STATISTICAL EVALUATION OF THE TOUGHNESS CHARACTERISTICS OF A BOILER STEEL

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Statistical parameters of fracture toughness values have been determined on TPB specimens of different size and shape and compared. It is shown that the parameters are effected by the type of specimens. The correlation between the fracture toughness and other material parameters has been also investigated.

INTRODUCTION

Single-specimen methods with side-grooved test pieces are often used to determine J-integral in a simple and easy way. If the crack propagates in an unstable mode, the measured value should be examined according to some validity criterium. This value has to be considered, however, as a statistical one, since further measurements certainly yield different values.

In the present paper some observations are described connected with the statistical approach of fracture toughness with respect also to the scatter using test pieces of different size.

EXPERIMENTS

The measurements were performed on a low-alloyed boiler steel, which had been in service for many years. More details are given by Havas and Czoboly (1), where the effect of side-grooving has been described. TPB specimens were used with a gross area, B x W

25x25 mm (Type A), 12,5X25 mm (Type B), 10x10 mm (Type C)

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After completing the fatigue crack the specimens were side-grooved to a depth of 7,5% each side. The tests were carried out at R.T. and at -40° C.

Critical CTOD and J-integral values were determined at the onset of unstable crack growth, the later with the well known formula:

$$J_c = 2U/(B.(W-a)) \quad (1)$$

The validity of the calculated values have been checked by the criterium given by Paris,

$$J_c = J_{Ic}, \text{ if } B,a,(W-a) > 25\, J_c/\sigma_{flow}$$

Table 1 shows the mean values and the standard deviations of critical CTOD and J_{Ic} values assuming a normal distribution. The sample size is also indicated. (In the case of Charpy-size specimens no valid J_{Ic} values could be determined at R.T.)

TABLE 1-Distribution Parameters of the Groups Tested.

Specimen type:		A	B	C
CTOD	R.T.	0,235/0,127/9^{+}	0,352/0,152/9	0,241/0,087/9
(mm)	-40°C	0,074/0,021/9	0,116/0,031/8	0,076/0,019/9
J_{Ic}	R.T.	93/40/7	102/53/3	- / - / -
(kJ/mm)	-40°C	34/13/9	65/27/8	41/8/5

+ mean value/ standard deviation/sample size

The values were further examined by t- and F-significance tests, comparing always two groups with each other. The t-distribution is related to the mean values, while the F-distribution compares the standard deviations. A difference at a confidence level of 95% was taken as "significant" and at a level of 97,5% as "very significant". These results are summarized in Table 2.

TABLE 2-Results of the Significance Tests.

Groups compared	Test	CTOD (mm)		J_{Ic} (kJ/mm^2)	
		R.T.	-40° C	R.T.	-40° C
A and B	F	o	o	o	+
	t	+	++	o	++
B and C	F	o	o	-	++
	t	+	++	-	+
C and A	F	o	o	-	o
	t	o	o	-	o

o the differences are not significant
+ the differences are significant
++ the differences are very significant

Furthermore, Charpy impact test pieces and tensile specimens with a diameter of 4 mm were machined from the broken A-type specimens. Impact energy KV, ultimate tensile strength σ_{TS} and absorbed specific energy till fracture W_c - characterizing the toughness of the material - have been determined. W_c was calculated by the formula given by Gillemot (2).

All values of KV, σ_{TS} and W_c together with the J_c determined on the same specimen are plotted in Figs.1 and 2. as a function of CTOD at R.T and at -40^{0}C.

CONCLUSIONS

The results of the single-specimen-methods should be handled carefully, because not only the thickness of the specimen, but also the ratio of ligament to thickness influences the "valid" J_{IC} values. Similar results were obtained by Dahl and Zeislmair (3) as well as Cayerd and Bradley (4). As it was shown, the increasing ligament/thickness ratio promotes the plane stress condition even in the presence of side-grooves, therefore the toughness parameters increase.

The relation of CTOD and J_c values - measured on the same specimen - are nearly linear.

Fracture toughness values did not correlate with Charpy impact energy values, although the Charpy specimens were machined from the broken halfs of the TPB test pieces. The absorbed specific energy slightly increased with increasing fracture toughness, but no correlation was found with the ultimate tensile strength.

SYMBOLS USED.

U = area under the load-deflection curve (kJ)
σ_{flow} = flow stress (MPa)
t,F = symbols of significance tests
W_c = absorbed specific energy till fracture (MJ/m^3)
KV = Charpy impact energy (J)

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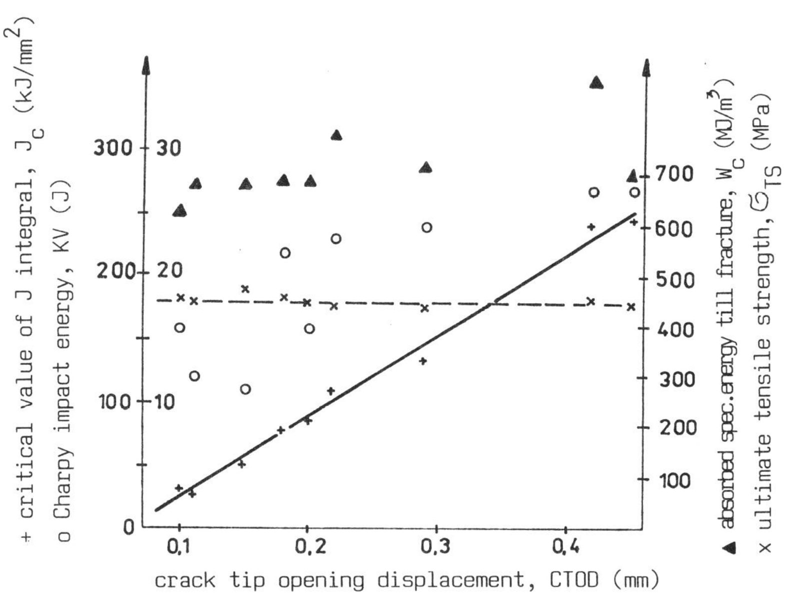

Figure 1 J_c, KV, W_c and σ_{TS} values plotted as a function of CTOD at R.T.

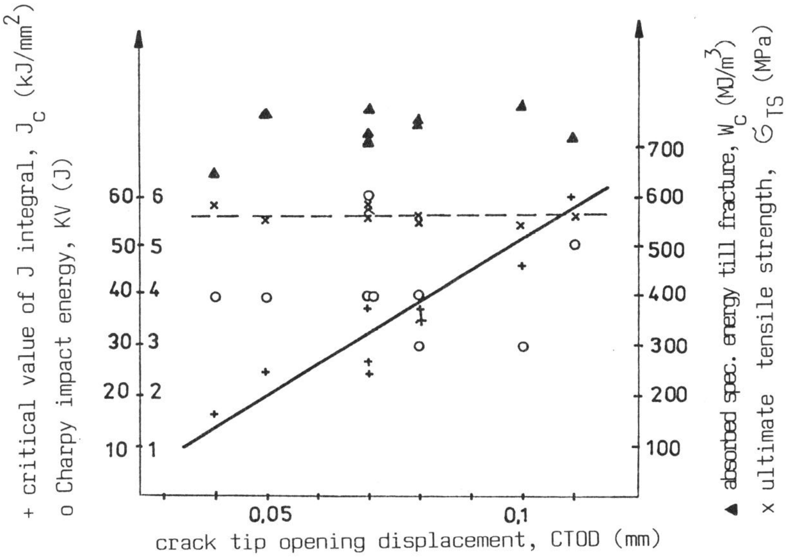

Figure 2 J_c, KV, W_c and σ_{TS} values plotted as a function of CTOD at -40^o C.