§22. Standardization of the Fracture Toughness Test Method by Round Bar with Circumferential Notch

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1. Introduction

Standardized test methods of plain strain fracture toughness K_{IC} and elastic-prastic fracture toughness J_{IC} are time-consuming and expensive. 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.[1-2] Since JETT is not standardized yet, the size of JETT specimen should be carefully selected. In this research, the FEM calculations for the comparison of the strain constraint around the notch or crack tip of both specimens were conducted. Next to the previous year's consideration about the strain constraint around the notch tip of various work hardening materials, the consideration about that of elastic – perfectly plastic materials was given.

2. Definition of the specimen size of round bar

Q-factor is the one of the indexes of the strain constraint around notch or crack tip. It shows the difference of the magnitude of the open mode stresses between a JETT specimen and the standardized specimens at the same distance from a tip on the ligament.

In this research, the obtained critical J by JETT is defined to be valid when the following conditions are fulfilled.

a) $Q = 0 \pm 0.1$
b) Max location, the position on the ligament where the maximum open mode stress is generated, is not at the axis of the bar, but around the notch root.

These two conditions can be verified by Fig.1. The left vertical axis shows Q-factor and the right vertical axis shows Max location. The similarity of stress fields around the notch tips can be evaluated by the normalized J, abscissa of the figure. Since the Q-factor vs. normalized J of specimens with the same a/R (similar figure specimen) converge to one curve, the stress fields of these specimens are also similar. Therefore if an obtained normalized critical J is within the range fulfilling conditions a) and b), this critical J and selected size of specimen are valid. On the contrary, if it is out of the range, another test with bigger or smaller specimen according to abscissa of the figure is needed. On the other hand, two Q-factor curves of elastic – perfectly plastic materials, aluminum alloy and high strength steel, are almost converged to the same curve due to the proof stress in the denominator of normalized J.

Fig.1 shows FEM calculated data of high strength steel. The specimen with a/R=0.7 and R=6mm fulfills condition b) when an obtained critical $J/\sigma_0 R$ is less than 0.023. However, when $J/\sigma_0 R$ is less than 0.023, Q is less than -0.14. Both conditions are not compatible even if another similar size specimen, a bigger or a smaller one, is used. Therefore in the case of elastic – perfectly plastic materials, the critical J corresponding to that obtained by standardized test cannot be obtained by JETT.

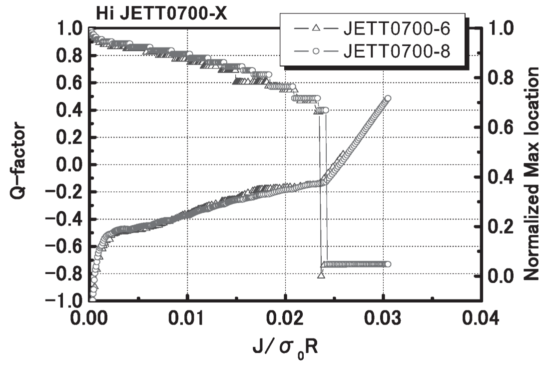

Fig.1 Q-factor and the position on the ligament where the maximum open mode stress is generated

3. Experiment

The specimens for JETT with a/R=0.6 and R=3, 6mm and that for standardized test were used for experiment. Fig.2 shows the results of JETT experiments. The obtained critical J, 20 kJ/m^2 and 35 kJ/m^2, were overestimate, while real fracture toughness obtained by standardized test was 12 kJ/m^2. Although the critical J of the high strength steel obtained by JETT was the same as that by standardized test, the condition b) was not fulfilled and the fracture mode is different between them. As supposed by FEM, it is difficult to obtain the critical J of the elastic – perfectly plastic materials by JETT.

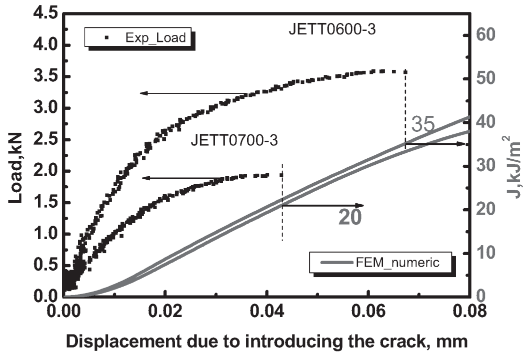

Fig.2 Experimental Load - Displacement and J of JETT

1) Shabara MAN. et al. :Engng. Fracture Mech. **54**(1996) 533.
2) Nishimura A. et al. : Adv. Cryogenic Engng. **46**(2000) 33.