SOME CONSIDERATION ABOUT THE BEHAVIOUR OF VOIDS

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I. INTRODUCTION

The problems of void nucleation, growth and coalescense are by no means modern one, as there are so many papers about them and they were introduced in the text books [1]. But it is one of the most important basic problems on the ductile fracture and also the gate which should be solved in order to clarify its mechanism.

Recently, from the experimental aspect, due to the remarkable development of the fractography and other experimental techniques, the secrets of the fracture mechanism are becoming clearer. Also, from the theoretical aspect many progress has been done, among it the analytical expression of the behavior of the voided materials [2] promote the behavior of the voided material easier than before.

Roughly speaking, the study about the mechanical behavior of voids can be classified into three categories. The first is the study about the behavior of a single void. This is called the hole growth model, and there were several models due to Rice and Tracey [3]. The second is the study which account for the interaction of the voids, among them the classical theory due to McClintock [4] and so on. The third is the modern theory, which treat the group behavior of voids due to the analytical expression of the constitutive law of the voided materials. This is the localization of the plastic deformation [5].

In this paper, the mechanical behavior of the CT specimen are evaluated due to the two different methods.

II. THE INTERACTION OF THE PROCESS ZONE AND A VOID.

By using both the finite element method (F.E.M.) and the slip line theory, the analysis of the shape of the crack tip opening (CTO) and the D-zone is carried out about the 1 CT specimen. The material is A533B

Class 1 steel, and its mechanical properties are shown in Tab.1.

First, the case without void is analyzed. Two dimensional mesh break down is shown in Fig.1. The change of the CTO due to the increase of δ, the loadpoint displacement, is shown in Fig.2. The shape of the CTO is nearly semi-circle. The shape change of the D-zone due to the increase of δ are shown in Fig.3.

Next the case with void is trested. In this case the center of a 4 μm void is situated 10 μm from the crack tip. The change of the CTO due to the increase of δ is shown in Fig.4. Growth of a void, and the shape change of the D-zone and a void due to the change of δ are shown in Fig.5 and 6, respectively.

The P-δ curves in the cases with and without a void coincide with each other completely as shown in Fig.7, from which a microscopic event which occurs at the crack tip deservedly has little influence upon the macroscopic behavior as P-δ. But in this case, for example, assuming J_{IC} = 98 kN/m, the ratios of P and δ value in the case with to without void become nearly 75% and 70% at $J=J_{IC}$. The relations between J/σ_Y and CTOD are given as follows from Fig.8:

without void; $$CTOD = 0.5J/\sigma_Y \tag{1}$$

with void; $$CTOD = 0.05J/\sigma_Y \tag{2}$$

III. MECHANICAL BEHAVIOR OF THE VOIDED MATERIALS.

By using the constitutive relations for void-containing materials by Yamamoto the mechanical behaviors of a plate in tension and a 1 CT specimen of the voided materials are studied. The stress-strain curve, the void volume fraction-strain, and the localization are discussed as the function of the initial void volume fraction and the strain-hardening coefficient.

Fig.9 shows a plate in tension, both sides of which are constrained. The initial void volume fractions are f_0=0%, 1.0%, and 2.5%. The strain-hardening coefficients are N=0.01 and 0.05. The σ_y-ε_y curves as the results of calculations are shown in Fig.10-11. When the initial void volume fraction is small, the σ_y-ε_y curve is initiated in the upper side. In the case N=0.01 the localization occurs at A and B according to

f_0 =1.0% and 2.5%, respectively. This means that in the materials with smaller void volume fraction the localization is hard to occur. But in the case N=0.05 the localization occurs at C and D, and this is the opposite to the former case. This can be explained as follows.

Tab.2 shows the ratio of the increase of the void volume fraction $\Delta f/f_0$ to the initial void volume fraction, f_0. In the case N=0.01, $\Delta f/f_0$ of f_0 =2.5% is larger than that of f_0=1.0% and the localization occurs earlier than the latter. In the case N=0.05, $\Delta f/f_0$ of f_0=2.5% is smaller than that of f_0=1.0% and the localization occurs later than the latter.

CT specimens are analyzed in the case of both an ideal crack (radius of the crack tip ρ=0mm) and a notch (ρ=0.1mm). Due to Rice and Johnson [6], the strain concentration does not occur in the case of an ideal crack, but it occurs at the crack tip in the case of a blunted crack. A notch is a model of a blunted crack. The mechanical properties are shown in Tab.3. Fig.12 shows the strain and the void distributions. In the case of a notch they are situated at the crack tip(D-zone), in an ideal crack tip in the C-zone. The localization occurs at A and B in the case of notch (Fig.12 (a)), and at C in the case of an ideal crack (Fig.12 (c)).

IV. CONCLUSION.

Although this paper treats the elementary problems due to two different analytical methods, these methods are promising to the application of the anlaysis for the mechanism of the ductile fracture. The results will be published in near future.

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Table 1 Mechanical characteristics of A533B steel.

Young's Mosulus	E(GPa)	206
Poisson's Ratio	ν	0.3
Yield Stress	σ_Y(MPa)	549.2
Constitutive Equation		$\varepsilon = \frac{\sigma}{E} + \{(\frac{\sigma}{E'})^n - (\frac{\sigma_Y}{E'})\}$ n = 0.3, E' = 1609 (MPa)

Table 2

		infinitesimal deformation	
		N = 0.01	N = 0.05
$\Delta f/f_0$	f_0 = 1.0 %	0.01506	0.53883
	f_0 = 2.5 %	0.02007	0.26316
ε_{y_1}		0.00702	0.01502

Table 3 Mechanical characteristics of material.

Young's Modulus	E (GPa)	206
Poisson's Ratio	ν	0.3
Yield Stress	σ_Y(MPa)	618
Strain Hardening Coefficient		0.01

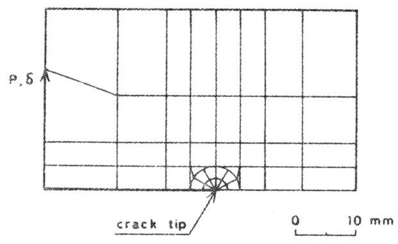


Fig.1 Break down.

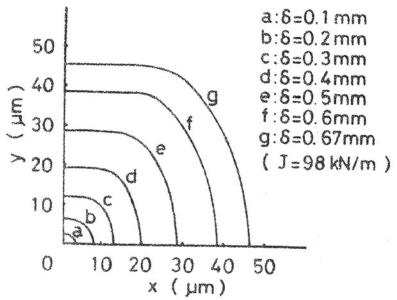


Fig.2 Change of CTO due to the increase of δ.

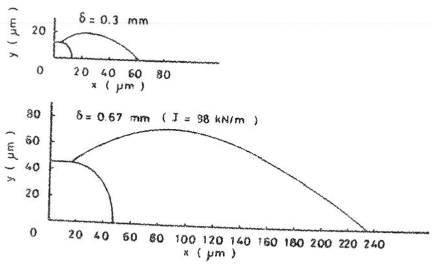


Fig.3 Shape change of D-zone due to the increase of δ.

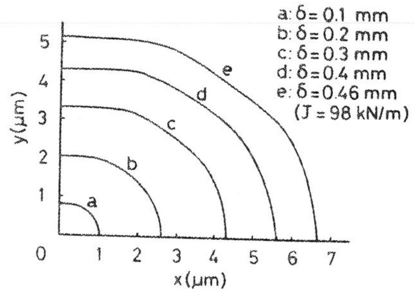


Fig.4 Change of CTO due to the increase of δ.

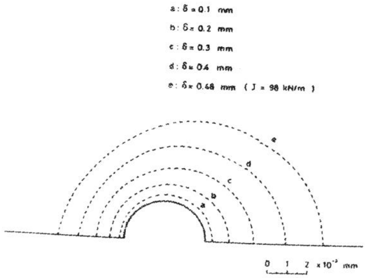


Fig.5 Void growth due to the increase of δ.

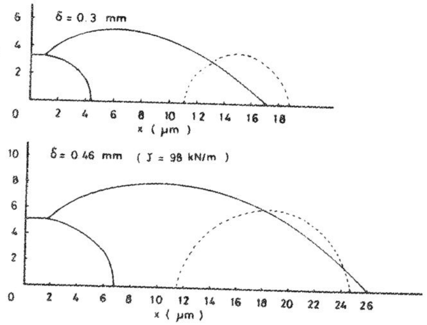


Fig.6 Shape change of D-zone due to the increase of δ.

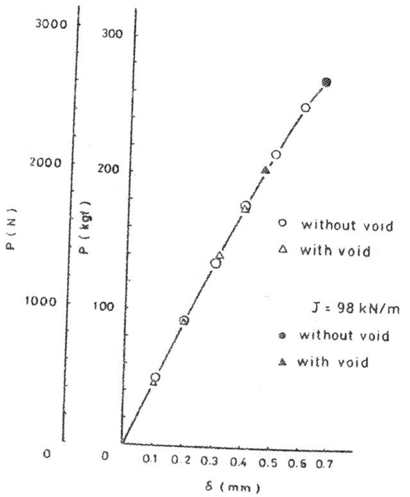


Fig.7 P-δ curve.

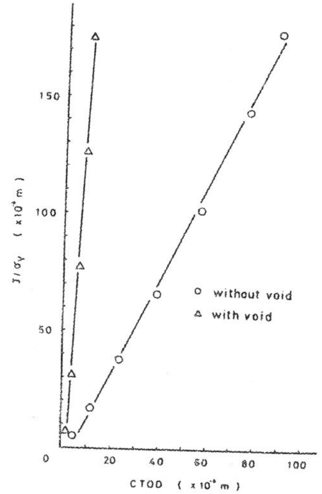


Fig.8 J/σ_Y-CTOD curve.

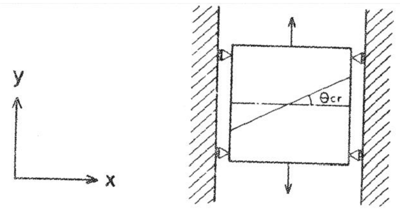


Fig.9 A plate in tension.

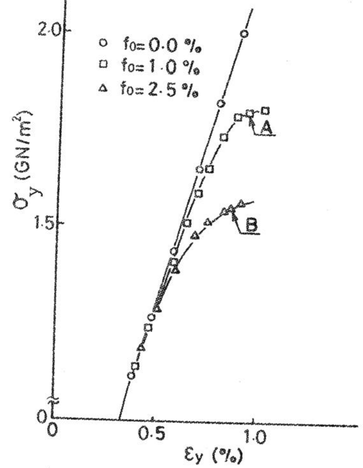


Fig.10 σ_y-ε_y curve (N=0.01).

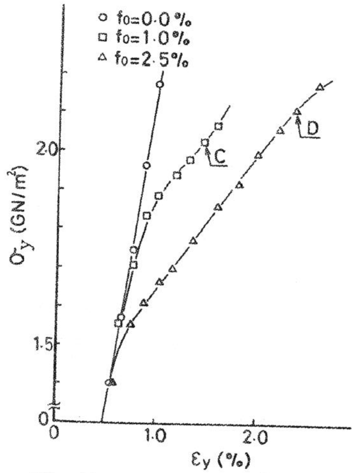
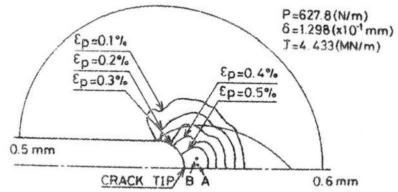
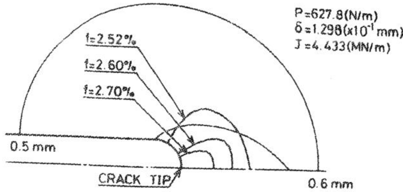


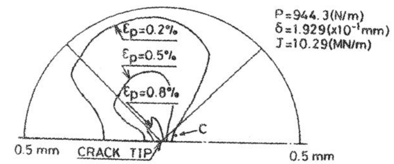
Fig.11 σ_y-ε_y curve (N=0.05).



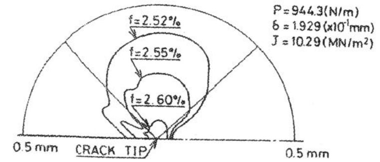
(a) Distribution of $\bar{\varepsilon}_p$.



(b) Distribution of void volume fraction.



(c) Distribution of $\bar{\varepsilon}_p$.



(d) Distribution of void volume fraction.

Fig.12 Distribution of $\bar{\varepsilon}_p$ and f.