INVESTIGATION OF CRACK INITIATION ON FERRITIC AND AUSTENITIC STEELS

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Different methods to determine the crack initiation toughness parameters are considered for a ferritic and an austenitic steel using static and impact loading. It has been shown that it is necessary to differentiate between the "physical" J_i-values, based on stretch zone measurements, and the "technical" values, based on a stable crack growth Δa=0.2mm. Recommended crack initiation toughness parameters are J_{iSZWc} for material characterization and $J_{0.2}$ for fracture-safe integrity assessment.

INTRODUCTION

Crack initiation toughness is an essential input in elastic-plastic integrity assessments. For this reason the event of crack initiation at the crack tip must be clearly defined. Before the condition for stable crack initiation is fullfilled, a stretch zone as the characteristic feature of the transition region between the fatigue precrack and the final fracture surface has been formed by crack tip blunting. Measurements of the stretch zone width and height make possible to determine the "physical" crack initiation point at the R-curve J-Δa or δ-Δa (1-3). This method is very important for impact loading, because in this case it is not easy to use other techniques to detect the crack initiation event (4).

The aim of this study was to compare different proposals to determine the crack initiation toughness parameters depending on different microstructures and loading rates.

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EXPERIMENTAL

Static and low-blow impact tests at room temperature were carried out on CHARPY-specimens of the ferritic steel StE 460 and austenitic steel X6CrNi1810 (Table 1). Specimens were loaded in the blunting and in the stable crack growth stage.

TABLE 1- Chemical composition in % and mechanical properties (T-L-orientation)

steel	C	Si	Mn	P	S	Cr	Ni	Mo	V	Ti
StE 460	0.17	0.28	1.52	0.009	0.009	0.04	0.62	0.01	0.18	-
X6CrNi 1810	0.053	0.57	1.07	0.022	0.005	18.1	8.5	0.14	$\leq$0.1	$\leq$0.01

steel	$R_{p0.2}$ [MPa]	R_m [MPa]	E 10^5 [MPa]	A [%]	Z [%]
StE 460	467	626	2.05	21	65
X6CrNi1810	240	592	1.95	18	80

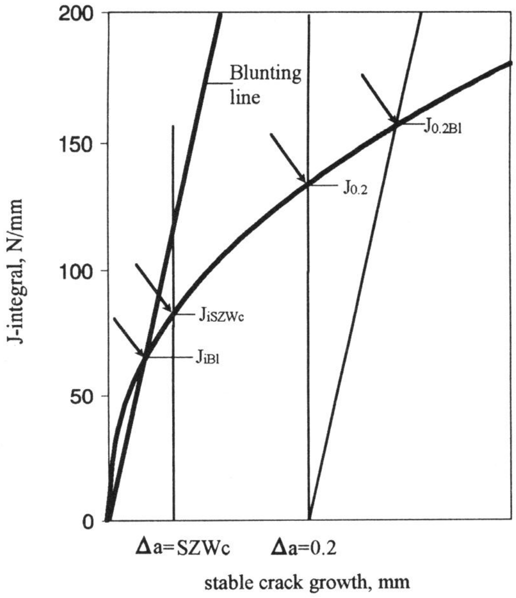
The low-blow tests were performed on an instrumented Charpy impact test machine. The multiple specimen J-Δa-curves are fitted by the ordinary power law:

$$J = A \, \Delta a^{B} \quad (1)$$

Stretch zone measurements on both halves of the specimen were made by SEM combined with an image analyzing system IBAS (5). This method is very useful because of the irregular shape of the stretch zone, especially on the austenitic steel. In this material the stretch zone profile shows an alternating process of crack tip blunting and ductile tearing.

The different definitions of the crack initiation point at the J-Δa-curve are given in Fig. 1. The J_{iSZWc} parameter has been estimated by the recommendation (1). Another possibility is the intersection point between the blunting line and the fitted J-Δa-curve. The slope of the blunting line can be evaluated analytically by:

$$\Delta aBl = 0.4 \, d_n^* \frac{J}{E} \quad (2)$$



crack initiation toughness parameter	estimated by
J_{iSZWc}	$\Delta a = SZW_c$
$J_{iBl/theor.}$	analytical blunting line slope $\Delta aBl = 0.4\, d_n^* \frac{J}{E}$
$J_{iBl/exp.}$	experimental blunting line slope $\Delta aBl = \frac{SZWc}{SZHc}\, d_n^* \frac{J}{E}$
$J_{0.2}$	$\Delta a = 0.2$mm
$J_{0.2Bl/theor.}$	parallel shift of the analytical blunting line
$J_{0.2Bl/exp.}$	parallel shift of the experimental blunting line

Figure 1 Definitions of crack initiation toughness parameters

The proportionality constant d_n^* is a function of the strain hardening exponent n, its determination from tensile properties is given in Appendix 6 of (1). The factor 0.4 has been derived from the experimental observation of the stretch zone profile $SZW_c \approx 0.4\ SZH_c$ (6). But since the relation $SZW_c{:}SZH_c$ can be changed for different microstructures and loading rate conditions, it seems necessary to define an experimental blunting line using the "true" $SZW_c{:}SZH_c$ factor measured by SEM (Table 2).

TABLE 2- Relation $SZW_c{:}SZH_c$

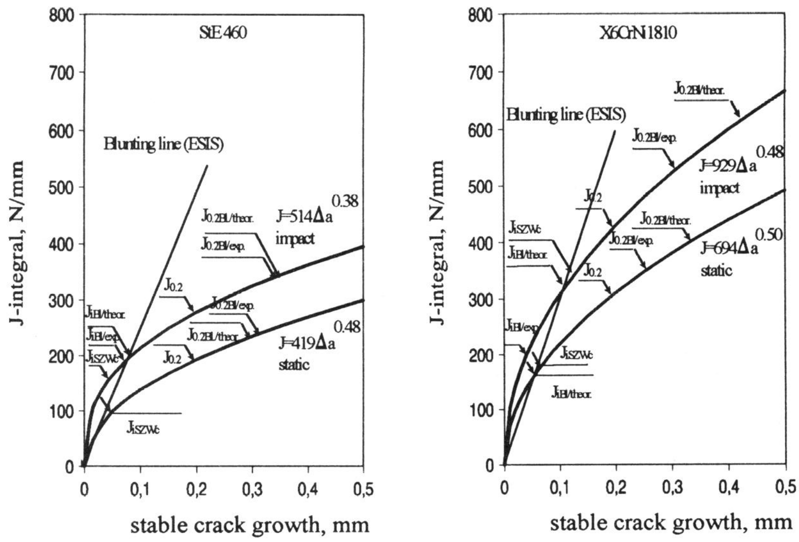
	StE 460		X6CrNi1810	
	static	impact	static	impact
$SZW_c{:}SZH_c$	0,45	0,36	0,21	0,24

Similar to the "physical" J_i-values "technical" initiation toughness parameters $J_{0.2}$; $J_{0.2Bl/theor.}$ and $J_{0.2Bl/exp.}$, based on a stable crack growth Δa=0.2mm, can be estimated .

RESULTS

The J-Δa-curves for both steels and loading conditions and the crack initiation points estimated with 6 methods are plotted in Fig. 2. It is interesting that the J-Δa-curves estimated by the low-blow technique show a clearly higher level than the static bending curves. As explanation for this result can be assumed, that in the upper shelf the predominant factor affecting the crack resistance is the work-hardening, which results in a higher yield stress.

It was found that both blunting lines of the steel StE 460 are in a nearly good agreement, but the experimental blunting line for the austenitic steel has a higher slope than the analytical one. Since an intersection point between the blunting line and the J-Δa-curve does not always exists, the initiation value J_{iSZWc}, which reflect the influence of the microstructure and the constraint conditions on the local damage process at the crack tip, should be used as the only parameter for material characterization. For engineering purposes a more reproductible determination is needed, and therefore the technical values based on Δa=0.2mm are a proper definition. But it must be taken into account, that the slope of the blunting line is sensitive to the microstructure and loading rate, and consequently a realistic estimation of the $J_{0.2Bl}$ requires the measurement of stretch zone width and height by SEM. If this is not acceptable, $J_{0.2}$ as a lower bound value compared with $J_{0.2Bl}$ provides a practicable engineering definition.



J-value [N/mm]	StE 460		X6CrNi1810	
	static	impact	static	impact
$J_{iBl/exp.}$	*	203	*	205
$J_{iBl/theor.}$	*	217	170	327
J_{iSZWc}	103	152	178	347
$J_{0.2}$	194	267	311	431
$J_{0.2Bl/exp.}$	230	337	356	532
$J_{0.2Bl/theor.}$	225	345	403	633

* no intersection point

Figure 2 J-Δa-curves and crack initiation toughness values

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