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WIDE RANGE STRESS INTENSITY FACTOR EXPRESSIONS FOR ASTM E 399 STANDARD FRACTURE TOUGHNESS SPECIMENS

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For each of the two types of specimens, bend and compact, described in the ASTM Standard Method of Test for Plane Strain Fracture Toughness of Materials, E 399, a polynominal expression is given for calculation of the stress intensity factor, K, from the applied force, P, and the specimen dimensions. It is explicitly stated, however, that these expressions should not be used outside the range of relative crack length, a/W, from 0.45 to 0.55. While this range is sufficient for the purpose of E 399, the same specimen types are often used for other purposes over a much wider range of a/W; for example, in the study of fatigue crack growth. It is the purpose of this report to present new expressions which are at least as accurate as those in E 399-74, and which cover much wider ranges of a/W: for the three-point bend specimen from 0 to 1; for the compact specimen from 0.2 to 1. The range has to be restricted for the compact specimen because of the proximity of the loading pin holes to the crackline, which causes the stress intensity factor to be sensitive to small variations in dimensions when a/W is small. This is a penalty inherently associated with the compactness of the specimen.

The proposed expression <u>for the three-point bend specimen</u> is:

$$\frac{KBW^{1/2}}{P} = \frac{3(S/W)\,\alpha^{1/2}(1.99 - \alpha(1 - \alpha)(2.15 - 3.93\alpha + 2.7\alpha^2))}{2(1 + 2\alpha)(1 - \alpha)^{3/2}} \qquad (1)$$

for: $0 \leq \alpha = a/W \leq 1$

where: B = thickness, W = width (depth), a = average crack length, and S = support span (= 4W ± 0.01W).

The proposed expression for the compact specimen is:

$$\frac{KBW^{1/2}}{P} = \frac{(2 + \alpha)(0.886 + 4.64\alpha - 13.32\alpha^2 + 14.72\alpha^3 - 5.6\alpha^4)}{(1 - \alpha)^{3/2}} \quad (2)$$

for: $0.2 \leq \alpha \leq 1$

Equations (1) and (2) were devised to fit those available analytical results considered likely to be most accurate and reliable [refs. 1, 2, 3]. To examine the fidelity of these interpolation expressions it is convenient to re-express them in terms of dimensionless quantities which have finite, nonzero values throughout the range of a/W from 0 to 1, namely: for bend specimens, with S/W = 4, $F_B = (1 - \alpha)^{3/2}KBW/Pa^{1/2}$; and for compact specimens, $F_C = (1 - \alpha)^{3/2}KBW^{1/2}/P$. Table 1 shows the comparison in these terms of the values F_{B1} and F_{C2}, obtained from expressions (1) and (2) respectively, with the primary results, F_{BO} and F_{CO}, obtained from the sources indicated by the appended references. The accuracy of these primary results is not expected to be better than ±0.25 percent, but the values are given to a higher degree of precision for the purpose of calculation of relative deviations.

From Table 1 it is apparent that expression (1) for the bend specimen agrees with the primary results within ±0.02 percent, and that expression (2) for the compact specimen agrees with the primary results within ±0.04 percent. Also, in both cases, the deviations are unsystematic and have very small average values. The polynomial interpolation expression in (2) also provides a good fit to the finite element analysis results of that reference, but was considered unsatisfactory because it has a finite value at a/W = 1 instead of the limit value, $3.978/(1 - \alpha)^{3/2}$.

REFERENCES

1. Srawley, J. E. and Gross, B., Engineering Fracture Mechanics, Vol. 4, No. 3, Sept. 1972, pp. 587-589.

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3. Bentham, J. T. and Koiter, W. T. in Mechanics of Fracture I - Methods of Analysis and Solution of Crack Problems, G. C. Sih, Ed., Noordhoff International Publications, Leyden, The Netherlands, 1973, pp. 159-162.

TABLE 1. - COMPARISON OF INTERPOLATION EXPRESSION VALUES

WITH PRIMARY RESULTS

$\alpha = a/W$	BEND SPECIMENS (S/W = 4)			COMPACT SPECIMENS		
	F_{BO} *	F_{B1}	$F_{B1}/F_{BO} - 1$	F_{CO} *	F_{C1}	$F_{C2}/F_{CO} - 1$
0	11.932 [3]	11.940	0.0007	(indefinite)	1.772	-------
.1	------ --	9.147	------	---------	2.585	-------
.2	7.513 [1]	7.519	0.0008	3.070 [2]	3.058	-0.0038
.3	6.518 [1]	6.506	-0.0018	3.297 [2]	3.292	-0.0016
.4	5.834 [1]	5.825	-0.0016	3.379 [2]	3.383	0.0012
.5	5.317 [1]	5.325	0.0014	3.405 [2]	3.415	0.0030
.6	4.919 [1]	4.927	0.0017	3.451 [2]	3.454	0.0010
.7	4.602 [1]	4.596	-0.0012	3.544 [2]	3.541	-0.0008
.8	----- --	4.321	------	3.679 [2]	3.685	0.0017
.9	----- --	4.110	------	---------	3.856	-------
1.0	3.978 [3]	3.980	0.0005	3.978 [3]	3.978	0

*Reference number indicates source of primary result: [1] boundary collocation method; [2] finite element method; [3] asymptotic method.