ON J-INTEGRAL AND J-INITIATION VALUES AS MATERIAL PARAMETERS IN THE FIELD OF ELASTIC-PLASTIC FRACTURE MECHANICS

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In the field of elastic-plastic fracture mechanics (EPFM) several fracture mechanics characteristic values can be determined according to different test standards or proposals. These characteristic parameters are evaluated from Finite-Element (FE)-calculations of CT-specimens, on the basis of damage models, and then compared with the theoretical result.

The influence of specimen geometry and size on the J_R-curve is shown for different large scale specimens, and these are compared with J_R-curves of CT-specimens.

MATERIAL PARAMETERS

The most commonly used elastic-plastic fracture mechanics (EPFM) characteristic parameter is J_{Ic}, according to ASTM E 813. The formerly used evaluating procedure [1] was modified in 1987 [2]. In [2] the equation to evaluate J was modified as well as the regression line approximation method. An additional standard for evaluating J_R-curves was also established [3], using a different procedure for calculating the J-integral. At the same time EGF [4] and DVM [5] have made proposals for the determination of elastic-plastic fracture mechanics parameters based on other definitions. This has led to a broad scatterband of J-Δa-values for the same CT-specimen. All these standards and proposals are based on a power law fit to characterize the course of the crack-resistance behaviour, i.e. the J_R-curve. The material parameters are derived from the intersection of the J_R-curve with blunting- or offset-lines. One effective fracture mechanics characteristic value,

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named J_i [5, 6], is derived by a vertical cut of the J_R-curve with an offset line $\Delta a = \Delta a_i$, which is the width of the stretched zone. Hence, with this parameter, only the section of the J_R-curve representing the blunting of the crack tip is used. This 'stretched zone' is usually ignored by the other procedures.

FINITE ELEMENT (FE) ANALYSIS

Using FE-calculation with the damage model acc. to [7] which incorporates crack extension in the model, the load-COD-curve of a CT-specimen was calculated. This was a CT-25 specimen made of a low alloyed 20 MnMoNi 55 fine grain structural steel. This calculated curve fits very well with experimentally determined curves of two CT-25 specimens. The J-Δa-curve was also calculated from the virtual crack extension (VCE) method [8] using the far field J [9]. This method also fits well with experimental results, see Fig. 1. The evaluation procedures given in the test standards and proposals can be prooved using calculated F-COD results as input. In Table 1, J-values are summarized for initiation and maximum crack extension. This prooves, that the procedures acc. to [5, 6] and [10] are close to the theoretical results, see also Fig. 1.

CT-25 specimen	J (initiation) N/mm	J (Δa=4.1 mm N/mm	Deviation %
VCE	-	1552	0
ASTM E 813-81, J_{Ic}	772	1378	-11
ASTM E 813-88, J_{Ic}	822	1528	-2
ASTM E1152-87	-	1390	-10
EGF, $J_{0.2}$	371	1498	-3
EGF, $J_{0.2bl}$	644	1498	-3
MPA, J_i	327	1595	+3
DVM, J_i	327	1641	+6

Table 1: J-values, determined from a calculated F-COD-curve, on the basis of damage models

INFLUENCE OF SIZE AND GEOMETRY

To investigate the influence of specimen geometry on the J_R-curve, several large scale specimens, (cross section up to 200 x 500 mm²) were tested and there resistance curves were evaluated. The specimens were made from modified 22 NiMoCr 3 7 fine grain structural steel. It can be seen in Fig. 2, that the J-Δa-curve determined acc. to the η-method [10] depends strongly on the specimens size and geometry.

The effective J_i-value, however, determined using the stretched zone width, seems to be independent of specimen geometry and size within the scattering of the material, Fig. 3.

SENT-specimens of the same size but made from materials of varying toughness (22 NiMoCr 3 7, C_v = 90 J, 22 NiMoCr 3 7 mod, C_v = 40 J and 20 MnMoNi 5 5 C_v = 200 J in the upper shelf of the C_v-T-curve) tested at these conditions show an evident dependence on the materials toughness, Fig. 4. The specimen of the low tough 22 NiMoCr 3 7 mod yields small J-values, small crack resistance and small stable crack extension. The SENT-specimen made of the high tough material 20 MnMoNi 5 5 however yield high J-values, a higher crack resistance and more stable crack extension. This behaviour can be quantified by the course of the quotient of multiaxiality q. Low q-values mean a high multiaxiality and reduced crack extension.

CONCLUSIONS

It could be shown, that J-procedures according to different test standards and proposals yield different characteristic values. Certain procedures are relatively close to the theoretical solution which was determined on the basis of a damage model using the far field J-value.

Cracked large specimens show a considerable influence of the stress state on the course of the J_R-curve. In contrast, the effective crack initiation value J_i is independent of these effects.

If one geometry is regarded, the material toughness has a dominant influence on the crack resistance behaviour. With increasing toughness the J_i-value and the crack resistance increases. This can be explained with the quotient of multiaxiality q.

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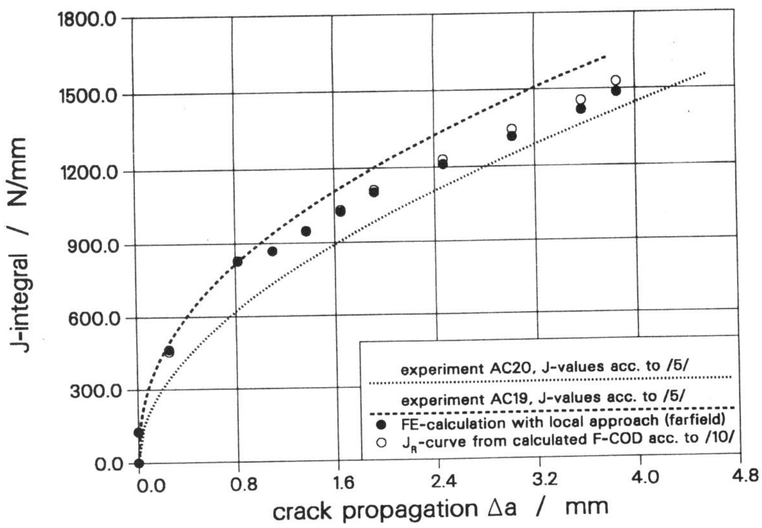

Fig. 1: Experimentally and numerically obtained J_R-curves, CT-25 specimen, 20 MnMoNi 5 5, 80°C

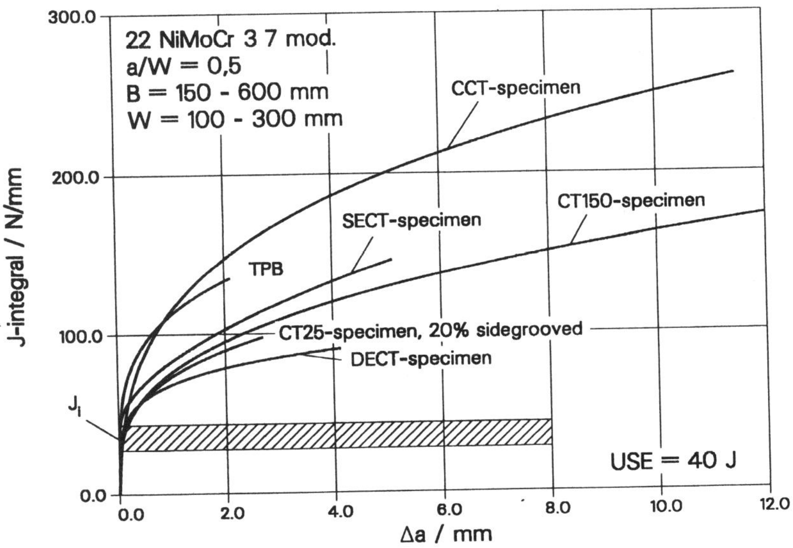

Fig. 2: J_R-curves of specimens of different geometries, 22 NiMoCr 3 7 mod., 80°C

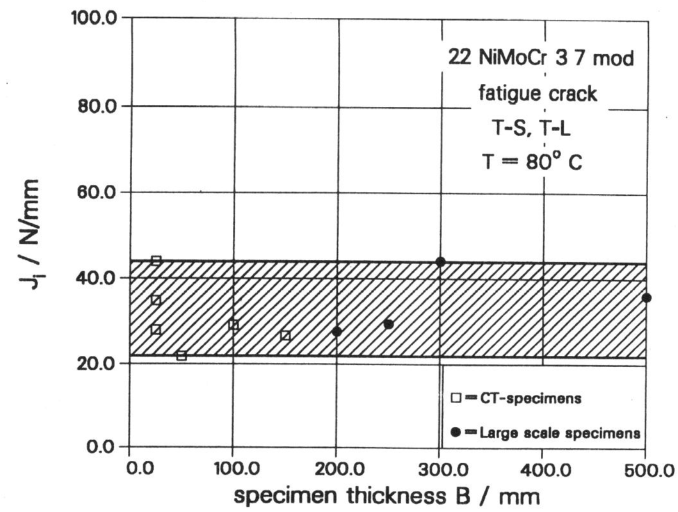

Fig. 3: J_i-values of specimen of different thickness, 22 NiMoCr 3 7 mod., 80°C

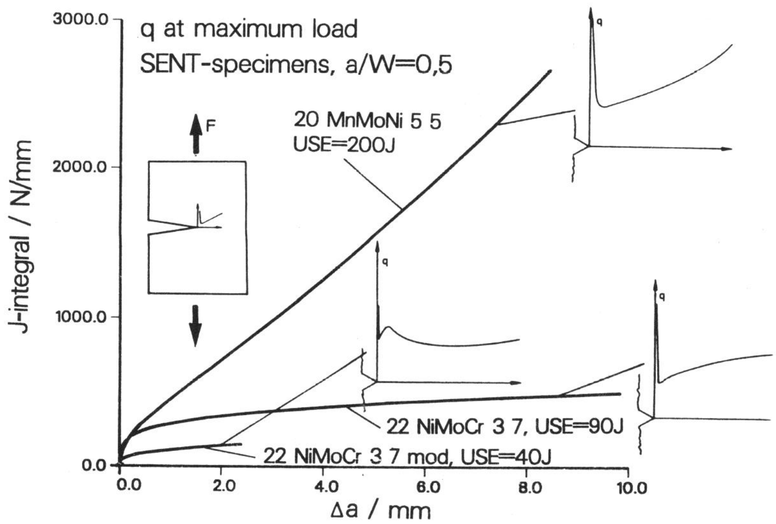

Fig. 4: The influence of materials toughness of the J_R-curve and the course of the quotient of multiaxiality q, SENT-specimen, a/W = 0.5