# A Study of the COD Concept for Brittle Fracture Initiation

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This paper gives comprehensive discussion on the validity and practical applicability of "Critical COD concept" to assess significance of defects in welded steel structures or susceptibility to brittle fracture on the basis of the authors' investigations subsequent to those reported in the paper presented to The 2nd ICF, Brighton, 1969. Further information about utility and limitation of the concept is given and a simple procedure to evaluate critical COD value is proposed.

Uniqueness of Critical COD

It is one of necessary conditions for "the critical COD value $\Phi c$" to be a quantity taken as fracture criterion that it is practically independent of specimen size or pre-existing defect size and type of loading to initiate fracture (e.g. tension, bending,etc.). Using specimens with various sizes (e.g. width of tensile specimen and crack length ranged from 90 to 700 and 20 to 210 mm respectively) and comparing tensile test with bend test, the validity of critical COD concept was practically confirmed. Examples of the experimental veri-

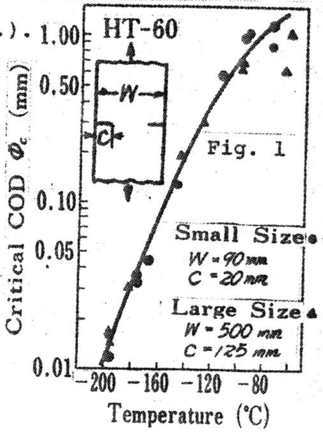


Fig. 1

fication are shown in Fig.1, Fig,2 (fracture stress vs. temperature for large size specimen predicted by $\Phi c$ obtained from small size test) and Fig. 3.

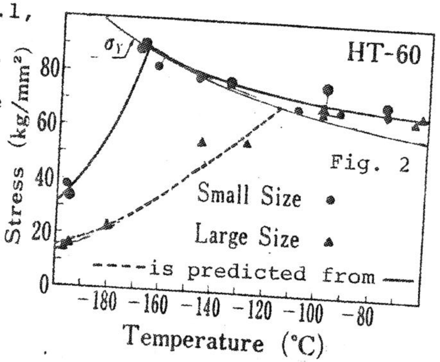

Fig. 2

Effect of Initial Stress on Critical COD

The validity of critical COD concept in fracture under the effect of initial stresses due to welding, preloading (overstressing), etc. is another important aspect to be investigated. The fracture stress in the presence of initial stresses is estimated on basis of COD concept and the theoretically predicted values are compared with the experimental values. It is found that fracture criterion is simply expressed as $\Phi = \Phi c$ where $\Phi$ is crack opening displacement produced by "the final loading". Four different initial stress states as shown in Fig. 4 were considered. The results for case (2') is shown in Fig. 5 as an example. The measured fracture stress is compared well with the estimated one as shown in Fig. 6.

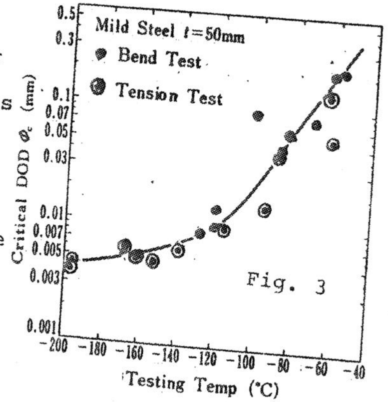

Fig. 3

Effect of Constraint

The effect of mechanical constraint (the state of tri-





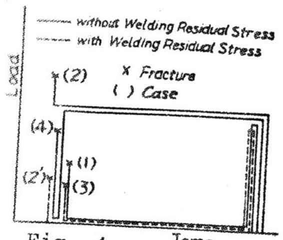

Fig. 4

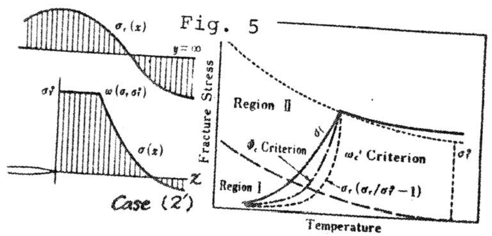

Fig. 5

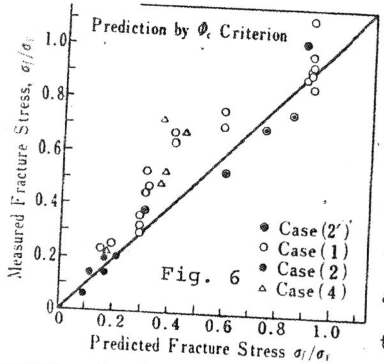

Fig. 6

axial stress state at crack tip) due to structural discontinuity was investigated using severely constrained structural member (Constraint Tensile Test) as shown in Fig. 7. Deformation at notch tip in plate thickness direction is highly constrained and high stress concentration is developed by the discontinuity in the stiffner. The results are shown in Fig. 8, which are compared with those obtained from small size deep notch test (◉), large size deep notch test (○) and deep notch test with longitudinal weld beads (Δ). It is found that the structural constraint has a remarkable effect on the $\Phi c$ value.

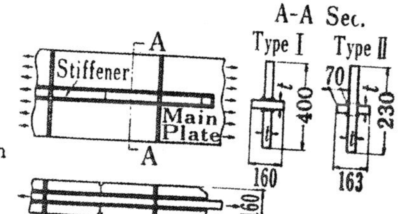

Fig. 7

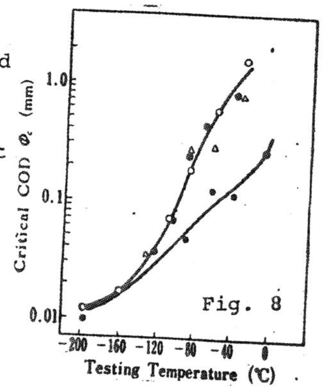

Fig. 8

Effect of Notch Acuity on The Critical COD

Effect of notch acuity seen in

bend tests is shown in Fig. 9 as an example, where $\rho$ denotes notche tip radius. It reveals that the effect of notch root radius on the critical COD is slight so far as it is smaller than 0.1 mm.

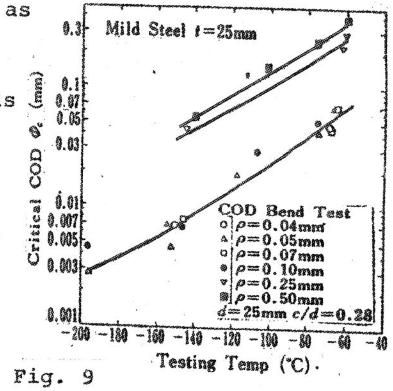

Fig. 9

## Temperature Dependence and Scatter of Critical COD Value

From our experiments it seems difficult to give an analytical expression to temperature dependence of critical COD value. It would be convenient to plot $\Phi$c in logarithmic scale against temperature (°C) in linear scale as shown in Fig. 1 & 3. One of the features to be noted is that the $\Phi$c vs. T relation generally has relatively large scatter as seen in the figures. It is necessary to clarify the causes of this scatter and statistical treatment would be necessary when quantitative prediction of fracture strength is made on the basis of $\Phi$c concept.

## COD Bend Test as a Fundamental Material Test

Bend test could be very useful evaluation test method from practical and industrial points of view, because specimens can be made smaller and can fracture at considerably lower load comparing with tensile test. As mentioned above $\Phi$c values obtained from bend test are in good agreement with those obtained from tensile test.

A COD bend test method as a fundamental material test is proposed. The flow diagram of the procedure is shown in





Fig. 10. The proposed standard specimen size is identical to ASTM recommendation. According to this method the critical COD can be evaluated simply from fracture load and yield point with the use of the relation of $E\Phi/d\sigma_Y$ vs. $\sigma_N/\sigma_Y$ (Fig. 11) obtained from the finite element method (FEM). It is to be noted that troublesome procedure in measuring COD value is not needed in the proposed method.

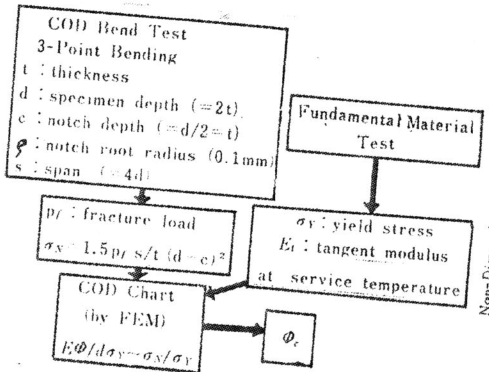

Fig. 10

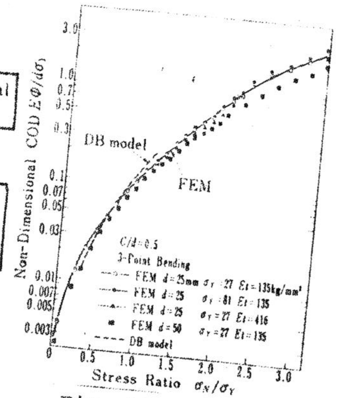

Fig. 11

## Closing Remark

One of the troubles associated with practical application of COD concept to the evaluation of significance of defects in welded steel structures and selection of proper material is the fact that $\Phi$c value is to be taken as a quantity dependent not only on the temperature but also on such mechanical factors of the material around defect as strain rate and stress triaxiality. Further extensive investigations into this aspect of $\Phi$c value is most recommended in future research works.