**Zeitschrift:** IABSE congress report = Rapport du congrès AIPC = IVBH Kongressbericht

**Band:** 10 (1976)

**Artikel:** Fatigue life prediction of hybrid members

**Autor:** Yamasaki, T. / Hara, M. / Kawai, Y.

**DOI:** https://doi.org/10.5169/seals-10554

# Fatigue Life Prediction of Hybrid Members

Prédiction de la résistance à la fatigue d'éléments hybrides

Vorhersage der Lebensdauer von auf Ermüdung beanspruchten hybriden Elementen

T. YAMASAKI, General Manager
M. HARA, Senior Research Engineer
Y. KAWAI, Research Engineer
Structure Research Center, Kawasaki Steel Co., Ltd.
Chiba, Japan

## 1. INTRODUCTION

In the Preliminary Report for 10th Congress of the IABSE, 1976, fatigue crack growth rate observations were illustrated on the hybrid tee-shaped specimens to explore a possibility of the estimation of fatigue lives by using fracture mechanics(1).

Additional fatigue crack propagation test was conducted on a center-notched hybrid plate specimen to warrant the fatigue life prediction method for hybrid members.

## 2. FATIGUE CRACK PROPAGATION TEST

The configuration of the specimen is shown in Fig.1. One specimen consisting of JIS-SS41 (with specified tensile strength of 41 kg/mm$^2$) and WES-HW70 (with specified tensile strength of 80 kg/mm$^2$) was longitudinally butt welded along the specimen center line, and an artificial notch was introduced into its center to start a fatigue crack. The chemical analysis and mechanical properties of the materials are shown in Table 1.

The fatigue test was carried out in a 100-ton electro-hydraulic alternating testing machine under stress ranges of 15 kg/mm$^2$ and 10 kg/mm$^2$ and at a stress ratio of zero. Fatigue crack growth rate was observed on both the SS41 plate and the HW70 plate by using crack gauges and a 15 power magnifying glass with 1/20 mm micro scales.

The fatigue crack propagation results obtained, fatigue crack growth rate, da/dN, and stress intensity factor ranges, $\Delta K$, were plotted in the conventional manner(2), that is, log-log plots of da/dN as a function of $\Delta K$ represented in the form of

$$\frac{da}{dN} = C\,(\Delta K)^m \qquad (1)$$

to evaluate the material constants, C and m, that characterize the fatigue crack propagation behavior of hybrid members.

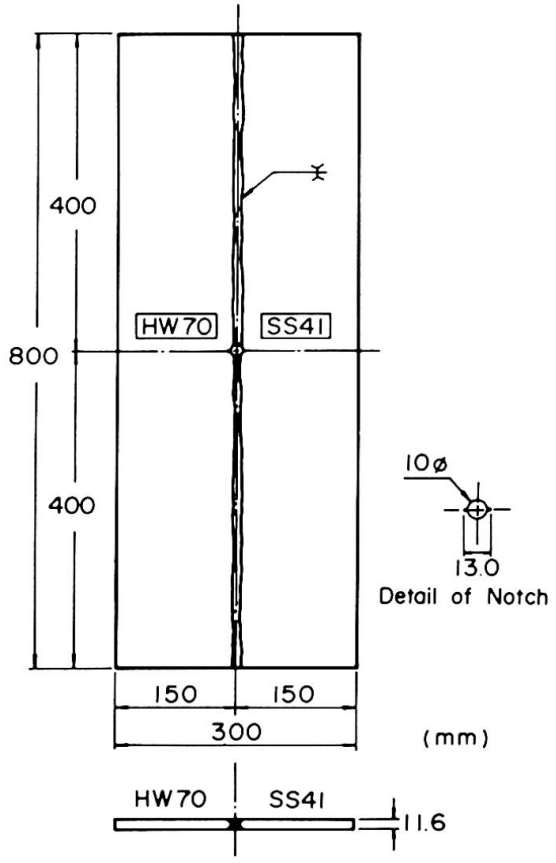
An effect of a slight difference of crack growth rate between SS41 and HW70 can be considered by using the Ishida's formula for an eccentrical crack in a finite plate (3) in calculating the value of K, based on the fact that the crack center shifted from the plate center as the crack grew. The eccentricity caused by the difference

of the crack growth rate, however, was small compared with the plate width, as was noted in previous report (1), such effect proved to be macroscopically negligible. The exposed fracture surface of the specimen is shown in Fig.2.

Table 1 Chemical Analysis and Mechanical Properties of Materials

| Chemical Composition (Wt. %) | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | C | Si | Mn | P | S | Cu | Ni | Cr | Mo | V | B |
| WES-HW70 | 0.10 | 0.30 | 0.85 | 0.007 | 0.010 | 0.19 | 0.78 | 0.46 | 0.33 | 0.035 | 0.004 |
| JIS-SS41 | 0.18 | 0.04 | 0.95 | 0.014 | 0.028 | -- | -- | -- | -- | -- | -- |

| Mechanical Properties | | | | |
|---|---|---|---|---|
| | Y.P.(kg/mm$^2$) | U.T.S.(kg/mm$^2$) | Elong.(%) | $_vE_{-5}$(kg·m) |
| WES-HW70 | 80 | 84 | 27 | 15.6 |
| JIS-SS41 | 27 | 46 | 30 | -- |



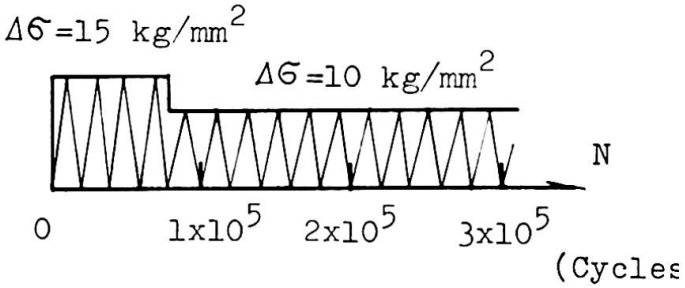
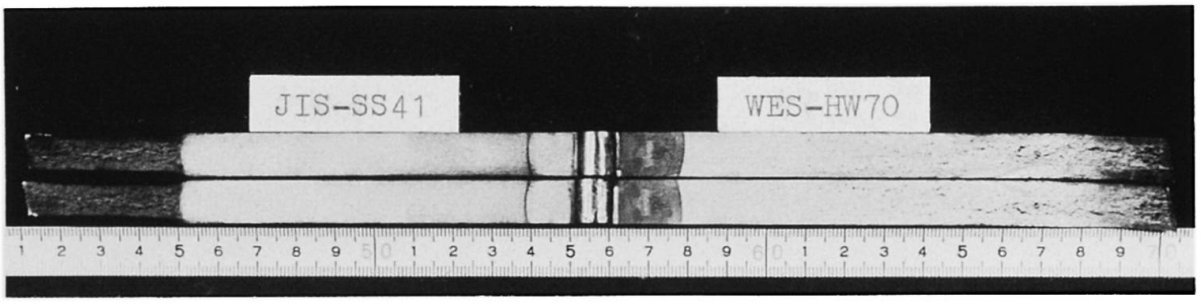




Fig.1 Configuration of Specimen and Stress Sequence

Fig.2 Exposed Fracture Surface



Fatigue crack growth rates, da/dN, in terms of Eq.(1) were shown in Fig.3, and the best fitted line by the method of least squares is also given in comparison with the derived crack-growth relationship given by Fisher et al.(4), a conservative upper bound for growth rates on ferrite-pearlite steels proposed by Barsom(5) and the authors' previous test results(1). The calculated material constants, C and m, were $1.2\times10^{-11}$ and 3.6, respectively, namely the fatigue crack growth rate is numerically represented as

$$\frac{da}{dN} = 1.2\times10^{-11}\times(\Delta K)^{3.6} \qquad (2).$$

## 3. FATIGUE LIFE PREDICTION

To predict the fatigue lives on the previous hybrid tee-shaped specimens(1), these material constants and the value of K for a disk-like penny shaped crack in infinite body (6),

$$K = \frac{2}{\pi}\sigma\sqrt{\pi a} \quad ,$$

can be used, and the estimated S-N curves are calculated from the integrated version of Eq.(2).

The calculated S-N curves are shown in Fig.4 for various initial crack sizes, $a_i$, together with the test results on the hybrid tee-shaped specimens. The figure reveals that the predicted S-N curve taking the initial crack size, $a_i$, as 0.5 mm agrees well with the test results. This crack size of 0.5 mm is the same as the previously assumed one(1).

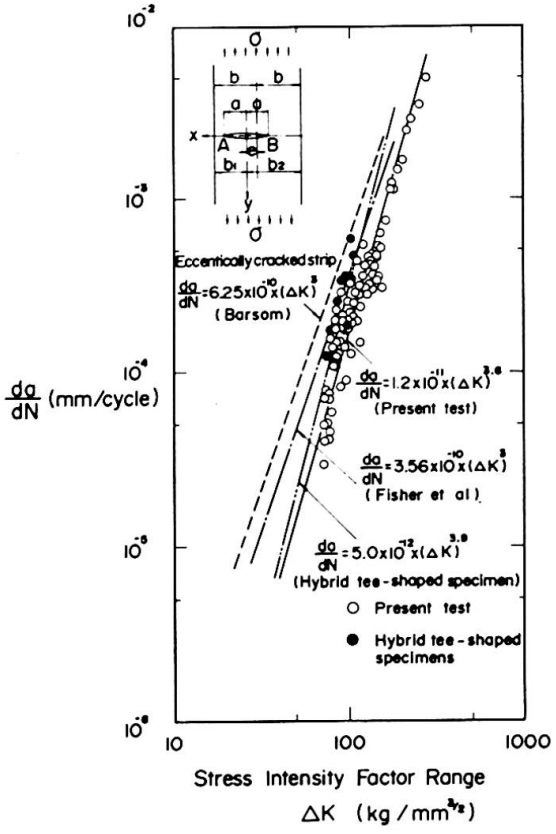



Fig.3 Summary of Fatigue Crack Growth Rate

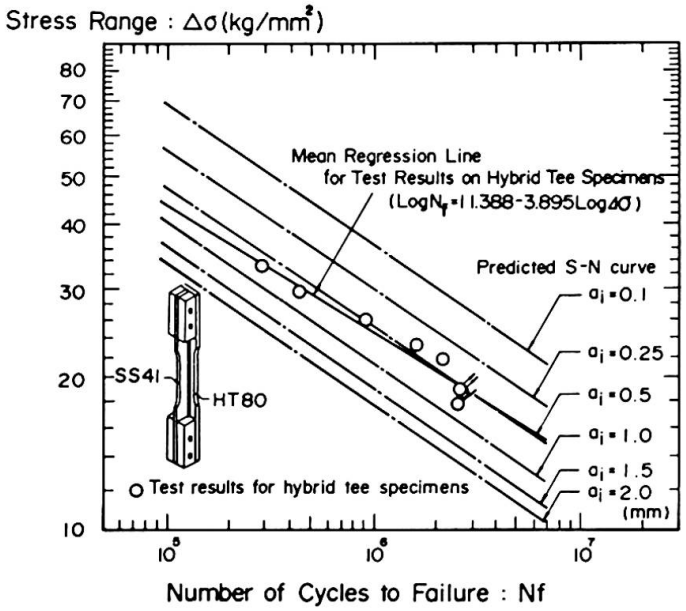



Fig.4 Comparison of Predicted S-N Curves and Previous Fatigue Test Results on Hybrid Tee-shaped Specimen(1)

## 4. CONCLUDING REMARK

The calculated S-N curve by using fracture mechanics, taking the initial crak size of 0.5 mm, successfully agreed well with the test results. Consequently, the fatigue life prediction method by fracture mechanics approach proved to be an effective tool for also hybrid members, if only a pertinent initial crack size can be evaluated.

## REFERENCE

1) T.Yamasaki, M.Hara, Y.Kawai;Preliminary Report, IABSE, 10th Congress, 1976
2) P.C.Paris, F.Erdogan;Trans. of ASME, Series D, Vol.85, No.4, 1963
3) M.Ishida;Trans. of ASME, Series E, Vol.33, No.3, 1966
4) M.A.Hirt, J.W.Fisher;Eng. Frac. Mech., Vol.5, 1973
5) J.M.Barsom;U.S. Steel Corp., Applies Res. Lab. Rpt., 1971
6) I.N.Sneddon;Proc. Royal Soc., London, Vol.A-187, 1946

SUMMARY

A fatigue crack propagation test was conducted on a longitudinally butt welded 'WES-HW70' --'JIS-SS41' hybrid plate specimen to predict fatigue lives of hybrid members. The fatigue crack growth rates obtained were represented as a function of stress intensity factor ranges in the form of the so-called Paris' law. By using the material constants and fracture mechanics approach, the fatigue lives were successfully estimated on the hybrid tee-shaped specimens which were previously tested.

RESUME

La propagation d'une fissure due à la fatigue a été étudiée sur une plaque hybride en WES-HW70/JIS-SS41 soudée bout à bout, afin de prédire la résistance à la fatigue. Le développement de la fissure ainsi obtenue a été représenté en fonction des facteurs de concentration de contraintes, selon la loi dite de Paris. Au moyen des constantes des matériaux et de la mécanique de fissure, on a pu déterminer la résistance à la fatigue d'échantillons en forme de T qui avaient fait auparavant l'objet d'essais.

ZUSAMMENFASSUNG

Die Ausbreitung eines Ermüdungsrisses wurde an einer stumpf geschweissten hybriden Platte aus WES-HW70/JIS-SS41 untersucht, um daraus die Lebensdauer von hybriden Elementen vorhersagen zu können. Die gewonnene Rissausbreitungsgeschwindigkeit wurde in Funktion des Spannungskonzentrationfaktors nach dem sogenannten Paris'schen Gesetz dargestellt. Ausgehend von den Materialkonstanten lieferte die Bruchmechanik eine Vorhersage für die Lebensdauer von T-förmigen hybriden Proben, die vorher experimentell untersucht worden waren.