agrees well with test result if parameters (a_o, a/b) are set to be adequate values. (2)The analytical result in longer life region seems to be sensitive to initial condition (initiation life and initial crack size) and crack shape.

Reference (1)Hani G. Melhem and Karl H. Klippstein, A Study on Variable Amplitude Load Fatigue: Work-in Progress, Research Report No.ST-6, January, 1990