§17. Development of the R Curve Fracture Toughness Test of Round Bar with Circumferential Notch by Using Hardening Curves of Each Virtual Crack Length

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1. Introduction

Standardized test methods of plain strain fracture toughness K_{IC} and elastic-plastic fracture toughness J_{IC} are time-consuming and expensive. *R* curve by which a material resistance to a crack growth is expressed is required to be obtained in standardized test methods. On the other hand, a convenient new test method, named *J* evaluation on tensile test (JETT) of round bar with circumferential notch, has been proposed to evaluate the fracture toughness of the tough materials. Although critical *J* can be obtained by JETT without *R* curve, the validity of the method is limited to some materials. *R* curve with JETT may expand their possibilities for J_{IC} test. Accurate measurement of crack length and calculation of *J* integral are needed for available *R* curve. In this report, improved experimental *J* integral calculation of JETT specimens is proposed.

2. Load separation method for JETT specimens.

Sharobeam[1] and Matvienko[2] showed *J* integral could be obtained experimentally by load separation method. Whether this method can apply to JETT specimens or not depends on the effectiveness of one of the following load separation relationships,

$$P = G\left(\frac{b}{D}\right) H\left(\frac{\delta_{crack.pl}}{a}\right) \qquad (1)$$

where P is load, $\delta_{crack.pl}$ is nonlinear displacement introduced by crack, D is radius of round bar, a is notch depth, b is ligament length, G and H are the functions related to specimen shape and material properties respectively. Fig.1 shows experimental results of P-$\delta_{crack.pl}/a$ curves of Al alloy with D=6mm series. Since the ratios of P between arbitrary two specimens except for a/D=0.504 are almost constant under $\delta_{crack.pl} / a <$

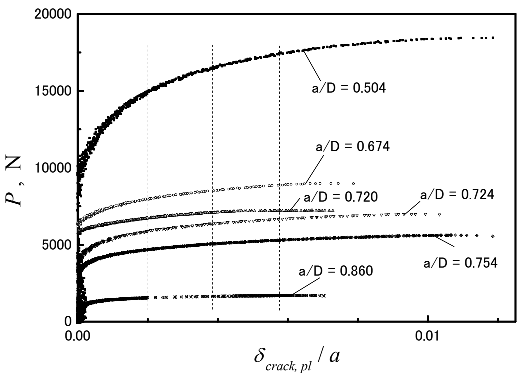

Fig.1 P-$\delta_{notch.pl}/a$ curves of Al alloy(D=6mm)

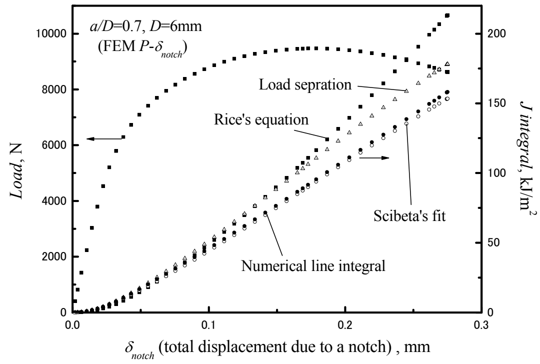

Fig.2 Load separation and the other *J* integrals.

0.007, eq.(1) is effective within the range. In these experiments, linearity was shown in the log-log relationship of S_{ij}-b/D, where S_{ij} is a ratio of $G(b/D=0.28)$ to G of the other specimens. Therefore S_{ij} can be expressed by the following equation.

$$S_{ij} = G\left(\frac{b}{D}\right) \Big/ G(0.28) = \left(\frac{b}{D}\right)^m \Big/ (0.28)^m = \left(\frac{b}{0.28D}\right)^m \qquad (2)$$

where m is the slop read from the log-log relationship of S_{ij}-b/D.

If appropriate η value with a shape of the specimen is known, plastic component of experimental *J* integral can be calculated by the following equation.

$$J_{pl} = \eta \frac{1}{\pi b^2} \int_0^{\delta_{crack.pl}} P \, d\delta_{crack.pl} \qquad (3)$$

Rice's approximate formula and Scibeta's[3] FEM fit proposed each η value. On the other hand, eq.(1) and (2) introduces another η value.

$$\begin{aligned} \eta &= \frac{\pi b^2}{2\pi b} \cdot \frac{-\int_0^{\delta_{crack,pl}} \frac{\partial}{\partial a}(G \cdot H) d\delta_{crack,pl}}{\int_0^{\delta_{crack,pl}} G \cdot H d\delta_{crack,pl}} \\ &= \frac{b}{2}\left(\frac{\frac{\partial G}{\partial b}}{G} - \frac{1}{a} \right) + \frac{\frac{b}{2a}\delta_{crack,pl} \cdot P}{\int_0^{\delta_{crack,pl}} G \cdot H d\delta_{crack,pl}} \end{aligned} \qquad (4)$$

Fig.2 shows *J* integrals of FEM P-δ_{notch} curve of round bars with circumferential notch (a/D=0.7, D=6mm), where stress-strain curve and *m* in *G* function are that corresponding to Al alloy shown in Fig.1. Since this alloy was fractured less than 30 kJ/m^2, P-$\delta_{crack.pl}$ and *J* integrals over that are the ones of virtual tougher materials.

The same *J* integrals were obtained irrespective of integral method under low *J*. On the other hand, experimental *J* integral, Rice's and load separation, showed overestimated values to numerical and fit solutions under high *J*. However load separation shows nearer value to numerical ones than Rice's.

1) M.H.Sharobeam et.al, Int. J Fracture 47:81-104,1991
2) YU.G.Matvienko, Int. J Fracture 129:265-278,2004.
3) Scibeta et. al., Int. J Fracture 104 :145-168,2000