AD-A284 364

Carderock Division
Naval Surface Warfare Center
Bethesda, Md. 20084-5000

CARDIVNSWC-SSM-61-93/23 June 1994

Survivability, Structures, and Materials Directorate

Research and Development Report

Effects of Tensile Loading on Upper Shelf Fracture Toughness

by

J.A. Joyce
R.E. Link

125Pg

94-29372

Approved for public release; distribution is unlimited.

94 9 07 178

Effects of Tensile Loading on Upper Shelf Fracture Toughness

CARDIVNSWC-SSM-61-93/23

Carderock Division
Naval Surface Warfare Center
Bethesda, MD 20084–5000

CARDIVNSWC–SSM–61–93/23 June 1994

Survivability, Structures, and Materials Directorate
Research and Development Report

Effects of Tensile Loading on Upper Shelf Fracture Toughness

by
J.A. Joyce
R.E. Link

ABSTRACT

Constraint has been an important consideration in fracture mechanics from the earliest work that was done to develop the 1974 version of the ASTM Standard E399. Stringent thickness and size requirements were placed on the test samples, in terms of the measured plastic zone size. These requirements often invalidate the results in practical application sizes. Similar size requirements have been incorporated into more recent elastic-plastic fracture test standards like ASTM E813 and ASTM E1152, even though experimental data has not shown a clear and direct relationship between specimen size and the resulting initiation toughness or the resistance curve shape.

O'Dowd and Shih (1991) have proposed that the difference in crack tip stress fields between the small scale yielding (SSY) finite element solution and the finite body solution can be quantified in terms of a field quantity that they have call Q. The Q quantity is a function of J, the crack shape and size, the structural geometry, mode of loading and on the level of deformation and can only be calculated from a high resolution elastic-plastic computational analysis. O'Dowd and Shih propose that a J-Q fracture locus can be developed experimentally for a particular material, with higher Q's meaning higher constraint and resulting in lower J measures at cleavage or at ductile crack initiation, or at whatever critical measurement point is to be used. This procedure avoids the need to start with a fracture criterion, which is a serious difficulty if one wishes to apply the Dodds and Anderson approach to the case of ductile crack extension.

A similar, simpler, but more controversial approach has been suggested by Betégon and Hancock (1991), who use the non-singular term of the elastic, Williams (1957), crack singularity solution, called the T-Stress", as a measure of elastic-plastic crack tip constraint. This quantity is only dependent on the initial geometry and loading and hence is relatively easy to calculate, and is available in the literature for many geometries.

The objective of this work is to develop some upper shelf, elastic-plastic experimental results to attempt to investigate the applicability of the Q and T stress parameters to the correlation of upper shelf initiation toughness and J resistance curves. The first objective was to obtain upper shelf J resistance curves, J_{Ic}, and tearing resistance, T_{mat}, results for a range of applied constraint. The J-Q and J-T stress loci were developed and compared with the expectations of the O'Dowd and Shih and the Betégon and Hancock analyses. Constraint was varied by changing the crack length and also by changing the mode of loading from bending to predominantly tensile.

The principal conclusions of this work are that J_{Ic} does not appear to be dependent on T stress or Q while the material tearing resistance is dependent on T stress and Q, with the tearing modulus increasing as constraint decreases.

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ADMINISTRATIVE INFORMATION

The work reported herein was performed at the U.S. Naval Academy and the Carderock Division, Naval Surface Warfare Center under the "Elastic-Plastic Fracture Mechanics of LWR Alloys Program," R.E. Link, Program Manager. The program is sponsored by the Office of Nuclear Regulatory Research of the U.S. Nuclear Regulatory Commission under Interagency Agreement RES-78-104. The Technical Program monitor is Dr. S.N. Malik at the USNRC. This effort was performed at CRDKNSWC under the supervision of Mr. T.W. Montemarano, Head, Fatigue and Fracture Branch (Code 614).

ACKNOWLEDGEMENTS

The authors would like to acknowledge the help of Mr. Wayne Farmer and Mr. John Hein of the U.S. Naval Academy for technical assistance with several aspects of this project, and also the Technical Support Department of the U.S. Naval Academy Engineering and Weapons Division for specimen and fixture machining.

OBJECTIVES

Constraint has been an important consideration in fracture mechanics from the earliest work that was done to develop the 1974 version of the ASTM Standard E399. Stringent thickness and size requirements were placed on the test samples, in terms of the measured plastic zone size. These requirements often invalidated the results in practical application sizes. The restrictions have been retained in later revisions, often requiring the engineer to test in his application thickness and to work generally with "invalid" data, using engineering judgement and experience to avoid catastrophic failure of his structure. Similar size requirements have been incorporated into more recent elastic-plastic fracture test standards like ASTM E813 and ASTM E1152, even though experimental data has not shown a clear and direct relationship between specimen size and the resulting initiation toughness or the resistance curve shape.

Recent computational work by Anderson and Dodds (1991) and Dodds, Anderson and Kirk (1991) has sought to quantify constraint by comparing the stress field near a crack in an elastic-plastic body to the small-scale yielding (SSY) solution that corresponds to that geometry and material combination, as also determined by numerical computation. This SSY solution has been shown to be basically different than the Hutchinson (1968), Rice and Rosengren (1968) (HRR) solution, apparently due to the crack tip blunting which is invariably present near the crack tip. The Dodds, et al work has shown that constraint depends on specimen or structure thickness, on in-plane dimensions, and on the mode of loading. They also showed that the principal stress fields in two-dimensional cases are self-similar and a comparison of similar stressed volumes can be made which allows a comparison of constraint from one situation to another, i.e. a short-cracked bend geometry can be chosen to match the constraint of a much harder to test short cracked tensile geometry. In addition, they developed a scaling model to predict the effect of changes in constraint on the cleavage fracture toughness.

The Dodds, et al. scaling model has been applied predominantly to cleavage fracture, since as presently formulated, it assumes a fracture criteria similar to that proposed by Ritchie, Knott, and Rice (1973) (fracture occurs when the maximum principal stress reaches a critical value, σ_f, at a critical distance, r^*, from the crack tip). By scaling the remote J integral to achieve similar stress conditions near the crack tip a correction of the J integral values at cleavage initiation can be made which accounts, at least approximately, for the effects of constraint on fracture. The applicability of this technique in the lower shelf ductile-brittle transition regime of ferritic steels has been demonstrated by Sorem, Dodds and Rolfe (1991) and by Kirk, Koppenhoefer and Shih (1993).

O'Dowd and Shih (1991) have proposed that the difference in crack tip stress fields between the SSY solution and the finite body solution can be quantified in terms of a field quantity that they have call Q. The Q quantity is a function of J, the crack shape and size, the structural geometry, mode of loading and on the level of deformation and can only be calculated from a high resolution elastic-plastic computational analysis. O'Dowd and Shih propose that a J-Q fracture locus can be developed experimentally for a particular material, with higher Q's meaning higher constraint and resulting in lower J measures at cleavage or at ductile crack initiation, or at whatever critical measurement point is to be used. This procedure avoids the need to start with a fracture criterion, which is a serious difficulty if one wishes to apply the Dodds and Anderson approach to the case of ductile crack extension. Examples of a J-Q fracture locus for the case of cleavage have been developed by Kirk, Koppenhoeffer and Shih (1993) and also by Sumpter and Forbes (1993), and these results seem to support the J-Q concept.

A similar, simpler, but more controversial approach has been suggested by Betégon and Hancock (1991), who use the first non-singular term of the elastic crack-tip stress field solution (Williams 1957) as a measure of elastic-plastic crack tip constraint. This quantity has been called the "T-stress", a notation used by Larsson and Carlsson (1973) who studied the effect of this term on the crack tip stress field. This quantity is only dependent on the initial geometry and loading and hence is relatively easy to calculate, and is available in the literature for many geometries. The application of this elastic quantity to elastic-plastic fracture is highly controversial, but published results have shown good correlation, and the ease of use is a strong selling point for this parameter.

The objective of this work is to develop some upper shelf, elastic-plastic experimental results to investigate the applicability of the Q and T stress parameters to the correlation of upper shelf initiation toughness and J resistance curves. The first objective was to obtain upper shelf J resistance curves, J_{Ic}, and tearing resistance, T_{mat}, results for a range of applied constraint. The J-Q and J-T stress loci were developed and compared with the expectations of the O'Dowd and Shih and the Betégon and Hancock analyses. Constraint was varied by changing the crack length and also by changing the mode of loading from bending to predominantly tensile. Test techniques and analysis have been developed as needed for the low constraint fracture test geometries. Two materials have been used in this study, an HY-100 high strength structural steel and an A533B pressure vessel steel. Some of the results for the HY-100 steel have been reported previously in NUREG/CR-5879 (Joyce, et al. 1992), they are repeated again here to demonstrate the consistency of the results found for the two materials.

1.0 EXPERIMENTAL DETAILS

1.1 Material Description

Two structural steels were tested in this study. The first material was HY-100, a high strength structural steel with tensile mechanical properties and chemistry as shown in Table 1. This material was from a 6.35 cm thick plate and all specimens were oriented so that the crack plane was in the T-L direction as designated by ASTM E399. The second material was an ASTM A533 Grade B pressure vessel steel with the tensile mechanical properties and chemistry also shown in Table 1. The plate for this material was originally 21.5 cm thick, but for these tests all samples were cut from the center 15 cm. All specimens of this material were oriented in the L-T orientation.

1.2 Specimen Details

Four distinct test geometries were studied in this work: the standard 1T compact specimen C(T), the single edge-notched bend specimen SE(B), the single edge-notched tensile specimen, SE(T) that was pin-loaded and the double edge-notched tensile, DE(T), specimen, also pin-loaded. The SE(B) specimens were tested in a standard deep notched configuration with crack length specimen width ratio $a/W = 0.6$, and also in a shallow notched configuration with $a/W = 0.15$. The SE(T) and DE(T) configurations were tested with a/W ratios from 0.35 to 0.7. Schematic drawings of the SE(T) and DE(T) geometries are shown in Figure 1. All specimens were 25 mm thick and side grooved to a total thickness reduction of 20%. All specimens were side grooved after precracking.

Some non-side grooved specimens of the HY-100 steel were tested and reported in Joyce, et al. (1992), however all specimen results presented here are for specimens which have been side grooved to a total reduction of 20%. Matrices of the test specimens are presented in Table 2 and 3 for the two materials tested and reported here.

Tests of the HY-100 steel were done at ambient temperature (25°C), wnile the A533B was tested at approximately 100°C to assure that the fracture mode for all tests were fully ductile throughout.

1.3 Specimen Precracking

The bend specimens and the tensile bars were precracked in bending using a three point bend apparatus. The short cracked HY-100 bend specimens were precracked starting from a wide specimen, with $W = 70$ mm, and precracked until the crack was about 27 mm long. The specimens were subsequently machined to remove the material at the crack flanks, until a final configuration was obtained with a crack length of about 7 mm in a remaining ligament of 50 mm. The precrack fronts obtained in this fashion for this material were found to be straight and accurate in all cases, but the method was expensive and arduous. The A533B short crack bend specimens were precracked by starting with a bar of width 50 mm with a short machined notch

Table 1 Chemical composition and mechanical properties of steel alloys used in this investigation (All element values in weight percent).

Element	HY-100 (FYO)	A533, Grade B (H13)
Carbon	0.16	0.22
Manganese	0.26	1.48
Phosphorus	0.003	0.012
Sulfur	0.009	0.018
Silicon	0.19	0.25
Nickel	2.78	0.68
Chromium	1.57	-
Molybdenum	0.42	-
Vanadium	0.003	-
0.2% Yield Strength, MPa (ksi)	747 (109)	397 (58)
Ultimate Strength, MPa (ksi)	877 (128)	555 (81)
Elongation in 25 mm (%)	16.5	26
Reduction of Area (%)	57	68

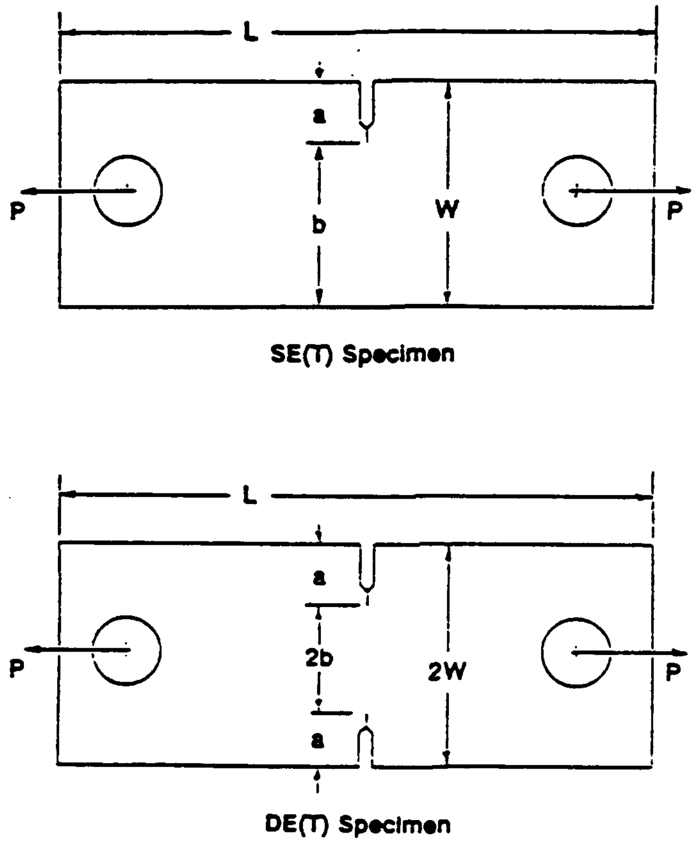

Figure 1 Schematic drawings of the SE(T) and DE(T) geometries tested in this investigation.

5 mm in depth. Then a single large reverse bending load was applied that was calculated to introduce a compressive plastic zone of 0.5 mm in extent. The specimen was then fatigue precracked as usual. The crack length was monitored using a computer controlled servo-hydraulic test machine, and the short crack compliance equation obtained by Joyce (1992), until the final precrack length of approximately 7 mm was obtained. These cracks were found to be straight, and the single load reversal method was much simpler than the double machining process used on the HY-100 short cracked bend specimens. This technique has become standard practice, even on large, shallow cracked bend bars.

The SE(T) specimens were precracked in three point bending, starting with machined notches with a/W = 0.15, and grown to a/W values of between 0.35 and 0.65 for testing. The DE(T) specimens were precracked in four point bending, with two rollers placed tightly across the compression side notch. The initial notch depths were kept at a/W = 0.15 in the DE(T) specimens even though deep cracks were desired so that the ligament during precracking was a large as possible. A tightly fitting wedge was pushed into the compression side notch, and this allowed using standard bend compliance equations for monitoring the crack length of the DE(T) specimens during precracking. The specimens were reversed several times to obtain even precracks on both sides. Matching the bend compliances in the two directions seemed to accurately match the lengths of the two cracks. As a final check the specimen was loaded in tension and the outputs of two clip gages mounted across the two cracks were compared. It was generally found that the bending compliance matched cracks were of equal length and any remaining difference in COD output was usually do to misalignment of the test machine load train.

1.4 Test Technique

All tests were conducted using a single specimen, computer interactive, unloading compliance test procedure which allowed monitoring the specimen crack length and the applied J integral during the course of the test. Equations were presented in Joyce, et al. (1992) for the required elastic and plastic components of the J integral and for estimating the crack length or lengths from the experimentally measured crack opening compliance. A simple rotation correction procedure greatly improves the crack length estimation accuracy of the SE(T) specimen. The rotation correction that is used here is similar to that used in ASTM E1152 for the C(T) specimen, a correction that is, of course, used for the C(T) specimens tested in this work. The SE(T) specimen rotation correction is developed in the next section. The results presented here for the HY-100 alloy SE(T) specimens are altered considerably from that reported previously (Joyce, et al. 1993) because the SE(T) specimen rotation correction is used here.

In all cases, crack growth corrected J equations are used here, as developed in Joyce, et al. (1992), which are similar to those required for the deep SE(B) specimens and the C(T) specimens by ASTM E1152. All data was stored on magnetic media for subsequent re-analysis as needed.

The SE(B) specimens were tested with standard bend fixtures which were made much

Table 2 List of HY-100 specimens tested in this investigation.

Specimen ID	Type	a/W	Side Groove (Y/N)	B (mm)	B_N (mm)	W (mm)
FYO 1	SE(B)	0.66	Y	50.	40.	50.
FYO 3	SE(B)	0.66	Y	50.	40.	50.
FYO 21	SE(B)	0.14	Y	50.	40.	50.
FYO 26	SE(B)	0.13	Y	25.	20.	50.
FYO 27	SE(B)	0.14	Y	25.	20.	50.
FYO 150	SE(B)	0.61	Y	25.	20.	50.
FYO 151	SE(B)	0.61	Y	25.	20.	50.
FYO 158	SE(B)	0.60	Y	12.5	10.	50.
FYO 159	SE(B)	0.62	Y	12.5	10.	50.
FYO 160	SE(B)	0.11	Y	12.5	10.	50.
FYO 161	SE(B)	0.11	Y	12.5	10.	50.
FYO 2SB	SE(T)	0.40	Y	25.	20.	64.
FYO 3SB	SE(T)	0.47	Y	25.	20.	64.
FYO 4SA	SE(T)	0.65	Y	25.	20.	64.
FYO 10SA	SE(T)	0.35	Y	25.	20.	64.
FYO 11SB	DE(T)	0.68	Y	25.	20.	32.
FYO 12SA	DE(T)	0.61	Y	25.	20.	32.

Table 3 List of A533B specimens tested in this investigation.

Specimen ID	Type	a/W	Side Groove? (Y/N)	B (mm)	B_N (mm)	W (mm)
CT3	C(T)	0.6	Y	25.	20.	50.
CT9	C(T)	0.6	Y	25.	20.	50.
CT10	C(T)	0.6	Y	25.	20.	50.
DB1	SE(B)	0.62	Y	25.	20.	50.
DB2	SE(B)	0.62	Y	25.	20.	50.
DB3	SE(B)	0.62	Y	25.	20.	50.
SB1	SE(B)	0.15	Y	25.	20.	50.
SB2	SE(B)	0.15	Y	25.	20.	50.
SB3	SE(B)	0.15	Y	25.	20.	50.
SEN1	SE(T)	0.41	Y	25.	20.	63.5
SEN2	SE(T)	0.38	Y	25.	20.	63.5
SEN4	SE(T)	0.66	Y	25.	20.	63.5
SEN9	SE(T)	0.41	Y	25.	20.	63.5
SEN10	SE(T)	0.62	Y	25.	20.	63.5
SE5D	DE(T)	0.7	Y	25.	20.	31.8
SE6D	DE(T)	0.7	Y	25.	20.	31.8
SE7D	DE(T)	0.68	Y	25.	20.	31.8

sturdier than usual to accommodate the higher loads typical of short crack specimens. The procedures used for the short crack tests were presented by Joyce (1992) which showed clearly that unloading compliance was a viable test technique for SE(B) specimens with a/W as short as 0.1. The compliance equations are much less sensitive in the short crack region, but the load applied increases with $(W-a)^2$ so that for the short crack specimens the unloadings become much larger, and the crack opening displacement (COD) continues to be adequately large and can be measured with a high resolution digital voltmeter. The combination of high loads and less sensitive unloading compliance makes these test more difficult, but if care is taken, excellent results can be obtained. A flex bar was used to measure the load line displacements for all SE(B) specimens as described previously (Hackett and Joyce, 1986) since significant indentations did occur at the rollers for these specimens.

The SE(T) and DE(T) specimens were loaded with oversized tension clevises similar to what is used for standard C(T) specimens. The HY-100 tests were done with clevises that had round holes while the A533B tests were done with clevises that had holes with loading flats to allow for the loading pin to roll as the specimen rotated during test. It was found that allowing the specimen half to rotate freely, and correcting for the rotation effects was the preferred method for the SE(T) tests. For DE(T) specimens, however, it was found that round holes were preferred, providing an initial alignment that was essential to accurately test the DE(T) specimen both at the start of test and as crack growth proceeded. For the SE(T) specimens a standard clip gage was installed to measure the crack mouth opening displacement, which was used for crack length estimation, and an LVDT gage was installed on the initial specimen load line to measure the load line extension of the specimen. For the DE(T) specimen, two COD gages were used as well as an LVDT gage on the specimen centerline. In general the average COD displacement was used to estimate the average crack length for the DE(T) specimen. Both COD gage readings were recorded in the data file and can be plotted separately, if desired.

2.0 ANALYSIS

2.1 J Integral Analysis

The J integral is calculated here by summing the elastic and plastic components, with the components calculated separately. The elastic J component, J_{el}, is calculated from:

$$J_{el} = \frac{K^2}{E'} \tag{1}$$

where K is the elastic stress intensity factor for the specimen, $E' = E/(1-\nu^2)$, and E and ν are the elastic modulus and Poisson's ratio, respectively. The plastic J component, J_{pl}, is calculated using the ASTM Standard E1152 J_{pl} equation:

$$J_{pl(i)} = J_{pl(i-1)} + \frac{\eta_i}{b_i}\left[\frac{A_{pl(i)} - A_{pl(i-1)}}{B_N}\right]\left[1 - \frac{\gamma_i\,(a_i - a_{(i-1)})}{b_i}\right] \tag{2}$$

with:

A_{pli} = area under the load versus plastic load line displacement curve to increment i,
B_N = net specimen thickness at the side groove roots,
η_i = the plastic η factor at crack length a_i
b_i = the incremental remaining ligament
W = the specimen width and

$$\gamma_i = \left[\eta_i - 1 - \frac{b_i}{W}\,\frac{\eta_i'}{\eta_i}\right] \tag{3}$$

evaluated at the crack length a_i, and:

$$\eta_i' = d\eta_i/d(a_i/W) \tag{4}$$

Formulas for the K's, η's, and γ's used for the SE(B), SE(T), and DE(T) specimens are presented in the next subsections.

2.2 SE(B) Analysis

Previous work by Joyce (1992) has shown that unloading compliance can be used to evaluate J-R curves for short crack bend specimens. As the crack becomes very short the compliance equation becomes less sensitive to crack length but the specimen limit load also increases, which increases the length of the allowed elastic unloading, and the total effective crack length measurement resolution is only slightly degraded. Results obtained by Joyce (1992) appeared to be fully adequate for J_{Ic} and J-R curve testing for a/W ratios as small as 0.15. In this work similar success was found for a/W ratios as small as 0.1. To test in this a/W range a new equation to estimate crack length from the specimen COD compliance is needed since the equation available in ASTM E813 and E1152 does not apply for a/W ratios below 0.4. An equation for bend specimen compliance as a function of a/W that is good for all a/W is available in *The Stress Analysis of Cracks Handbook* (*The Handbook*) (Tada, Paris and Irwin 1985). This equation is:

$$\frac{\delta}{P} = \frac{24(a/W)}{\left(\frac{BWE'}{S/4}\right)}\left[0.76 - 2.28\left(\frac{a}{W}\right) + 3.87\left(\frac{a}{W}\right)^2 - 2.04\left(\frac{a}{W}\right)^3 + \frac{0.66}{(1-a/W)^2}\right] \tag{5}$$

where: δ = crack mouth opening displacement at the specimen edge
P = load
B = specimen thickness
S = specimen span

For the short crack range a reverse fit to calculate the crack size, a/W, from the measured compliance was obtained by Joyce (1992) using a standard fifth order polynomial by restricting the a/W range to between 0.05 and 0.45. The fit is accurate to within 0.06% which is acceptable for the unloading compliance method. The Joyce relationship is:

$$\frac{a}{W} = 1.01878 - 4.5367u + 9.0101u^2 - 27.333u^3 + 74.4u^4 - 71.489u^5$$

$$u = \frac{1}{\left(\frac{B_e WE'C}{S/4}\right)^{1/2} + 1} \tag{6}$$

where C = unloading compliance, δ/P, and has been used for the short crack SE(B) specimens presented below. The standard equation of ASTM E1152 was used for the deep cracked bend specimens analyzed below.

For the deep cracked SE(B) specimens the η and γ factors of ASTM E1152, (η = 2.0 and γ = 1.0), are used in Eq. 2 to evaluate J. For the short crack specimens, however, these coefficients must be changed to accurately evaluate J. This problem has been investigated by Haigh and Richards (1974), Sumpter (1987), and by Joyce (1992). A comparison of various estimates of η is shown in Figure 2 which includes results of the above authors and results derived by Joyce (1992) from *Elastic-Plastic Fracture Analysis (EPRI Handbook)* (Kumar, German and Shih 1981). The ABAQUS results were obtained by Joyce (1992) using a 2D elastic plastic finite element analysis incorporating incremental plasticity. In the work that follows the polynomial function for η_i developed by Sumpter (1987) is used for all short cracked SE(B) specimens with a/W < 0.282. This polynomial expression is:

$$\eta = 0.32 + 12(a/W) - 49.5(a/W)^2 + 99.8(a/W)^3 \tag{7}$$

This equation gives $\eta < 2.0$ for a/W < 0.282. Sumpter switches to $\eta = 2.0$ when the crack length exceeds a/W = 0.282. In this work the short crack specimens were started and completed with a/W < 0.282. Equation (7) was used because it was complete in the range of interest and because of the correspondence with the *EPRI Handbook* results.

The γ factor is calculated from η using Eq. 3. For the short crack specimens γ was obtained by differentiating Eq. (7) to give:

$$\gamma = \frac{-12.22 + 106.7\left(\frac{a}{W}\right) - 236.6\left(\frac{a}{W}\right)^2 - 924.6\left(\frac{a}{W}\right)^3 + 4845.4\left(\frac{a}{W}\right)^4 - 9880\left(\frac{a}{W}\right)^5 + 9960\left(\frac{a}{W}\right)^6}{0.32 + 12\left(\frac{a}{W}\right) - 49.5\left(\frac{a}{W}\right)^2 + 99.8\left(\frac{a}{W}\right)^3} \tag{8}$$

Recent work by Kirk and Dodds (1993) has suggested that J should be calculated using an η_{COD} based on the crack mouth opening displacement rather than on the load line displacement. Kirk and Dodds show with computational calculations that η_{COD} is much less dependent on strain hardening than is the standard load line η. The equation used then to calculate J using η_{COD} is:

$$J = J_{el} + \frac{\eta_{COD} A_{CODpl(i)}}{b_i B_N} \tag{9}$$

where: $A_{CODpl(i)}$ = area under the load versus plastic crack opening displacement curve to increment i.

This equation does not include the crack growth correction term used in all other equations in this work, and this causes it to have serious problems since the crack growth correction is essential for the development of a correct J-R curve beyond 1 mm of crack growth.

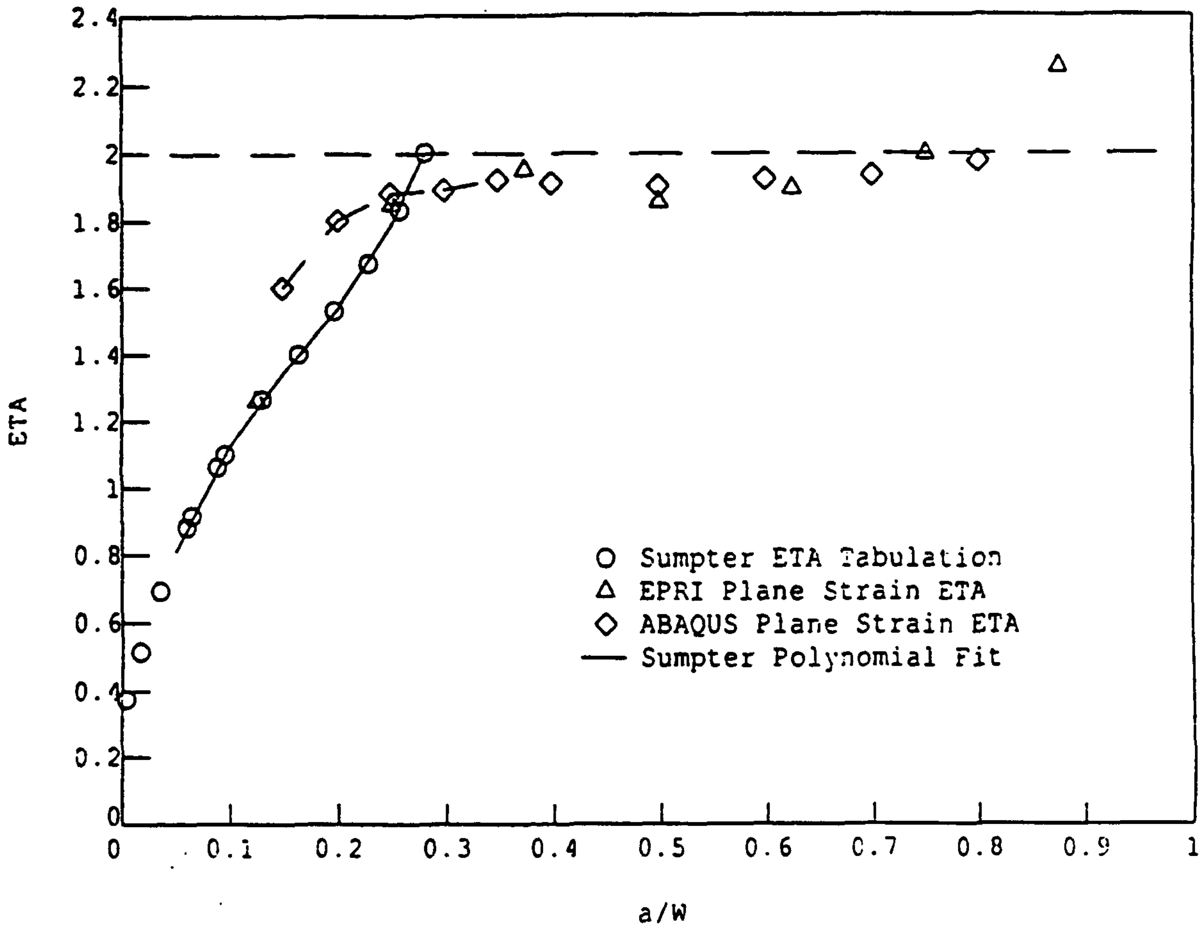

Figure 2 Predicted plastic η factors for SE(B) specimens.

2.3 SE(T) Analysis

For unloading compliance testing of SE(T) specimens equations are required for K, η, and γ, as functions of a/W. The equations used in this work are presented in the following sections.

2.3.1 SE(T) K Expression

Since the SE(T) specimens tested here had pin loading, the K expressions for fixed end loading in *The Handbook* were checked with ABAQUS finite element analysis. A total of 14 different SE(T) finite element grids were developed with $0.12 \le a/W \le 0.80$. These grids were used to develop both the elastic stress intensity factor K and the plastic η factor as described below. The stress intensity factor relationship was assumed to have the form:

$$K = \sqrt{\pi a}\,\frac{P}{WB}\,F\left(\frac{a}{W}\right) \tag{10}$$

and F(a/W) was fit with a polynomial to give:

$$\begin{aligned} F(a/W) = -0.0917 + 22.392(a/W) - 141.96(a/W)^2 + 449.72(a/W)^3 \\ - 645.59(a/W)^4 + 363.52(a/W)^5 \end{aligned} \tag{11}$$

This equation fit the ABAQUS results within ±2% over the a/W range from 0.12 to 0.80. A comparison is presented in Figure 3 with the ABAQUS results and a standard form taken from *The Handbook.* Clearly *The Handbook* equation, the polynomial fit, and the ABAQUS results agree very well in the range of $0.12 \le a/W \le 0.80$. In the experimental work presented below the polynomial form for F(a/W) presented in Eq. (10) has been used for all SE(T) specimens.

2.3.2 SE(T) η Factor

In Joyce, et al. (1992) several methods were used to estimate the η for the SE(T) specimen including elastic-plastic finite elements analysis, the *EPRI Handbook*, and published results by Wu, et al. (1990) and Sharobeam, et al.(1991). A comparison of all of these results from Joyce, et al. (1992) is shown in Figure 4.

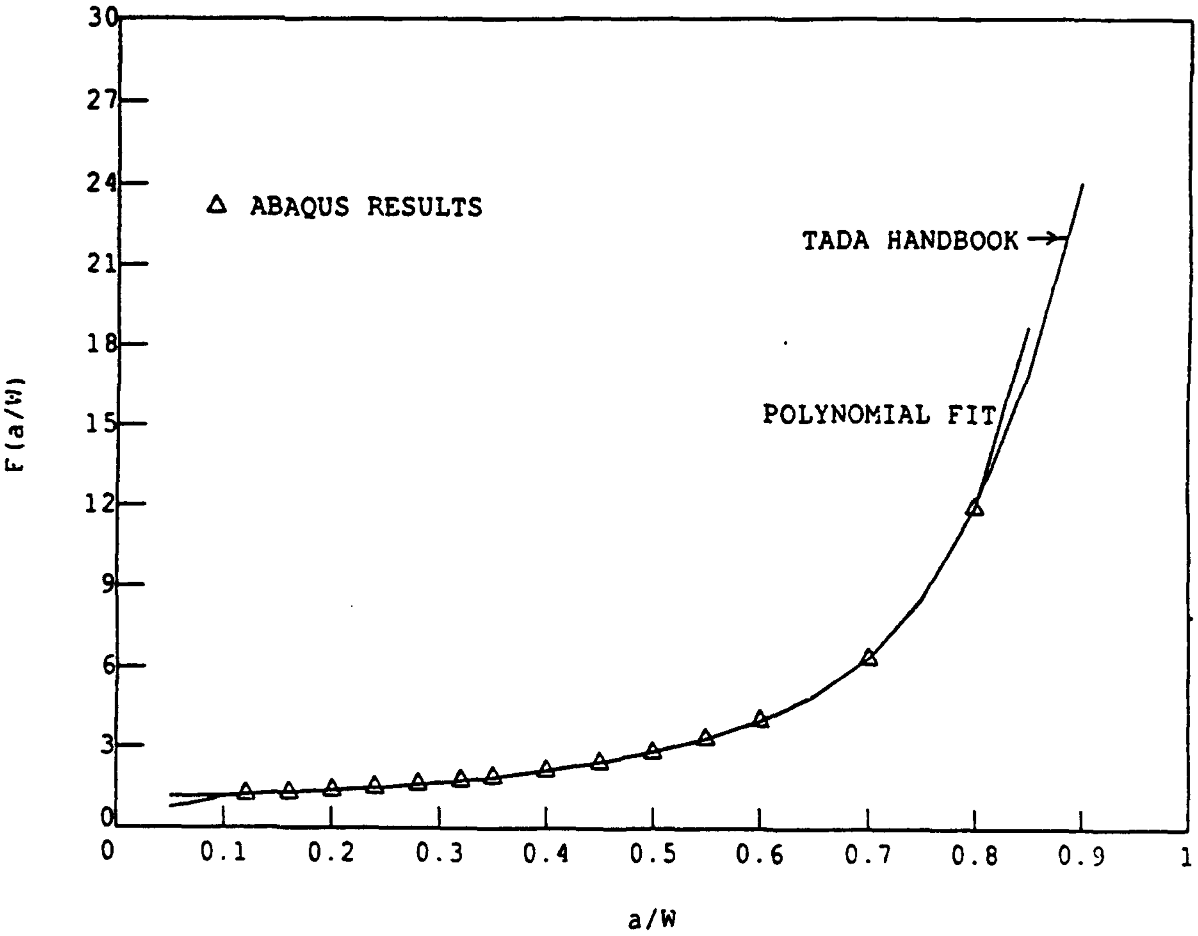

Figure 3 Comparison of stress intensity factor relationships for the SE(T) specimen.

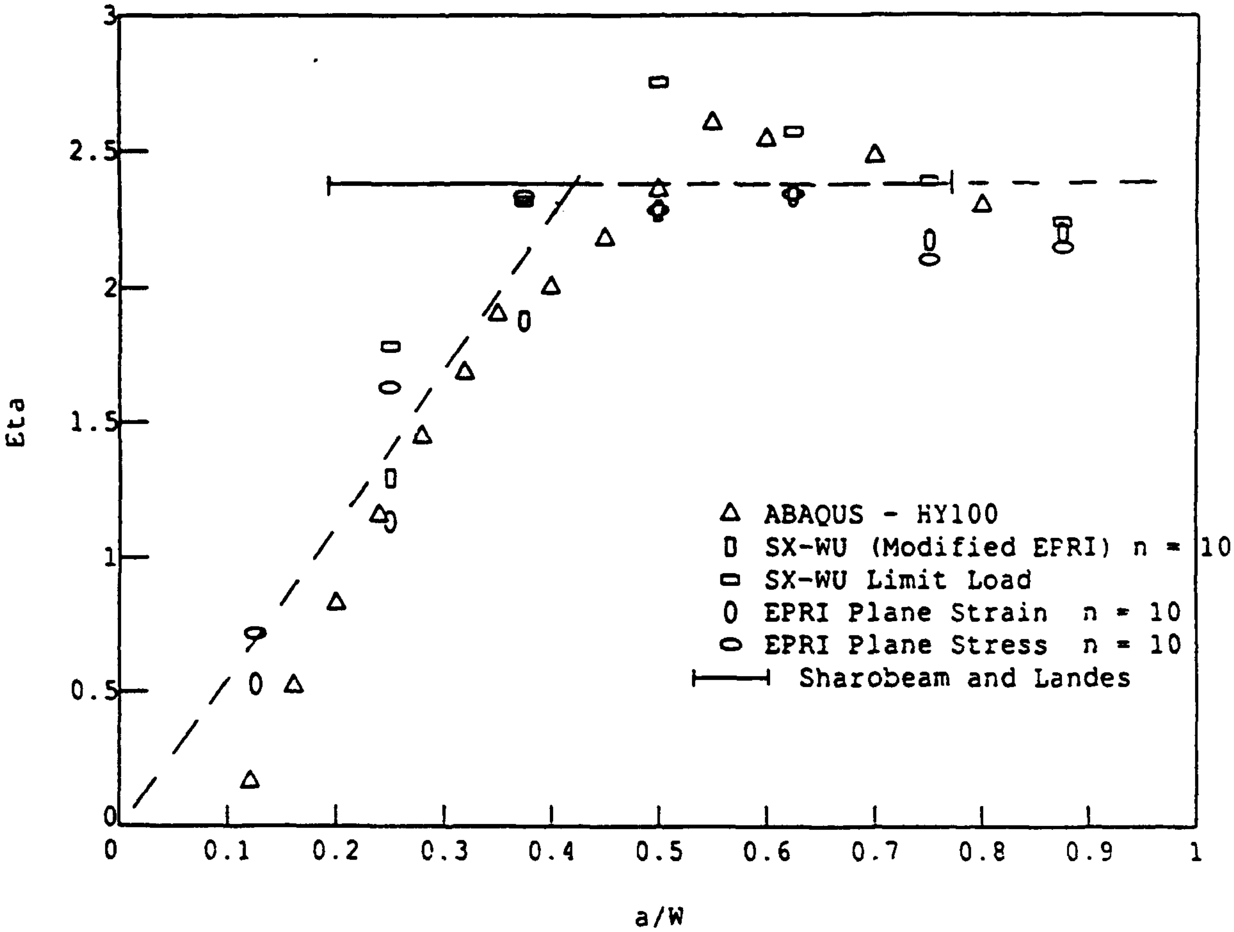

Figure 4 Predicted plastic η factors for the SE(T) geometry

In the experimental work that follows the dashed bi-linear relationship shown in Figure 4 was used to evaluate η_i at each crack length a_i. This form also allowed calculating γ_i, from Eq. (3) which is necessary to calculate J_{pl} using Eq. (2). The equations used to evaluate η_i and γ_i for the SE(T) specimen are thus:

$$\eta_i = 5.71\ (a_i/W) \qquad 0 \le a_i/W \le 0.417 \tag{12}$$

$$\eta_i = 2.38 \qquad 0.417 < a_i/W \le 1.0 \tag{13}$$

$$\gamma_i = \eta_i - 1 - (b_i/W)\left(\frac{5.71}{\eta_i}\right) \qquad 0 < a_i/W \le 0.417 \tag{14}$$

$$\gamma_i = 1.38 \qquad 0.417 < a_i/W \le 1.0 \tag{15}$$

2.3.3 SE(T) Crack Length Estimation

Since the SE(T) specimen is of a rather short length and has the load applied through the centered pin holes, the compliance equations in standard fracture mechanics handbooks like *The Handbook* are not necessarily applicable. The standard forms available assume uniform stresses at the loading edges and the SE(T) configuration used here was not thought to be long enough to allow the direct use of equations based on the uniform stress assumption. A finite element analysis was used in Joyce, et al. (1992) to develop a polynomial equation giving the crack length as a function of the COD compliance for the SE(T) specimen geometry used here. This equation has the form:

$$\begin{aligned} a/W = {} & 1.012525 - 2.95323(u')^1 + 6.68(u')^2 - 17.7954(u')^3 \\ & + 25.3517(u')^4 - 12.9747(u')^5 \end{aligned} \tag{16}$$

with:

$$u' = \frac{1}{1 + \sqrt{\dfrac{E'B\delta}{P}}} \tag{17}$$

For side grooved specimens the thickness B is replaced by B_e where:

$$B_e = B - \frac{(B - B_n)^2}{B} \tag{18}$$

where B_n is the net specimen thickness at the side groove roots. This effective thickness formulation is consistent with ASTM E813 and E1152.

2.3.4 SE(T) Rotation Correction

A rotation correction can be developed for the SE(T) specimen using the notation of Figure 5. Two separate corrections are needed, one to correct the knife edge COD displacement for the effect of rotation, the second to correct the load for the effect of rotation (Loss 1977; Merkle, 198x).

The objective of the first correction is to correct the measured displacement, $\Delta d_{m/2}$ increment during an unloading to obtain the corrected displacement increment, $\Delta d_{c/2}$, as shown in Figure 5a. Using the geometry of Figure 5a, the rotation angle, θ, is:

$$\theta = \sin^{-1}\left[\frac{(d_{m/2} + D)}{(D^2 + R_G^2)^{1/2}}\right] - \tan^{-1}\frac{D}{R_G} \tag{19}$$

Using similar triangles, it can be shown that :

$$\frac{\Delta d_{c/2}}{\Delta d_{m/2}} = \frac{R}{R - y} \tag{20}$$

where y is the horizontal shift of the displacement measurement point due to rotation of the specimen. The quantity (R-y) is obtained from the relationship

$$\cos(\theta + \beta) = \frac{R-y}{\sqrt{D^2 + R^2}} \tag{21}$$

Using the identity for cos(x+y)

$$\cos(\theta + \beta) = \cos\theta\cos\beta - \sin\theta\sin\beta \tag{22}$$

and noting that

$$\sin\beta = \frac{D}{\sqrt{D^2 + R^2}} \qquad \cos\beta = \frac{R}{\sqrt{D^2 + R^2}} \tag{23}$$

eq. (21) can be solved for (R-y). Substituting the resulting expression for (R-y) into (20) and rearranging terms leads to the following expression

$$\frac{d_{c/2}}{d_{m/2}} = \frac{1}{\left(\cos\theta - \frac{D}{R}\sin\theta\right)} \tag{24}$$

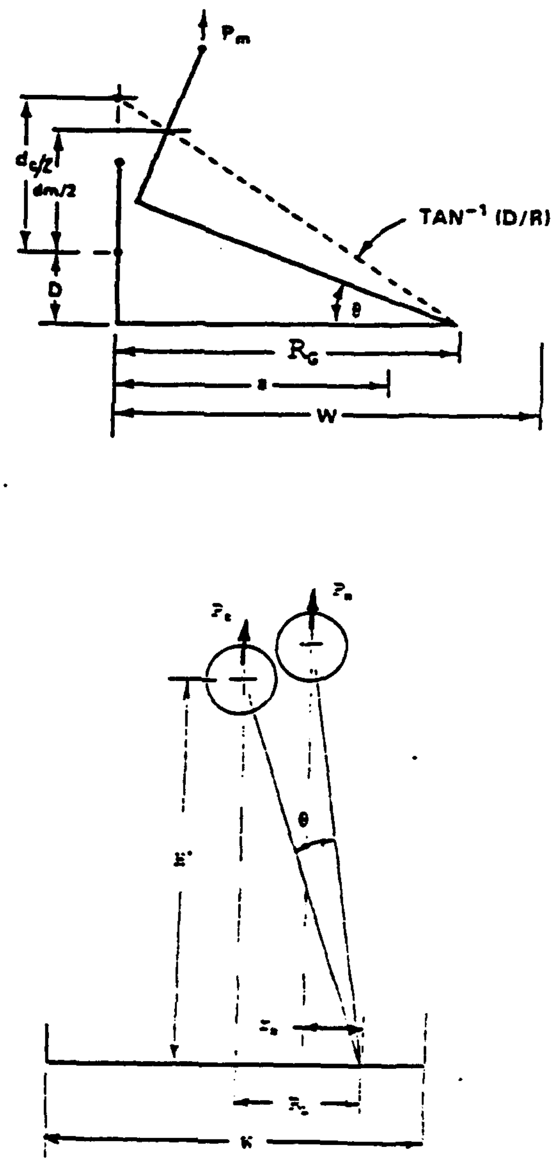

Figure 5 Geometric relationship of variables used in rotation correction development.

The load rotation correction is obtained by requiring:

$$P_c R_L = P_m R_m \tag{25}$$

where P_m is the measured load and P_c is the corrected load. From Figure 5b,

$$R_m = R_L \cos\theta - H^* \sin\theta \tag{26}$$

Substituting and reducing gives:

$$\frac{P_c}{P_m} = (\cos\theta - \frac{H^* \sin\theta}{R_L}) \tag{27}$$

Combining these correction factors gives:

$$C_c = \frac{C_m}{(\cos\theta - \frac{D\tan\theta}{2R_G})(\cos\theta - \frac{H^* \sin\theta}{R_L})} \tag{28}$$

This equation was used to correct the measured compliance C_m to obtain the corrected compliance C_c before calculation of the estimated crack length for the partial unloading.

It was also necessary to apply a rotation correction to the load line compliance so that accurate separation of the measured J into elastic and plastic components was possible. This correction is effectively just the load component of the COD correction of Eq. 29 giving:

$$C_{LLDc} = \frac{C_{LLDm}}{(\cos\theta - \frac{H^* \sin\theta}{R_L})} \tag{29}$$

This equation was used to correct the measured load line compliance C_{LLDm} to obtain the corrected load line compliance, C_{LLDc}, before calculating the elastic and plastic area components used to calculated the elastic and plastic J components.

To use this analysis it is necessary to assume a position for the center of rotation for the SE(T) specimen. In the standard C(T) analysis of ASTM E1152 the center of rotation is assumed to be at the center of the remaining ligament, and that assumption was also used here, i.e. $R_G = (a + W)/2$ and $R_L = R_G - W/2$.

2.4 DE(T) Analysis

For unloading compliance testing of the DE(T) specimens, equations are required for calculation of K, η, and γ as functions of a/W and for a/W as a function of the COD compliance, δ/P. The equations used for this project are presented in the following sections.

2.4.1 DE(T) K Expression

The K equation for the DE(T) specimen with a deeply cracked geometry can be taken directly from *The Handbook*. The equation used has the form:

$$K = \sqrt{\pi a}\left[\frac{P}{2WB}\right]F(a/W) \tag{30}$$

with:

$$F(a/W) = \frac{1.122 - 0.561\left(\frac{a}{W}\right) + 0.205\left(\frac{a}{W}\right)^2 + 0.471\left(\frac{a}{W}\right)^3 - 0.19\left(\frac{a}{W}\right)^4}{\sqrt{1 - a/W}} \tag{31}$$

This equation should be accurate to ±0.5% for any a/W, but is limited to a/W > 0.6 by the pin hole loading. Three finite element computations by Joyce et al.(1992) showed that this equation is accurate within ±2% for deeply cracked DE(T) specimens including the center pin holes.

2.4.2 DE(T) η and γ Factors

The η factor for the DE(T) specimen geometry was obtained from both elastic-plastic finite element analysis using ABAQUS and from the *EPRI Handbook*. The η factor used here is taken to relate the J integral at each crack to the total plastic work applied to the specimen, i.e.:

$$J_{pl} = \frac{\eta A_{pl}}{Bb} \tag{32}$$

where:

A_{pl} = plastic area under the specimen load versus plastic load line displacement plot
b = specimen half remaining ligament
B = specimen thickness
η = plastic η factor.

Analytical work by Wu, et al. (1990) based on limit load theory, shows that η should be nearly constant for the DE(T) specimen over the a/W range of interest here. A value of approximately 0.27, instead of the usual 2.0, is also predicted in Wu, et al. (1990) with only a very slight dependence on strain hardening. These predictions are confirmed here by both the finite element analysis and the EPRI analysis.

Deeply notched DE(T) specimens with three different crack sizes were analyzed using finite elements and the results shown in Figure 6, compared to the results of Wu, et al. (1990) Other results shown on Figure 6 include calculations from the *EPRI Handbook*. The agreement is excellent.

For the experimental work described below a constant value of η was used for all tests. DE(T) specimens were restricted to $0.6 \leq a/W \leq 0.9$ and for all tests η was set equal to 0.27 while γ was taken as $(\eta - 1)$ or -0.73. The negative γ did not have a strong effect on these tests because of the small amount of crack extension investigated using the DE(T) specimens.

2.4.3 DE(T) Crack Length Estimation

The DE(T) specimen is tested with a small remaining ligament, generally in the range of $0.6 \leq a/W \leq 0.9$. In this range *The Handbook* compliance equation would be very accurate even for the pin loaded specimen used here. The compliance equation used has the form:

$$\delta/P = \frac{24a}{E'}\frac{V(a/W)}{WB} \tag{33}$$

with:

$$V(a/W) = \frac{1}{u^*}\{0.454\sin u^* - 0.065\sin^3 u^* - 0.007\sin^5 u^* + \cosh^{-1}[\sec(u^*)]\} \tag{34}$$

where:

$$u^* = \frac{\pi a}{2W} \tag{35}$$

This equation must be inverted to be used for unloading compliance. This inversion can be performed in a standard fashion to give a polynomial compliance equation of the form:

$$a/W = 0.0955026 - 0.097503\nu' + 0.245981(\nu')^2 - 0.115274(\nu')^3 + 0.0205763(\nu')^4 - 0.0013593(\nu')^5 \tag{36}$$

with:

$$\nu' = \frac{E'B\delta}{P} \tag{37}$$

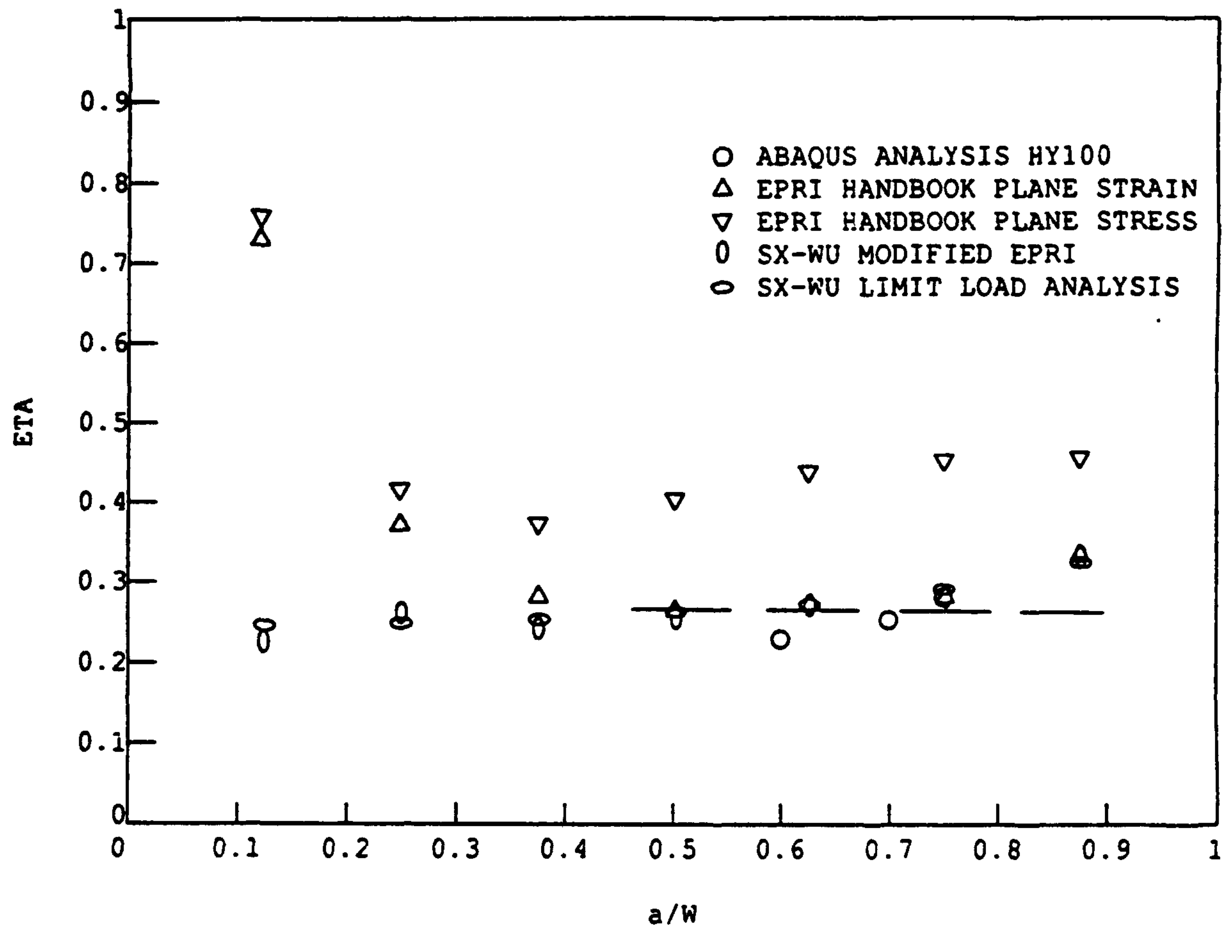

Figure 6 Predicted plastic η factors for the DE(T) specimen.

2.5 Constraint Correlations

Recently two quantities have been proposed to quantify the "constraint" present for a given combination of crack geometry, mode of loading, and material toughness. These are the "T-stress" approach (Betégon and Hancock 1992, Al-Ani and Hancock 1991) and the Q parameter of O'Dowd and Shih (1991,1992). These two quantities are described and utilized separately in the next two subsections.

2.5.1 T Stress Indexing Parameter

The linear elastic crack tip stress field for a crack along the negative x-axis, with its tip at the origin, has the form:

$$\sigma_{xx} = \frac{K}{\sqrt{2\pi r}} f_{xx}(\theta) + T_\sigma \tag{38}$$

$$\sigma_{yy} = \frac{K}{\sqrt{2\pi r}} f_{yy}(\theta) \tag{39}$$

$$\sigma_{xy} = \frac{K}{\sqrt{2\pi r}} f_{xy}(\theta) \tag{40}$$

where the T_σ term is the only term of order r^0 that exists, and it only affects σ_{xx}. Larsson and Carlsson (1973) showed that the sign and magnitude of this term does alter the size and shape of the plastic zone, and recently Betegón and Hancock (1992) and Al-Ani and Hancock (1991) have suggested that the amplitude of the T_σ term may be an effective constraint indexing parameter, even in the elastic-plastic regime. They show that low constraint geometries like short crack or tensilely loaded geometries have different T_σ values than deep cracked bend geometries, and they suggest that the T_σ difference causes higher apparent toughnesses to be found in such cases.

To assess the effect of T_σ, a biaxiality parameter is used having the form

$$\beta = T_\sigma \frac{\sqrt{\pi a}}{K} \tag{41}$$

This quantity has been evaluated for various test geometries using finite element and other methods and is available in the literature (Leevers and Radon 1982, Kfouri 1986, Sham 1991). Results for SE(B), SE(T), and DE(T) specimens are shown in Figure 7. For convenience, this data has been used to develop polynomial relationships giving β in terms of a/W:

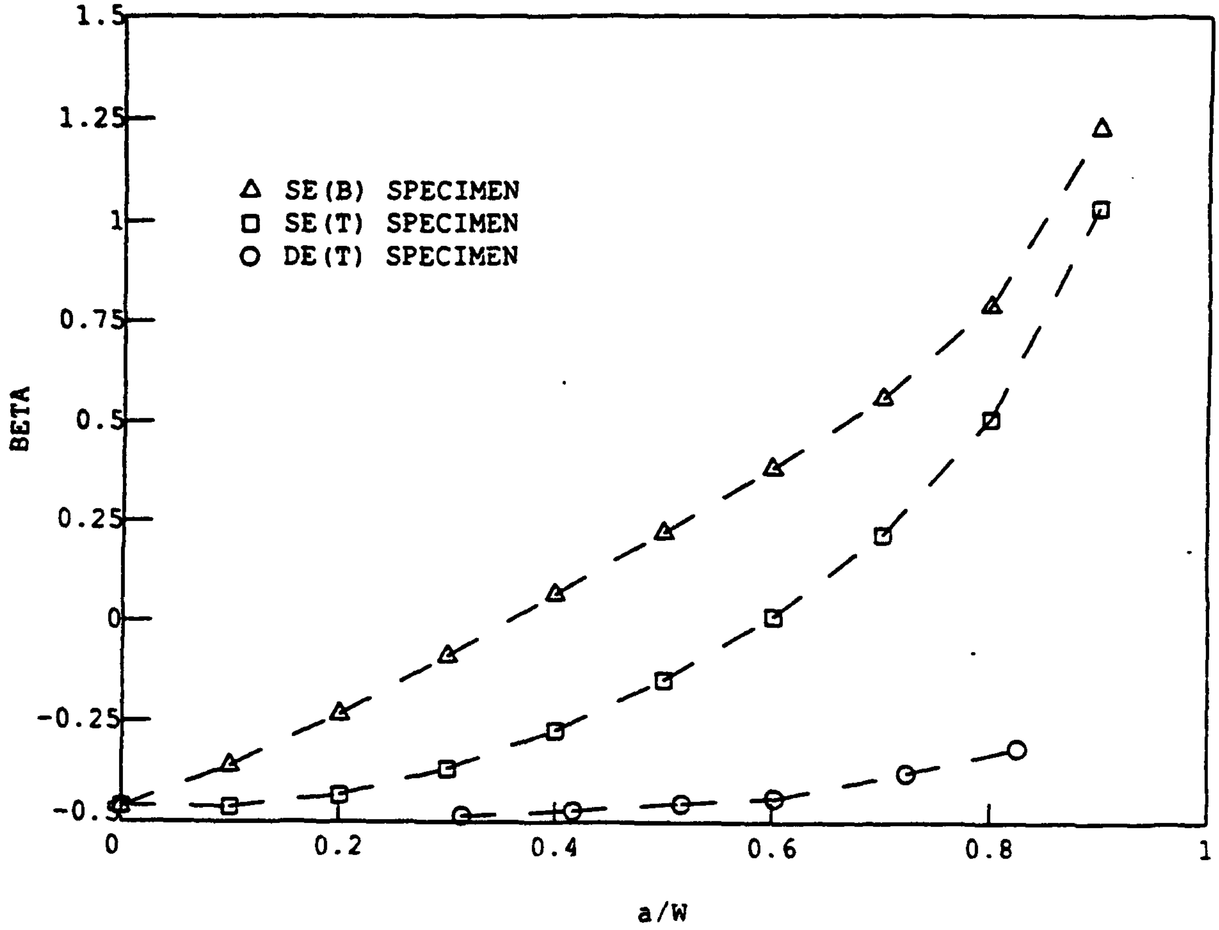

Figure 7 Biaxiality factor, β, for three specimen geometries.

SE(B):

$$\beta = -0.463 + 1.1207\left(\frac{a}{W}\right) - 1.4441\left(\frac{a}{W}\right)^2 + 11.264\left(\frac{a}{W}\right)^3 - 20.950\left(\frac{a}{W}\right)^4 + 12.5\left(\frac{a}{W}\right)^5 \tag{42}$$

SE(T):

$$\beta = -0.463 + 0.1012\left(\frac{a}{W}\right) - 1.6844\left(\frac{a}{W}\right)^2 + 13.344\left(\frac{a}{W}\right)^3 - 21.926\left(\frac{a}{W}\right)^4 + 12.5641\left(\frac{a}{W}\right)^5 \tag{43}$$

DE(T):

$$\beta = -0.5844 + 0.6249\left(\frac{a}{W}\right) - 1.3527\left(\frac{a}{W}\right)^2 + 1.2031\left(\frac{a}{W}\right)^3 \tag{44}$$

Using these relationships the value of β for each test geometry in this study has been calculated as shown below. Using the relationships for K as a function of load and a/W the T_σ value at the crack initiation (J_{Ic}) point, has also been evaluated for each specimen tested. These results will be discussed in subsequent sections.

2.5.2 The Q Indexing Parameter

The Q parameter has been proposed by O'Dowd and Shih (1991,1992) as an extension of the T_σ concept to deformation plasticity. They take the second term of the stress fields around the crack tip in a power law hardening material and propose that its intensity can be represented by a Q parameter, and that this parameter can be used to index the relative constraint of a test geometry. The authors basically relate the "true" finite body stress components in front of the crack to those of the small scale yielding (SSY), infinite body case in the form:

$$\sigma_{xx} = \sigma_{xx}|_{SSY} + Q\sigma_o \tag{45}$$

$$\sigma_{yy} = \sigma_{yy}|_{SSY} + Q\sigma_o \tag{46}$$

$$\sigma_{xy} = \sigma_{xy}|_{SSY} \tag{47}$$

where σ_0 is the power law material yield stress and Q is a dimensionless parameter found by O'Dowd and Shih to be between 0.2 and -2, in front of the crack. Q must be evaluated using precise finite element techniques so that the differences between the true stress field and the SSY stress field can be accurately determined. Results for Q for the SE(B) geometry from O'Dowd and Shih (1992) for the case of n = 10 are shown in Figure 8, and used to estimate Q values for

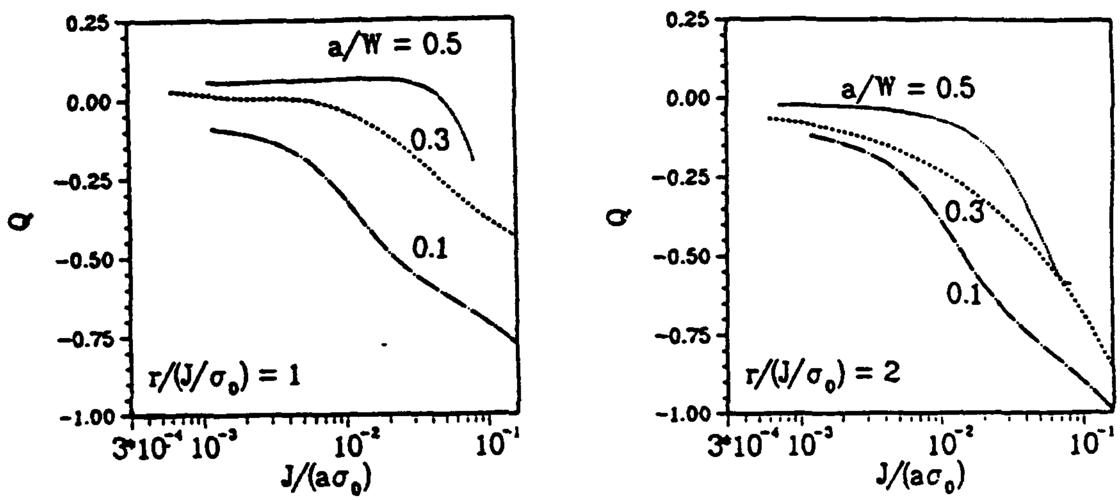

Figure 8 The Q constraint factor for SE(B) specimens with short and deep cracks, n=10 (O'Dowd and Shih, 1992).

the SE(B) specimens tested in this program. Q values for the SE(T) and DE(T) specimens have been obtained from analysis provided by Dodds[1] as shown in Figure 9-11 for two SE(T) and one DE(T) geometry.

2.6 Calculation of J_{Ic}

In order to compare J_{Ic} across a range of specimen types, special care had to be taken in its evaluation. The J_{Ic} value calculated is dramatically affected by the initial crack length, a_0, used to calculate the crack extension, Δa, during the test. The ASTM Task Group E8.08.03 has proposed a method to utilize the initial test data to determine a best a_o for use in calculating Δa and hence in J_{Ic} calculations[2]. The proposed method involves fitting a straight line of slope $2\sigma_Y$ to the initial J - Δa data, and choosing the best fit line to the data in the interval $0.2J_Q \leq J \leq 0.6J_Q$. Since the choice of a_o affects the subsequent J_Q value, an iterative process is necessary to obtain the final best fit a_o, J_Q, and hence a J_{Ic} value from a particular experimental data set. The proposed method also adds the requirement that at least three data pairs exist in the region $0.2J_Q \leq J \leq 0.6J_Q$ so relatively dense data is required for a_o and J_{Ic} evaluation.

This method was initially used in this program, but it was found that the method disqualified some specimens due to a lack of data in the region $0.2J_Q \leq J \leq 0.6J_Q$. In place of the above ASTM method an alternative method was developed that was not so dependent on the early data on the J-R curve. In this method the relationship:

$$a_i = a_o + AJ_i^2 + BJ_i^3 \qquad (48)$$

was fit to the a_i - J_i data of each set from the minimum a_i to a_i + 2.5 mm of crack growth, as shown in Figure 12. A least squares procedure was used to evaluate the coefficients a_0, A, and B, and the a_o parameter was the desired, best-fit, initial crack length which was then used to calculate the Δa_i quantities for the J-R curve. This method worked well on all specimens analyzed here and in all cases adequate data was available for the fit, no iteration was needed, and the least squares technique gave a unique and fully defined average crack length for each specimen, while the proposed ASTM method gives only a range from which each investigator could chose a somewhat different result based on the details of his iteration procedure.

[1]Private communication, R.H. Dodds, Jr. 1993.

[2] "New Standard Method for J-Integral Characterization of Fracture Toughness," Draft Standard of ASTM Subcommittee E08.08, March 1993, American Society for Testing and Materials, Philadelphia, PA.

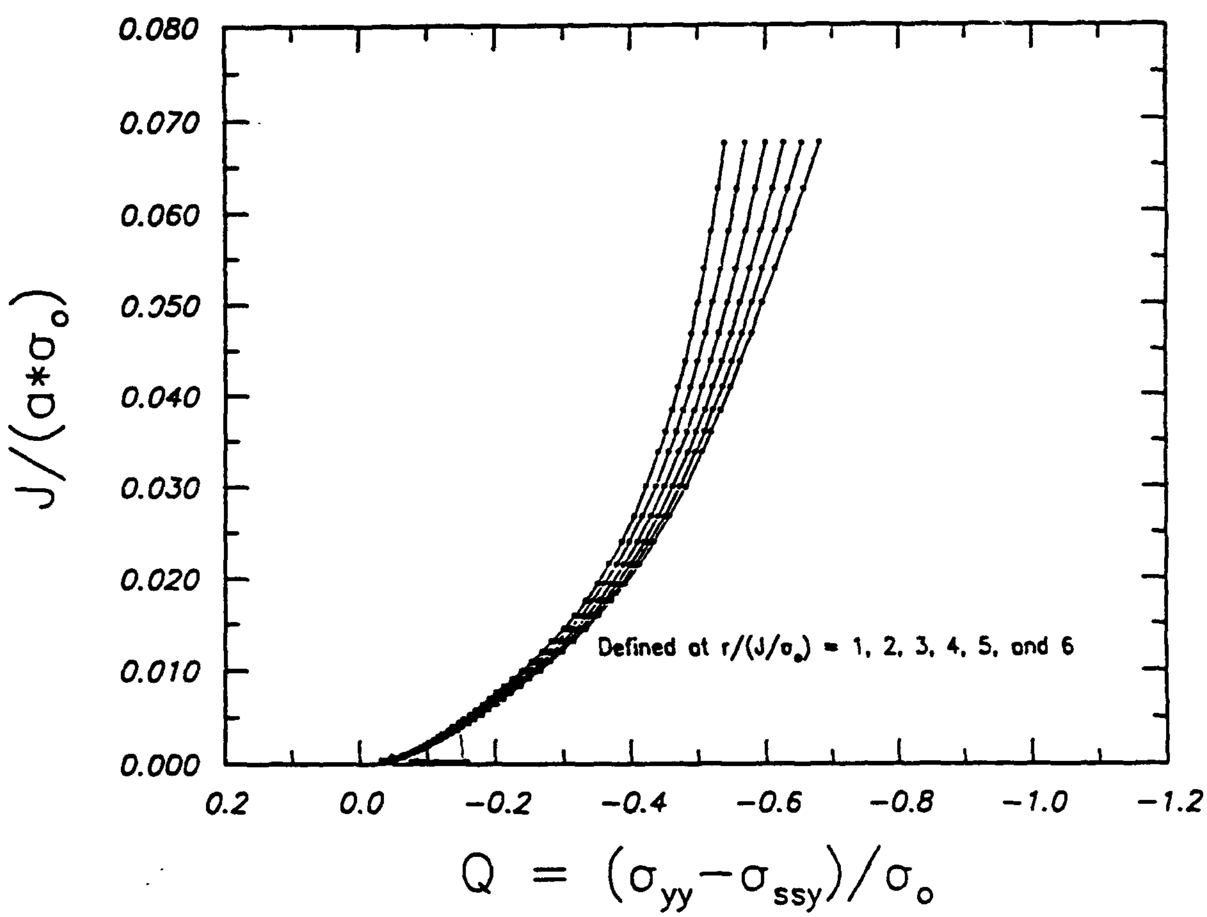

Figure 9 The Q constraint parameter for the SE(T) specimen with a/W=0.4, n=10 (R.H. Dodds, Private Communication).

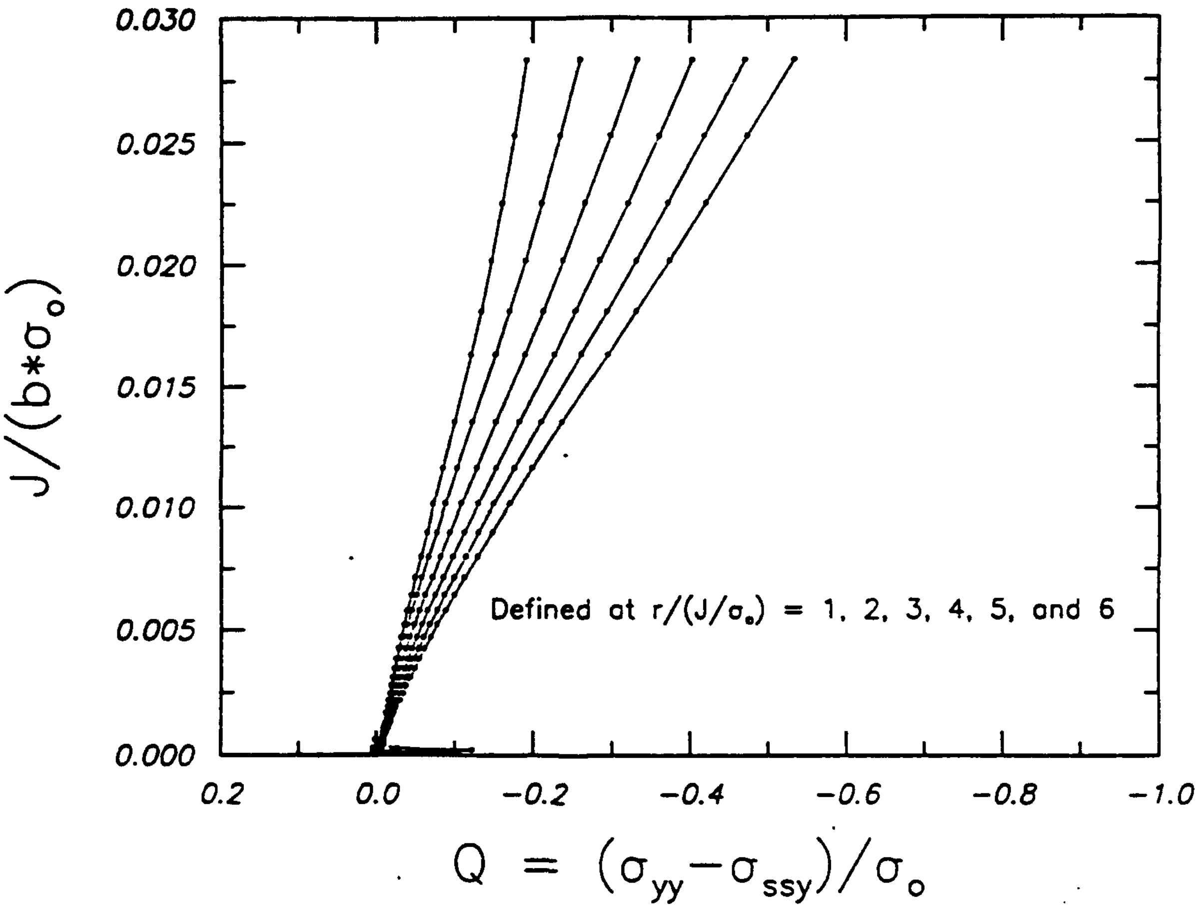

Figure 10 The Q constraint parameter for the SE(T) specimen, a/W=0.6, n=10 (R.H. Dodds, Private communication).

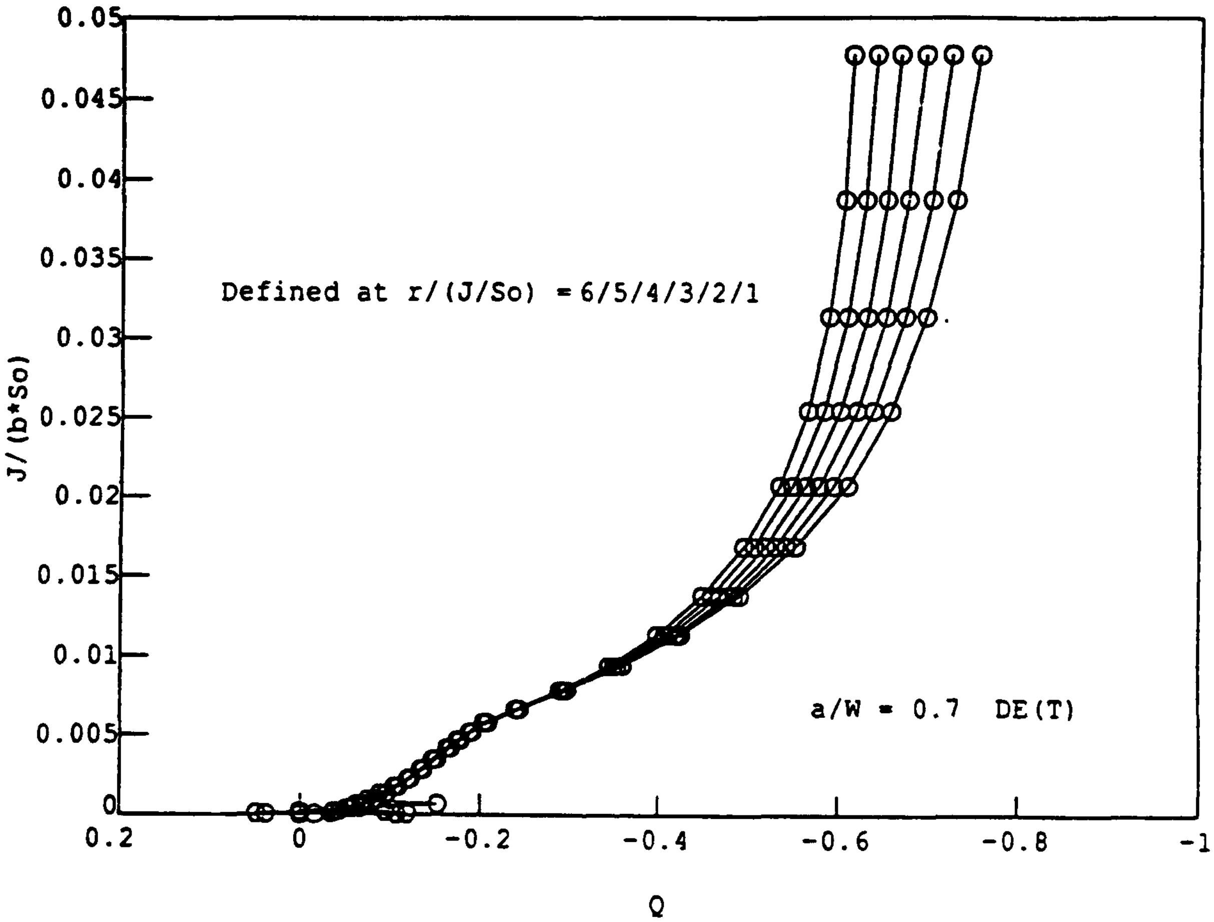

Figure 11 The Q constraint parameter for the DE(T) specimen with a/W=0.7, n=10 (R.H. Dodds, Private communication).

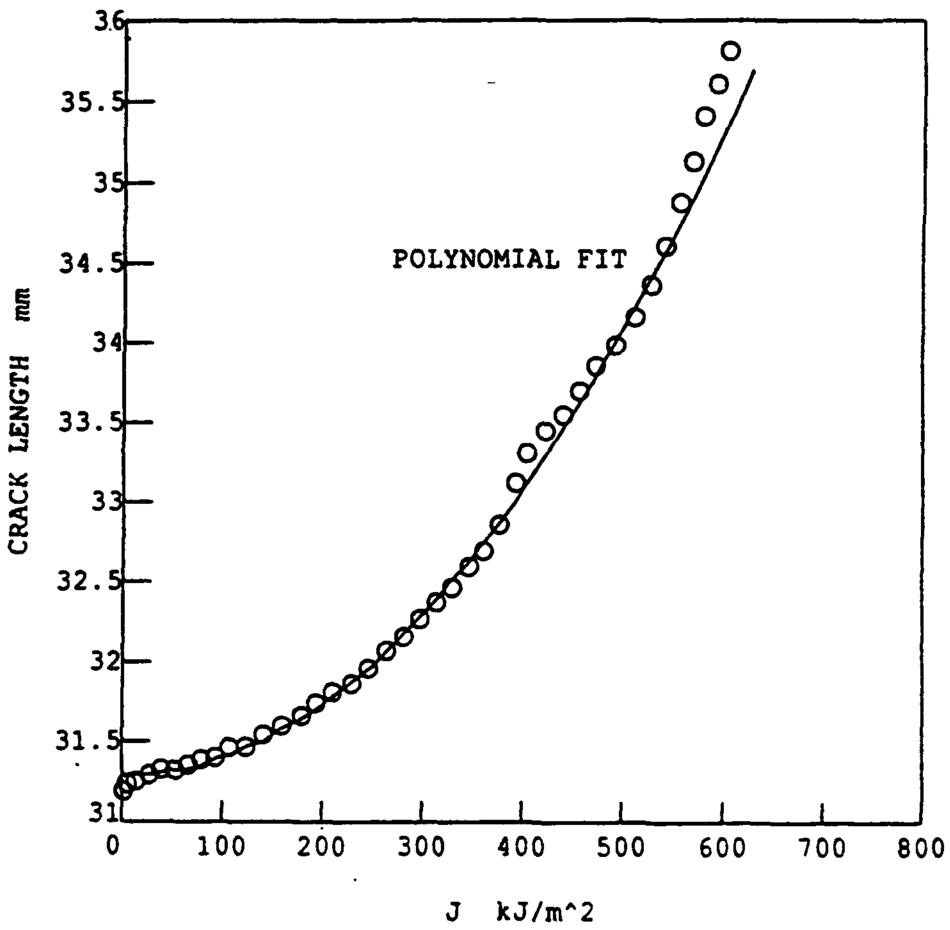

Figure 12 Polynomial fit of crack length versus J for determining the best-fit initial crack length, a_o.

3.0 DISCUSSION

3.1 The Rotation Correction

The SE(T) specimens were a new geometry and problems were encountered in developing test procedures for this geometry. One obstinate problem encountered in testing this geometry was the initial hook, or "crack backup" observed in the J-R curve obtained from these specimens as shown in Figure 13. The unloading compliance measurements show a clear increase in specimen stiffness as one brings up the load on these specimens, both in the elastic and the elastic-plastic regimes. This problem was initially assumed to result from the round hole clevises that were used for the first tests of HY-100 (FYO). New clevises were machined with flat bottomed holes and hardened to allow a free rotation of the specimen halves during the test. This change did not improve the results however, and it was then that a rotation correction was proposed as a possible solution. The rotation correction was developed, as detailed in Section 2.3.4, in a fashion similar to that used in ASTM E1152 for the C(T) specimen.

The effect of the rotation correction was to remove the initial crack backup without making much of a change in the remainder of the J-R curve, as shown in two examples in Figure 14 and Figure 15 The most dramatic effect is at the start of the J-R curve where the apparent initial stiffening of the specimen is corrected to show an improved resistance curve, especially in the initial portion, which improved the consistency of the calculated J_{Ic} results.

The resistance curve slope, T_{mat}, measured at 1 mm of crack growth, was not found to be changed markedly by the application of the rotation correction, being beyond where most of the effects of the rotation correction was felt.

3.2 J_{Ic} and T_{mat} Effects

J_{Ic} was calculated for all specimens included in this study using the polynomial relationship - least squares fit approach described above to determine the initial crack length, a_0. The results for both materials are shown in Table 4 and Table 5, and plotted as a function of specimen type in Figure 16 and Figure 17. J_{Ic} does not appear, from these plots, to be very sensitive to the specimen type, at least compared to the large variability demonstrated by each specimen type taken individually.

The material tearing resistance, T_{mat}, introduced by Paris, et al. (1979), was also evaluated for these specimens:

$$T_{mat} = \frac{\sigma_y^2}{E}\frac{dJ}{da}$$

where σ_y is the material yield stress and dJ/da is evaluated by fitting a two parameter power law, as used to evaluated J_{Ic}, to the J-R curve data in the standard ASTM E813 exclusion zone, and

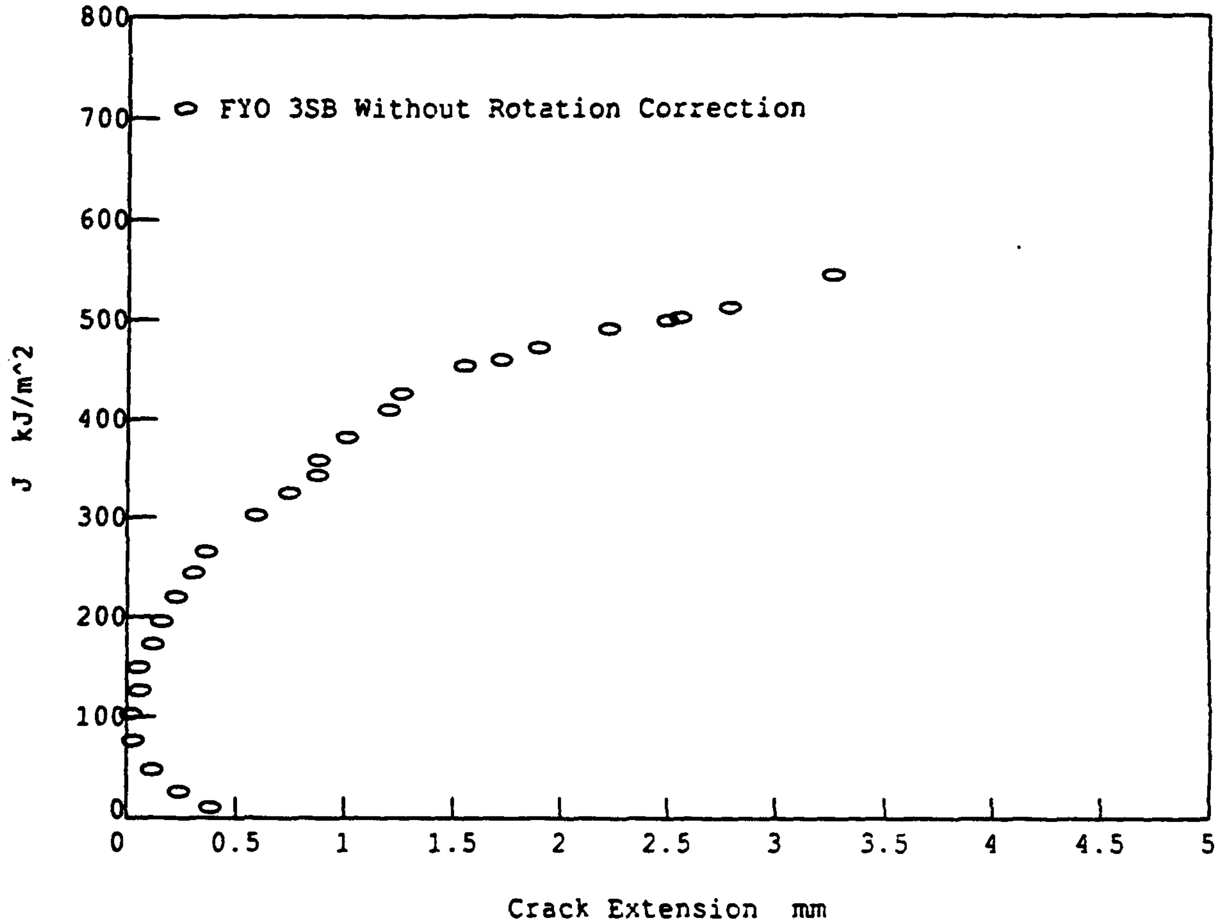

Figure 13 J-Resistance curve from an SE(T) specimen exhibiting "crack backup" in the early portion of the test.

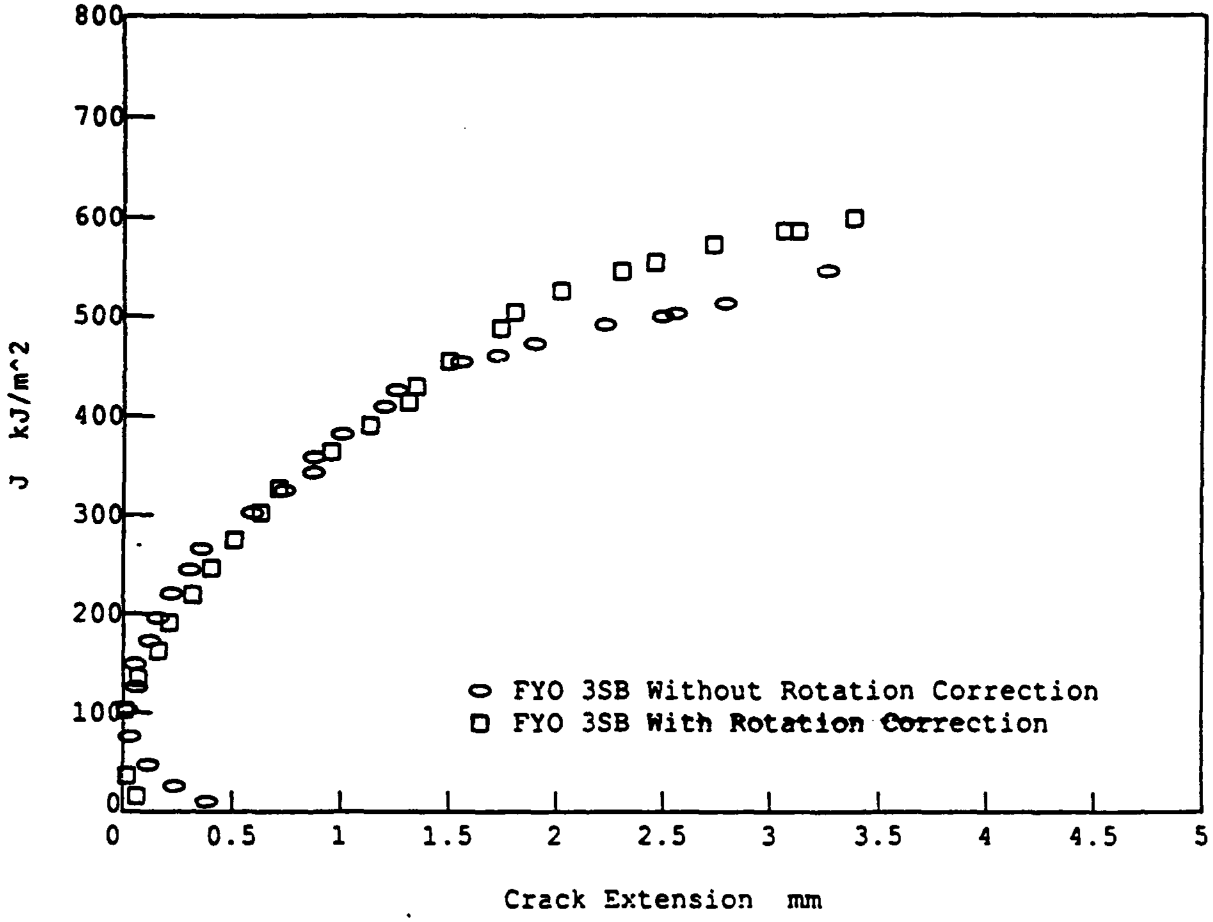

Figure 14 Comparison of J-R curves for an HY-100 SE(T) specimen with and without rotation correction.

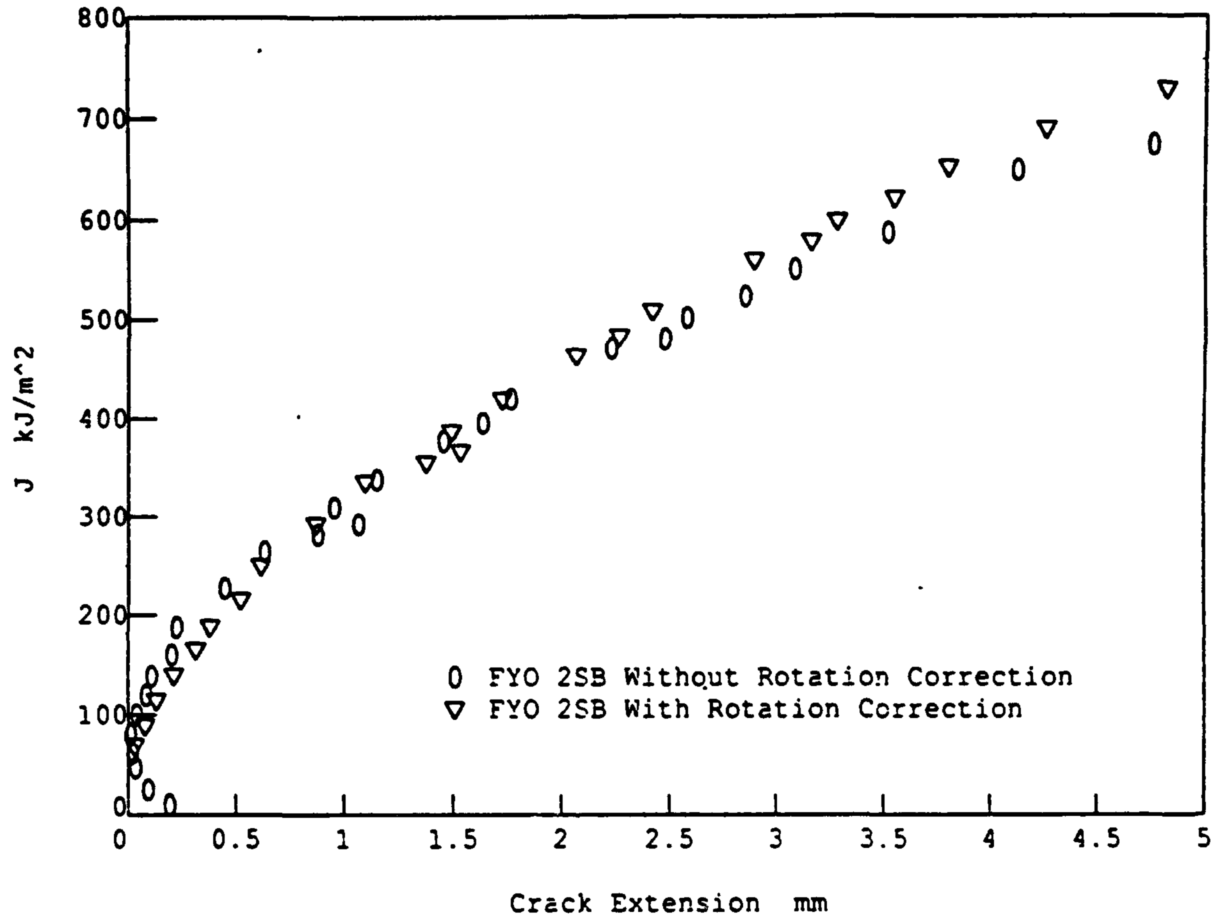

Figure 15 J-R curve for an HY-100 SE(T) specimen with and without rotation correction.

Table 4 Fracture toughness and tearing modulus for HY-100 specimens.

Specimen ID	Type	a/W	B (mm)	J_{Ic} (kJ/mm^2)	T_{mat} (1 mm)
FYO 1	SE(B)	0.66	50.	111.7	25.2
FYO 3	SE(B)	0.66	50.	137.8	31.2
FYO 21	SE(B)	0.14	50.	177.2	49.9
FYO 26	SE(B)	0.13	25.	163.7	35.6
FYO 27	SE(B)	0.14	25.	173.7	48.0
FYO 150	SE(B)	0.61	25.	145.1	21.3
FYO 151	SE(B)	0.61	25.	129.7	26.6
FYO 158	SE(B)	0.60	12.5	140.5	23.8
FYO 159	SE(B)	0.62	12.5	179.9	24.2
FYO 160	SE(B)	0.11	12.5	120.1	38.2
FYO 161	SE(B)	0.11	12.5	113.9	40.9
FYO 2SB	SE(T)	0.40	25.	166.7	47.9
FYO 3SB	SE(T)	0.47	25.	245.0	50.1
FYO 4SA	SE(T)	0.65	25.	254.1	31.5
FYO 10SA	SE(T)	0.35	25.	201.8	57.6
FYO 11SB	DE(T)	0.68	25.	88.4	31.0
FYO 12SA	DE(T)	0.61	25.	107.1	39.2

Table 5 Fracture toughness and tearing modulus for A533B specimens.

Specimen ID	Type	a/W	J_{Ic} kJ/m^2	T_{mat} (1 mm)
CT3	C(T)	0.6	244.4	122.4
CT9	C(T)	0.6	265.0	125.3
CT10	C(T)	0.6	239.2	112.1.
DB1	SE(B)	0.62	240.3	149.9
DB2	SE(B)	0.62	308.5	142.9
DB3	SE(B)	0.62	323.8	160.5
SB1	SE(B)	0.15	306.3	238.2
SB2	SE(B)	0.15	228.7	260.8
SB3	SE(B)	0.15	333.0	239.2
SEN1	SE(T)	0.40	145.5	228.7
SEN2	SE(T)	0.36	159.5	289.8
SEN4	SE(T)	0.60	305.2	229.1
SEN9	SE(T)	0.40	598.6	288.4
SEN10	SE(T)	0.60	231.8	178.6
SE5D	DE(T)	0.7	164.6	301.1
SE6D	DE(T)	0.7	182.1	257.3
SE7D	DE(T)	0.68	189.8	253.3
SE8D	DE(T)	0.71	226.6	255.0

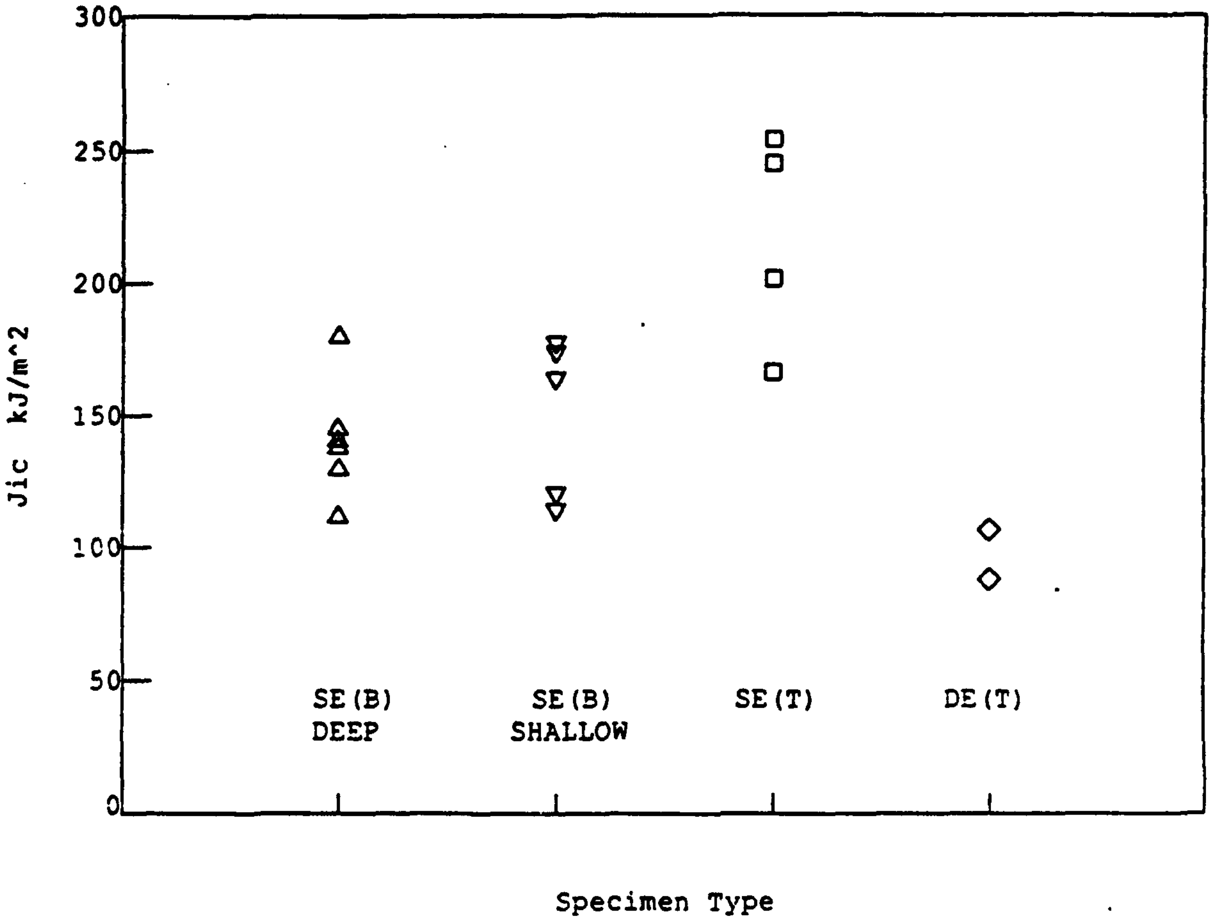

Figure 16 Fracture toughness of HY-100 as a function of specimen type.

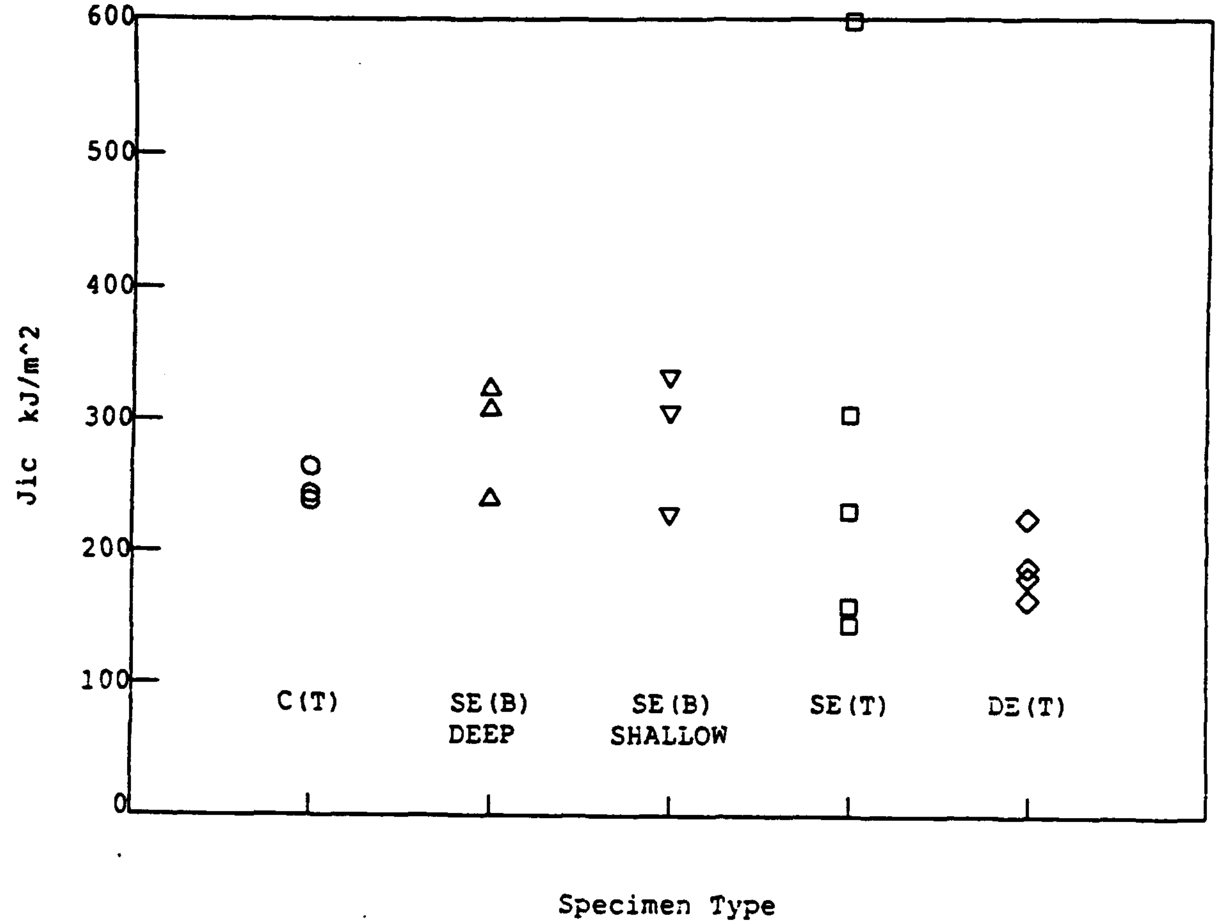

Figure 17 Fracture toughness of A533B as a function of specimen type.

then evaluating dJ/da at a crack extension of 1 mm (0.04 in). The measured T_{mat} values obtained from this set of specimens are shown in Table 4 and Table 5 and plotted as a function of specimen type in Figure 18 and Figure 19. The tearing resistance varies for each material by a factor of about 2.5 and appears to be dependent on the specimen type.

In the following sections these results for J_{Ic} and T_{mat} will be correlated with the T_σ and Q constraint parameters introduced in Section 2.

3.3 J-R Curves

Figure 20 and Figure 21 show the measured J-R curves for the baseline, deep notched SE(B) and C(T) specimens of each material. The variability shown in these figures is assumed to be due to material variability, and is typical of what is usually found for structural steels. The dashed bounding lines shown in the figures will be used on later plots for comparison of the baseline results and results from the non-standard specimens. Comparisons of these baseline J-R curves with the J-R curves of the short cracked SE(B), SE(T), and DE(T) specimens for both materials are shown in Figures 22-27. The most immediate observation that can be made from these figures is that short cracks and tensile loading seem to have little effect on the J_{Ic} value, but a measurable effect on the slope of the J-R curve, or T_{mat} values, with higher slopes being found for all of the short crack and tensilely loaded specimens in comparison with the standard, deeply notched geometries.

The SE(T) specimen, SEN9, appears to be an outlier, with crack initiation being delayed for some unknown reason. This specimen has been explored extensively, but no reason has been found for its elevated toughness behavior. The pre-crack was straight, the initial and final crack lengths were estimated accurately by the compliance technique, and the load displacement curves seem correct in every respect. Figure 28 shows a plot of the load versus COD record for specimen SEN9 and also specimen SEN1, which had a nearly identical crack length. Specimen SEN9 is clearly much tougher, showing a continually rising load displacement record throughout the test, while specimen SEN1 rises to a maximum load and falls. The compliance method predicted crack initiation as shown on Figure 28, with the crack initiation of specimen SEN1 occurring at about the separation point of the two curves, while the crack initiation point for specimen SEN9 was much later. In both cases the extent of ductile crack growth agreed well with the post test optical measurement.

3.4 Constraint Correlations

3.4.1 T_σ Correlation

The T_σ quantity was calculated for each specimen from the applicable K, a/W, and β at J_{Ic} and is tabulated in Table 6 and Table 7. Figure 29 and Figure 30 show plots of J_{Ic} versus T_σ for each material. The short and deep SE(B) specimens for both materials, and the C(T) specimens for the A533B alloy, appear to be insensitive to the applied T_σ. The tension-loaded SE(T) and DE(T) specimens are in general agreement, with the exception of specimen SEN9 for the A533B material, which was discussed previously as an apparent outlier. The HY100 tension-

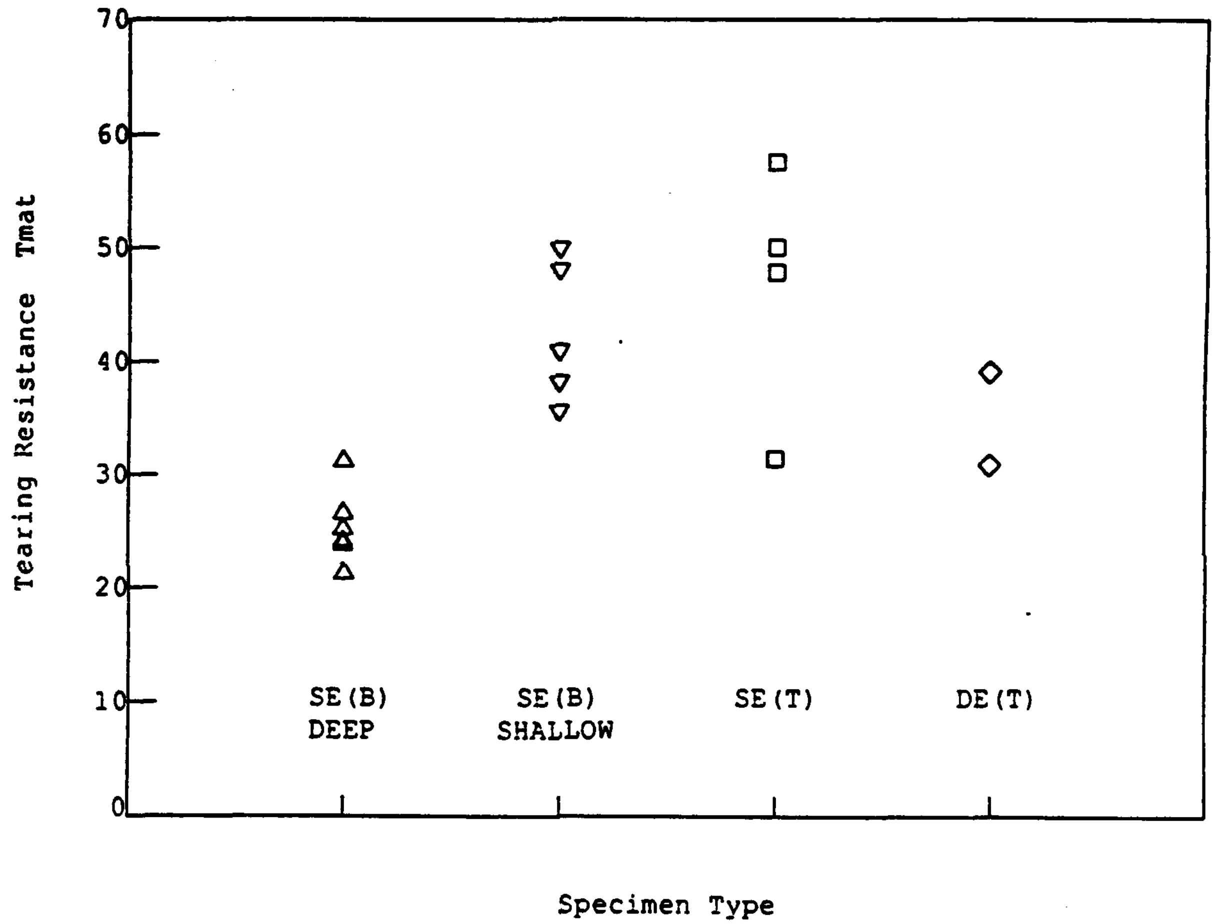

Figure 18 Tearing modulus of HY-100 as a function of specimen type.

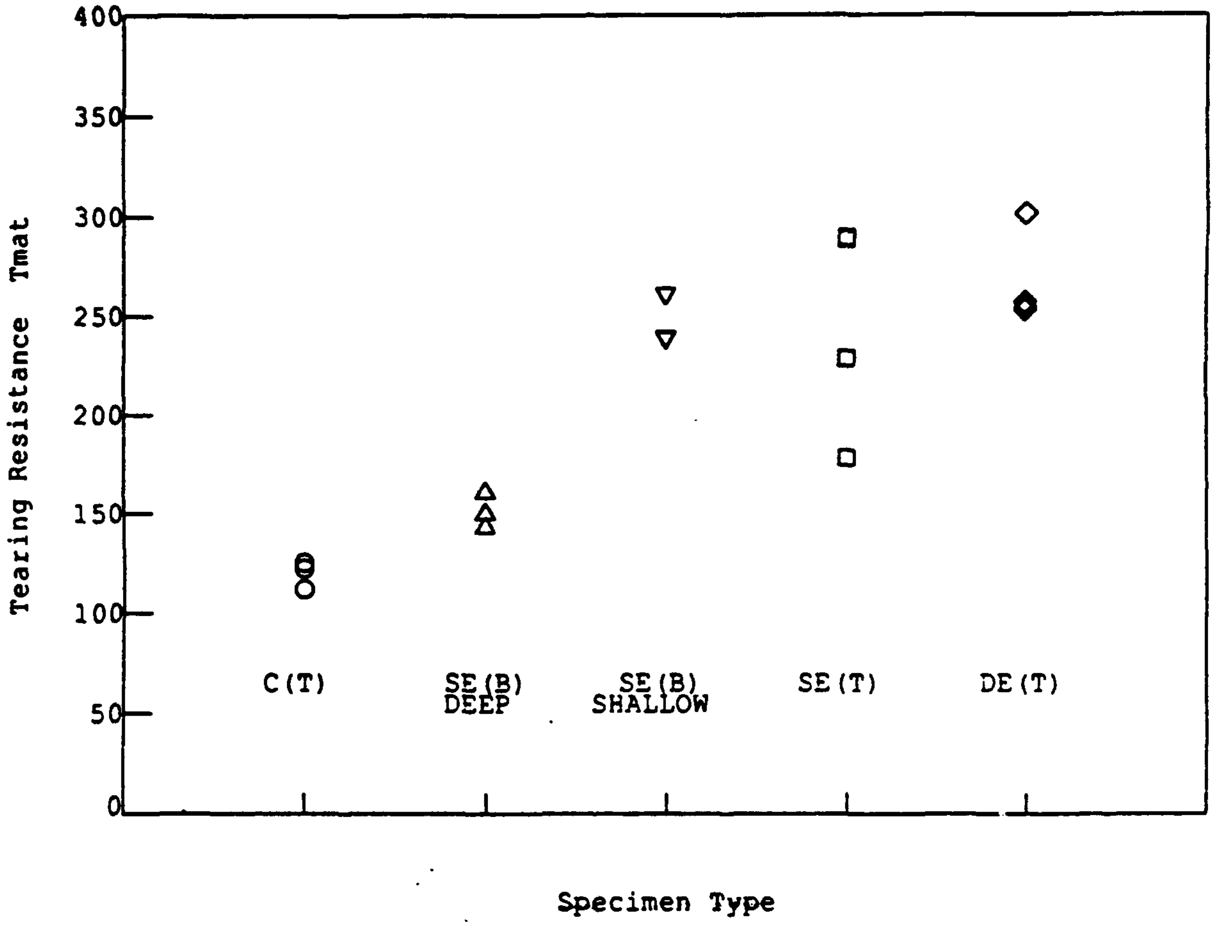

Figure 19 Tearing modulus of A533B as a function of specimen type.

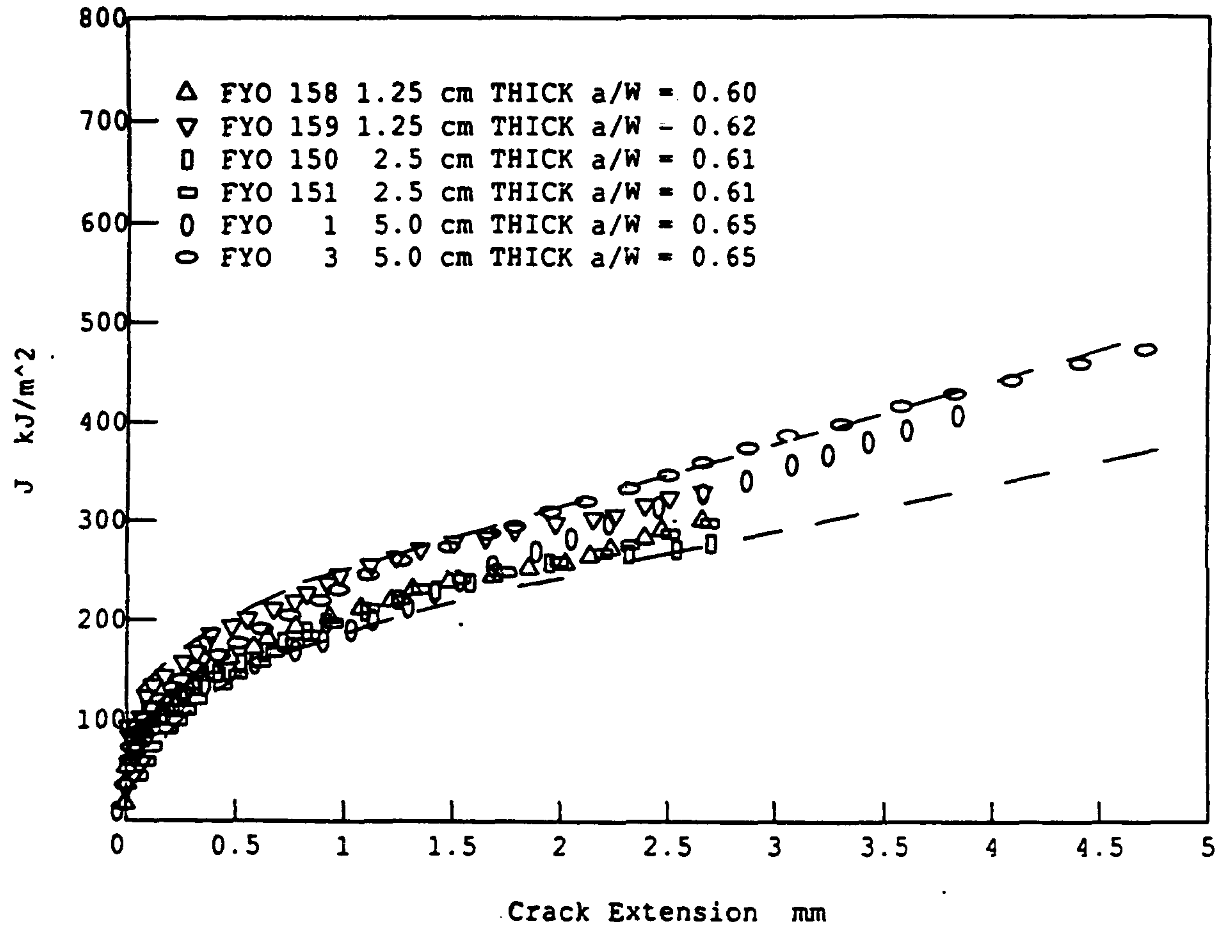

Figure 20 Baseline J-R curves for HY-100 from deep-cracked SE(B) specimens.

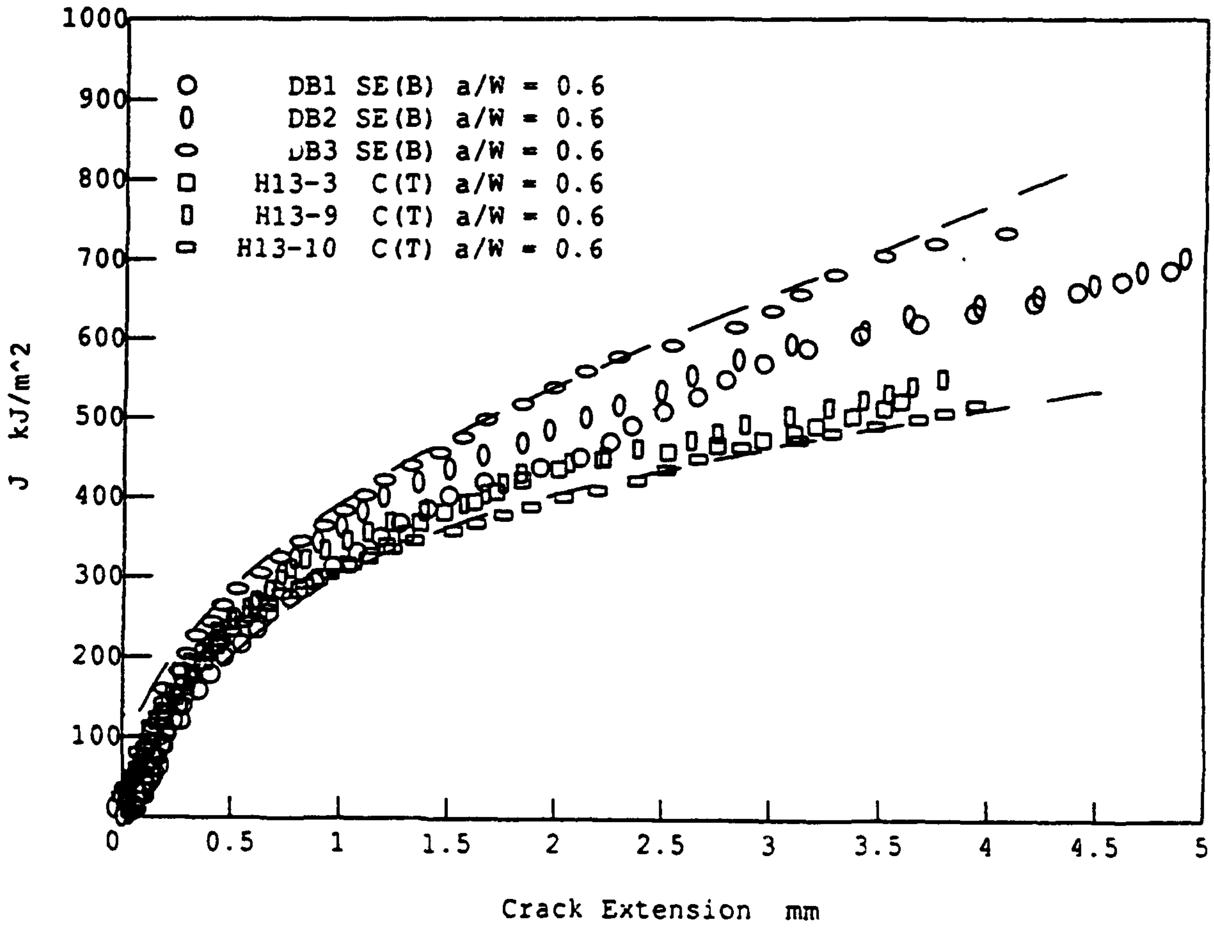

Figure 21 Baseline J-R curves for A533B from deep-cracked SE(B) and C(T) specimens.

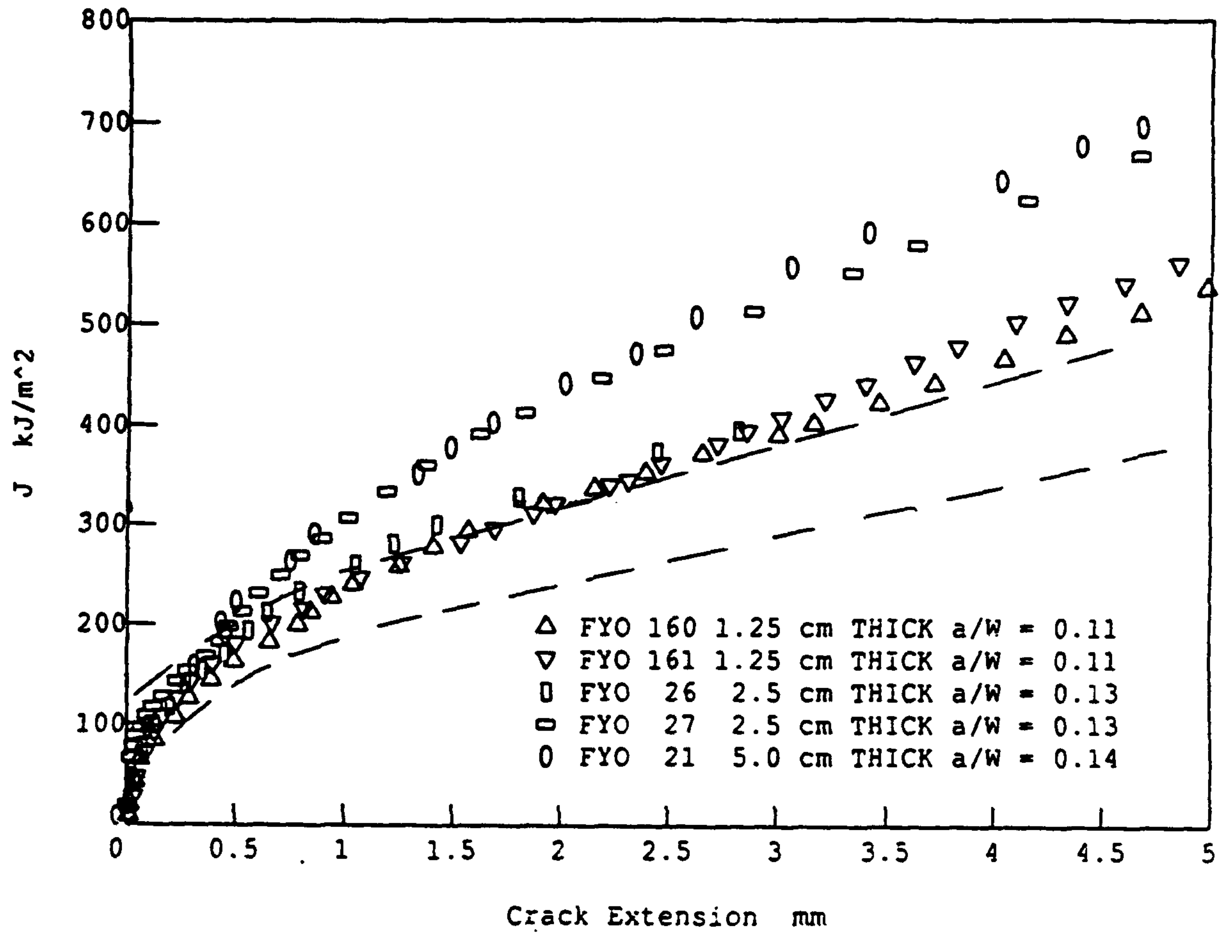

Figure 22 J-R curves for HY-100 from short-cracked SE(B) specimens.

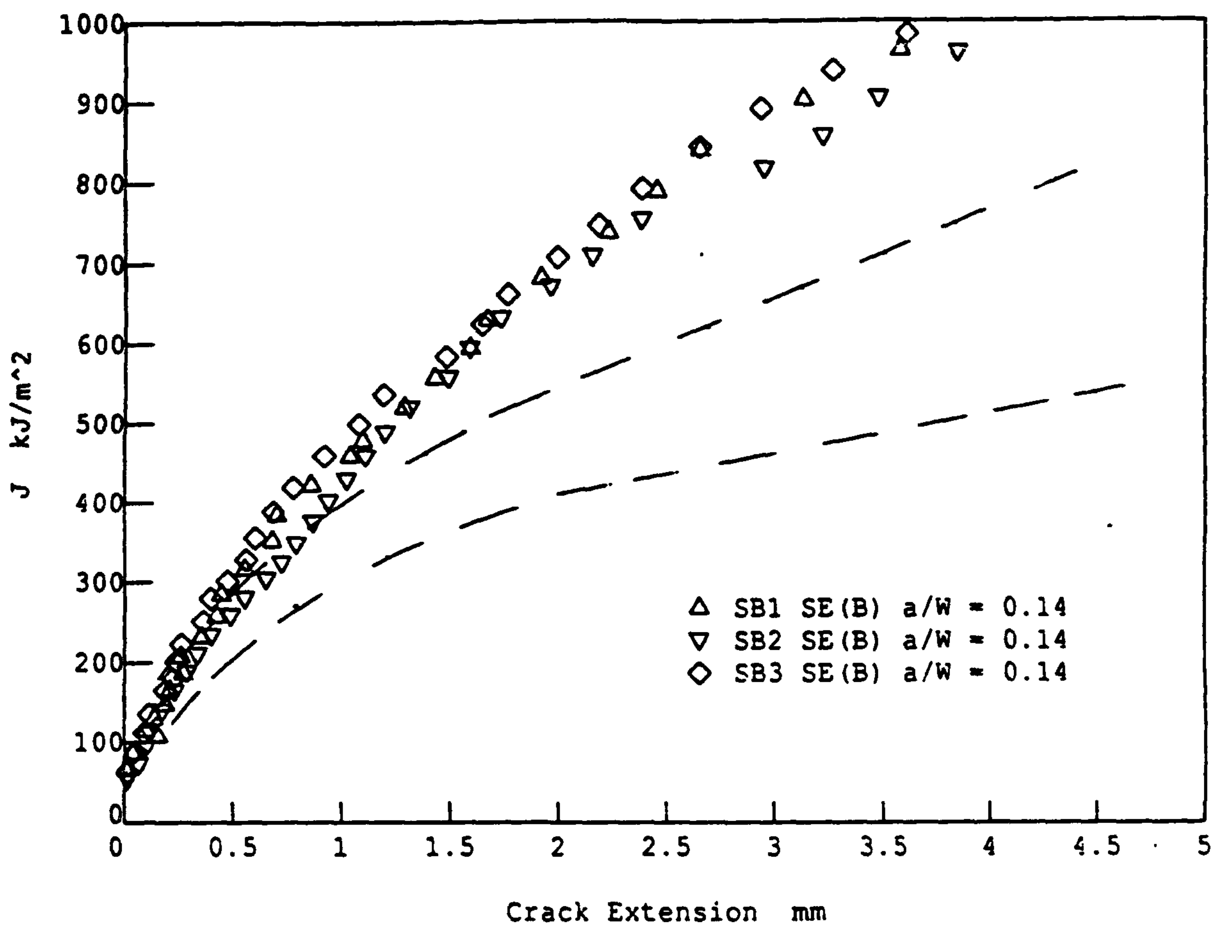

Figure 23 J-R curves for A533B from short-cracked SE(B) specimens.

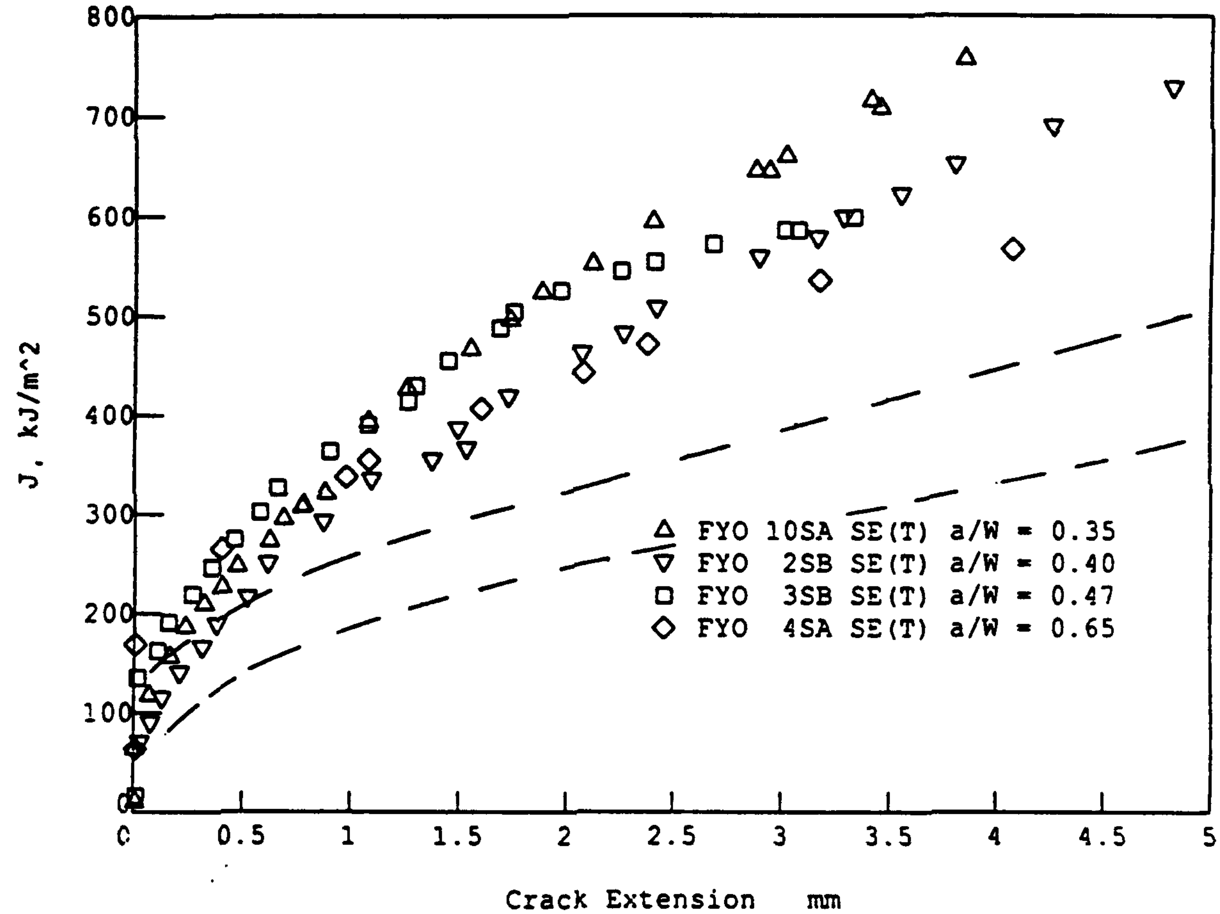

Figure 24 J-R curves for HY-100 from SE(T) specimens (with rotation correction).

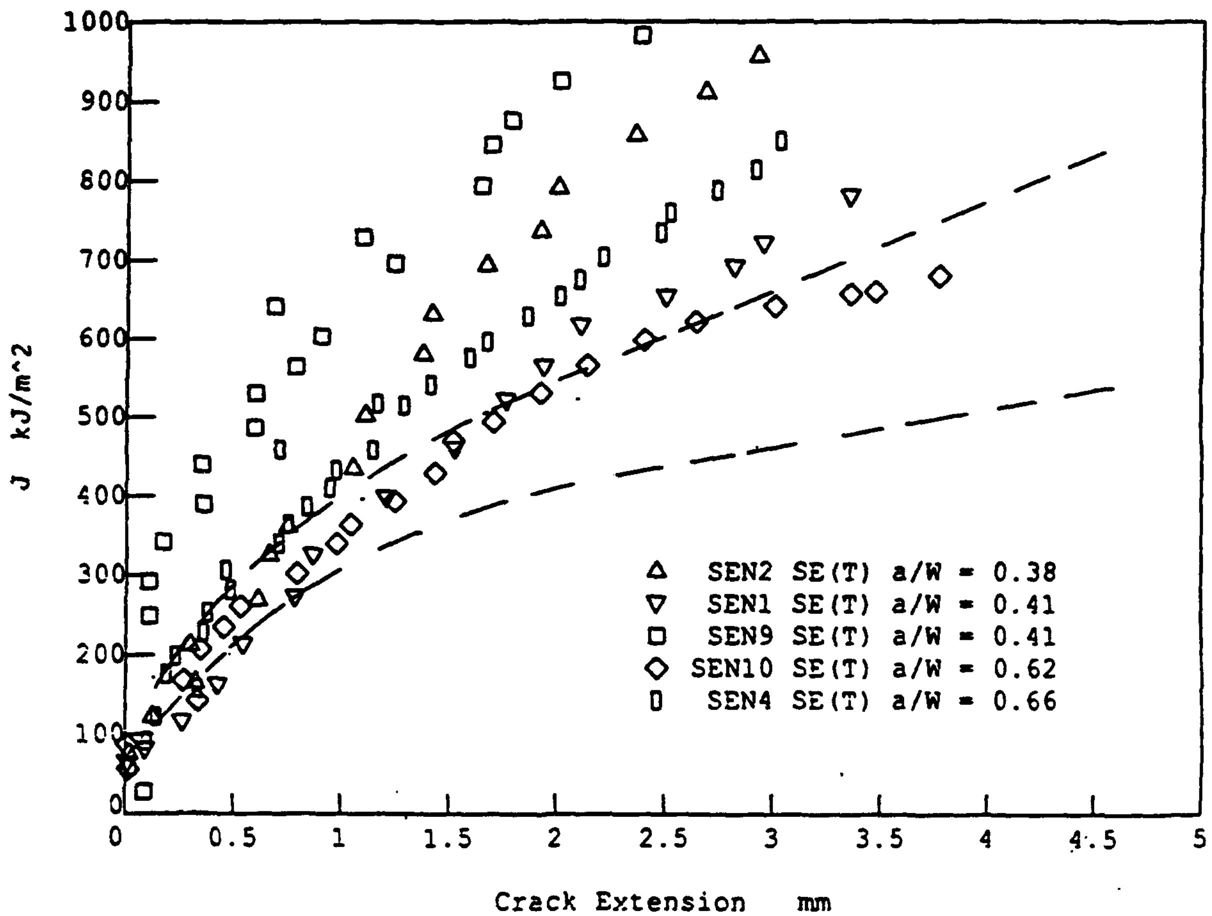

Figure 25 J-R curves for A533B from SE(T) specimens (with rotation correction).

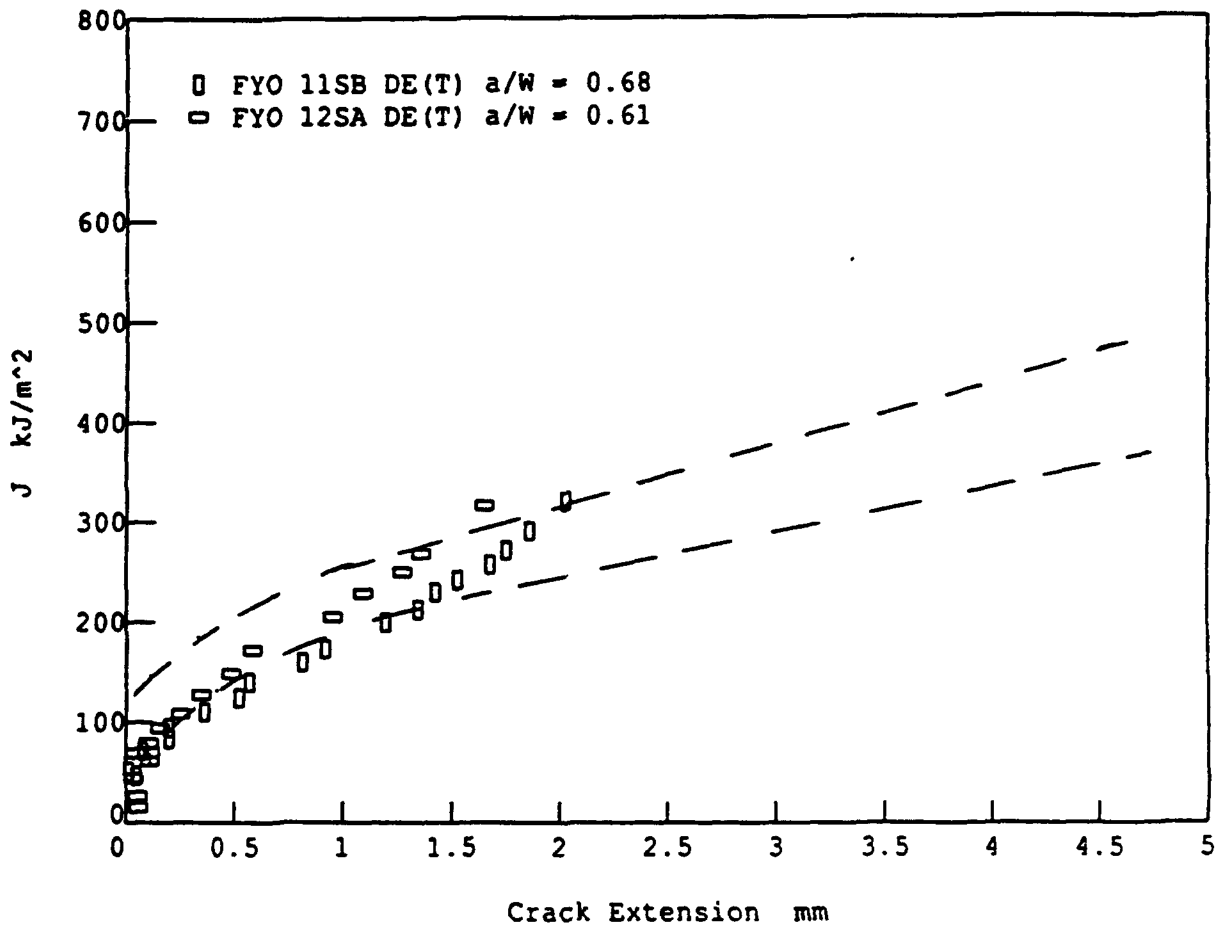

Figure 26 J-R curves for HY-100 from DE(T) specimens.

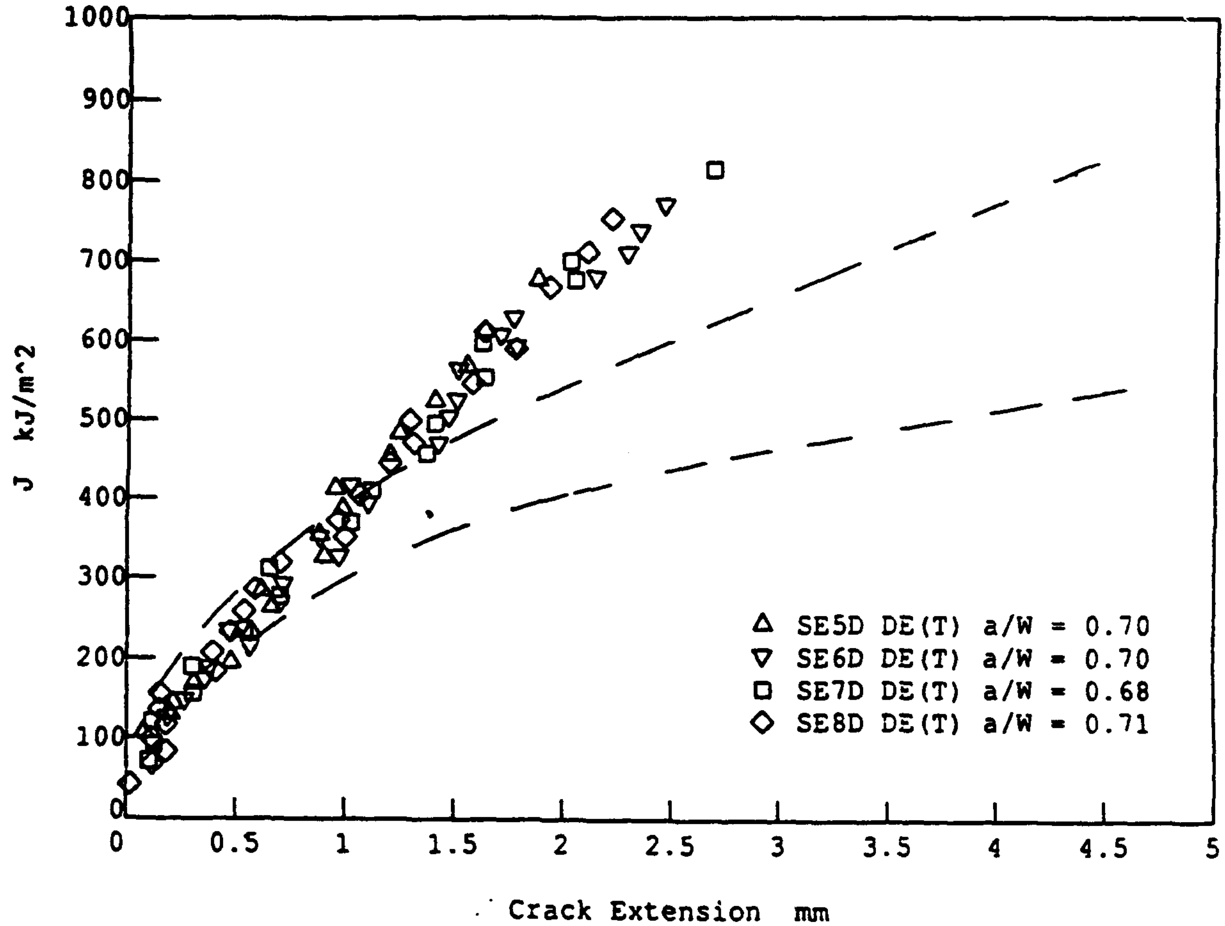

Figure 27 J-R curves for A533B from DE(T) specimens.

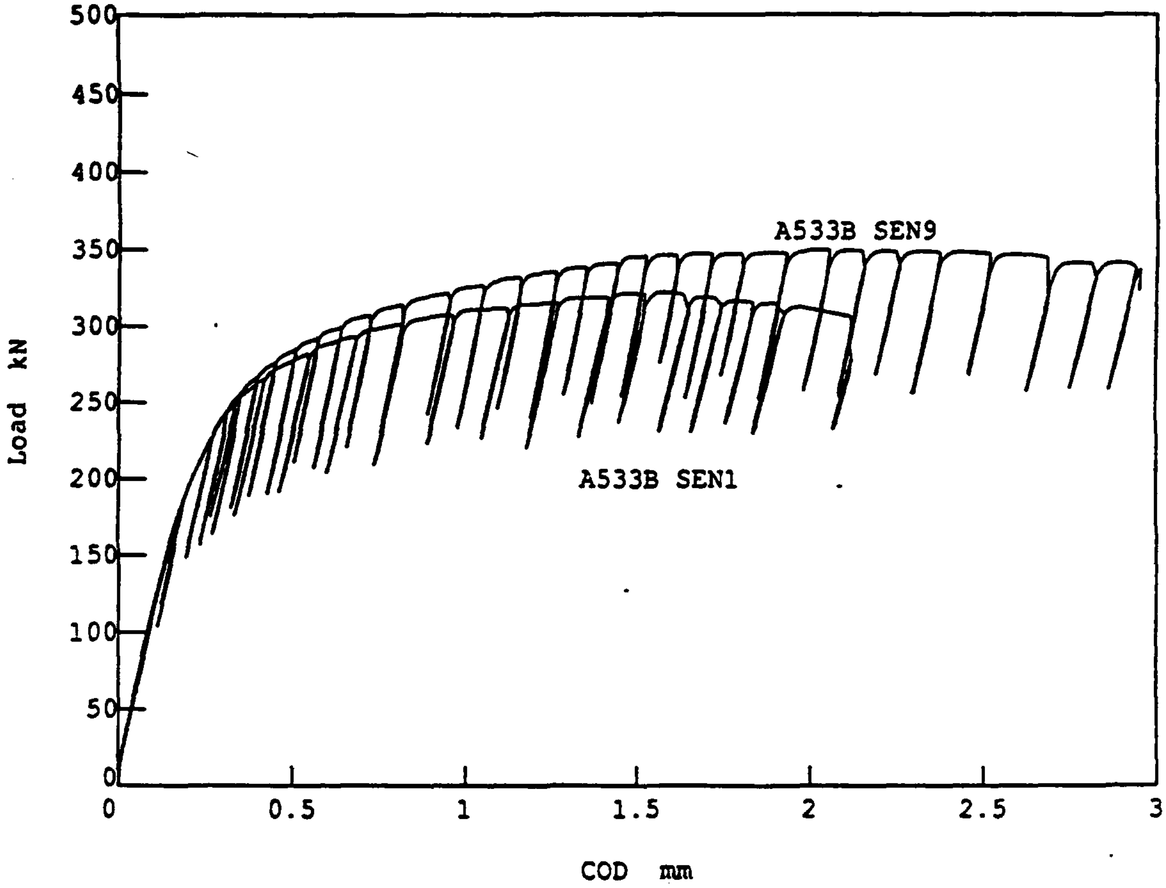

Figure 28 Load versus COD curves for specimens SEN9 and SEN1 of A533B.

Table 6 Constraint parameters β, T_σ, and Q at crack initiation in the HY-100 specimens.

Specimen ID	Type	a/W	B mm	β	T_σ @ J_{Ic} MPa	Q @ J_{Ic}
FYO 1	SE(B)	0.66	50.	0.476	229.	-0.1
FYO 3	SE(B)	0.66	50.	0.476	255.	-0.1
FYO 21	SE(B)	0.14	50.	-0.311	-410.	-0.8
FYO 26	SE(B)	0.13	25.	-0.322	-425.	-0.8
FYO 27	SE(B)	0.14	25.	-0.311	-406.	-0.8
FYO 150	SE(B)	0.61	25.	0.395	226.	-0.1
FYO 151	SE(B)	0.61	25.	0.395	213.	-0.1
FYO 158	SE(B)	0.60	12.5	0.381	216.	-0.1
FYO 159	SE(B)	0.62	12.5	0.411	259.	-0.1
FYO 160	SE(B)	0.11	12.5	-0.345	-423.	-0.8
FYO 161	SE(B)	0.11	12.5	-0.345	-412.	-0.8
FYO 2SB	SE(T)	0.40	25.	-0.270	-182.	-0.25
FYO 3SB	SE(T)	0.47	25.	-0.183	-138	-0.30
FYO 4SA	SE(T)	0.65	25.	-0.101	-65.9	-0.11
FYO 10SA	SE(T)	0.35	25.	-0.325	-259.	-0.31
FYO 11SB	DE(T)	0.68	25.	-0.407	-217.	-0.43
FYO 12SA	DE(T)	0.61	25.	-0.433	-268.	-0.40

Table 7 Constraint parameters β, T_σ, and Q at crack initiation for the A533B specimens.

Specimen ID	Type	a/W	β	T_σ @ J_{Ic} MPa	Q @ J_{Ic}
CT3	C(T)	0.6	0.573	428.	-0.1
CT9	C(T)	0.6	0.573	446.	-0.1
CT10	C(T)	0.6	0.573	423.	-0.1
DB1	SE(B)	0.62	0.411	300.	-0.1
DB2	SE(B)	0.62	0.411	339.	-0.1
DB3	SE(B)	0.62	0.411	348.	-0.1
SB1	SE(B)	0.15	-0.299	-498.	-0.8
SB2	SE(B)	0.15	-0.299	-431.	-0.8
SB3	SE(B)	0.15	-0.299	-520.	-0.8
SEN1	SE(T)	0.40	-0.271	-172.	-0.30
SEN2	SE(T)	0.36	-0.315	-220.	-0.30
SEN4	SE(T)	0.60	0.009	6.7	-0.22
SEN9	SE(T)	0.40	-0.271	-348.	-0.60
SEN10	SE(T)	0.60	0.009	5.8	-0.20
SE5D	DE(T)	0.7	-.0397	-285.	-0.70
SE6D	DE(T)	0.7	-0.397	-300.	-0.71
SE7D	DE(T)	0.68	-0.407	-311.	-0.72
SE8D	DE(T)	0.71	-0.392	-335.	-0.76

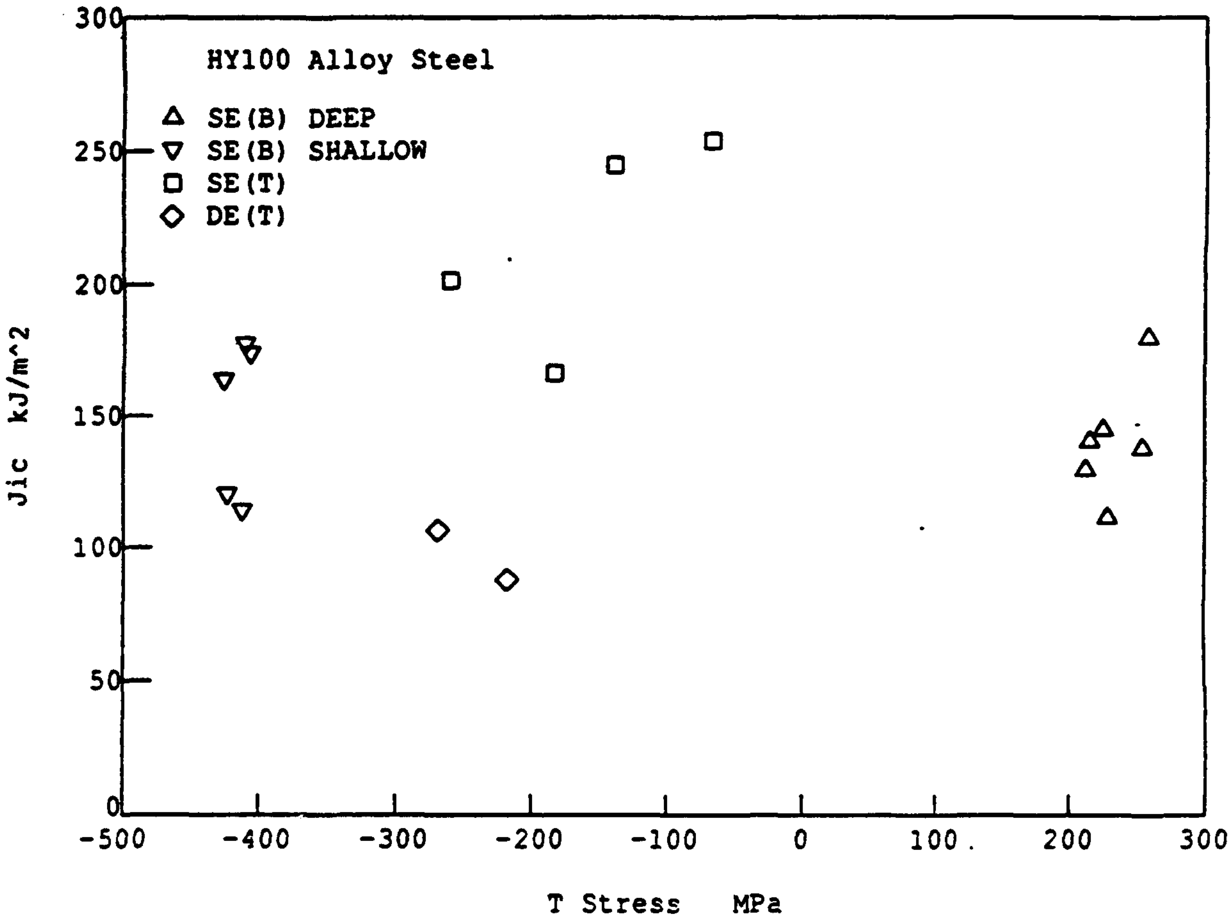

Figure 29 Fracture toughness, J_{Ic}, as a function of T_σ for the HY-100 specimens.

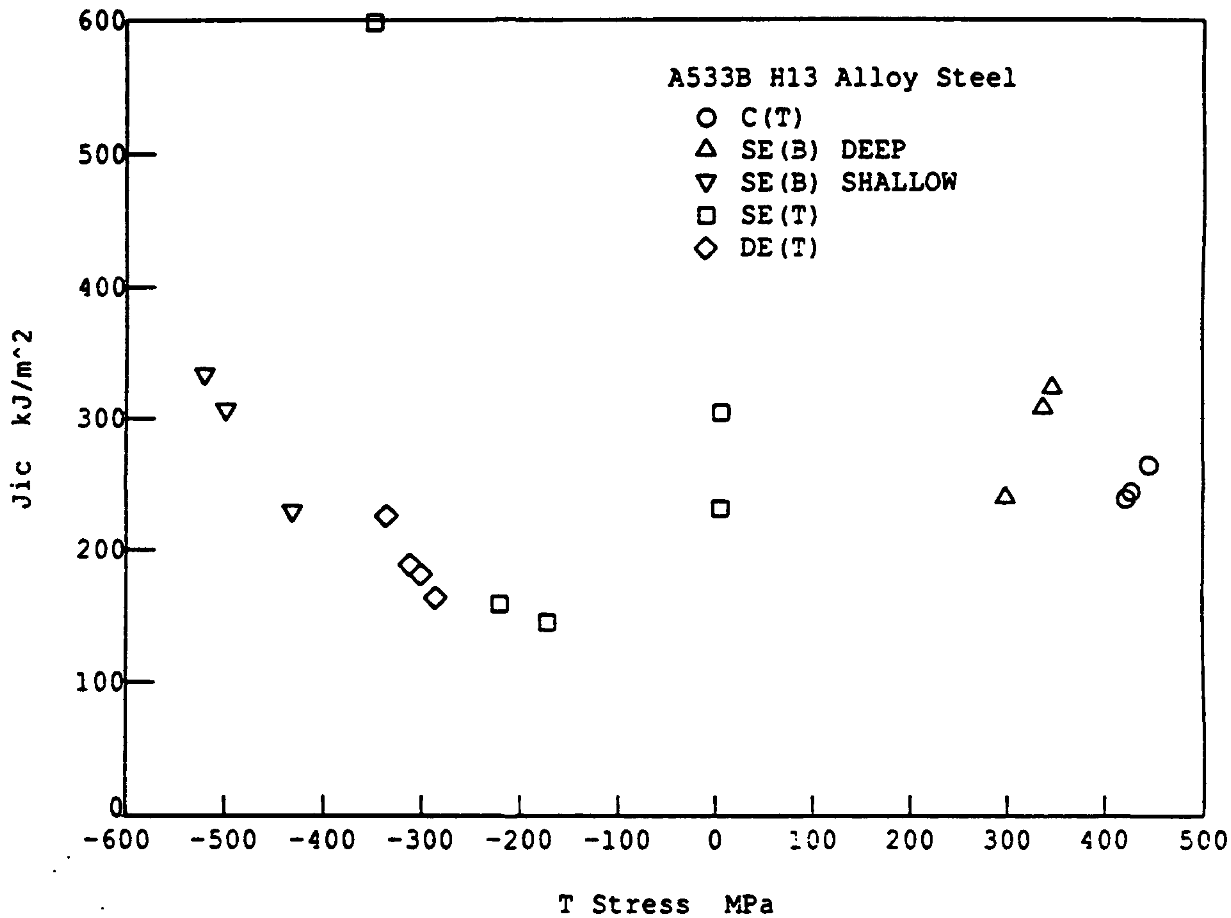

Figure 30 The fracture toughness, J_{Ic}, as a function of T_σ for the A533B specimens.

loaded specimens show considerable scatter, with the SE(T) specimens being high relative to the SE(B) results and the DE(T) specimens being low. It is quite possible that improvements in test technique that have been incorporated in the more recent A533B tests in part explain the reduction in scatter shown by the A533B tensile results, in comparison with the earlier HY100 results.

Figure 31 and Figure 32 show plots of T_{mat} versus T_{σ} for each material, and now a clear trend of material tearing resistance versus constraint is apparent in the data, with the tearing resistance being more than doubled when measured with the low constraint short crack SE(B) specimen, in comparison to the standard, high constraint, deeply notched bend or compact specimens. The HY100 again shows much more scatter in T_{mat} values than does the A533B material. This might be due, in part, to the much smaller T_{mat} values obtained from the HY100 material, as well as from basic improvements in the SE(T) and DE(T) test methods between the HY100 tests and the A533B tests. The appearance of these results is improved by the lower scatter for each specimen type demonstrated by the T_{mat} parameter, in comparison with the J_{Ic} parameter.

3.4.2 Q Correlation

The Q quantity was evaluated for each specimen from the applicable analysis using Figs. 8-10, and the J_{Ic} and a/W and is tabulated in Table 6 and Table 7 for each specimen tested. Figure 33 and Figure 34 show plots of J_{Ic} versus Q at J_{Ic} for all specimens of each material. As above, neither material shows dependence of J_{Ic} on Q, at least, any that can be separated from the material and test variability. The HY100 shows much more scatter than is shown by the A533B material. Overall it seems that J_{Ic} is not strongly affected by constraint, as measured by Q, in these specimen geometries.

Figure 35 and Figure 36 show plots of T_{mat} versus Q (at J_{Ic}) for each material. A clear trend is now shown, with higher constraint resulting in lower tearing resistance in these materials. For both materials there appears to be a rapid increase in T_{mat} with decreasing Q, then a leveling off at lower Q's.

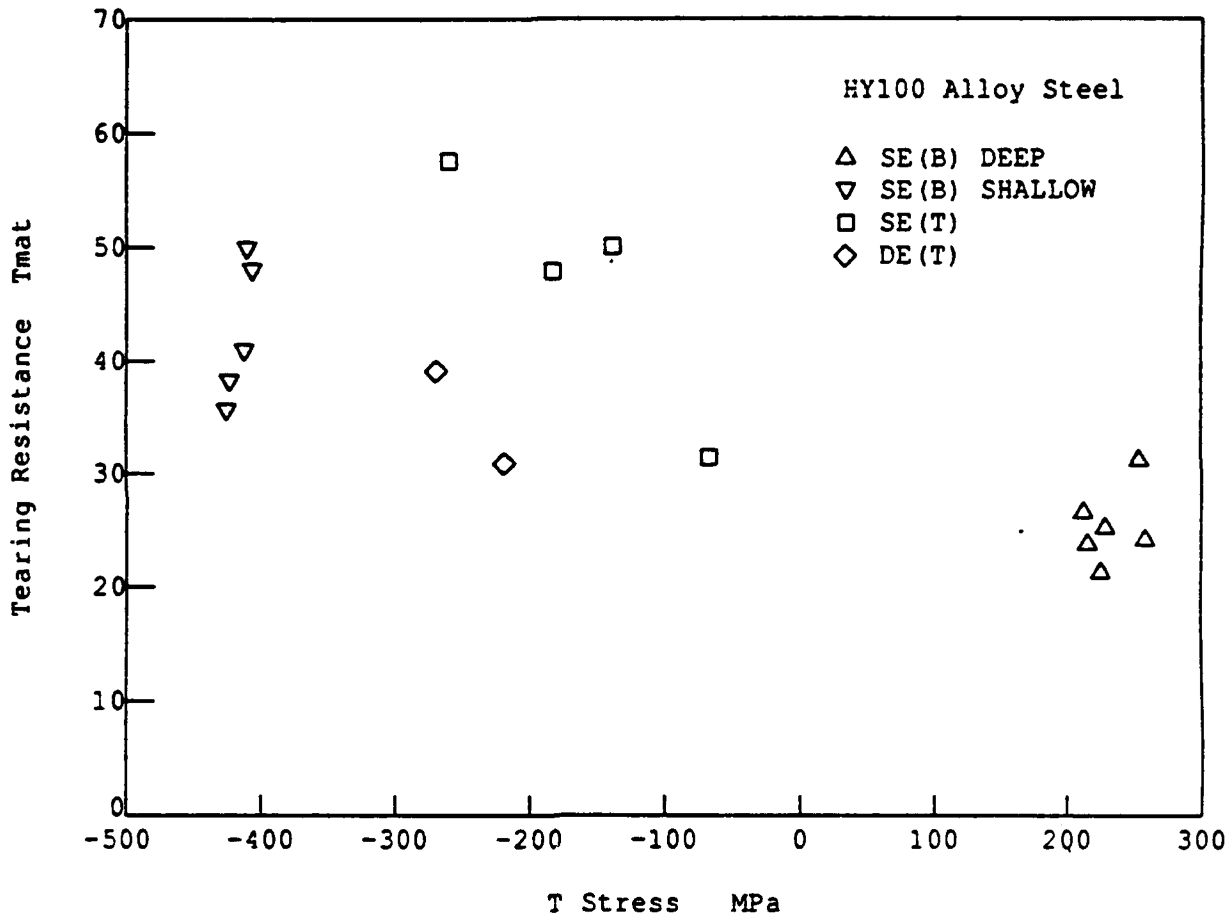

Figure 31 Tearing modulus, T_{mat}, as a function of T_{σ} for the HY-100 specimens.

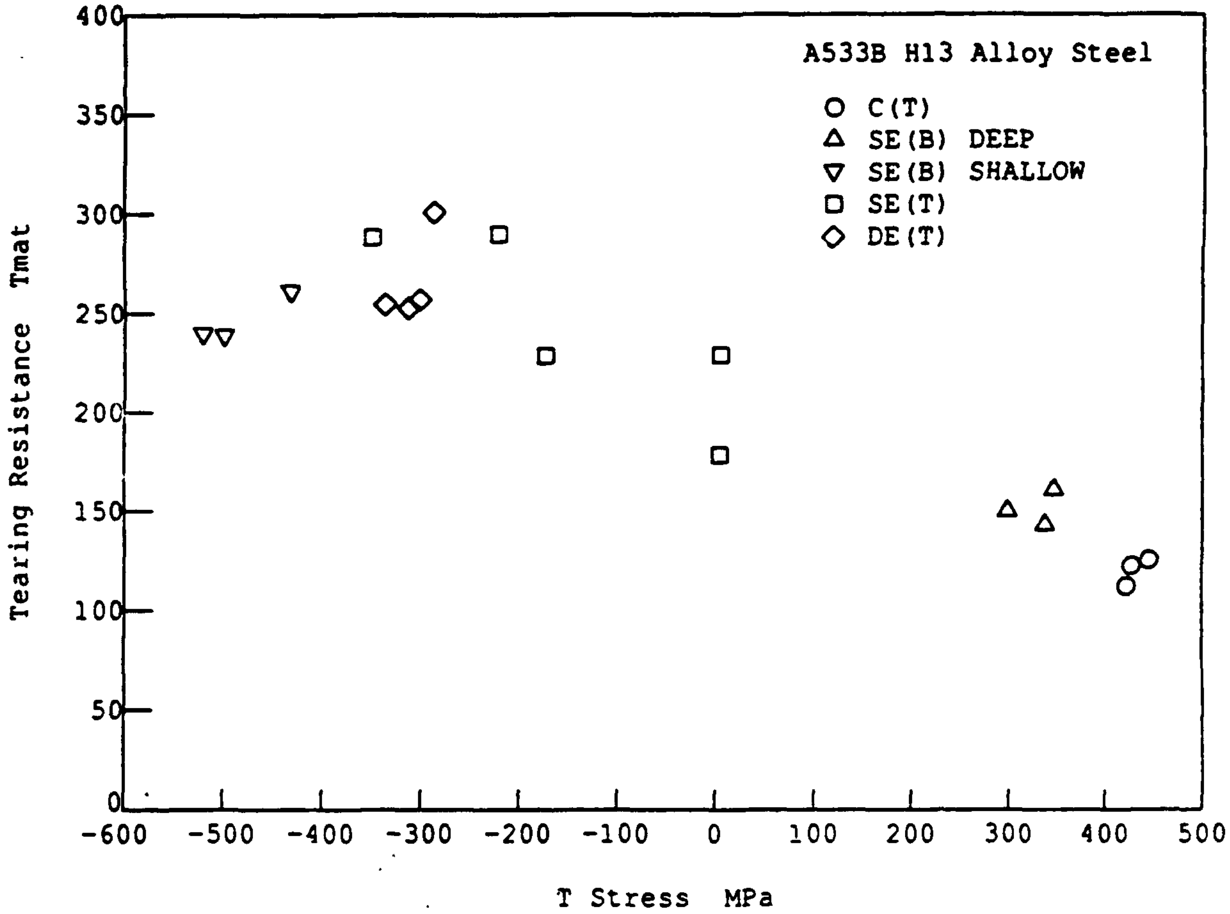

Figure 32 Tearing modulus, T_{mat}, as a function of T_{σ} for the A533B specimens.

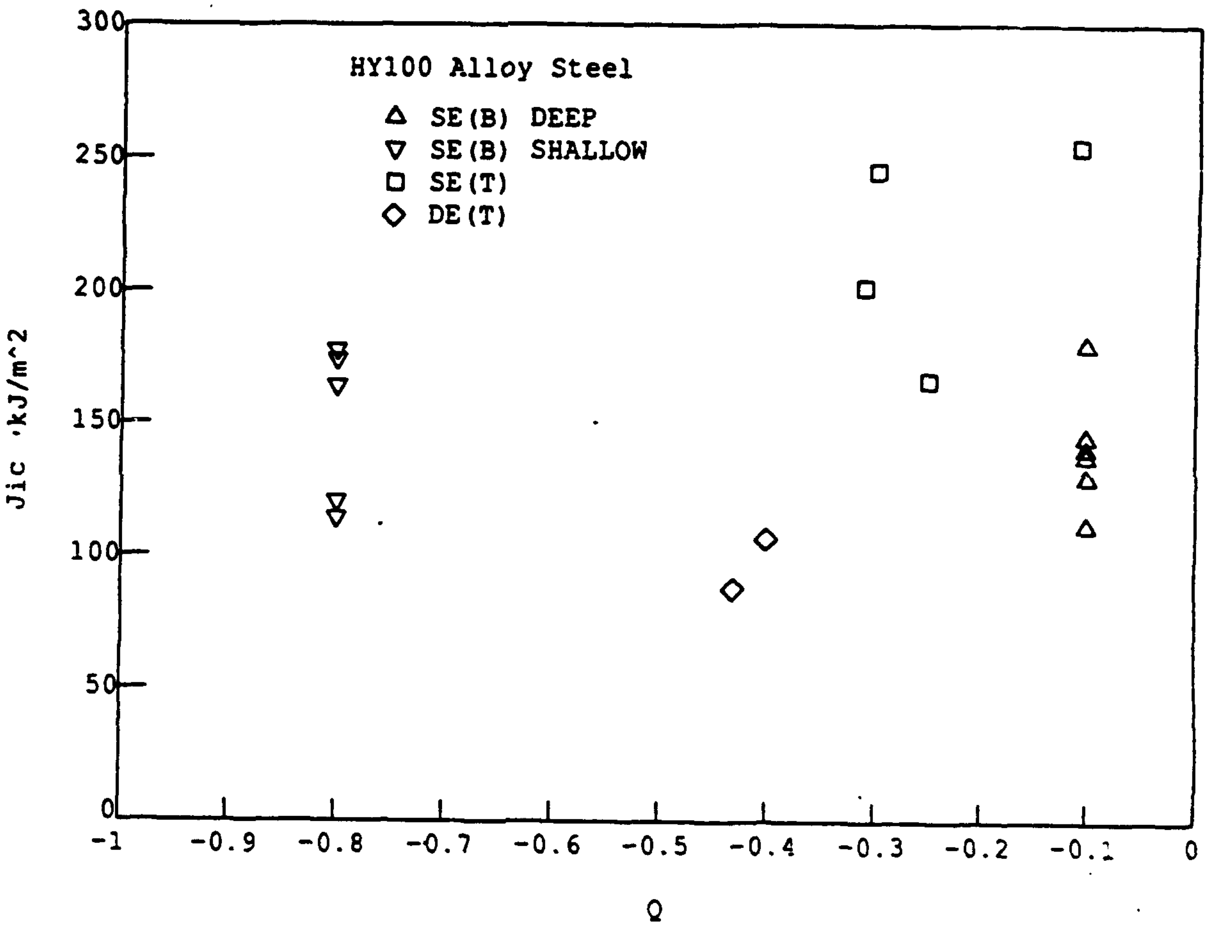

Figure 33 Fracture toughness, J_{Ic}, as a function of Q for the HY-100 specimens.

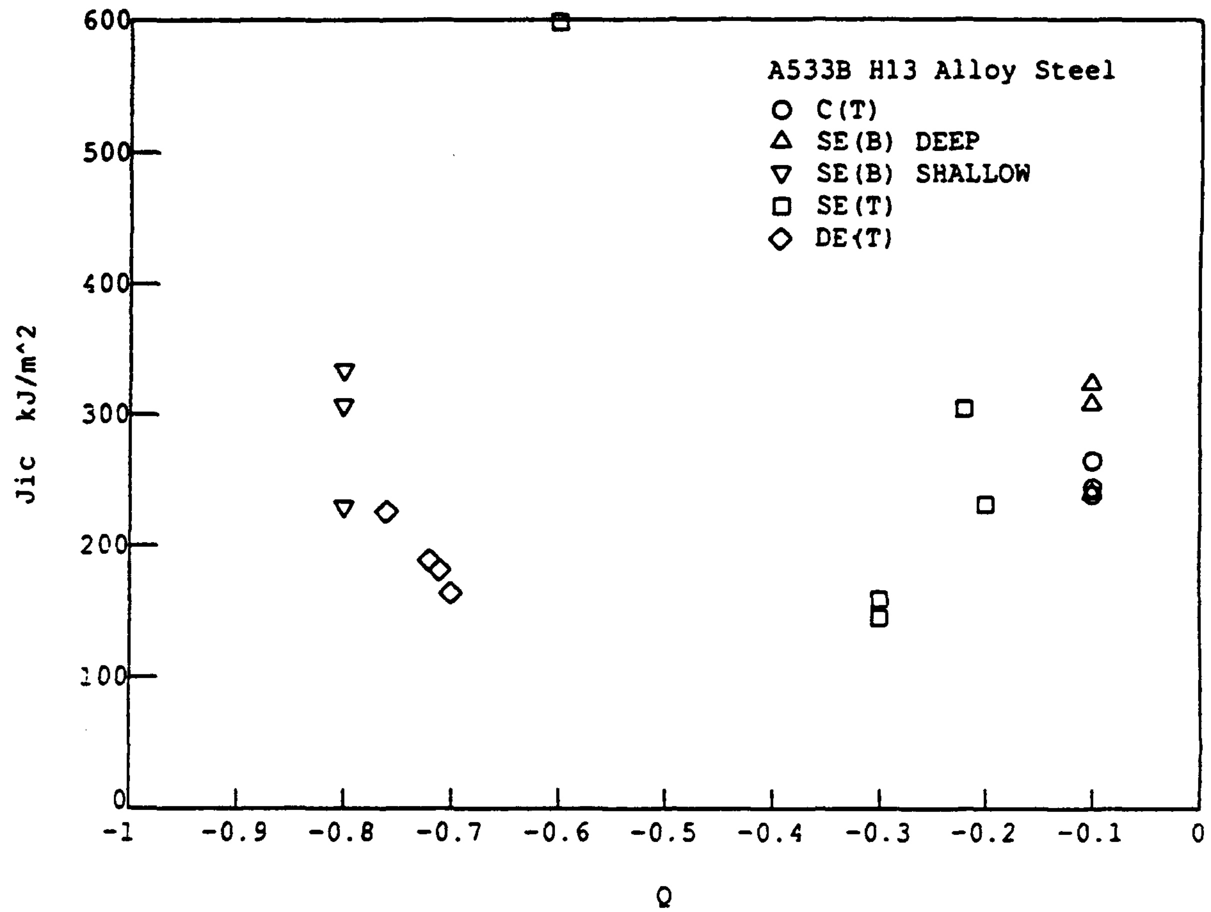

Figure 34 Fracture toughness, J_{Ic}, as a function of Q for the A533B specimens.

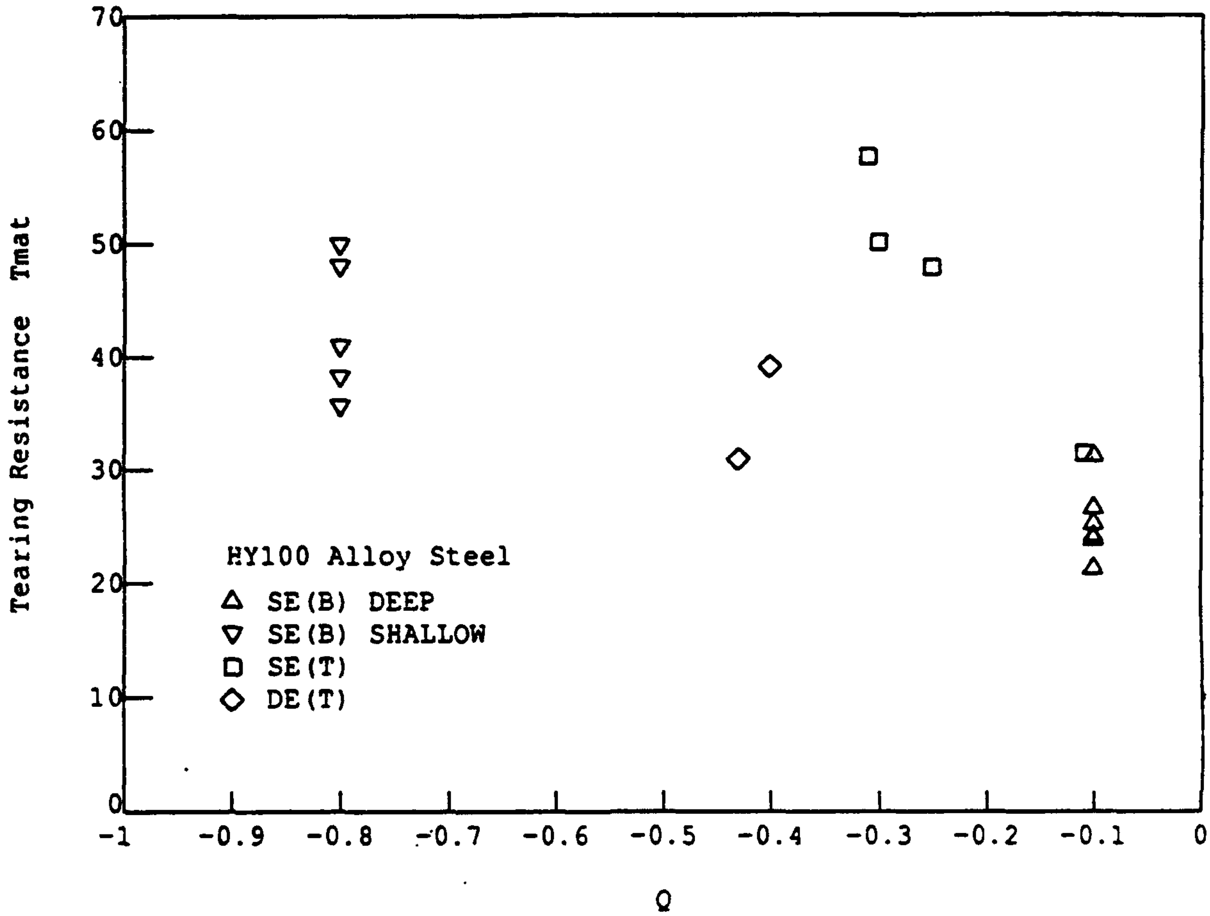

Figure 35 Tearing modulus, T_{mat}, as a function of Q for the HY-100 specimens.

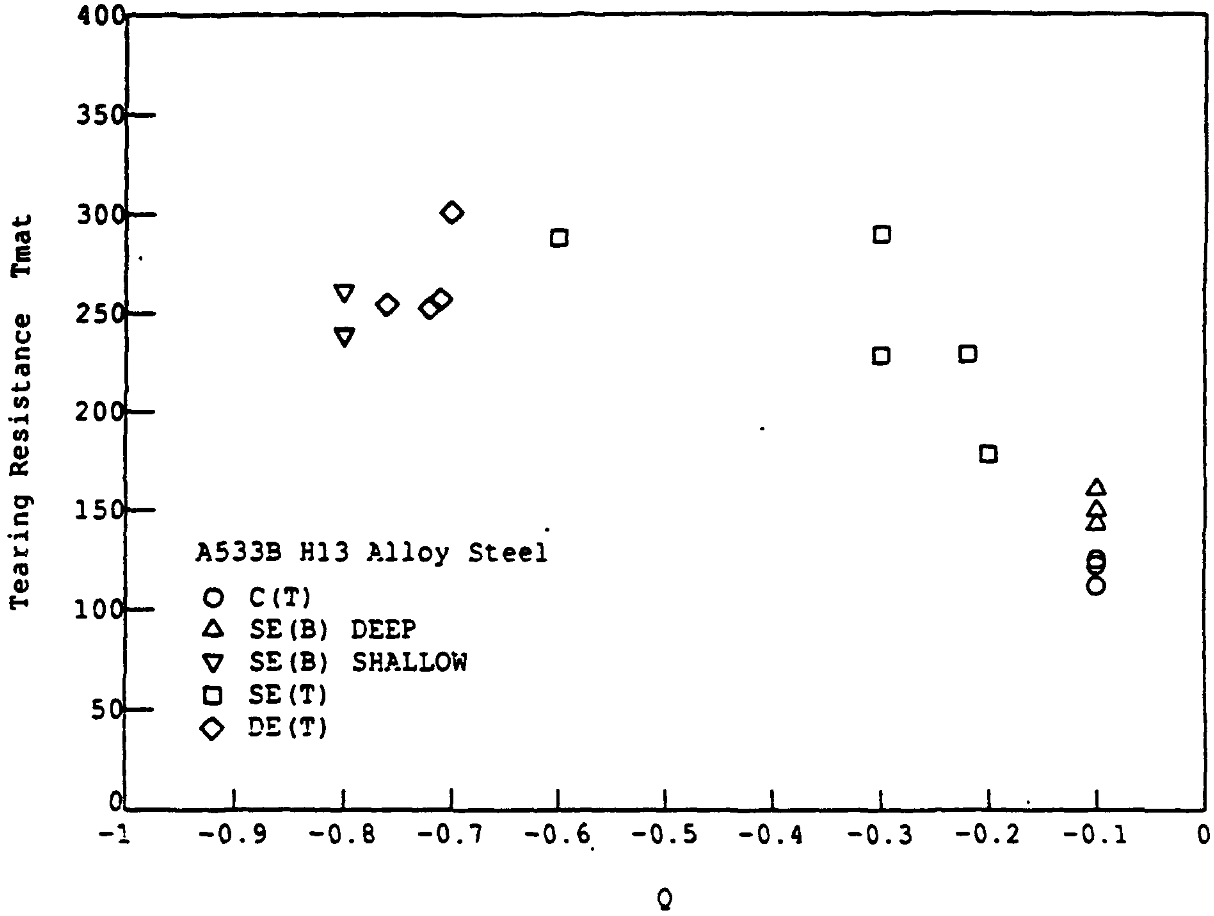

Figure 36 Tearing modulus, T_{mat}, as a function of Q for the A533B specimens.

4.0 SUMMARY

For these materials, at least, the J_{Ic} toughness parameter is relatively insensitive to constraint as characterized by T_σ or Q, while the tearing resistance is elevated by reduced constraint as measured by either T_σ or Q. Thus the J-Q fracture locus is inconsequential for fully ductile behavior, but the T_{mat} - Q locus is an important curve to measure the extent of toughness enhancement that would be expected under conditions of low constraint.

The best results for a low constraint specimen geometry are obtained from the short crack bend specimen. This specimen is now relatively easy to test in the laboratory, and has a low constraint by any measure, especially if the a/W is less than 0.15. Taken together, the deep and short crack bend specimens encompass the range of constraints available even with tension geomtries.

It has been demonstrated (Kirk and Dodds, 1993) that the plastic η for the sort crack bend geometry is dependent on the material strain hardening, and the suggestion has been made in the same work that the J integral should be measured using the crack mouth opening displacement using Eq. (9) presented earlier. This analysis was applied to the specimens of this program, with a typical result shown in Figure 37. Three methods are plotted in Figure 37. The first analysis is the COD J integral calculated using Eq. (9), the second analysis uses the Sumpter η analysis (1987), but does not apply the crack growth correction, and the third analysis uses the Sumpter η and applies the crack growth correction, the method used in the work presented above. In the initiation area there is essentially no difference between the three methods. Beyond the early region, the COD J integral is elevated above the load-line J calculations. In the later part of the resistance curve the two non-crack growth corrected methods cross over, staying above the crack growth corrected analysis. The maximum difference in J values at any given crack extension is on the order of 10%. It is not clear that there is any overriding reason to prefer any one of the three methods, though the use of a crack growth correction has strong analytical support, and has been used throughout this report.

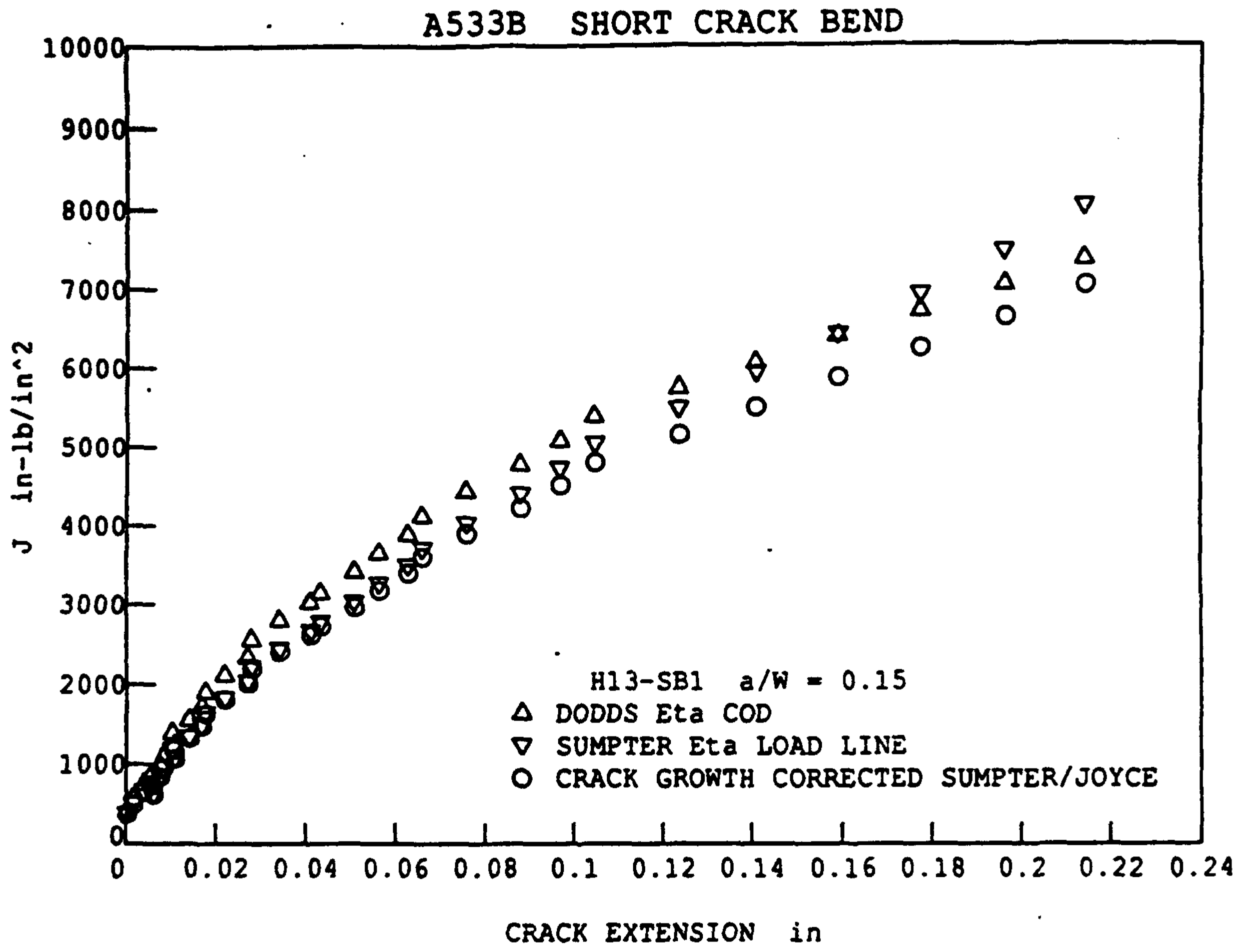

Figure 37 Comparison of J-Resistance curves calculated using three different J formulations.

5.0 CONCLUSIONS

The following conclusions are drawn from this work:

1) A rotation correction is essential for obtaining an accurate J_{Ic} or J-R curve from a SE(T) specimen of the type used in this work. The rotation correction developed here seems to greatly improve the appearance J-R curve.

2) J_{Ic} does not seem to be dependent on constraint, as applied in this study, at least as characterized by T_σ or Q.

3) The material tearing resistance, as characterized by T_{mat}, is strongly affected by constraint, with T_{mat} increasing rapidly with decreasing constraint. This is true whether constraint is measured with T_σ or Q.

4) The best low constraint test specimen geometry is the short crack bend specimen. Techniques have been developed which make it relatively easy to prepare and to test.

REFERENCES

Al-Ani, A. M. and Hancock, J. W. (1991) "J-Dominance in Short Cracks in Tension and Bending", *Journal of Mechanics and Physics of Solids,* Vol. 39, pp. 23-43.

Anderson, T.L. and Dodds, R.H., Jr. (1991) "Specimen Size Requirements for Fracture Toughness Testing in the Transition Region," *Journal of Testing and Evaluation,* JTEVA, Vol. 19, No. 2, March 1991, pp. 123-134.

Betegón, C. and Hancock, J. W. (1991) "Two-Parameter Characterization of Elastic-Plastic Crack-Tip Fields", *Journal of Applied Mechanics,* Vol. 58, pp. 104-110.

Dodds, R.H., Jr., Anderson, T.L., and Kirk, M.T. (1991) "A Framework to Correlate a/W Ratio Effects on Elastic-plastic Fracture Toughness (J_c)," *International Journal of Fracture,* Vol. 48, pp. 1-22.

Hackett, E.M and Joyce, J.A. (1986) "Dynamic J-R Curve Testing of a High Strength Steel Using the Key Curve and Multi-Specimen Techniques," *Fracture Mechanics, ASTM STP 905,* American Society for Testing and Materials, Philadelphia, pp. 741-774.

Haigh, J.R. and Richards, C.E. (1974) "Yield Point Loads and Compliance Functions of Fracture Mechanics Specimens," CEGB Report RD/L/M461, Central Electricity Generating Board, UK.

Hutchinson, J. W. (1968) "Singular Behavior at the End of a Tensile Crack in a Hardening Material", *Journal of Mechanics and Physics of Solids,* Vol. 16, pp. 13-31.

Joyce, J.A., Hackett, E.M. and Roe, C. (1992) "Comparison of J_{Ic} and J-R Curves for Short Crack and Tensilely Loaded Specimen Geometries of a High Strength Structural Steel," NUREG/CR-5879, U.S. Nuclear Regulatory Commission, Washington D.C.

Joyce, J.A. (1992) "J-Resistance Curve Testing of Short Crack Bend Specimens Using Unloading Compliance," *Fracture Mechanics: Twenty-Second Symposium (Volume I), ASTM STP 1131,* H.A. Ernst, A. Saxena, and D.L. McDowell, Eds., American Society for Testing and Materials, Philadelphia, pp. 904-924.

Kfouri, A.P. (1986) "Some Evaluations of the Elastic T-term using Eshelby's Method in *International Journal of Fracture, Vol.* 30, pp. 301-315.

Kirk, M.T. and Dodds, R.H., Jr. (1993) "J and CTOD Estimation Equations for Shallow Cracks in Single Edge Notch Bend Specimens," NUREG/CR-5969, U.S. Nuclear Regulatory Commission, Washington D.C.

Kirk, M.T., and Dodds, R.H. (1991) "An Analytical and Experimental Comparison of Jo Values for Shallow Through and Part Through Surface Cracks," *Engineering Fracture Mechanics*, Vol. 39, No. 3, pp. 535-551.

Kirk, M. T., Koppenhoefer, K. C., and Shih, C. F. (1993) "Effect of Constraint on Specimen Dimensions Needed to Obtain Structurally Relevant Toughness Measures." *Constraint Effects in Fracture, ASTM STP 1171*, E. M. Hackett, et al., Eds., American Society for Testing and Materials, Philadelphia, pp. 79-103.

Kumar, V., German, M.D. and Shih, C.F. (1981) *An Engineering Approach for Elastic-Plastic Fracture*, EPRI NP-1931, Electric Power Research Institute, Palo Alto.

Larrson, S.G. and Carlsson, A.J. (1973) "Influence of Non-Singular Stress Terms and Specimen Geometry on Small-Scale Yielding at Crack tips in an Elastic-Plastic Material," *Journal of Mechanics and Physics of Solids*, Vol. 21, pp. 263-278.

Leevers, P. S. and Radon, J. C. (1982) "Inherent Stress Biaxiality in Various Fracture Specimen Geometries", *International Journal of Fracture*, Vol. 19, pp. 311-325.

O'Dowd, N.P., and Shih, C.F. (1992) "Family of Crack-Tip Fields Characterized by a Triaxiality Parameter: Part II - Fracture Applications," *Journal of the Mechanics and Physics of Solids, Vol. 40,* pp. 939-963.

O'Dowd, N.P. and Shih, C.F. (1991) "Family of Crack-Tip Fields Characterized by a Triaxiality Parameter - I. Structure of Fields," *Journal of Mechanics and Physics of Solids*, Vol. 39, pp. 989-1015.

Paris, P.C., Tada, H., Zahoor, A. and Ernst, H. (1979) "The Theory of Instability of the Tearing Mode of Elastic-Plastic Crack Growth," *Elastic-Plastic Fracture, ASTM STP 668*, J.D. Landes, et al., Eds., American Society for Testing and Materials, Philadelphia, pp. 5-36.

Rice, J. R. and Rosengren, G. F. (1968) "Plane Strain Deformation Near a Crack Tip in a Power-Law Hardening Material", *Journal of Mechanics and Physics of Solids*, Vol. 16, pp. 1-12.

Ritchie, R.O., Knott, J.F. and Rice, J.R. (1973) "On the Relationship Between Critical Fracture Stress and Fracture Toughness in Mild Steel', *Journal of Mechanics and Physics of Solids*, Vol. 21, pp. 395-410.

Sham, T. L. (1991) "The Determination of the Elastic T-Term Using Higher Order Weight Functions", *International Journal of Fracture*, Vol. 48, pp. 81-102.

Sharobeam, M.H., Landes, J.D. and Herrera, R. (1991) "Development of ηFactors in Elastic-Plastic Testing Using a Load Separation Technique," *Elastic-Plastic Fracture Test Methods - The User's Experience, ASTM STP 1114*, J.A. Joyce, Ed., American Society for Testing and Materials, Philadelphia, pp. 114-132.

Sorem, W.A., Dodds, R H., and Rolfe, S.T. (1991) "Effects of Crack Depth on Elastic Plastic Fracture Toughness," *International Journal of Fracture*, Vol. 47, pp. 105-126.

Sumpter, J.D.G. (1987) "J_c Determination for Shallow Notch Welded Bend Specimens," *Fatigue and Fracture of Engineering Materials and Structures*, Vol. 10, No. 6, pp. 479-493.

Sumpter, J. D. G. and Forbes, A.T. (1992) "Constraint Based Analysis of Shallow Cracks in Mild Steel", Proceedings of TWI/EWI International. Conference on Shallow) Crack Fracture Mechanics, Toughness Tests and Applications, Cambridge, UK.

Tada, H., Paris, P.C. and Irwin, G.R. (1985) *The Stress Analysis of Cracks Handbook*, Paris Productions, Inc., St. Louis.

Williams, M. L. (1957) "On the Stress Distribution at the Base of a Stationary Crack", *Journal of Applied Mechanics*, Vol. 24, pp. 109-114.

Wu, S-X, Mai, Y-W and Cotterell, B. (1990) "Plastic η Factors for Specimens With Deep and Shallow Cracks," *International Journal of Fracture*, Vol. 45, pp. 1-18.

APPENDIX A

Data Tables for all Specimens

Specimen FYO-1

Unload No.	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)
1	57	444087	565500	0.9997	0.2	5113.7	0.0091	0.0117	-0.0008	50	0
2	61	446769	565021	0.9998	2	7261.8	0.0133	0.0166	-0.0006	104	3
3	65	444157	563943	0.9998	8.6	9956.3	0.0191	0.0231	0	203	15
4	66	444645	562307	0.9998	23	11986.3	0.0244	0.0291	0.0008	316	42
5	63	443463	560680	0.9998	41.1	13017.5	0.0278	0.0329	0.0016	400	75
6	67	443651	556389	0.9997	62.9	13718.8	0.0307	0.036	0.0037	477	115
7	66	439995	553763	0.9997	86.7	14069	0.033	0.0386	0.0051	543	159
8	71	438509	550207	0.9997	107	14355.9	0.0351	0.0408	0.0069	599	197
9	72	434981	545380	0.9997	132.1	14508.5	0.0372	0.0431	0.0093	658	243
10	72	430684	542519	0.9997	154.3	14599.5	0.0391	0.0451	0.0107	707	284
11	69	428959	536099	0.9997	184.1	14607.2	0.0413	0.0474	0.014	769	339
12	74	422901	527254	0.9997	218.1	14643.4	0.0436	0.05	0.0186	841	401
13	73	415610	518697	0.9996	249.2	14490.1	0.0457	0.0522	0.0231	896	457
14	75	404803	504889	0.9997	287.2	14364.6	0.0484	0.0551	0.0304	970	525
15	75	400354	495443	0.9997	315.4	14252.3	0.0508	0.0576	0.0355	1024	575
16	78	394360	486071	0.9996	348.2	14142.2	0.0531	0.0601	0.0406	1088	634
17	75	389232	478931	0.9997	380	14039	0.0555	0.0625	0.0445	1147	693
18	73	380141	467573	0.9996	417.8	13845.8	0.0581	0.0653	0.0509	1217	761
19	68	374372	458804	0.9996	462.2	13662.2	0.0614	0.0688	0.0558	1300	843
20	69	369337	450882	0.9996	497.6	13611	0.0642	0.0718	0.0604	1371	909
21	73	360018	440192	0.9996	543.1	13408.1	0.0673	0.0752	0.0666	1453	992
22	71	351862	426851	0.9995	590	13132.5	0.0707	0.0788	0.0745	1536	1075
23	74	343831	415952	0.9996	632.1	12909	0.074	0.0822	0.081	1612	1151
24	64	335094	404764	0.9994	680.7	12660.2	0.0777	0.0863	0.0879	1701	1239
25	64	327012	390486	0.9993	735.7	12332.2	0.0818	0.0906	0.0969	1792	1337
26	61	316169	377488	0.9994	781.5	11992.1	0.0853	0.0943	0.1052	1870	1416
27	62	307834	365461	0.9994	827.6	11701.2	0.0893	0.0983	0.1131	1946	1497
28	71	297717	352996	0.9994	877.1	11499.2	0.0936	0.103	0.1214	2037	1585
29	66	291365	343519	0.9993	913.7	11179.6	0.097	0.1064	0.1279	2094	1649
30	69	284592	333126	0.9993	955.2	10938.4	0.1006	0.1101	0.1351	2167	1721
31	71	276681	323079	0.9993	996.3	10673.4	0.1042	0.1137	0.1422	2233	1793
32	74	266852	310320	0.9993	1045.9	10412.6	0.1088	0.1185	0.1515	2318	1878

Specimen FYO-3

Unload No.	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in²)	J Plastic (in-lb/in²)
1	77	454949	567618	0.9999	0.5	5011.3	0.0085	0.0106	-0.0004	47	0
2	67	461483	568609	0.9999	2.5	7410.6	0.013	0.0162	-0.0009	107	3
3	97	459290	566837	0.9999	11.7	9880.8	0.0182	0.0224	0	204	20
4	102	461647	565221	0.9999	34.4	12235	0.0243	0.0295	0.0008	344	62
5	75	460135	564787	0.9998	53.3	13012.3	0.0268	0.0326	0.001	416	96
6	76	460169	562497	0.9998	76.6	13815.9	0.0298	0.0362	0.0021	502	139
7	74	459611	562099	0.9998	88.1	14089	0.0311	0.0376	0.0023	536	161
8	75	458699	559824	0.9998	102.7	14337.8	0.0325	0.0392	0.0035	578	187
9	72	457490	557583	0.9998	124.5	14600.3	0.0343	0.0413	0.0046	636	227
10	73	454562	554541	0.9998	144.3	14832.7	0.036	0.0432	0.0061	687	264
11	76	450524	549823	0.9998	172.8	15028.3	0.0383	0.0457	0.0085	753	316
12	75	447639	546654	0.9997	196.7	15029.3	0.0399	0.0476	0.0101	802	359
13	79	444623	541300	0.9997	227.2	15169.2	0.0422	0.0502	0.0128	870	415
14	84	438252	533768	0.9998	264.4	15068.3	0.0445	0.0527	0.0167	941	482
15	76	436064	527170	0.9997	298.6	15122.2	0.047	0.0555	0.0201	1012	545
16	77	427877	518799	0.9997	341.8	15015.7	0.0496	0.0582	0.0244	1093	623
17	78	421652	509486	0.9997	383.4	14888.8	0.0526	0.0614	0.0294	1171	698
18	82	416640	498962	0.9997	427.4	14806.2	0.0556	0.0646	0.035	1257	776
19	77	411182	492954	0.9997	462.5	14656.5	0.0579	0.0671	0.0382	1320	841
20	75	404632	483026	0.9997	508.2	14522	0.0609	0.0703	0.0437	1406	923
21	79	395310	471938	0.9997	551.6	14405	0.0639	0.0735	0.0498	1485	999
22	81	384127	456363	0.9996	601.1	14023.4	0.0672	0.0769	0.0586	1566	1083
23	78	374807	443503	0.9996	644.2	13798.5	0.0705	0.0804	0.066	1641	1157
24	80	369581	435772	0.9996	670.1	13584.5	0.0727	0.0826	0.0706	1682	1201
25	84	361607	424851	0.9996	717.6	13398.8	0.076	0.0861	0.0771	1768	1286
26	83	352066	413833	0.9995	756.8	13059.7	0.0788	0.0889	0.0837	1828	1353
27	84	342993	401200	0.9996	798.8	12793.7	0.0821	0.0923	0.0915	1899	1423
28	87	334721	389698	0.9996	843.5	12564.5	0.0857	0.0961	0.0987	1976	1501
29	91	326310	379650	0.9995	885.8	12342.6	0.0892	0.0997	0.1051	2049	1575
30	91	317061	367090	0.9995	936.7	12078.3	0.0933	0.1039	0.1133	2135	1663
31	91	307986	356040	0.9995	980.5	11784.6	0.097	0.1078	0.1207	2206	1738
32	92	297146	341815	0.9994	1028.6	11317.6	0.1008	0.1114	0.1304	2272	1815
33	92	285027	326534	0.9993	1089.6	10948.5	0.1062	0.117	0.1411	2372	1918

Specimen FYO-3

Unload Nr	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)
34	96	274768	312869	0.9994	1137.4	10609.1	0.1108	0.1217	0.1509	2444	1993
35	102	264175	298838	0.9993	1187.6	10271.6	0.1157	0.1267	0.1613	2521	2072
36	105	250078	282489	0.9993	1249.9	9821.7	0.1216	0.1327	0.1738	2614	2171
37	109	237851	267536	0.9993	1305.6	9423.5	0.1278	0.1389	0.1657	2692	2256

Specimen FYO-21

Unload No.	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)
1	62	2600303.8	11908627.4	0.99999	-14.1	40343.4	0.0034	0.01206	-0.0005	116.7	-6.7
2	43	2598908.9	11843644.1	0.99996	35.5	60575.6	0.00562	0.02192	0.00093	292.9	16.9
3	55	2598962.2	11710230.8	0.99996	220.9	77163	0.0084	0.03029	0.00389	555.9	105.7
4	55	2577295.1	11344671.4	0.99989	629.4	88180.6	0.01165	0.03987	0.01233	903.2	308.5
5	120	2552456.6	11113895.5	0.99986	875.6	91672.6	0.01337	0.03893	0.0179	1090	433.7
6	54	2553651.4	11148821.4	0.99992	939.8	91938	0.01448	0.03898	0.01704	1151.2	464.3
7	66	2548377.8	11036296.3	0.99994	1121.2	92701.8	0.01547	0.04102	0.01981	1270.5	556.5
8	83	2521481.7	10652450.6	0.99975	1464.2	96779.8	0.01696	0.04572	0.02963	1503.6	742.3
9	74	2505045.2	10488722.1	0.99992	1705.7	96011	0.01886	0.0484	0.034	1661.4	871.6
10	78	2457043.6	9832096.4	0.99961	2189.7	98767.4	0.02091	0.05364	0.05269	2004.6	1164.8
11	76	2430679.5	9632467.5	0.9998	2422	98703	0.0225	0.06273	0.05877	2157.6	1302.7
12	66	2415080.5	9387499.5	0.99978	2622.2	98006.4	0.02398	0.05908	0.0665	2301.1	1430.8
13	88	2372732.6	8990594.4	0.99939	2920.1	98419.6	0.02554	0.06846	0.07972	2525.5	1634.2
14	66	2334989.7	8628172.6	0.99957	3096.3	97423.8	0.02728	0.06445	0.09257	2694.6	1775
15	66	2310595.3	8334677.1	0.99976	3400	97035.8	0.02883	0.07539	0.10359	2902.3	1990.4
16	79	2251070.2	7902822.4	0.99969	3691.5	95766	0.03069	0.07661	0.12086	3180.4	2234.6
17	65	2213380.3	7581352.8	0.99962	3881.6	94332.2	0.03232	0.07845	0.13461	3372.9	2412.5
18	83	2197824.7	7056580.4	0.99946	4104.5	92980.6	0.03405	0.0777[illegible]	0.15889	3665.6	2677.2
19	52	2147274.6	6765973.7	0.99962	4269.8	91138.2	0.03514	0.07988	0.1734	3862.9	2867.8
20	76	2118415.4	6553691.6	0.9997	4349.4	89855.6	0.03615	0.08494	0.18454	3971.5	2988
21	65	2077551.6	6155706.7	0.99947	4509.6	88436.4	0.03745	0.08068	0.20673	4268.5	3248.1

Specimen FYO-26

Unload No.	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)
1	91	1341080	6239362.4	0.99985	-1.3	19646.2	0.00316	0.01465	0.00056	115.6	-1.2
2	102	1351762.7	6230853.6	0.99987	18.8	29200.1	0.00515	0.02231	0.0009	264.2	17.3
3	99	1332551.3	6182362.9	0.99985	72.7	35418.9	0.00702	0.02852	0.00287	439.5	67.4
4	99	1317869.1	6127514.2	0.99981	125.1	38907.6	0.00846	0.03288	0.00513	567.7	116.5
5	94	1318290.8	6062193.5	0.99976	182.6	41242.5	0.00979	0.0364	0.00787	670.5	171.1
6	96	1315963.6	5997058.7	0.99975	257.3	42901	0.01094	0.03931	0.01065	798.3	242.6
7	96	1309412	5929210.5	0.9997	316.3	44043.9	0.01188	0.04168	0.0136	876.5	300.1
8	96	1303162.2	5837405.9	0.99969	383.3	44957.5	0.01293	0.0441	0.01769	975.3	367
9	96	1299696.7	5744028	0.99971	479.6	45945.4	0.01426	0.04713	0.02197	1107.2	463.5
10	93	1295487.4	5670929.8	0.99966	559.8	46386.6	0.01533	0.04922	0.0254	1211	544.9
11	93	1286007.2	5548891.3	0.9996	647.8	47010.7	0.0165	0.0518	0.03129	1331.2	638.4
12	93	1275984.1	5349942.2	0.99953	757	47112.5	0.01797	0.05445	0.04139	1484.1	762.2
13	92	1270185.3	5219969.9	0.99957	832.1	47325	0.01906	0.05645	0.04832	1603.3	849.4
14	93	1256704.7	5077040.1	0.99962	916.9	47317.9	0.02019	0.0584	0.05628	1712.8	950.8
15	94	1242517.6	4824389.3	0.99957	1015.2	47115	0.02169	0.0607	0.07126	1873.4	1084.4
16	86	1216405.9	4438143.7	0.99951	1160.6	46175.8	0.02384	0.06349	0.09669	2136	1304.6
17	88	1202108	4236000.4	0.99955	1230	45900.9	0.02529	0.06556	0.11137	2257.5	1421.4

Specimen FYO-27

Unload No.	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)
1	94	1319160.6	6219615.4	0.99983	-2.5	19631.7	0.0032	0.01508	0.00036	110.3	-2.3
2	102	1349910.6	6228824.4	0.99983	10.8	29256.9	0.00523	0.02261	-0.00001	256.2	9.9
3	99	1328226.4	6206841.7	0.99987	52.1	33307.9	0.00637	0.02638	0.00087	378.3	48
4	99	1327370.6	6195222.1	0.99982	62.5	35819.5	0.00723	0.02906	0.00135	439.3	57.7
5	97	1330019.6	6185832.1	0.99982	89.4	37642.1	0.00793	0.03105	0.00173	502.8	82.6
6	96	1325862.1	6161016.5	0.99975	120.5	39030.6	0.00857	0.03289	0.00275	553.6	111.6
7	96	1329412.1	6139346.4	0.99973	147.7	40228.7	0.0092	0.03463	0.00364	619.9	137
8	96	1323237.2	6112482.9	0.99973	187.1	41229.4	0.00983	0.03623	0.00475	669.7	174.1
9	96	1320801	6068088	0.99973	220.7	42335.7	0.01053	0.03805	0.00662	731.5	206.1
10	96	1315273.8	6011221.3	0.9997	268.6	43313.5	0.01131	0.03993	0.00904	817.5	252.3
11	96	1312844.5	5966994.1	0.99968	320.2	44028.3	0.01214	0.04174	0.01095	879.5	302.1
12	95	1303893.6	5889593.7	0.99969	378.2	44902.6	0.01297	0.04384	0.01435	962.7	359.5
13	95	1307925	5831290.5	0.99966	434.2	45634.6	0.01385	0.04586	0.01697	1042.2	415.1
14	95	1298678.1	5799731.3	0.99964	507.9	46155.7	0.01476	0.04776	0.0184	1132.6	487
15	91	1296438.4	5745705.4	0.99959	569.8	46567	0.01566	0.04966	0.02089	1215.4	549.2
16	93	1290539.3	5681632.2	0.99955	652	47224.8	0.01669	0.05202	0.02389	1319.7	632.5
17	94	1287767.9	5598529	0.99956	734	47461.5	0.01774	0.05411	0.02787	1423.3	718.1
18	95	1277990	5528805.7	0.99957	823.7	47888.3	0.01886	0.05632	0.03129	1534.9	811.5
19	94	1277798.4	5445077.9	0.99959	902.3	48095	0.01989	0.05842	0.03548	1633.8	896.6
20	94	1274700.4	5356337.6	0.99953	995.2	48345.4	0.02099	0.0606	0.04005	1752.3	998.2
21	93	1266187.7	5225851.4	0.9994	1112.8	48264.8	0.02238	0.06304	0.047	1904.1	1132.2
22	91	1253507.6	5093526.6	0.99942	1224.7	48253	0.0238	0.06559	0.05435	2055.1	1264.5
23	90	1244213.1	4926743.8	0.99946	1339.7	48158.2	0.02536	0.06825	0.06405	2235.2	1410.2
24	91	1238065.4	4790891.8	0.99941	1432.6	48071.3	0.02662	0.07039	0.07234	2358.3	1532.3
25	90	1218301.4	4573471.2	0.99938	1559.6	47544.9	0.02825	0.07277	0.08641	2555.7	1714.5
26	88	1208249.2	4410676.7	0.99945	1641.6	47161.8	0.02965	0.07483	0.09762	2713.3	1843.3
27	90	1191990.8	4188342.5	0.99938	1765.7	46517.4	0.03139	0.07724	0.11398	2931.7	2046.4
28	92	1170423.7	3965836.2	0.99939	1884.1	45946.6	0.0333	0.07991	0.13167	3145.7	2259.8
29	93	1155780.1	3825107	0.99939	1960.1	45521.9	0.03473	0.08188	0.1436	3302.1	2405.5
30	88	1139695.4	3605203.9	0.99933	2077.7	44361	0.03654	0.08389	0.16352	3554.7	2653.2
31	86	1116530.2	3395362.3	0.99938	2173	43454.2	0.03823	0.08583	0.18414	3806.3	2893.5

Specimen FYO-150

Unload No.	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)
1	65	299916	405092	0.9998	0	4380.4	0.0105	0.014	-0.0012	94	0
2	59	299320	404585	0.9998	1.7	6262.2	0.0158	0.0207	-0.0008	198	5
3	57	297795	404145	0.9998	9	7530.1	0.0201	0.0261	-0.0005	308	29
4	63	297799	401300	0.9997	25	8568.7	0.0247	0.0318	0.0017	444	80
5	64	297172	398216	0.9997	38.5	8973.9	0.0272	0.0345	0.0041	521	123
6	63	294835	395412	0.9997	51	9278	0.0293	0.0371	0.0063	595	163
7	63	292424	393654	0.9997	61.9	9529.7	0.0313	0.0394	0.0076	656	198
8	63	291889	390527	0.9997	74	9721.7	0.0331	0.0414	0.0101	716	237
9	61	289685	387094	0.9997	88.2	9775.3	0.0347	0.0433	0.0128	775	282
10	62	287085	382539	0.9996	102.7	9883.5	0.0366	0.0453	0.0165	836	329
11	61	282226	377412	0.9996	118.7	9908.2	0.0384	0.0472	0.0206	895	379
12	63	278833	371893	0.9996	133.5	9929.2	0.0403	0.0496	0.0251	958	426
13	62	276834	368195	0.9996	149	9951.9	0.0421	0.0516	0.0281	1017	475
14	64	273208	362804	0.9995	167.4	9936.4	0.0439	0.0535	0.0326	1080	534
15	62	270137	358629	0.9995	181.1	9924.4	0.0455	0.0553	0.036	1129	577
16	65	264937	350119	0.9995	202.1	9806.6	0.0475	0.0573	0.0432	1195	642
17	62	261287	343416	0.9994	221.7	9700.2	0.0496	0.0597	0.049	1260	704
18	61	254975	335304	0.9993	239.4	9521.7	0.0512	0.0615	0.0561	1313	758
19	64	251290	328154	0.9993	255.1	9420	0.0532	0.0635	0.0624	1361	805
20	66	248169	322622	0.9993	270.6	9350	0.055	0.0655	0.0674	1414	854
21	64	239876	312117	0.9991	294.2	9092.9	0.057	0.0672	0.077	1473	925
22	63	231153	296624	0.9988	313.5	8786.8	0.0591	0.0695	0.0916	1520	975
23	63	224515	287561	0.9989	324.7	8603.3	0.061	0.0713	0.1003	1549	1003
24	65	219473	281136	0.9992	337.7	8432.1	0.0628	0.0734	0.1067	1584	1041

Specimen FYO-151

Unload No.	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)
1	44	286300	395188	0.9997	0	4416.6	0.0109	0.0144	-0.0002	100	0
2	65	295888	391920	0.9997	3.2	6863.9	0.0185	0.0237	0.0023	252	10
3	68	295699	390155	0.9998	14.1	7538.7	0.0212	0.0269	0.0037	338	46
4	72	296954	388932	0.9998	24.2	8166.6	0.0241	0.0301	0.0047	418	78
5	76	292840	385286	0.9997	41.1	8660	0.0271	0.0337	0.0076	520	133
6	73	290727	383195	0.9997	46.9	8915.1	0.0288	0.0358	0.0092	567	152
7	75	288122	381211	0.9997	57.6	9157	0.0308	0.038	0.0108	626	187
8	75	286140	378635	0.9997	70.7	9345.6	0.0329	0.0404	0.0129	690	229
9	75	282334	373122	0.9997	88.8	9492.4	0.0352	0.0431	0.0174	773	288
10	71	278756	369776	0.9997	102.7	9600.6	0.0372	0.0455	0.0201	834	333
11	70	276200	364734	0.9996	119.9	9665.4	0.0394	0.0478	0.0243	903	388
12	67	273382	361850	0.9996	135.5	9687.7	0.0412	0.0499	0.0267	963	439
13	68	270252	357461	0.9996	149.2	9689.8	0.0428	0.0516	0.0303	1013	483
14	69	269147	354060	0.9996	162.1	9685.1	0.0444	0.0532	0.0332	1056	525
15	71	264757	349172	0.9996	181.3	9703.5	0.0463	0.0554	0.0374	1129	587
16	71	259551	341453	0.9995	205.7	9579.9	0.0487	0.058	0.044	1209	664
17	74	256707	335206	0.9995	220.4	9498.3	0.0505	0.06	0.0495	1258	710
18	75	253093	331126	0.9995	238.2	9438.1	0.0524	0.0623	0.0531	1322	768
19	73	247297	322581	0.9995	258.1	9307	0.0543	0.0643	0.0607	1383	829
20	71	240608	313427	0.9994	275.2	9047.1	0.056	0.0658	0.0691	1419	879
21	72	234196	303133	0.9993	293.3	8902.2	0.0583	0.0684	0.0787	1479	931
22	75	228781	294561	0.9993	310.5	8752.2	0.0604	0.0705	0.0869	1528	982
23	73	224827	289436	0.9993	324.9	8639.5	0.0623	0.0728	0.0918	1575	1028
24	76	219955	281934	0.9992	345.6	8519.8	0.0647	0.075	0.0992	1638	1093
25	76	215986	274735	0.9992	364.5	8406.3	0.0671	0.0778	0.1064	1701	1151

Specimen FYO-158

Unload No	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)
1	94	160034	207768	0.9999	0	2258.8	0.0105	0.0136	0	96	0
2	77	160201	207548	0.9998	2	3223.8	0.016	0.0206	0.0003	211	12
3	80	159322	207568	0.9998	6.2	3734.4	0.0196	0.0249	0.0003	303	39
4	78	159398	207214	0.9998	8.6	3947.4	0.0214	0.0271	0.0008	350	54
5	87	158990	206548	0.9998	12.8	4136.4	0.0233	0.0293	0.0018	407	81
6	87	157716	206251	0.9998	17.1	4288.6	0.025	0.0314	0.0023	458	108
7	86	157226	205760	0.9998	21.5	4423.4	0.0267	0.0333	0.003	507	136
8	90	156686	204801	0.9998	26.9	4537	0.0284	0.0354	0.0045	564	170
9	95	156200	203566	0.9997	33.4	4649.7	0.0304	0.0377	0.0064	628	211
10	98	155509	202417	0.9997	39.9	4729.1	0.0321	0.0396	0.0081	683	252
11	95	154551	201477	0.9997	44.4	4756.6	0.0332	0.0409	0.0096	721	281
12	94	153152	199906	0.9997	51.7	4804.1	0.035	0.0429	0.012	779	327
13	92	151721	198826	0.9996	58	4837.6	0.0366	0.0446	0.0137	828	367
14	88	151127	197759	0.9997	64.1	4852.5	0.0381	0.0463	0.0153	873	405
15	81	149747	195614	0.9996	71.6	4847.3	0.0395	0.0479	0.0187	925	452
16	73	147974	192903	0.9996	79.6	4840.8	0.0412	0.0499	0.023	982	502
17	71	146327	191412	0.9996	87.4	4858	0.0431	0.052	0.0254	1039	552
18	76	144242	188199	0.9995	97.4	4823.4	0.0451	0.0542	0.0306	1103	613
19	76	141688	184455	0.9993	107.4	4739.4	0.0469	0.0562	0.0367	1160	674
20	78	139271	181004	0.9994	115.9	4695.9	0.0488	0.0581	0.0424	1212	726
21	79	137214	177688	0.9994	123.2	4634.7	0.0504	0.0599	0.0479	1257	769
22	82	135716	175396	0.9995	132.7	4624.3	0.0526	0.0622	0.0518	1318	830
23	77	132899	171480	0.9994	141.6	4524.6	0.0541	0.0639	0.0585	1365	882
24	76	129897	166921	0.9993	148.6	4416.7	0.0556	0.0655	0.0665	1398	920
25	76	127111	163183	0.9994	156.1	4351.4	0.0574	0.0673	0.0732	1439	964
26	79	124987	159396	0.9993	161.4	4313.6	0.059	0.0689	0.08	1470	992
27	80	123175	156872	0.9992	168.8	4245.6	0.0606	0.0708	0.0846	1514	1037
28	82	122272	154879	0.9994	175.2	4228.8	0.0623	0.0726	0.0883	1555	1078
29	84	120056	151590	0.9992	184.8	4161.9	0.0642	0.0746	0.0945	1613	1137
30	87	119488	149955	0.9993	191.9	4134.9	0.0662	0.0767	0.0976	1660	1183
31	92	117463	146042	0.9992	202.4	4059	0.0681	0.0786	0.1051	1717	1246

Specimen FYO-159

Unload No.	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)
1	56	143763	192616	0.9996	0	2169.1	0.0111	0.0144	-0.0017	99	0
2	54	142988	193574	0.9996	0.7	2990.2	0.0162	0.0206	-0.0032	189	5
3	54	142204	192462	0.9996	2	3337.9	0.0188	0.0237	-0.0014	245	13
4	53	142373	192634	0.9996	4.2	3582.7	0.0209	0.0262	-0.0017	296	28
5	53	142199	192484	0.9997	8	3822.7	0.0233	0.029	-0.0014	358	53
6	52	141117	191887	0.9996	12.5	3993.3	0.0254	0.0313	-0.0005	414	81
7	51	141454	191185	0.9996	16.4	4145.3	0.0273	0.0336	0.0006	467	107
8	51	140802	191338	0.9997	22.2	4248.5	0.0292	0.0357	0.0004	523	145
9	51	141169	189944	0.9996	27.1	4348.1	0.0309	0.0376	0.0026	576	177
10	51	140870	188859	0.9996	33.7	4425	0.0327	0.0396	0.0044	636	220
11	51	141226	189245	0.9993	41	4502.2	0.0347	0.0418	0.0037	697	269
12	51	139430	188540	0.9994	48.8	4545.8	0.0366	0.0439	0.0049	760	320
13	51	139542	187304	0.9995	55	4607.4	0.0385	0.0459	0.0069	814	360
14	51	138595	185245	0.9993	65.5	4647.1	0.0408	0.0485	0.0103	895	428
15	51	137144	183753	0.9992	72.7	4660.8	0.0426	0.0504	0.0127	950	474
16	51	137672	182645	0.9992	79.4	4674.3	0.0443	0.0523	0.0145	1000	518
17	51	136384	182236	0.9991	87.2	4669.5	0.0458	0.0537	0.0152	1051	569
18	53	134662	179966	0.9992	94.7	4636.9	0.0474	0.0555	0.019	1101	617
19	53	134069	178271	0.9995	101.9	4603.4	0.0491	0.057	0.0218	1142	663
20	53	132422	175503	0.9994	110.3	4589.3	0.0508	0.059	0.0265	1200	715
21	53	130951	173294	0.9994	116.7	4552.6	0.0524	0.0605	0.0303	1242	755
22	55	129753	172019	0.9995	124.1	4529.3	0.0541	0.0624	0.0325	1290	803
23	55	129004	169833	0.9994	133	4483.7	0.056	0.0644	0.0363	1347	860
24	55	127986	168522	0.9991	139.9	4495.7	0.0577	0.0661	0.0386	1395	905
25	56	125961	165333	0.9991	149.8	4417.6	0.0596	0.0681	0.0442	1453	966
26	56	124286	162687	0.9991	158	4358.9	0.0615	0.0699	0.0489	1497	1017
27	55	122650	160199	0.999	166	4291.7	0.0632	0.0716	0.0534	1543	1066
28	55	120013	156805	0.999	172.9	4252.6	0.065	0.0733	0.0596	1584	1106
29	54	117471	153682	0.9989	178.6	4171.6	0.0664	0.0749	0.0654	1612	1137
30	56	115677	150955	0.999	185.4	4136.6	0.0684	0.0769	0.0706	1652	1177
31	58	113014	147002	0.9989	193.7	4050.8	0.0703	0.0787	0.0781	1694	1224
32	57	110133	143418	0.999	199.3	3983	0.0719	0.0804	0.0851	1723	1253
33	57	108943	141421	0.9992	203.5	3919.5	0.0733	0.0816	0.089	1739	1276

Specimen FYO-159

Unload No.	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)
34	60	107717	138685	0.999	211.9	3890.2	0.0755	0.0841	0.0945	1797	1329
35	61	106268	136457	0.9989	218.8	3863	0.0774	0.0858	0.099	1839	1371
36	63	104614	133395	0.9989	225.3	3802.1	0.079	0.0875	0.1052	1874	1407

Specimen FYO-160

Unload No.	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)
1	92	708246.6	3733138.2	0.99942	0.6	7198.3	0.00183	0.00977	0.00071	54.2	1
2	55	703380.5	3728577.5	0.99845	3.5	10454.3	0.00283	0.01451	0.00098	116.7	5.9
3	56	707201.3	3713487.5	0.99886	11	14819.4	0.00451	0.02137	0.00185	240.5	18.4
4	55	707706.3	3700816.5	0.99907	33.9	17621	0.00607	0.0266	0.00259	370.6	56.8
5	71	713371.2	3654276.2	0.99923	62.7	19247.6	0.00741	0.03045	0.00536	481.2	106.1
6	84	713881.8	3595747.7	0.9994	103	20521.3	0.00882	0.03402	0.00893	608.5	175.9
7	89	711043.7	3556632.1	0.99939	141.4	21312.5	0.01006	0.03686	0.01137	719.4	243
8	71	709746.3	3493864.5	0.99913	182.4	21878.7	0.01136	0.03967	0.01541	822.3	316.8
9	78	704187.9	3430653.8	0.99915	225.7	22435.1	0.01267	0.04245	0.01962	931.6	395.9
10	80	700753.4	3339309.4	0.99931	265.8	22839.5	0.01399	0.04513	0.02595	1041.7	473.6
11	83	699631.9	3269552.4	0.99936	302.3	23113.1	0.01508	0.04706	0.03101	1140.3	544.9
12	78	695774.2	3236614.4	0.99933	336	23288.8	0.01601	0.04885	0.03346	1211.7	608.9
13	77	693018.1	3188252.1	0.99943	367	23448.4	0.01696	0.0506	0.03715	1297.2	670.3
14	69	688339.1	3139332.8	0.99927	400.8	23420.7	0.01792	0.05211	0.04099	1370.4	738.1
15	70	684017.1	3035732	0.99944	440.3	23446	0.01918	0.05408	0.04947	1475.1	826.2
16	68	679616.9	2964077	0.99928	482.7	23523.6	0.02046	0.05623	0.05565	1582.5	917.8
17	72	677817.5	2891162.4	0.99935	518.3	23503.6	0.02156	0.05784	0.0622	1676	999
18	59	670387.8	2749831.1	0.99906	578.9	23154.4	0.02324	0.05996	0.07574	1834.6	1147.9
19	57	662956.5	2658458.3	0.99915	604.2	23048	0.02427	0.06123	0.08512	1921.4	1220.1
20	68	663222.1	2571594.1	0.99932	628.9	23001.4	0.02528	0.06268	0.09455	2011.1	1293.3
21	69	659743.2	2480611.8	0.9991	666.5	22688.5	0.02628	0.06373	0.105	2122	1398.8
22	76	652328.2	2368346.9	0.99913	696.2	22388	0.02734	0.06489	0.11875	2229.7	1499.5
23	65	642731.3	2319000.5	0.99927	716.7	22236.7	0.02826	0.06595	0.12513	2296.9	1562.2
24	63	637879.4	2231760.6	0.99935	747.4	22017.9	0.02956	0.06752	0.13691	2411.8	1665.4
25	69	632216.8	2160709.3	0.99924	777.4	21844.5	0.03064	0.06878	0.14704	2521	1765.8
26	75	629253.3	2076642.8	0.99916	811.7	21700.8	0.03196	0.07052	0.15967	2657.2	1888.2
27	66	615587	2005531.6	0.99922	851.3	21391.8	0.03322	0.07192	0.17096	2795.6	2023.6
28	66	610159.8	1923977.6	0.99903	878.9	20978.4	0.03456	0.0733	0.18462	2916.6	2144.4
29	71	603065.5	1857028.1	0.9991	912.8	20770.5	0.03583	0.07483	0.19646	3056	2278.9

Specimen FYO-161

Unload No.	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)
1	71	712201.5	3933531.9	0.99909	0.4	6771.8	0.00158	0.00904	0.00073	46.5	0.6
2	67	707102.5	3919505.4	0.99893	5.8	11982	0.00314	0.01675	0.00146	153	9.4
3	65	705386.2	3908991.6	0.99906	17.3	15566.2	0.0046	0.02276	0.00201	261.1	28.1
4	64	704093.9	3883441.2	0.99916	45.6	18321.3	0.00626	0.02832	0.00337	399.7	74.5
5	77	702833.5	3849570.3	0.99935	82.2	20046.7	0.00779	0.03261	0.0052	523.9	135
6	78	704405	3823921.3	0.99939	113.7	21037.3	0.00897	0.03573	0.0066	614.9	187.4
7	77	703687.4	3775795.4	0.9993	153.6	21658.3	0.01009	0.03831	0.00928	714.7	255.1
8	74	701874.9	3733718.9	0.99933	192.6	22337	0.01127	0.04106	0.01168	812.5	321.9
9	72	700123.5	3666672.2	0.99929	233.4	22757.2	0.01249	0.04362	0.01561	912.9	394.3
10	75	693750.6	3598238.8	0.99926	284.8	23109.4	0.01382	0.0463	0.01977	1031.2	486.4
11	76	690067.4	3496566.8	0.99926	328.9	23312.5	0.01518	0.04881	0.02623	1146	571
12	74	685741	3408872.5	0.99942	361.7	23474.5	0.01621	0.05073	0.0321	1223.8	636.6
13	71	683855.8	3353745.2	0.99936	394.2	23556.9	0.01714	0.05224	0.03593	1308.2	700
14	72	681018.1	3265409	0.99932	431.1	23668.9	0.01821	0.05413	0.04231	1402.2	776.9
15	67	675726.8	3166443.6	0.9993	467	23506.6	0.0192	0.05545	0.04985	1485	855.8
16	71	669318.1	3033813.1	0.99923	506.4	23371.2	0.02047	0.05722	0.06064	1604.1	950.3
17	76	666198.1	2960632.4	0.9993	534.6	23430.2	0.02152	0.05884	0.06695	1684.7	1016.5
18	69	662358.7	2882689.3	0.99931	565.8	23371.9	0.02241	0.06021	0.07398	1774.1	1091.5
19	69	657390.8	2840456	0.99936	590.2	23374.7	0.0232	0.06145	0.07792	1829.1	1147.7
20	70	649758.4	2737474.7	0.9994	624	23227.6	0.02427	0.06295	0.08797	1934.4	1238.2
21	73	652924	2704574.4	0.99942	632.7	23156.4	0.02478	0.06372	0.09132	1964.3	1263.6
22	69	649082.9	2647260	0.99935	671.5	23058.2	0.02568	0.06505	0.09731	2060.7	1357.1
23	75	641123.1	2552820.4	0.99939	706.8	22852.7	0.02682	0.06642	0.10766	2172.8	1457.5
24	70	633651.8	2506153.7	0.99932	731.8	22763.7	0.02779	0.0677	0.11301	2246.4	1524.5
25	73	633396.9	2453589.9	0.9993	752.9	22672.1	0.02867	0.06904	0.11922	2323.8	1587
26	77	627060.8	2389561	0.9993	789.2	22579	0.02967	0.0705	0.12708	2426.2	1688.6
27	74	623521.6	2332441.9	0.99931	815.8	22426.4	0.03062	0.07166	0.13437	2511.2	1769.6
28	70	619148.6	2265397.3	0.99935	855.2	22207.8	0.03184	0.07324	0.14329	2637.1	1886.8
29	67	614317.7	2209155.1	0.99935	882.5	22042.9	0.03283	0.07455	0.15108	2726.5	1975.7
30	64	607549.6	2135032.4	0.99927	921.5	21749.6	0.0341	0.07608	0.16182	2863.5	2105.3
31	70	601415.2	2074612.1	0.9995	949.9	21676	0.03523	0.07765	0.17099	2971.6	2207.9
32	67	595803.1	2008664.6	0.99929	977.5	21294.1	0.03625	0.07873	0.18145	3080.3	2317.3
33	61	588695	1950406.1	0.99934	998.5	21108.8	0.03708	0.07967	0.1911	3186.9	2410.8

Specimen FYO-2SB

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	82	0.0053	5616064	1.0000	0.0029	8019924	0.9991	30430	2	-3	1.0596	-0.0006	100	0	0.0000	0.0000
2	200	0.0081	5616085	1.0000	0.0048	8136351	0.9995	45890	-2	-7	1.0596	-0.0006	219	-9	0.0000	0.0000
3	85	0.0109	5587539	1.0000	0.0065	8090098	0.9999	59385	21	4	1.0614	0.0012	398	14	0.0000	0.0000
4	107	0.0126	5557910	1.0000	0.0074	8124071	0.9999	66411	47	10	1.0633	0.0031	509	25	0.0000	0.0000
5	133	0.0144	5525846	1.0000	0.0085	8167988	0.9999	73127	86	26	1.0654	0.0052	650	60	0.0000	0.0000
6	169	0.0162	5476552	1.0000	0.0093	8168976	1.0000	78591	137	49	1.0686	0.0084	795	106	0.0000	0.0000
7	112	0.0179	5415084	1.0000	0.0103	8151694	1.0000	83470	193	73	1.0727	0.0125	943	156	0.0000	0.0000
8	150	0.0194	5376731	1.0000	0.0108	8152035	1.0000	86956	257	100	1.0753	0.0151	1074	213	0.0000	0.0000
9	198	0.0211	5293345	0.9999	0.0116	8113760	1.0000	90476	337	133	1.0809	0.0207	1229	280	0.0000	0.0000
10	67	0.0233	5240089	1.0000	0.0129	8099657	1.0000	94234	452	184	1.0845	0.0243	1426	385	0.0000	0.0000
11	70	0.0256	5095065	0.9999	0.0136	8021584	1.0000	96306	619	261	1.0947	0.0345	1666	542	0.0000	0.0000
12	112	0.0282	4970982	0.9999	0.0147	7923607	1.0000	98757	776	334	1.1036	0.0434	1908	692	0.0000	0.0000
13	179	0.0300	4738143	0.9997	0.0155	7706599	0.9999	99765	884	378	1.1209	0.0607	2085	774	0.0000	0.0000
14	153	0.0306	4820617	0.9999	0.0162	7833191	0.9999	99403	855	362	1.1147	0.0545	2019	743	0.0000	0.0000
15	181	0.0319	4758198	0.9999	0.0166	7796316	1.0000	100134	1006	429	1.1194	0.0592	2200	885	0.0000	0.0000
16	94	0.0337	4638729	0.9999	0.0173	7674749	0.9999	101062	1133	490	1.1285	0.0683	2385	1006	0.0000	0.0000
17	95	0.0363	4468136	0.9998	0.0184	7515667	0.9999	101550	1331	577	1.1421	0.0819	2635	1181	0.0000	0.0000
18	101	0.0380	4373510	0.9998	0.0193	7426796	0.9999	101247	1425	619	1.1498	0.0896	2745	1265	0.0000	0.0000
19	101	0.0398	4301155	0.9998	0.0199	7364667	0.9999	101052	1564	680	1.1558	0.0956	2894	1391	0.0000	0.0000
20	155	0.0434	3964939	0.9991	0.0209	7044305	0.9996	100374	1899	824	1.1851	0.1249	3291	1663	0.0000	0.0000
21	103	0.0443	4083137	0.9999	0.0212	7184853	0.9999	98436	1848	818	1.1745	0.1143	3181	1667	0.0000	0.0000
22	107	0.0456	3913218	0.9998	0.0223	7012878	0.9999	98501	2046	896	1.1898	0.1296	3408	1816	0.0000	0.0000
23	107	0.0477	3800780	0.9997	0.0228	6914778	0.9998	97922	2158	947	1.2002	0.1401	3537	1911	0.0000	0.0000
24	98	0.0499	3696868	0.9996	0.0236	6805105	0.9996	97059	2319	1022	1.2102	0.1500	3711	2062	0.0000	0.0000
25	98	0.0524	3515297	0.9993	0.0243	6609103	0.9997	95589	2530	1115	1.2282	0.1680	3929	2235	0.0000	0.0000
26	84	0.0560	3303412	0.9998	0.0254	6364645	0.9999	88823	2919	1289	1.2503	0.1901	4153	2583	0.0000	0.0000
27	80	0.0594	3082933	0.9997	0.0268	6055154	0.9998	86846	3134	1393	1.2747	0.2145	4380	2757	0.0000	0.0000

Specimen FYO-3SB

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	69	0.0059	3556527	1.0000	0.0033	6124949	0.9999	22387	2	−2	1.2240	0.0005	93	1	0.0000	0.0000
2	70	0.0095	3573553	1.0000	0.0053	6173353	0.9999	34412	3	−4	1.2223	−0.0012	212	−3	0.0000	0.0000
3	101	0.0129	3582663	1.0000	0.0071	6193687	1.0000	44686	26	4	1.2214	−0.0021	377	15	0.0000	0.0000
4	108	0.0165	3577314	1.0000	0.0089	6254355	1.0000	53982	77	23	1.2219	−0.0016	587	58	0.0000	0.0000
5	136	0.0191	3554404	1.0000	0.0102	6248385	1.0000	59642	134	50	1.2242	0.0007	772	121	0.0000	0.0000
6	180	0.0213	3518105	1.0000	0.0111	6268865	1.0000	63691	197	75	1.2279	0.0044	930	178	0.0000	0.0000
7	134	0.0234	3499517	1.0000	0.0121	6276275	1.0000	67204	252	106	1.2298	0.0063	1093	252	0.0000	0.0000
8	153	0.0253	3457579	1.0000	0.0130	6238168	1.0000	70009	325	139	1.2341	0.0106	1253	327	0.0000	0.0000
9	124	0.0273	3424606	1.0000	0.0141	6231073	1.0000	72483	399	172	1.2375	0.0140	1407	404	0.0000	0.0000
10	142	0.0293	3385166	1.0000	0.0149	6207208	1.0000	74431	489	213	1.2416	0.0181	1571	499	0.0000	0.0000
11	165	0.0313	3340204	1.0000	0.0155	6166284	[illegible]	75995	583	255	1.2464	0.0229	1729	595	0.0000	0.0000
12	95	0.0330	3308659	1.0000	0.0163	6142547	1.0000	77363	662	291	1.2497	0.0262	1868	679	0.0000	0.0000
13	93	0.0355	3221129	1.0000	0.0173	6059114	1.0000	77799	831	362	1.2592	0.0357	2078	839	0.0000	0.0000
14	130	0.0375	3158764	0.9999	0.0182	5985819	1.0000	78378	925	409	1.2662	0.0427	2231	945	0.0000	0.0000
15	185	0.0392	3094926	0.9998	0.0189	5914497	1.0000	79014	1007	446	1.2734	0.0499	2364	1026	0.0000	0.0000
16	172	0.0406	3082644	0.9999	0.0196	5898638	1.0000	79041	1074	481	1.2748	0.0513	2454	1109	0.0000	0.0000
17	118	0.0423	3030951	0.9999	0.0201	5851293	1.0000	79394	1193	528	1.2807	0.0572	2599	1216	0.0000	0.0000
18	99	0.0445	2950660	0.9998	0.0211	5810027	0.9999	79911	1316	585	1.2902	0.0667	2787	1343	0.0000	0.0000
19	82	0.0459	2929489	0.9999	0.0217	5791555	0.9994	79464	1382	626	1.2927	0.0692	2880	1440	0.0000	0.0000
20	81	0.0477	2858580	0.9999	0.0221	5645739	1.0000	77645	1558	693	1.3013	0.0778	3002	1588	0.0000	0.0000
21	146	0.0494	2768588	0.9997	0.0231	5563459	0.9999	78336	1618	713	1.3125	0.0890	3111	1619	0.0000	0.0000
22	156	0.0505	2719929	0.9998	0.0235	5511474	0.9999	77476	1660	740	1.3187	0.0952	3164	1675	0.0000	0.0000
23	171	0.0522	2638091	0.9997	0.0238	5391929	0.9999	76086	1789	789	1.3293	0.1058	3265	1777	0.0000	0.0000
24	168	0.0539	2540203	0.9994	0.0245	5284984	0.9999	74894	1885	825	1.3424	0.1189	3344	1839	0.0000	0.0000
25	185	0.0552	2522549	0.9998	0.0249	5244165	0.9999	73985	1927	835	1.3448	0.1213	3341	1860	0.0000	0.0000
26	100	0.0565	2450115	0.9997	0.0256	5289226	0.9989	73497	2022	861	1.3548	0.1313	3414	1903	0.0000	0.0000

Specimen FYO-4SA

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	61	0.0086	1054072	1.0000	0.0021	2372649	0.9998	10503	3	-4	1.6269	0.0081	107	20	0.0000	0.0000
2	89	0.0192	1081139	1.0000	0.0068	2327990	1.0000	20269	17	7	1.6193	0.0005	368	57	0.0000	0.0000
3	84	0.0262	1090958	1.0000	0.0100	2338890	1.0000	25484	76	25	1.6166	-0.0022	606	119	0.0000	0.0000
4	103	0.0342	1081912	1.0000	0.0136	2336382	1.0000	29983	190	74	1.6191	0.0003	964	283	0.0000	0.0000
5	127	0.0448	1026974	0.9998	0.0183	2260996	0.9998	33408	421	173	1.6347	0.0158	1513	608	0.0000	0.0000
6	123	0.0530	950256	0.9997	0.0217	2123435	0.9997	33807	629	266	1.6576	0.0387	1929	901	0.0000	0.0000
7	77	0.0572	936854	0.9998	0.0232	2100992	0.9998	33784	685	290	1.6617	0.0429	2026	981	0.0000	0.0000
8	69	0.0627	872685	0.9995	0.0253	1984408	0.9996	33144	872	367	1.6823	0.0634	2323	1216	0.0000	0.0000
9	75	0.0687	817443	0.9996	0.0275	1884248	0.9996	31624	1040	437	1.7009	0.0821	2529	1429	0.0000	0.0000
10	77	0.0739	783706	0.9997	0.0295	1822518	0.9997	30883	1155	486	1.7128	0.0940	2690	1579	0.0000	0.0000
11	88	0.0830	699988	0.9996	0.0330	1652422	0.9995	28716	1461	606	1.7441	0.1253	3057	1937	0.0000	0.0000
12	80	0.0922	614083	0.9997	0.0363	1466157	0.9995	25625	1707	700	1.7794	0.1606	3233	2166	0.0000	0.0000

Specimen FYO-10SA

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	95	0.0033	8167687	0.9999	0.0022	10099430	0.9995	29986	1	-1	0.9267	0.0005	62	-1	0.0000	0.0000
2	146	0.0059	8218552	1.0000	0.0044	10153550	0.9999	50191	-0	1	0.9245	-0.0017	177	1	0.0000	0.0000
3	107	0.0087	8171849	1.0000	0.0065	10301710	1.0000	70470	25	11	0.9265	0.0003	368	19	0.0000	0.0000
4	87	0.0122	8110693	1.0000	0.0088	10360230	1.0000	90673	104	52	0.9291	0.0029	671	88	0.0000	0.0000
5	105	0.0145	8023986	1.0000	0.0101	10432370	1.0000	100674	197	98	0.9328	0.0066	895	166	0.0000	0.0000
6	118	0.0161	7960724	1.0000	0.0109	10397600	1.0000	106650	279	142	0.9356	0.0094	1066	242	0.0000	0.0000
7	94	0.0174	7886380	1.0000	0.0118	10377490	1.0000	110690	352	176	0.9389	0.0127	1198	300	0.0000	0.0000
8	90	0.0184	7812250	1.0000	0.0120	10394250	1.0000	112818	416	206	0.9422	0.0160	1296	353	0.0000	0.0000
9	97	0.0195	7750983	1.0000	0.0128	10387670	1.0000	115417	487	245	0.9449	0.0187	1416	420	0.0000	0.0000
10	83	0.0207	7619816	1.0000	0.0134	10380140	1.0000	117636	589	293	0.9509	0.0247	1559	505	0.0000	0.0000
11	53	0.0220	7566131	1.0000	0.0140	10348160	1.0000	119560	675	341	0.9534	0.0272	1688	590	0.0000	0.0000
12	37	0.0226	7494444	1.0000	0.0144	10310300	1.0000	120179	728	365	0.9567	0.0305	1756	634	0.0000	0.0000
13	39	0.0228	7487886	1.0000	0.0147	10319910	1.0000	120592	728	368	0.9570	0.0308	1768	638	0.0000	0.0000
14	61	0.0236	7401214	1.0000	0.0142	11110930	1.0000	120936	817	392	0.9611	0.0349	1833	681	0.0000	0.0000
15	72	0.0252	7238051	0.9999	0.0151	10998130	0.9999	125054	921	557	0.9690	0.0428	2246	983	0.0000	0.0000
16	84	0.0269	7094342	0.9998	0.0159	10882520	0.9999	126663	1064	626	0.9760	0.0498	2437	1111	0.0000	0.0000
17	96	0.0291	6866687	0.9998	0.0167	10694610	0.9999	127209	1280	714	0.9876	0.0614	2665	1276	0.0000	0.0000
18	99	0.0307	6728332	0.9998	0.0174	10624000	0.9999	127914	1403	776	0.9948	0.0686	2833	1395	0.0000	0.0000
19	92	0.0323	6619400	0.9998	0.0179	10519890	0.9998	127511	1562	848	1.0006	0.0744	2990	1534	0.0000	0.0000
20	107	0.0340	6448162	0.9999	0.0184	10449290	0.9999	126198	1763	923	1.0100	0.0838	3151	1681	0.0000	0.0000
21	86	0.0358	6251293	0.9998	0.0193	10287270	0.9999	127217	1917	1004	1.0211	0.0949	3390	1841	0.0000	0.0000
22	100	0.0379	5933263	0.9995	0.0205	10073510	0.9998	127341	2096	1099	1.0398	0.1136	3683	2035	0.0000	0.0000
23	96	0.0388	5891925	0.9998	0.0210	10081300	0.9998	125272	2121	1117	1.0423	0.1161	3679	2072	0.0000	0.0000
24	97	0.0398	5842120	0.9999	0.0207	10045260	0.9998	124543	2239	1164	1.0454	0.1192	3767	2162	0.0000	0.0000
25	73	0.0415	5569795	0.9999	0.0220	9842932	0.9998	125087	2422	1263	1.0625	0.1363	4038	2327	0.0000	0.0000
26	67	0.0431	5596685	0.9999	0.0221	9801679	0.9996	123457	2518	1308	1.0608	0.1346	4083	2426	0.0000	0.0000
27	45	0.0449	5334878	0.9997	0.0227	9566421	0.9996	123711	2753	1396	1.0781	0.1519	4324	2566	0.0000	0.0000

Specimen FYO-11SB

Unload No.	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)
5	47	11136938.4	16135552.9	0.99996	37.4	94120.6	0.00667	0.00961	-0.00312	233.4	26
6	93	11025869.4	16070599.5	0.99998	41.5	99304.8	0.00712	0.01012	0.00196	262.5	28.8
7	58	11189833.8	16084360.8	0.99994	40.2	105495.6	0.00772	0.01075	0.00058	290.8	27.9
8	42	11108950.7	16025578.9	0.99992	71.2	111151.8	0.00837	0.01142	-0.00078	340.2	49.2
9	56	11010743.4	15919502.3	0.99995	85.3	115181.8	0.00896	0.01197	0.00522	376	59
10	55	10977309.9	15869206.4	0.99996	101.5	118525.4	0.00953	0.01251	0.00312	404.2	70.2
11	61	10926467.8	15797248.7	0.99993	162.1	122899	0.01055	0.01344	0.00794	476	112.7
12	31	10889315.7	15688359.2	0.99996	229.2	125732.8	0.01149	0.01429	0.00773	539.7	159.6
13	50	10778931	15529039.7	0.99984	324.6	128131	0.0126	0.0153	0.01432	628.4	227.3
14	49	10672189.2	15364624.4	0.99984	415.5	129827.6	0.01387	0.0162	0.02055	710.9	292.6
15	58	10608222.2	15228652	0.99986	527.5	130666.8	0.01506	0.01722	0.02244	799.2	373.5
16	72	10475059.6	15047091.1	0.99979	661.5	131413.4	0.01642	0.01839	0.03216	913.5	472.3
17	73	10448053.9	15109717.9	0.99988	759.8	131351.2	0.01755	0.01921	0.03618	990.7	545.4
18	54	10328401.8	14902505.5	0.99977	933.9	132176.8	0.01901	0.02083	0.04724	1141.9	678.1
19	65	10258880	14753652.6	0.99971	1023.9	131901.8	0.01998	0.02164	0.05311	1216.6	747.6
20	50	10187916.1	14632325.2	0.99971	1141	132126.2	0.02108	0.02264	0.05627	1313.2	838.7
21	69	10149913.3	14595619.7	0.99978	1232.9	131400.8	0.02198	0.02335	0.06036	1385.3	910.9
22	48	10069604.7	14542387.3	0.99976	1325.6	131724	0.02291	0.02415	0.06627	1469	984.8
23	68	10048852.2	14272331.5	0.99978	1429.4	131075.8	0.02383	0.02497	0.0692	1551.3	1068.1
24	40	10012989.5	14144781	0.99965	1558.4	131198.8	0.02494	0.026	0.07345	1662.2	1172.5
25	42	9832728.4	13936210.5	0.99982	1758.4	130547.4	0.0265	0.02687	0.08006	1830.8	1337.2

Specimen FYO-12SA

Unload No.	No. Data Points	Loadline Slope (lb/in)	COD Slope (lb/in)	Corr.	Plastic Area (in-lb)	Load (lb.)	Loadline (in.)	COD (in.)	Delta a (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)
4	44	11707145.2	10121711.1	0.99959	12.1	24718.8	0.00234	0.0026	−0.00156	48	20.1
5	47	9557465.3	10009092.6	0.99986	19.2	30148.2	0.00287	0.00331	−0.00659	69.4	28.8
6	48	9471299.4	10237968.1	0.9999	9.2	38982.4	0.00374	0.00448	0.00227	86.5	16.1
7	51	9536447.1	10099908.8	0.99988	25.4	49927.4	0.00487	0.00603	0.00209	152.1	36.7
8	54	9107879.1	9985361.5	0.99994	67.3	59459.4	0.006	0.00775	0.00146	253.1	89.9
9	67	9037268.7	9997426.3	0.99994	109.1	66002.4	0.00709	0.00941	0.00445	347.2	143.7
10	93	8736515.8	9864483.7	0.99996	138.3	68130.2	0.00759	0.01013	0.0018	395.4	180.8
11	97	8678076.5	9829879.2	0.99997	168.9	70400.8	0.00823	0.01099	0.00422	451.4	220.1
12	80	8524456.9	9751349.7	0.99997	221	72517.2	0.00895	0.01194	0.00618	534.9	287.6
13	98	8487294.7	9693463.1	0.99995	272.1	74321.8	0.00988	0.01316	0.00993	618.4	354.6
14	95	8424739	9603447.7	0.99996	343.4	75579.8	0.01079	0.01429	0.01369	726.6	449.7
15	56	8352693	9512307.4	0.99994	422.5	76735.6	0.01178	0.01554	0.0192	849.4	557.3
16	60	8214421	9439541	0.99994	512.9	77293.2	0.01286	0.01686	0.023	983.5	682.4
17	59	8048762.2	9251871.2	0.99978	626.9	77457.8	0.01427	0.01835	0.03768	1172.6	850.1
18	60	7940704.9	9104203.9	0.99978	712	77137.8	0.01525	0.01975	0.04316	1306.5	978.5
19	66	7770095.8	8996885.6	0.9997	787.3	76341.4	0.01615	0.02066	0.05034	1427.9	1095.7
20	56	7761336.5	9055291.9	0.99994	854.7	75433.8	0.01693	0.02175	0.05373	1532.1	1202.5
21	58	7536374.5	8811559.3	0.99996	1017.7	73616.4	0.01833	0.02295	0.06511	1807.1	1475

Specimen CT-3

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	79	0.0038	449080	0.9997	0.0038	449080	0.9997	1974	−0	−0	1.1927	−0.0025	14	0	−0.0001	−0.0002
2	68	0.0037	449493	0.9996	0.0037	449493	0.9996	1921	0	0	1.1924	−0.0028	14	1	−0.0000	−0.0001
3	146	0.0064	448523	0.9999	0.0064	448523	0.9999	3007	1	1	1.1932	−0.0021	35	3	0.0002	−0.0001
4	123	0.0093	448056	0.9998	0.0093	448056	0.9998	3968	4	4	1.1935	−0.0017	68	12	0.0005	0.0001
5	99	0.0130	446203	0.9996	0.0130	446203	0.9996	4962	11	11	1.1949	−0.0003	125	36	0.0012	0.0006
6	100	0.0154	445540	0.9995	0.0154	445540	0.9995	5452	17	17	1.1955	0.0002	166	59	0.0017	0.0009
7	98	0.0185	444139	0.9996	0.0185	444139	0.9996	5934	28	28	1.1965	0.0013	225	98	0.0024	0.0015
8	104	0.0235	442661	0.9996	0.0235	442661	0.9996	6538	52	52	1.1977	0.0024	332	177	0.0036	0.0025
9	103	0.0262	441521	0.9996	0.0262	441521	0.9996	6790	66	66	1.1986	0.0033	392	225	0.0042	0.0030
10	100	0.0293	440743	0.9996	0.0293	440743	0.9996	7023	83	83	1.1992	0.0039	464	285	0.0050	0.0037
11	98	0.0321	439995	0.9995	0.0321	439995	0.9995	7188	101	101	1.1997	0.0045	533	345	0.0058	0.0044
12	99	0.0347	439312	0.9995	0.0347	439312	0.9995	7287	118	118	1.2003	0.0050	599	405	0.0065	0.0051
13	99	0.0379	437400	0.9995	0.0379	437400	0.9995	7423	139	139	1.2017	0.0065	678	475	0.0073	0.0058
14	100	0.0409	436055	0.9994	0.0409	436055	0.9994	7511	160	160	1.2028	0.0076	756	547	0.0081	0.0066
15	98	0.0430	434974	0.9994	0.0430	434974	0.9994	7592	174	174	1.2036	0.0084	809	595	0.0087	0.0071
16	119	0.0458	433996	0.9996	0.0458	433996	0.9996	7680	194	194	1.2044	0.0092	883	663	0.0094	0.0078
17	154	0.0486	431960	0.9999	0.0486	431960	0.9999	7749	214	214	1.2060	0.0108	956	731	0.0102	0.0086
18	152	0.0517	432275	0.9998	0.0517	432275	0.9998	7800	237	237	1.2058	0.0105	1038	811	0.0110	0.0094
19	155	0.0542	429701	0.9997	0.0542	429701	0.9997	7845	256	256	1.2078	0.0126	1106	874	0.0117	0.0101
20	152	0.0570	427041	0.9998	0.0570	427041	0.9998	7864	277	277	1.2099	0.0147	1180	945	0.0125	0.0108
21	135	0.0607	423554	0.9999	0.0607	423554	0.9999	7876	305	305	1.2126	0.0174	1276	1038	0.0135	0.0118
22	127	0.0636	420856	0.9997	0.0636	420856	0.9997	7910	326	326	1.2148	0.0196	1352	1109	0.0143	0.0126
23	131	0.0671	416491	0.9997	0.0671	416491	0.9997	7894	354	354	1.2183	0.0231	1444	1199	0.0154	0.0136
24	135	0.0705	412247	0.9998	0.0705	412247	0.9998	7887	379	379	1.2217	0.0265	1529	1281	0.0163	0.0145
25	135	0.0745	405722	0.9998	0.0745	405722	0.9998	7846	410	410	1.2270	0.0318	1630	1379	0.0175	0.0157
26	136	0.0779	401150	0.9997	0.0779	401150	0.9997	7804	436	436	1.2308	0.0355	1713	1461	0.0184	0.0166
27	133	0.0817	394812	0.9996	0.0817	394812	0.9996	7744	465	465	1.2360	0.0408	1806	1553	0.0196	0.0178
28	136	0.0844	390005	0.9997	0.0844	390005	0.9997	7741	484	484	1.2400	0.0448	1870	1612	0.0204	0.0185
29	141	0.0873	386649	0.9997	0.0873	386649	0.9997	7747	505	505	1.2428	0.0476	1939	1678	0.0212	0.0193
30	134	0.0909	382407	0.9997	0.0909	382407	0.9997	7714	532	532	1.2464	0.0512	2029	1766	0.0222	0.0203
31	130	0.0942	379360	0.9997	0.0942	379360	0.9997	7691	556	556	1.2490	0.0538	2111	1847	0.0232	0.0213
32	128	0.0973	374065	0.9996	0.0973	374065	0.9996	7619	581	581	1.2535	0.0583	2187	1923	0.0241	0.0222
33	128	0.1007	367684	0.9996	0.1007	367684	0.9996	7553	606	606	1.2591	0.0638	2263	1997	0.0252	0.0233
34	126	0.1040	363020	0.9996	0.1040	363020	0.9996	7516	629	629	1.2631	0.0679	2336	2069	0.0261	0.0242
35	125	0.1077	357628	0.9995	0.1077	357628	0.9995	7427	657	657	1.2679	0.0727	2420	2153	0.0273	0.0253
36	127	0.1115	349965	0.9995	0.1115	349965	0.9995	7257	686	686	1.2747	0.0795	2499	2237	0.0285	0.0266
37	127	0.1153	340965	0.9993	0.1153	340965	0.9993	7068	715	715	1.2829	0.0876	2570	2312	0.0297	0.0279
38	127	0.1191	327950	0.9993	0.1191	327950	0.9993	6867	742	742	1.2949	0.0996	2623	2366	0.0311	0.0292
39	136	0.1228	318374	0.9992	0.1228	318374	0.9992	6727	765	765	1.3039	0.1087	2672	2415	0.0322	0.0304

Specimen CT-3

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
40	131	0.1259	309780	0.9993	0.1259	309780	0.9993	6604	785	785	1.3121	0.1169	2712	2455	0.0333	0.0314
41	139	0.1291	303800	0.9993	0.1291	303800	0.9993	6562	803	803	1.3179	0.1227	2760	2499	0.0342	0.0323
42	137	0.1320	299832	0.9993	0.1320	299832	0.9993	6491	821	821	1.3218	0.1266	2814	2554	0.0351	0.0332
43	140	0.1357	293224	0.9994	0.1357	293224	0.9994	6409	845	845	1.3284	0.1332	2880	2618	0.0363	0.0345
44	144	0.1393	287417	0.9993	0.1393	287417	0.9993	6292	867	867	1.3342	0.1390	2939	2680	0.0375	0.0356
45	143	0.1422	284406	0.9993	0.1422	284406	0.9993	6252	884	884	1.3373	0.1421	2991	2731	0.0383	0.0365

Specimen CT-9

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	156	0.0041	450967	0.9999	0.0041	450967	0.9999	1982	0	0	1.1913	-0.0018	14	-0	0.0000	-0.0001
2	155	0.0054	451842	0.9999	0.0054	451842	0.9999	2504	0	0	1.1906	-0.0025	23	1	0.0001	-0.0001
3	167	0.0065	452000	0.9998	0.0065	452000	0.9998	2983	1	1	1.1905	-0.0026	33	2	0.0002	-0.0000
4	171	0.0074	451689	0.9999	0.0074	451689	0.9999	3297	1	1	1.1907	-0.0024	42	3	0.0003	0.0000
5	162	0.0085	450532	0.9999	0.0085	450532	0.9999	3689	2	2	1.1916	-0.0015	54	6	0.0004	0.0001
6	138	0.0100	450603	0.9999	0.0100	450603	0.9999	4188	3	3	1.1916	-0.0016	73	11	0.0006	0.0002
7	124	0.0112	449362	0.9998	0.0112	449362	0.9998	4529	5	5	1.1925	-0.0006	91	18	0.0009	0.0003
8	122	0.0129	448262	0.9997	0.0129	448262	0.9997	4970	9	9	1.1934	0.0002	117	29	0.0012	0.0005
9	122	0.0142	447845	0.9998	0.0142	447845	0.9998	5280	12	12	1.1937	0.0006	139	40	0.0014	0.0007
10	122	0.0157	447221	0.9998	0.0157	447221	0.9998	5570	16	16	1.1942	0.0010	165	55	0.0017	0.0009
11	117	0.0173	446732	0.9997	0.0173	446732	0.9997	5847	22	22	1.1945	0.0014	197	74	0.0021	0.0012
12	124	0.0185	447014	0.9997	0.0185	447014	0.9997	6065	26	26	1.1943	0.0012	220	88	0.0023	0.0014
13	121	0.0196	446163	0.9997	0.0196	446163	0.9997	6235	31	31	1.1950	0.0018	244	105	0.0026	0.0016
14	126	0.0210	445653	0.9997	0.0210	445653	0.9997	6393	37	37	1.1954	0.0022	273	126	0.0029	0.0019
15	125	0.0225	444586	0.9997	0.0225	444586	0.9997	6598	43	43	1.1962	0.0031	305	148	0.0033	0.0021
16	129	0.0242	444148	0.9997	0.0242	444148	0.9997	6767	52	52	1.1965	0.0034	344	179	0.0037	0.0025
17	130	0.0259	443878	0.9997	0.0259	443878	0.9997	6918	62	62	1.1967	0.0036	383	210	0.0041	0.0029
18	126	0.0277	443644	0.9997	0.0277	443644	0.9997	7049	72	72	1.1969	0.0038	425	246	0.0046	0.0033
19	127	0.0296	442570	0.9997	0.0296	442570	0.9997	7190	84	84	1.1977	0.0046	474	287	0.0051	0.0038
20	128	0.0313	441745	0.9997	0.0313	441745	0.9997	7328	93	93	1.1984	0.0052	514	319	0.0055	0.0041
21	124	0.0338	440755	0.9997	0.0338	440755	0.9997	7426	111	111	1.1991	0.0060	579	378	0.0062	0.0048
22	127	0.0355	442776	0.9993	0.0355	442776	0.9993	7558	120	120	1.1976	0.0045	620	413	0.0066	0.0051
23	125	0.0379	441223	0.9996	0.0379	441223	0.9996	7635	138	138	1.1988	0.0057	686	473	0.0073	0.0058
24	126	0.0403	438583	0.9995	0.0403	438583	0.9995	7733	154	154	1.2008	0.0077	746	526	0.0079	0.0064
25	125	0.0425	436811	0.9996	0.0425	436811	0.9996	7789	170	170	1.2022	0.0091	804	581	0.0086	0.0069
26	124	0.0447	435462	0.9996	0.0447	435462	0.9996	7880	185	185	1.2033	0.0101	860	630	0.0091	0.0075
27	146	0.0473	433312	0.9997	0.0473	433312	0.9997	7923	204	204	1.2049	0.0118	930	696	0.0098	0.0082
28	162	0.0506	431654	0.9999	0.0506	431654	0.9999	7989	229	229	1.2062	0.0131	1019	780	0.0107	0.0090
29	170	0.0562	428343	0.9998	0.0562	428343	0.9998	8065	273	273	1.2088	0.0157	1176	929	0.0123	0.0106
30	160	0.0588	427422	0.9998	0.0588	427422	0.9998	8136	291	291	1.2096	0.0164	1244	992	0.0130	0.0112
31	165	0.0615	426853	0.9998	0.0615	426853	0.9998	8167	313	313	1.2100	0.0169	1320	1067	0.0138	0.0119
32	161	0.0645	423365	0.9997	0.0645	423365	0.9997	8191	336	336	1.2128	0.0197	1401	1143	0.0146	0.0128
33	163	0.0677	419478	0.9998	0.0677	419478	0.9998	8212	361	361	1.2159	0.0228	1488	1225	0.0155	0.0136
34	167	0.0698	417768	0.9998	0.0698	417768	0.9998	8240	377	377	1.2173	0.0241	1542	1277	0.0161	0.0142
35	164	0.0729	414684	0.9998	0.0729	414684	0.9998	8227	402	402	1.2197	0.0266	1628	1361	0.0170	0.0151
36	164	0.0756	412417	0.9998	0.0756	412417	0.9998	8248	423	423	1.2216	0.0284	1700	1429	0.0177	0.0158
37	163	0.0784	410008	0.9998	0.0784	410008	0.9998	8235	445	445	1.2235	0.0304	1777	1504	0.0185	0.0166
38	167	0.0808	406843	0.9998	0.0808	406843	0.9998	8200	465	465	1.2261	0.0330	1842	1569	0.0193	0.0173
39	175	0.0836	402562	0.9998	0.0836	402562	0.9998	8157	488	488	1.2296	0.0365	1912	1638	0.0201	0.0181

Specimen CT-9

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
40	164	0.0864	397637	0.9997	0.0864	397637	0.9997	8064	511	511	1.2337	0.0405	1981	1709	0.0209	0.0190
41	156	0.0889	393099	0.9997	0.0889	393099	0.9997	8018	530	530	1.2374	0.0443	2042	1769	0.0217	0.0197
42	150	0.0919	388200	0.9997	0.0919	388200	0.9997	7937	554	554	1.2415	0.0484	2114	1842	0.0226	0.0206
43	152	0.0952	380911	0.9996	0.0952	380911	0.9996	7819	580	580	1.2477	0.0546	2189	1918	0.0236	0.0216
44	149	0.0981	372121	0.9997	0.0981	372121	0.9997	7742	602	602	1.2552	0.0621	2245	1971	0.0245	0.0225
45	152	0.1013	367574	0.9997	0.1013	367574	0.9997	7675	625	625	1.2592	0.0660	2316	2042	0.0254	0.0234
46	158	0.1046	363963	0.9996	0.1046	363963	0.9996	7647	649	649	1.2623	0.0692	2395	2119	0.0264	0.0244
47	154	0.1077	360027	0.9996	0.1077	360027	0.9996	7565	672	672	1.2658	0.0726	2468	2194	0.0273	0.0253
48	161	0.1114	349995	0.9993	0.1114	349995	0.9993	7370	703	703	1.2747	0.0816	2543	2273	0.0286	0.0267
49	156	0.1143	342861	0.9994	0.1143	342861	0.9994	7317	721	721	1.2811	0.0880	2590	2316	0.0295	0.0275
50	155	0.1174	336263	0.9995	0.1174	336263	0.9995	7215	743	743	1.2872	0.0940	2646	2372	0.0304	0.0285
51	161	0.1210	325569	0.9993	0.1210	325569	0.9993	7043	770	770	1.2971	0.1040	2705	2432	0.0317	0.0298
52	156	0.1241	320502	0.9995	0.1241	320502	0.9995	6982	788	788	1.3019	0.1087	2758	2484	0.0326	0.0306
53	155	0.1274	315277	0.9994	0.1274	315277	0.9994	6886	811	811	1.3068	0.1137	2824	2551	0.0337	0.0317
54	156	0.1311	306799	0.9993	0.1311	306799	0.9993	6732	838	838	1.3150	0.1219	2886	2615	0.0349	0.0330
55	134	0.1349	299600	0.9993	0.1349	299600	0.9993	6625	861	861	1.3221	0.1289	2945	2674	0.0361	0.0342
56	134	0.1381	293356	0.9993	0.1381	293356	0.9993	6522	882	882	1.3283	0.1351	2996	2726	0.0372	0.0353
57	136	0.1410	288885	0.9993	0.1410	288885	0.9993	6494	898	898	1.3328	0.1396	3042	2768	0.0381	0.0361
58	139	0.1439	284501	0.9993	0.1439	284501	0.9993	6411	917	917	1.3372	0.1441	3094	2821	0.0390	0.0371
59	155	0.1472	279191	0.9993	0.1472	279191	0.9993	6321	938	938	1.3426	0.1495	3152	2880	0.0402	0.0382

Specimen CT-10

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in²)	J Plastic (in-lb/in²)	CTOD (in.)	CTOD Plastic (in.)
1	152	0.0042	452812	0.9996	0.0042	452812	0.9996	1994	0	0	1.1899	-0.0039	14	-0	0.0000	-0.0001
2	156	0.0056	451119	0.9998	0.0056	451119	0.9998	2640	0	0	1.1912	-0.0026	25	1	0.0001	-0.0001
3	172	0.0070	451380	0.9999	0.0070	451380	0.9999	3152	1	1	1.1910	-0.0028	38	2	0.0003	0.0000
4	169	0.0080	451178	0.9998	0.0080	451178	0.9998	3521	1	1	1.1911	-0.0026	48	5	0.0004	0.0001
5	147	0.0094	449826	0.9998	0.0094	449826	0.9998	3995	3	3	1.1922	-0.0016	66	9	0.0006	0.0001
6	129	0.0108	449003	0.9998	0.0108	449003	0.9998	4417	5	5	1.1928	-0.0010	85	16	0.0008	0.0003
7	127	0.0119	448261	0.9998	0.0119	448261	0.9998	4723	7	7	1.1934	-0.0004	103	23	0.0010	0.0004
8	125	0.0132	447919	0.9998	0.0132	447919	0.9998	5029	9	9	1.1936	-0.0001	122	32	0.0012	0.0006
9	124	0.0144	447707	0.9997	0.0144	447707	0.9997	5306	13	13	1.1938	0.0000	143	43	0.0014	0.0007
10	129	0.0158	446274	0.9997	0.0158	446274	0.9997	5588	17	17	1.1949	0.0011	169	58	0.0018	0.0009
11	129	0.0170	446332	0.9997	0.0170	446332	0.9997	5801	20	20	1.1948	0.0011	191	70	0.0020	0.0011
12	129	0.0180	446852	0.9997	0.0180	446852	0.9997	5966	25	25	1.1944	0.0007	211	84	0.0022	0.0013
13	132	0.0194	445643	0.9997	0.0194	445643	0.9997	6180	30	30	1.1954	0.0016	239	102	0.0025	0.0015
14	132	0.0209	445217	0.9997	0.0209	445217	0.9997	6371	36	36	1.1957	0.0019	271	125	0.0029	0.0018
15	133	0.0220	445678	0.9997	0.0220	445678	0.9997	6516	41	41	1.1953	0.0016	294	142	0.0032	0.0021
16	135	0.0231	443560	0.9998	0.0231	443560	0.9998	6642	47	47	1.1970	0.0032	320	161	0.0034	0.0023
17	134	0.0248	443715	0.9997	0.0248	443715	0.9997	6794	56	56	1.1969	0.0031	357	190	0.0039	0.0027
18	133	0.0258	440944	0.9999	0.0258	440944	0.9999	6881	61	61	1.1990	0.0052	380	208	0.0041	0.0029
19	132	0.0273	441849	0.9998	0.0273	441849	0.9998	7004	69	69	1.1983	0.0045	415	236	0.0045	0.0032
20	132	0.0291	443827	0.9993	0.0291	443827	0.9993	7099	81	81	1.1968	0.0030	458	276	0.0050	0.0036
21	115	0.0307	441910	0.9995	0.0307	441910	0.9995	7219	91	91	1.1982	0.0045	500	310	0.0054	0.0040
22	110	0.0326	440662	0.9996	0.0326	440662	0.9996	7312	102	102	1.1992	0.0054	545	350	0.0059	0.0045
23	111	0.0348	437249	0.9998	0.0348	437249	0.9998	7415	117	117	1.2019	0.0081	602	400	0.0065	0.0051
24	116	0.0370	437775	0.9997	0.0370	437775	0.9997	7510	131	131	1.2015	0.0077	655	448	0.0071	0.0056
25	114	0.0392	437682	0.9996	0.0392	437682	0.9996	7592	146	146	1.2015	0.0078	712	500	0.0076	0.0061
26	109	0.0414	438203	0.9993	0.0414	438203	0.9993	7689	161	161	1.2011	0.0074	770	553	0.0082	0.0067
27	112	0.0435	436542	0.9993	0.0435	436542	0.9993	7721	178	178	1.2024	0.0086	828	608	0.0088	0.0073
28	128	0.0461	434733	0.9996	0.0461	434733	0.9996	7802	196	196	1.2038	0.0101	897	671	0.0095	0.0079
29	174	0.0485	432705	0.9999	0.0485	432705	0.9999	7875	213	213	1.2054	0.0116	959	727	0.0102	0.0085
30	173	0.0508	431059	0.9999	0.0508	431059	0.9999	7902	231	231	1.2067	0.0129	1021	786	0.0108	0.0091
31	178	0.0531	428941	0.9999	0.0531	428941	0.9999	7948	247	247	1.2084	0.0146	1081	843	0.0115	0.0097
32	174	0.0556	427440	0.9998	0.0556	427440	0.9998	7979	266	266	1.2096	0.0158	1147	905	0.0121	0.0104
33	168	0.0575	426196	0.9998	0.0575	426196	0.9998	8024	280	280	1.2105	0.0168	1199	954	0.0127	0.0109
34	174	0.0596	424686	0.9998	0.0596	424686	0.9998	8054	295	295	1.2117	0.0180	1253	1005	0.0132	0.0114
35	171	0.0621	422198	0.9998	0.0621	422198	0.9998	8054	316	316	1.2137	0.0199	1323	1073	0.0140	0.0122
36	170	0.0646	419783	0.9998	0.0646	419783	0.9998	8056	335	335	1.2156	0.0219	1388	1136	0.0147	0.0128
37	171	0.0671	416595	0.9998	0.0671	416595	0.9998	8046	355	355	1.2182	0.0244	1456	1201	0.0154	0.0136
38	168	0.0696	413927	0.9998	0.0696	413927	0.9998	8078	372	372	1.2203	0.0266	1519	1260	0.0161	0.0142
39	167	0.0723	411483	0.9998	0.0723	411483	0.9998	8039	395	395	1.2223	0.0286	1593	1335	0.0169	0.0150

Specimen CT-10

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
40	169	0.0753	406198	0.9998	0.0753	406198	0.9998	7999	419	419	1.2266	0.0328	1669	1409	0.0177	0.0159
41	163	0.0781	400615	0.9997	0.0781	400615	0.9997	7947	440	440	1.2312	0.0374	1735	1474	0.0186	0.0167
42	162	0.0809	395526	0.9998	0.0809	395526	0.9998	7916	461	461	1.2354	0.0416	1802	1538	0.0194	0.0175
43	162	0.0832	392133	0.9997	0.0832	392133	0.9997	7895	.477	477	1.2382	0.0445	1856	1590	0.0200	0.0181
44	167	0.0858	387051	0.9997	0.0858	387051	0.9997	7821	498	498	1.2425	0.0487	1919	1653	0.0208	0.0189
45	162	0.0884	382207	0.9996	0.0884	382207	0.9996	7720	519	519	1.2466	0.0528	1982	1719	0.0216	0.0197
46	166	0.0917	373821	0.9997	0.0917	373821	0.9997	7644	544	544	1.2538	0.0600	2051	1785	0.0226	0.0207
47	167	0.0943	368879	0.9997	0.0943	368879	0.9997	7569	562	562	1.2580	0.0643	2107	1841	0.0234	0.0215
48	168	0.0972	363169	0.9996	0.0972	363169	0.9996	7521	583	583	1.2630	0.0692	2167	1900	0.0243	0.0223
49	176	0.1000	357365	0.9996	0.1000	357365	0.9996	7473	603	603	1.2681	0.0743	2227	1957	0.0251	0.0232
50	167	0.1031	350474	0.9995	0.1031	350474	0.9995	7342	626	626	1.2743	0.0805	2291	2024	0.0261	0.0242
51	172	0.1059	343670	0.9995	0.1059	343670	0.9995	7250	646	646	1.2804	0.0866	2344	2075	0.0270	0.0251
52	171	0.1095	335728	0.9995	0.1095	335728	0.9995	7180	670	670	1.2876	0.0939	2413	2141	0.0281	0.0262
53	169	0.1134	329837	0.9996	0.1134	329837	0.9996	7079	697	697	1.2931	0.0993	2494	2223	0.0293	0.0274
54	148	0.1172	323559	0.9995	0.1172	323559	0.9995	6979	724	724	1.2990	0.1052	2572	2302	0.0305	0.0286
55	149	0.1217	315291	0.9992	0.1217	315291	0.9992	6782	756	756	1.3068	0.1131	2659	2395	0.0320	0.0301
56	147	0.1253	304423	0.9992	0.1253	304423	0.9992	6584	782	782	1.3173	0.1236	2710	2448	0.0333	0.0314
57	148	0.1287	298301	0.9993	0.1287	298301	0.9993	6474	802	802	1.3234	0.1296	2760	2500	0.0343	0.0324
58	157	0.1321	290393	0.9991	0.1321	290393	0.9991	6380	823	823	1.3312	0.1375	2810	2547	0.0355	0.0336
59	155	0.1357	282608	0.9991	0.1357	282608	0.9991	6260	844	844	1.3391	0.1454	2859	2597	0.0367	0.0348
60	153	0.1387	278112	0.9993	0.1387	278112	0.9993	6215	860	860	1.3438	0.1500	2904	2640	0.0375	0.0356
61	155	0.1422	272695	0.9991	0.1422	272695	0.9991	6091	883	883	1.3494	0.1556	2964	2703	0.0387	0.0369

Specimen DB-1

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	96	0.0034	394477	0.9999	0.0044	301203	0.9993	1543	-0	-0	1.2289	-0.0000	12	0	-0.0000	-0.0001
2	105	0.0060	392108	0.9999	0.0077	302088	0.9988	2493	0	0	1.2308	0.0019	33	1	0.0002	-0.0001
3	54	0.0105	391435	0.9997	0.0132	306013	0.9995	3842	4	4	1.2313	0.0024	89	13	0.0007	0.0002
4	56	0.0155	389365	0.9997	0.0193	306064	0.9994	4740	16	18	1.2329	0.0040	175	60	0.0016	0.0008
5	64	0.0196	387678	0.9998	0.0241	305911	0.9990	5161	31	35	1.2343	0.0054	251	116	0.0024	0.0014
6	69	0.0240	387920	0.9998	0.0292	305995	0.9988	5354	51	59	1.2341	0.0052	340	194	0.0033	0.0022
7	72	0.0279	386336	0.9997	0.0338	304760	0.9985	5510	71	82	1.2353	0.0064	422	267	0.0041	0.0030
8	74	0.0318	384723	0.9998	0.0384	304547	0.9988	5615	91	105	1.2366	0.0077	506	344	0.0050	0.0038
9	72	0.0360	383938	0.9999	0.0432	302268	0.9983	5717	113	131	1.2373	0.0083	595	427	0.0058	0.0046
10	69	0.0401	380968	0.9998	0.0481	300869	0.9977	5802	135	157	1.2396	0.0107	685	511	0.0068	0.0055
11	70	0.0449	380737	0.9999	0.0536	299984	0.9972	5883	162	188	1.2398	0.0109	790	612	0.0078	0.0065
12	75	0.0499	377087	0.9999	0.0593	299706	0.9979	5909	191	221	1.2428	0.0138	903	718	0.0089	0.0076
13	68	0.0550	374376	0.9998	0.0654	295361	0.9968	6009	219	255	1.2450	0.0160	1019	828	0.0100	0.0086
14	72	0.0606	371361	0.9998	0.0717	290860	0.9957	6018	252	292	1.2474	0.0185	1143	948	0.0113	0.0099
15	68	0.0650	367546	0.9999	0.0767	287113	0.9938	6052	278	320	1.2506	0.0216	1236	1037	0.0123	0.0108
16	66	0.0698	364180	0.9990	0.0822	285244	0.9930	6072	306	351	1.2533	0.0244	1341	1139	0.0134	0.0119
17	69	0.0751	361683	0.9999	0.0883	284317	0.9946	6083	337	387	1.2554	0.0265	1462	1257	0.0145	0.0131
18	70	0.0799	357171	0.9998	0.0937	283178	0.9940	6067	366	421	1.2592	0.0303	1569	1362	0.0157	0.0142
19	70	0.0850	352033	0.9999	0.0996	280022	0.9934	6072	397	456	1.2635	0.0346	1685	1474	0.0169	0.0154
20	66	0.0899	348030	0.9999	0.1052	274448	0.9917	6048	426	490	1.2669	0.0380	1793	1580	0.0180	0.0165
21	72	0.0950	342936	0.9999	0.1109	271567	0.9926	6021	456	522	1.2713	0.0424	1896	1682	0.0193	0.0177
22	68	0.1000	338156	0.9998	0.1165	267540	0.9910	5967	486	556	1.2755	0.0466	2003	1789	0.0205	0.0189
23	70	0.1049	334044	0.9998	0.1219	264949	0.9913	5914	515	588	1.2791	0.0502	2103	1890	0.0217	0.0201
24	72	0.1102	328238	0.9999	0.1277	260021	0.9910	5901	545	622	1.2843	0.0553	2210	1993	0.0230	0.0214
25	71	0.1150	323854	0.9998	0.1330	258413	0.9904	5828	573	652	1.2882	0.0593	2303	2089	0.0242	0.0226
26	72	0.1199	316724	0.9998	0.1384	255013	0.9924	5695	603	686	1.2947	0.0657	2401	2189	0.0255	0.0240
27	75	0.1251	305566	0.9997	0.1452	247223	0.9934	5629	637	724	1.3050	0.0761	2507	2291	0.0272	0.0257
28	75	0.1308	297764	0.9998	0.1503	243065	0.9920	5559	661	751	1.3124	0.0835	2579	2362	0.0285	0.0269
29	79	0.1370	291976	0.9999	0.1570	238255	0.9923	5520	694	787	1.3180	0.0890	2694	2475	0.0301	0.0285
30	72	0.1430	287927	0.9998	0.1635	234047	0.9901	5475	726	822	1.3219	0.0930	2810	2589	0.0316	0.0300
31	69	0.1490	281913	0.9998	0.1702	229327	0.9916	5438	758	857	1.3278	0.0989	2916	2694	0.0332	0.0316
32	74	0.1551	275754	0.9997	0.1767	225044	0.9922	5335	792	892	1.3340	0.1051	3021	2801	0.0349	0.0333
33	70	0.1619	270773	0.9997	0.1840	220097	0.9895	5267	827	931	1.3390	0.1101	3143	2923	0.0367	0.0351
34	73	0.1689	264029	0.9997	0.1915	214313	0.9879	5167	864	970	1.3460	0.1171	3263	3043	0.0387	0.0372
35	72	0.1759	256456	0.9995	0.1989	205626	0.9873	5053	900	1008	1.3539	0.1250	3367	3149	0.0407	0.0392
36	76	0.1831	247589	0.9994	0.2065	200744	0.9869	4919	936	1045	1.3634	0.1345	3458	3243	0.0429	0.0414
37	75	0.1901	237880	0.9993	0.2137	195575	0.9878	4737	970	1081	1.3741	0.1452	3543	3332	0.0451	0.0436
38	79	0.1970	229057	0.9992	0.2209	184251	0.9857	4612	1002	1115	1.3840	0.1551	3624	3415	0.0473	0.0457
39	70	0.2042	219633	0.9990	0.2285	179705	0.9917	4481	1034	1147	1.3949	0.1660	3691	3482	0.0496	0.0481

Specimen DB-1

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J ($in-lb/in^2$)	J Plastic ($in-lb/in^2$)	CTOD (in.)	CTOD Plastic (in.)
40	73	0.2109	213055	0.9989	0.2355	171910	0.9892	4366	1063	1179	1.4027	0.1738	3773	3566	0.0516	0.0501
41	74	0.2180	206351	0.9991	0.2430	166640	0.9885	4287	1093	1209	1.4108	0.1819	3850	3643	0.0538	0.0523
42	74	0.2251	199164	0.9990	0.2504	161142	0.9894	4181	1123	1240	1.4197	0.1908	3926	3719	0.0561	0.0546
43	78	0.2312	192718	0.9989	0.2566	155444	0.9891	4056	1147	1265	1.4279	0.1990	3978	3776	0.0580	0.0566

Specimen DB-2

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	69	0.0033	392732	0.9999	0.0045	288761	0.9986	1562	-0	-0	1.2303	0.0000	13	0	-0.0001	-0.0001
2	135	0.0048	390897	0.9999	0.0064	290842	0.9989	2119	0	-0	1.2317	0.0014	24	1	0.0000	-0.0001
3	90	0.0093	389181	0.9999	0.0121	295163	0.9994	3567	2	2	1.2331	0.0028	72	8	0.0005	0.0000
4	79	0.0153	386502	0.9998	0.0195	294333	0.9991	4762	15	18	1.2352	0.0049	174	58	0.0015	0.0007
5	76	0.0177	386624	0.9998	0.0224	293951	0.9990	5021	23	27	1.2351	0.0048	219	89	0.0020	0.0010
6	73	0.0220	384642	0.9997	0.0276	293963	0.9990	5298	42	49	1.2367	0.0064	307	162	0.0029	0.0018
7	86	0.0251	383567	0.9998	0.0313	293336	0.9985	5443	56	67	1.2376	0.0073	372	219	0.0035	0.0024
8	88	0.0279	384585	0.9998	0.0347	291927	0.9982	5559	70	83	1.2367	0.0064	430	272	0.0041	0.0029
9	89	0.0320	382975	0.9998	0.0395	291938	0.9983	5659	92	108	1.2380	0.0077	519	354	0.0050	0.0038
10	85	0.0362	382026	0.9998	0.0446	290488	0.9979	5767	114	135	1.2388	0.0085	613	442	0.0058	0.0046
11	85	0.0399	380267	0.9996	0.0489	289815	0.9981	5794	135	160	1.2402	0.0099	697	522	0.0067	0.0054
12	86	0.0440	379361	0.9997	0.0537	289043	0.9980	5882	157	186	1.2409	0.0106	789	608	0.0075	0.0062
13	86	0.0482	377615	0.9996	0.0587	288034	0.9980	5953	181	214	1.2423	0.0120	885	700	0.0085	0.0071
14	90	0.0520	377046	0.9997	0.0633	287093	0.9979	6011	203	240	1.2428	0.0125	975	785	0.0093	0.0079
15	87	0.0571	375150	0.9996	0.0693	285357	0.9978	6048	233	275	1.2443	0.0140	1094	899	0.0104	0.0090
16	82	0.0620	373274	0.9995	0.0751	284756	0.9974	6084	263	309	1.2459	0.0156	1208	1011	0.0115	0.0101
17	79	0.0670	369578	0.9995	0.0810	281289	0.9969	6095	293	346	1.2489	0.0186	1327	1127	0.0127	0.0112
18	79	0.0709	367414	0.9996	0.0855	280093	0.9961	6107	315	371	1.2507	0.0204	1412	1210	0.0135	0.0121
19	80	0.0753	363341	0.9996	0.0907	277179	0.9967	6153	342	402	1.2540	0.0237	1514	1307	0.0145	0.0130
20	82	0.0798	360031	0.9996	0.0960	275380	0.9966	6148	368	434	1.2568	0.0265	1618	1408	0.0156	0.0141
21	84	0.0851	357352	0.9997	0.1022	271504	0.9960	6183	400	470	1.2590	0.0287	1741	1527	0.0168	0.0152
22	82	0.0900	354604	0.9996	0.1078	270387	0.9961	6158	430	504	1.2614	0.0311	1851	1636	0.0179	0.0163
23	88	0.0951	349706	0.9995	0.1137	269285	0.9967	6167	461	540	1.2655	0.0352	1968	1749	0.0191	0.0175
24	87	0.1000	344679	0.9995	0.1194	265602	0.9970	6161	490	575	1.2698	0.0395	2078	1857	0.0203	0.0187
25	88	0.1050	340266	0.9996	0.1251	259903	0.9964	6139	520	609	1.2737	0.0434	2188	1964	0.0215	0.0199
26	81	0.1101	335893	0.9994	0.1309	257480	0.9962	6094	551	643	1.2775	0.0472	2295	2070	0.0227	0.0211
27	79	0.1151	328676	0.9994	0.1365	254070	0.9962	6023	581	678	1.2839	0.0536	2398	2172	0.0240	0.0224
28	82	0.1200	322186	0.9993	0.1420	249479	0.9960	5934	610	712	1.2897	0.0594	2499	2273	0.0253	0.0237
29	84	0.1251	315410	0.9995	0.1479	244875	0.9955	5927	639	744	1.2959	0.0656	2596	2367	0.0266	0.0250
30	86	0.1301	307588	0.9994	0.1534	239041	0.9936	5844	667	776	1.3031	0.0728	2686	2456	0.0280	0.0263
31	88	0.1350	302272	0.9994	0.1588	235390	0.9933	5778	695	807	1.3081	0.0778	2778	2547	0.0292	0.0276
32	84	0.1400	295173	0.9994	0.1646	230294	0.9918	5730	723	838	1.3149	0.0846	2870	2637	0.0306	0.0289
33	85	0.1451	289019	0.9994	0.1701	225523	0.9906	5644	751	869	1.3208	0.0906	2958	2727	0.0320	0.0303
34	86	0.1511	281146	0.9993	0.1767	220635	0.9916	5527	785	907	1.3286	0.0983	3064	2832	0.0337	0.0320
35	87	0.1571	275519	0.9993	0.1832	216564	0.9906	5439	817	943	1.3342	0.1039	3173	2943	0.0353	0.0336
36	85	0.1640	267148	0.9992	0.1909	210967	0.9915	5352	854	984	1.3428	0.1125	3289	3059	0.0372	0.0356
37	90	0.1711	257909	0.9991	0.1986	205159	0.9939	5196	892	1025	1.3524	0.1221	3399	3171	0.0394	0.0377
38	83	0.1782	245705	0.9991	0.2063	196348	0.9937	5028	929	1066	1.3655	0.1352	3489	3262	0.0416	0.0400
39	84	0.1859	238285	0.9991	0.2146	190557	0.9930	4894	965	1105	1.3736	0.1433	3600	3376	0.0438	0.0422

Specimen DB-2

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J ($in-lb/in^2$)	J Plastic ($in-lb/in^2$)	CTOD (in.)	CTOD Plastic (in.)
40	88	0.1930	227126	0.9987	0.2222	182905	0.9936	4717	1000	1143	1.3862	0.1559	3678	3457	0.0462	0.0446
41	90	0.1997	217857	0.9988	0.2293	174912	0.9903	4587	1030	1175	1.3970	0.1667	3745	3525	0.0483	0.0467
42	93	0.2071	209383	0.9987	0.2372	168259	0.9883	4480	1062	1209	1.4072	0.1769	3826	3604	0.0506	0.0490
43	96	0.2148	202308	0.9989	0.2453	162662	0.9877	4382	1095	1243	1.4158	0.1855	3916	3695	0.0529	0.0513
44	101	0.2227	196033	0.9987	0.2536	159577	0.9896	4257	1129	1279	1.4237	0.1934	4016	3798	0.0553	0.0538

Specimen DB-3

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	54	0.0035	386475	0.9996	0.0048	285689	0.9985	1538	-0	-0	1.2352	-0.0000	13	0	-0.0000	-0.0001
2	98	0.0050	384133	0.9999	0.0067	286057	0.9985	2091	0	-0	1.2371	0.0019	23	0	0.0001	-0.0001
3	108	0.0072	383317	0.9999	0.0096	284526	0.9981	2859	1	0	1.2378	0.0025	45	2	0.0003	-0.0000
4	64	0.0097	383113	0.9998	0.0127	290132	0.9988	3619	2	2	1.2379	0.0027	75	7	0.0006	0.0001
5	77	0.0136	381501	0.9998	0.0175	288783	0.9984	4470	9	10	1.2392	0.0040	139	35	0.0012	0.0004
6	72	0.0173	380884	0.9998	0.0220	288220	0.9981	5001	20	23	1.2397	0.0045	207	76	0.0018	0.0009
7	71	0.0204	380609	0.9998	0.0258	288474	0.9981	5279	32	37	1.2399	0.0047	268	124	0.0025	0.0014
8	74	0.0248	380883	0.9998	0.0310	288735	0.9982	5492	53	62	1.2397	0.0045	362	205	0.0034	0.0022
9	59	0.0290	378904	0.9997	0.0361	287746	0.9978	5650	74	87	1.2413	0.0061	454	287	0.0043	0.0031
10	58	0.0331	378566	0.9997	0.0409	286120	0.9978	5771	96	112	1.2416	0.0063	543	369	0.0051	0.0039
11	67	0.0370	379153	0.9997	0.0456	284365	0.9968	5864	117	137	1.2411	0.0059	630	451	0.0059	0.0047
12	68	0.0411	377685	0.9997	0.0503	284559	0.9972	5917	141	163	1.2423	0.0070	722	538	0.0068	0.0055
13	69	0.0451	377178	0.9998	0.0551	284089	0.9971	5992	164	191	1.2427	0.0075	816	627	0.0077	0.0063
14	67	0.0492	377088	0.9997	0.0599	281485	0.9968	6070	187	218	1.2428	0.0075	911	718	0.0086	0.0072
15	71	0.0548	373573	0.9997	0.0663	281481	0.9965	6121	221	256	1.2456	0.0104	1039	840	0.0098	0.0084
16	83	0.0599	371791	0.9996	0.0724	280454	0.9974	6193	250	292	1.2471	0.0118	1162	957	0.0109	0.0094
17	65	0.0655	369804	0.9997	0.0789	276788	0.9955	6244	284	331	1.2487	0.0135	1294	1085	0.0121	0.0106
18	68	0.0699	366531	0.9998	0.0841	274671	0.9957	6280	311	361	1.2514	0.0162	1393	1180	0.0131	0.0116
19	68	0.0750	364155	0.9997	0.0899	273122	0.9952	6271	342	397	1.2534	0.0181	1513	1297	0.0142	0.0127
20	67	0.0798	361063	0.9997	0.0955	270415	0.9954	6275	372	432	1.2559	0.0207	1628	1409	0.0153	0.0138
21	68	0.0850	356047	0.9997	0.1014	267958	0.9948	6268	404	468	1.2601	0.0249	1746	1524	0.0166	0.0150
22	70	0.0900	351829	0.9997	0.1071	265634	0.9947	6266	434	503	1.2637	0.0285	1859	1635	0.0177	0.0161
23	71	0.0951	347522	0.9997	0.1130	261325	0.9944	6254	465	539	1.2674	0.0321	1974	1748	0.0189	0.0172
24	69	0.1001	342563	0.9995	0.1186	259018	0.9938	6192	497	573	1.2717	0.0364	2083	1856	0.0201	0.0185
25	71	0.1050	338437	0.9996	0.1243	255890	0.9937	6182	526	608	1.2752	0.0400	2194	1965	0.0212	0.0196
26	71	0.1100	334198	0.9996	0.1299	253088	0.9943	6176	556	641	1.2790	0.0437	2303	2071	0.0224	0.0208
27	71	0.1150	330063	0.9997	0.1357	250339	0.9933	6176	586	676	1.2826	0.0474	2414	2179	0.0236	0.0219
28	70	0.1200	324549	0.9996	0.1411	243206	0.9909	6083	617	710	1.2876	0.0523	2519	2285	0.0249	0.0232
29	72	0.1250	318663	0.9996	0.1468	241228	0.9900	6074	646	741	1.2929	0.0577	2614	2375	0.0262	0.0244
30	75	0.1300	313966	0.9996	0.1524	240508	0.9922	6046	675	775	1.2972	0.0620	2722	2480	0.0274	0.0257
31	77	0.1360	309444	0.9997	0.1591	234495	0.9915	6007	710	816	1.3014	0.0662	2853	2612	0.0289	0.0271
32	77	0.1420	302219	0.9997	0.1658	230121	0.9891	5922	747	855	1.3082	0.0729	2966	2725	0.0305	0.0288
33	80	0.1481	296300	0.9995	0.1725	226387	0.9892	5866	781	893	1.3138	0.0786	3084	2841	0.0321	0.0303
34	80	0.1541	290197	0.9996	0.1792	220881	0.9867	5794	816	932	1.3197	0.0845	3202	2958	0.0337	0.0319
35	80	0.1600	284044	0.9995	0.1857	214477	0.9819	5715	849	968	1.3257	0.0905	3307	3064	0.0352	0.0335
36	82	0.1658	274118	0.9994	0.1919	209620	0.9852	5545	883	1003	1.3356	0.1004	3389	3149	0.0370	0.0353
37	66	0.1739	262876	0.9992	0.2006	203602	0.9859	5386	928	1053	1.3472	0.1119	3520	3279	0.0394	0.0377
38	61	0.1810	256585	0.9995	0.2084	195482	0.9821	5330	962	1092	1.3538	0.1185	3638	3397	0.0413	0.0395
39	63	0.1880	251766	0.9994	0.2160	193142	0.9822	5275	999	1129	1.3589	0.1237	3754	3511	0.0432	0.0414

Specimen DB-3

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
40	66	0.1958	246012	0.9993	0.2245	188588	0.9818	5209	1039	1174	1.3651	0.1299	3896	3652	0.0453	0.0436
41	64	0.2040	237944	0.9993	0.2334	182157	0.9759	5085	1082	1220	1.3740	0.1388	4026	3784	0.0478	0.0461
42	68	0.2111	229680	0.9992	0.2410	175404	0.9756	4945	1117	1258	1.3833	0.1481	4116	3876	0.0500	0.0483
43	73	0.2189	218756	0.9989	0.2490	168786	0.9784	4740	1156	1298	1.3960	0.1607	4192	3957	0.0526	0.0509

Specimen SB-1

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	78	0.0012	5601390	0.9999	0.0050	1338824	0.9996	8318	-6	-6	0.3057	-0.0043	19	-5	-0.0010	-0.0012
2	116	0.0026	5589843	0.9999	0.0101	1358625	0.9995	14818	9	7	0.3062	-0.0038	82	9	0.0005	-0.0000
3	124	0.0054	5528845	0.9997	0.0181	1379006	0.9997	21790	38	65	0.3093	-0.0007	226	67	0.0022	0.0011
4	100	0.0080	5509548	0.9994	0.0242	1377008	0.9997	24239	88	171	0.3103	0.0003	372	174	0.0040	0.0026
5	101	0.0101	5485111	0.9993	0.0288	1377228	0.9997	25423	135	266	0.3116	0.0016	487	271	0.0054	0.0039
6	120	0.0123	5397428	0.9992	0.0334	1376004	0.9998	26185	188	373	0.3162	0.0062	613	382	0.0070	0.0053
7	117	0.0130	5437822	0.9991	0.0350	1375451	0.9998	26508	204	407	0.3140	0.0040	652	416	0.0074	0.0057
8	115	0.0145	5409795	0.9992	0.0382	1371343	0.9997	26916	243	485	0.3155	0.0055	738	496	0.0085	0.0068
9	114	0.0162	5370063	0.9993	0.0416	1367841	0.9997	27090	290	575	0.3176	0.0076	838	589	0.0098	0.0080
10	105	0.0181	5356431	0.9994	0.0453	1371469	0.9997	27447	338	669	0.3183	0.0083	943	686	0.0110	0.0092
11	107	0.0200	5310725	0.9992	0.0493	1369624	0.9997	27800	390	774	0.3208	0.0108	1062	797	0.0124	0.0105
12	97	0.0220	5319411	0.9993	0.0533	1370473	0.9995	27986	445	883	0.3203	0.0103	1180	908	0.0138	0.0119
13	110	0.0244	5250658	0.9991	0.0581	1367325	0.9996	28493	511	1010	0.3241	0.0141	1325	1044	0.0155	0.0135
14	112	0.0267	5201608	0.9988	0.0626	1366657	0.9996	28607	574	1139	0.3268	0.0168	1469	1182	0.0171	0.0151
15	111	0.0292	5185969	0.9989	0.0677	1363051	0.9996	28947	644	1279	0.3277	0.0177	1623	1330	0.0189	0.0168
16	111	0.0320	5112188	0.9989	0.0733	1360585	0.9995	29078	726	1440	0.3319	0.0219	1806	1506	0.0209	0.0188
17	110	0.0350	5025476	0.9988	0.0793	1356483	0.9996	29542	810	1609	0.3370	0.0270	2006	1695	0.0230	0.0208
18	110	0.0380	5011216	0.9988	0.0852	1351978	0.9995	29763	895	1777	0.3379	0.0279	2195	1876	0.0251	0.0228
19	110	0.0411	4907296	0.9986	0.0912	1349278	0.9996	29841	988	1955	0.3442	0.0342	2408	2081	0.0273	0.0250
20	102	0.0440	4796400	0.9986	0.0968	1342955	0.9995	30087	1072	2121	0.3511	0.0411	2617	2280	0.0294	0.0270
21	98	0.0457	4760767	0.9987	0.0999	1339309	0.9994	30073	1119	2212	0.3534	0.0434	2727	2386	0.0305	0.0281
22	97	0.0491	4645390	0.9985	0.1063	1330674	0.9994	30287	1219	2400	0.3610	0.0510	2968	2615	0.0330	0.0305
23	96	0.0521	4564401	0.9987	0.1120	1321653	0.9992	30447	1307	2568	0.3665	0.0565	3181	2821	0.0351	0.0326
24	107	0.0551	4471934	0.9984	0.1174	1317674	0.9994	30500	1395	2730	0.3729	0.0629	3394	3025	0.0373	0.0346
25	95	0.0580	4427084	0.9986	0.1229	1312311	0.9990	30515	1483	2896	0.3761	0.0661	3601	3226	0.0394	0.0367
26	101	0.0619	4294268	0.9986	0.1298	1304963	0.9993	30476	1602	3110	0.3859	0.0759	3895	3512	0.0423	0.0395
27	117	0.0661	4135068	0.9982	0.1370	1299022	0.9997	30340	1727	3334	0.3982	0.0882	4220	3828	0.0453	0.0425
28	94	0.0700	4025826	0.9988	0.1436	1283575	0.9988	30307	1839	3536	0.4070	0.0970	4511	4109	0.0481	0.0452
29	92	0.0740	3932694	0.9987	0.1505	1269814	0.9986	30274	1954	3736	0.4148	0.1048	4800	4392	0.0509	0.0480
30	92	0.0780	3718386	0.9984	0.1566	1246125	0.9986	29676	2079	3933	0.4338	0.1238	5151	4737	0.0540	0.0511
31	90	0.0821	3535682	0.9984	0.1630	1226804	0.9985	29370	2189	4117	0.4511	0.1411	5498	5075	0.0569	0.0539
32	94	0.0862	3357620	0.9982	0.1693	1203046	0.9986	28773	2305	4307	0.4692	0.1592	5870	5444	0.0600	0.0570
33	95	0.0901	3189491	0.9981	0.1752	1179053	0.9987	28528	2406	4470	0.4875	0.1775	6232	5795	0.0628	0.0597
34	88	0.0941	3026638	0.9978	0.1807	1150153	0.9982	27726	2516	4638	0.5064	0.1964	6619	6182	0.0658	0.0627
35	85	0.0980	2881543	0.9985	0.1868	1127298	0.9975	27497	2617	4795	0.5243	0.2143	7016	6567	0.0687	0.0655

Specimen SB-2

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	76	0.0011	5668447	0.9996	0.0045	1313515	0.9997	6208	-3	-7	0.3043	-0.0057	8	-5	-0.0006	-0.0007
2	92	0.0022	5614829	0.9993	0.0091	1333018	0.9997	12246	4	4	0.3069	-0.0031	57	6	0.0004	0.0001
3	109	0.0041	5580488	0.9988	0.0153	1348620	0.9997	19023	15	24	0.3087	-0.0013	154	25	0.0014	0.0005
4	98	0.0067	5541349	0.9992	0.0223	1339572	0.9998	23689	53	106	0.3106	0.0006	297	109	0.0031	0.0017
5	109	0.0086	5500213	0.9997	0.0269	1343905	1.0000	25309	93	185	0.3128	0.0028	404	190	0.0044	0.0028
6	112	0.0106	5477157	0.9998	0.0313	1340213	0.9999	26362	139	283	0.3140	0.0040	519	289	0.0057	0.0041
7	106	0.0125	5461503	0.9998	0.0353	1334666	0.9999	26970	188	378	0.3148	0.0048	629	386	0.0071	0.0053
8	100	0.0152	5419377	0.9997	0.0409	1331716	0.9999	27583	259	520	0.3170	0.0070	789	533	0.0090	0.0072
9	103	0.0175	5375484	0.9995	0.0457	1330490	0.9999	28120	320	643	0.3193	0.0093	930	661	0.0106	0.0087
10	98	0.0196	5334672	0.9994	0.0502	1326036	0.9999	28435	379	765	0.3215	0.0115	1066	788	0.0121	0.0101
11	98	0.0216	5300207	0.9993	0.0545	1316509	0.9997	28834	434	878	0.3234	0.0134	1193	908	0.0135	0.0115
12	98	0.0237	5255326	0.9994	0.0588	1316604	0.9999	29046	493	997	0.3259	0.0159	1327	1034	0.0150	0.0129
13	110	0.0258	5191588	0.9994	0.0632	1310962	1.0000	29310	554	1121	0.3294	0.0194	1471	1169	0.0165	0.0143
14	105	0.0277	5148259	0.9995	0.0671	1306238	1.0000	29597	607	1229	0.3319	0.0219	1595	1286	0.0178	0.0156
15	106	0.0297	5080144	0.9995	0.0711	1299417	1.0000	29762	665	1345	0.3359	0.0259	1731	1415	0.0193	0.0170
16	104	0.0314	5030690	0.9996	0.0746	1293529	1.0000	29935	715	1444	0.3388	0.0288	1847	1526	0.0205	0.0182
17	101	0.0335	4986610	0.9996	0.0786	1288344	1.0000	30047	774	1561	0.3414	0.0314	1983	1656	0.0219	0.0195
18	104	0.0357	4936783	0.9996	0.0832	1282631	1.0000	30355	841	1693	0.3444	0.0344	2141	1804	0.0235	0.0211
19	99	0.0379	4892112	0.9996	0.0875	1277361	1.0000	30446	904	1818	0.3472	0.0372	2288	1945	0.0250	0.0226
20	98	0.0401	4837525	0.9997	0.0919	1269324	0.9999	30681	971	1948	0.3506	0.0406	2444	2095	0.0266	0.0241
21	102	0.0425	4784062	0.9995	0.0965	1261918	0.9997	30810	1042	2084	0.3540	0.0440	2609	2252	0.0283	0.0257
22	96	0.0450	4731295	0.9996	0.1014	1259834	1.0000	30903	1118	2230	0.3574	0.0474	2783	2422	0.0301	0.0275
23	90	0.0475	4663114	0.9996	0.1061	1248657	0.9999	31006	1194	2375	0.3620	0.0520	2965	2596	0.0319	0.0292
24	95	0.0504	4558776	0.9996	0.1115	1245016	0.9999	31010	1282	2540	0.3690	0.0590	3130	2804	0.0340	0.0313
25	95	0.0532	4502587	0.9996	0.1169	1228402	0.9998	31145	1367	2705	0.3730	0.0630	3388	3004	0.0359	0.0332
26	94	0.0562	4422675	0.9995	0.1225	1213864	0.9999	31205	1458	2871	0.3787	0.0687	3606	3214	0.0381	0.0353
27	92	0.0590	4301539	0.9993	0.1277	1200281	0.9999	31212	1545	3027	0.3876	0.0776	3830	3428	0.0402	0.0373
28	94	0.0618	4201367	0.9994	0.1328	1190583	0.9999	31211	1627	3178	0.3952	0.0852	4047	3636	0.0422	0.0392
29	92	0.0651	4087879	0.9996	0.1386	1174613	0.9999	31062	1728	3359	0.4042	0.0942	4306	3891	0.0446	0.0416
30	92	0.0690	3823951	0.9992	0.1446	1154260	0.9998	30305	1846	3557	0.4266	0.1166	4659	4238	0.0475	0.0445
31	85	0.0717	3705759	0.9993	0.1493	1131508	0.9996	30188	1918	3691	0.4373	0.1273	4890	4460	0.0494	0.0463
32	86	0.0751	3600312	0.9993	0.1549	1117661	0.9995	30094	2013	3849	0.4473	0.1373	5157	4718	0.0517	0.0486
33	86	0.0786	3453664	0.9993	0.1607	1098954	0.9996	29691	2116	4026	0.4617	0.1517	5481	5038	0.0544	0.0512
34	90	0.0822	3317182	0.9995	0.1665	1080019	0.9998	29346	2218	4198	0.4760	0.1660	5811	5362	0.0570	0.0538
35	88	0.0859	3166411	0.9996	0.1722	1055883	0.9997	28835	2320	4366	0.4926	0.1826	6164	5713	0.0597	0.0565
36	86	0.0893	3002597	0.9996	0.1772	1031192	0.9995	28160	2413	4511	0.5118	0.2018	6520	6068	0.0623	0.0590

Specimen SB-3

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in²)	J Plastic (in-lb/in²)	CTOD (in.)	CTOD Plastic (in.)
1	90	0.0009	5809567	0.9998	0.0037	1400462	1.0000	5460	-2	-3	0.2928	-0.0032	8	-2	-0.0005	-0.0005
2	104	0.0017	5793068	0.9998	0.0070	1389553	1.0000	9973	2	3	0.2936	-0.0024	36	4	0.0002	0.0000
3	119	0.0030	5779673	0.9997	0.0118	1376350	1.0000	15806	7	11	0.2942	-0.0018	92	11	0.0008	0.0002
4	108	0.0047	5766104	0.9996	0.0171	1376462	1.0000	20721	23	41	0.2948	-0.0012	179	41	0.0018	0.0008
5	93	0.0081	5726208	0.9999	0.0255	1374582	0.9999	24623	85	171	0.2967	0.0007	360	168	0.0041	0.0027
6	100	0.0106	5696771	0.9997	0.0312	1366025	0.9999	25903	144	294	0.2981	0.0021	504	290	0.0059	0.0044
7	105	0.0130	5664016	0.9996	0.0364	1368479	1.0000	26666	204	415	0.2997	0.0037	637	410	0.0076	0.0060
8	94	0.0152	5646861	0.9995	0.0412	1367369	1.0000	27199	261	536	0.3006	0.0046	768	530	0.0092	0.0075
9	103	0.0180	5587673	0.9994	0.0472	1363706	1.0000	27615	337	696	0.3035	0.0075	939	692	0.0112	0.0095
10	112	0.0195	5558580	0.9992	0.0503	1361972	1.0000	27994	374	774	0.3049	0.0089	1027	771	0.0122	0.0104
11	98	0.0214	5546410	0.9994	0.0545	1360863	1.0000	28223	428	888	0.3055	0.0095	1146	885	0.0136	0.0117
12	92	0.0234	5527983	0.9995	0.0587	1358944	0.9999	28511	485	1005	0.3065	0.0105	1270	1004	0.0151	0.0131
13	102	0.0259	5449813	0.9994	0.0641	1355647	0.9999	28823	556	1152	0.3105	0.0145	1433	1158	0.0169	0.0149
14	94	0.0285	5424896	0.9993	0.0695	1351591	0.9999	29124	629	1305	0.3118	0.0158	1596	1314	0.0187	0.0167
15	98	0.0304	5367021	0.9994	0.0734	1348557	0.9999	29357	682	1414	0.3148	0.0188	1720	1430	0.0201	0.0180
16	100	0.0327	5304456	0.9994	0.0782	1344888	0.9999	29539	749	1553	0.3182	0.0222	1876	1579	0.0217	0.0196
17	90	0.0351	5273148	0.9995	0.0831	1343335	1.0000	29784	817	1695	0.3199	0.0239	2031	1728	0.0234	0.0212
18	89	0.0379	5211639	0.9995	0.0889	1338402	1.0000	30042	900	1864	0.3233	0.0273	2220	1911	0.0254	0.0232
19	96	0.0403	5146864	0.9993	0.0939	1332584	0.9999	30258	973	2012	0.3269	0.0309	2391	2074	0.0272	0.0249
20	96	0.0436	5049776	0.9994	0.1005	1326866	0.9999	30452	1071	2209	0.3325	0.0365	2622	2295	0.0296	0.0272
21	101	0.0468	4946480	0.9994	0.1069	1317317	0.9999	30652	1166	2398	0.3387	0.0427	2849	2513	0.0319	0.0295
22	94	0.0499	4872554	0.9995	0.1128	1312413	0.9999	30684	1259	2579	0.3432	0.0472	3063	2721	.0.0341	0.0316
23	105	0.0534	4693497	0.9993	0.1193	1299496	0.9999	30676	1366	2780	0.3546	0.0586	3332	2979	0.0367	0.0342
24	103	0.0567	4594844	0.9994	0.1254	1290140	0.9999	30750	1460	2962	0.3612	0.0652	3565	3203	0.0390	0.0364
25	100	0.0597	4526351	0.9995	0.1312	1285971	0.9999	30982	1549	3133	0.3659	0.0699	3782	3411	0.0412	0.0385
26	98	0.0631	4398990	0.9994	0.1374	1276346	0.9999	30833	1655	3328	0.3749	0.0789	4044	3669	0.0437	0.0410
27	97	0.0661	4297059	0.9995	0.1427	1262473	1.0000	30742	1743	3492	0.3823	0.0863	4272	3889	0.0459	0.0431
28	95	0.0696	4192172	0.9995	0.1488	1255776	1.0000	30668	1847	3676	0.3903	0.0943	4530	4139	0.0484	0.0456
29	102	0.0731	4060060	0.9993	0.1550	1238966	1.0000	30511	1955	3872	0.4008	0.1048	4818	4421	0.0511	0.0482
30	95	0.0765	3925128	0.9994	0.1607	1222208	1.0000	30267	2054	4042	0.4120	0.1160	5088	4684	0.0536	0.0507
31	90	0.0798	3775994	0.9991	0.1658	1205498	0.9997	29820	2150	4200	0.4250	0.1290	5356	4950	0.0560	0.0531
32	90	0.0828	3630872	0.9995	0.1706	1181587	1.0000	29627	2233	4339	0.4384	0.1424	5616	5202	0.0582	0.0553
33	98	0.0864	3456406	0.9991	0.1760	1159602	0.9998	29234	2335	4496	0.4554	0.1594	5930	5511	0.0610	0.0579
34	101	0.0890	3344877	0.9994	0.1799	1142027	1.0000	29088	2400	4602	0.4669	0.1709	6158	5728	0.0628	0.0597

Specimen SEN-1

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in²)	J Plastic (in-lb/in²)	CTOD (in.)	CTOD Plastic (in.)
1	68	0.0030	5965038	1.0000	0.0015	10624600	0.9980	20353	-1	1	1.0379	-0.0113	43	2	0.0000	0.0000
2	93	0.0053	5850558	1.0000	0.0028	10790690	0.9993	32315	8	5	1.0448	-0.0043	117	9	0.0000	0.0000
3	70	0.0071	5818195	1.0000	0.0037	10826920	0.9996	39988	25	14	1.0468	-0.0023	195	29	0.0000	0.0000
4	77	0.0107	5775952	0.9999	0.0050	10464380	0.9990	50029	107	49	1.0495	0.0003	362	100	0.0000	0.0000
5	88	0.0132	5721483	1.0000	0.0060	10363500	0.9991	53532	203	78	1.0529	0.0037	463	160	0.0000	0.0000
6	105	0.0165	5616556	0.9999	0.0078	9968147	0.9993	58482	340	142	1.0595	0.0103	659	289	0.0000	0.0000
7	67	0.0215	5516717	0.9999	0.0102	9903307	0.9993	62204	591	243	1.0660	0.0168	925	497	0.0000	0.0000
8	66	0.0270	5445918	0.9999	0.0120	9701122	0.9998	63719	909	372	1.0706	0.0215	1217	762	0.0000	0.0000
9	77	0.0323	5304970	0.9997	0.0148	9580219	0.9995	66453	1217	511	1.0801	0.0309	1554	1043	0.0000	0.0000
10	63	0.0380	5259057	0.9999	0.0167	9745429	0.9995	65172	1597	664	1.0832	0.0341	1855	1359	0.0000	0.0000
11	82	0.0444	5066077	0.9999	0.0194	9465190	0.9992	66660	2008	849	1.0967	0.0475	2272	1730	0.0000	0.0000
12	89	0.0501	4891848	0.9997	0.0220	9182186	0.9995	69338	2333	996	1.1094	0.0602	2628	2017	0.0000	0.0000
13	88	0.0559	4765410	0.9996	0.0246	8909041	0.9993	70141	2694	1153	1.1188	0.0696	2978	2334	0.0000	0.0000
14	84	0.0602	4675659	0.9997	0.0265	9137088	0.9989	70603	2960	1264	1.1257	0.0765	3223	2556	0.0000	0.0000
15	77	0.0652	4589528	0.9999	0.0282	8843632	0.9991	67990	3333	1427	1.1324	0.0832	3523	2891	0.0000	0.0000
16	88	0.0689	4395055	0.9998	0.0298	8643606	0.9993	69038	3557	1519	1.1480	0.0988	3729	3044	0.0000	0.0000
17	89	0.0725	4245726	0.9995	0.0315	8521231	0.9988	69464	3755	1618	1.1605	0.1113	3943	3222	0.0000	0.0000
18	72	0.0760	4183181	0.9998	0.0328	8135579	0.9992	67793	3981	1712	1.1658	0.1166	4111	3412	0.0000	0.0000
19	28	0.0835	4005280	0.9999	0.0356	8801837	0.9976	59487	4605	1949	1.1814	0.1323	4448	3882	0.0000	0.0000

Specimen SEN-2

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	57	0.0022	7414383	0.9998	0.0004	10757470	0.9995	19649	−2	−1	0.9605	−0.0145	29	−2	0.0000	0.0000
2	66	0.0046	7215492	0.9998	0.0019	10243110	0.9997	35306	8	3	0.9701	−0.0049	107	6	0.0000	0.0000
3	96	0.0066	7214518	0.9998	0.0030	10864240	0.9999	45345	28	6	0.9701	−0.0048	177	11	0.0000	0.0000
4	88	0.0094	7314779	0.9999	0.0040	10247020	0.9997	54483	108	43	0.9652	−0.0097	315	78	0.0000	0.0000
5	56	0.0122	7102680	0.9999	0.0053	10736360	0.9999	60912	227	70	0.9756	0.0007	434	127	0.0000	0.0000
6	77	0.0162	7017681	0.9997	0.0073	10282010	1.0000	66514	418	179	0.9799	0.0050	697	327	0.0000	0.0000
7	99	0.0207	6865116	0.9996	0.0096	10313610	0.9999	69980	682	285	0.9877	0.0127	946	525	0.0000	0.0000
8	74	0.0251	6884465	0.9999	0.0113	10282100	0.9998	71672	970	417	0.9867	0.0117	1211	772	0.0000	0.0000
9	95	0.0295	6647964	0.9996	0.0137	10179460	1.0000	74211	1262	561	0.9991	0.0242	1537	1046	0.0000	0.0000
10	86	0.0343	6612480	0.9997	0.0158	10075370	0.9999	75760	1583	717	1.0010	0.0261	1859	1344	0.0000	0.0000
11	63	0.0379	6548157	0.9999	0.0172	9919492	0.9999	73455	1879	837	1.0045	0.0296	2064	1575	0.0000	0.0000
12	79	0.0432	6333004	0.9996	0.0199	9811732	0.9997	78315	2229	1006	1.0164	0.0415	2487	1909	0.0000	0.0000
13	85	0.0484	6292686	0.9997	0.0228	9822737	0.9999	79402	2594	1193	1.0187	0.0438	2874	2276	0.0000	0.0000
14	61	0.0541	6111704	0.9996	0.0251	9527388	0.9998	80496	3025	1395	1.0292	0.0542	3316	2680	0.0000	0.0000
15	74	0.0588	6081534	0.9998	0.0271	9711223	0.9999	78394	3408	1555	1.0309	0.0560	3608	3001	0.0000	0.0000
16	73	0.0620	5914761	0.9995	0.0293	9644562	0.9999	81467	3620	1693	1.0409	0.0660	3960	3284	0.0000	0.0000
17	73	0.0662	5752572	0.9999	0.0305	9334755	0.9999	79842	3954	1831	1.0509	0.0760	4205	3534	0.0000	0.0000
18	72	0.0708	5702922	0.9997	0.0326	9301876	0.9999	80048	4294	1983	1.0540	0.0791	4516	3834	0.0000	0.0000
19	87	0.0752	5485079	0.9995	0.0352	9128878	0.9999	81876	4621	2163	1.0681	0.0931	4897	4151	0.0000	0.0000
20	85	0.0802	5292981	0.9995	0.0371	9001243	0.9998	81445	4985	2325	1.0809	0.1060	5203	4434	0.0000	0.0000
21	83	0.0835	5156575	0.9999	0.0388	9044198	0.9998	81441	5215	2456	1.0903	0.1154	5460	4667	0.0000	0.0000
22	49	0.0875	5074506	0.9998	0.0407	8667668	0.9998	81369	5507	2606	1.0961	0.1212	5764	4958	0.0000	0.0000
23	54	0.0927	4855994	0.9995	0.0425	8661276	0.9999	79052	5937	2746	1.1120	0.1371	5975	5175	0.0000	0.0000
24	46	0.0955	4860986	0.9999	0.0436	8636520	0.9999	77637	6133	2847	1.1116	0.1367	6164	5393	0.0000	0.0000
25	51	0.1020	4657607	0.9997	0.0463	8485046	0.9999	75908	6670	3076	1.1271	0.1521	6571	5796	0.0000	0.0000

Specimen SEN-4 JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD Area$_{pl}$ (in-lb)	LL Area$_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	32	0.0061	1427498	1.0000	0.0015	3752655	0.9985	10094	-3	-2	1.5336	-0.0095	60	6	0.0000	0.0000
2	60	0.0147	1410446	1.0000	0.0044	3519185	0.9998	18419	43	15	1.5374	-0.0057	240	57	0.0000	0.0000
3	72	0.0205	1386163	1.0000	0.0065	3494279	0.9999	21698	112	34	1.5429	-0.0003	374	114	0.0000	0.0000
4	88	0.0258	1368060	0.9999	0.0087	3414189	0.9999	24060	191	63	1.5470	0.0039	528	203	0.0000	0.0000
5	86	0.0319	1360647	0.9999	0.0107	3439928	0.9997	25086	318	108	1.5487	0.0056	699	343	0.0000	0.0000
6	90	0.0380	1328448	0.9998	0.0131	3387869	0.9995	26234	450	159	1.5562	0.0131	902	501	0.0000	0.0000
7	88	0.0418	1353081	0.9999	0.0144	3408681	0.9994	26650	532	189	1.5505	0.0073	1003	599	0.0000	0.0000
8	85	0.0460	1346086	0.9999	0.0157	3406492	0.9990	26590	655	231	1.5521	0.0090	1135	730	0.0000	0.0000
9	70	0.0508	1324479	0.9998	0.0178	3431236	0.9982	27431	766	277	1.5571	0.0140	1306	866	0.0000	0.0000
10	76	0.0552	1321325	0.9999	0.0192	3450574	0.9983	27322	882	323	1.5579	0.0148	1448	1010	0.0000	0.0000
11	82	0.0597	1303667	0.9998	0.0211	3347904	0.9982	27959	992	367	1.5621	0.0190	1609	1143	0.0000	0.0000
12	65	0.0648	1307148	0.9999	0.0228	3435686	0.9981	27814	1131	413	1.5612	0.0181	1752	1292	0.0000	0.0000
13	89	0.0696	1267196	0.9998	0.0248	3365415	0.9988	28346	1256	468	1.5709	0.0278	1943	1447	0.0000	0.0000
14	89	0.0742	1260008	0.9998	0.0264	3345582	0.9979	28545	1364	510	1.5726	0.0295	2084	1577	0.0000	0.0000
15	94	0.0781	1246254	0.9998	0.0282	3345445	0.9983	28665	1468	549	1.5760	0.0329	2213	1694	0.0000	0.0000
16	102	0.0823	1229242	0.9998	0.0298	3272721	0.9986	28705	1580	592	1.5803	0.0372	2350	1820	0.0000	0.0000
17	87	0.0867	1224899	0.9998	0.0309	3299973	0.9979	28511	1702	633	1.5814	0.0383	2477	1952	0.0000	0.0000
18	83	0.0906	1198186	0.9998	0.0326	3215180	0.9976	28790	1806	677	1.5881	0.0450	2625	2075	0.0000	0.0000
19	24	0.0910	1266572	1.0000	0.0324	4319342	0.9709	28087	1820	680	1.5710	0.0279	2623	2135	0.0000	0.0000
20	51	0.0955	1194741	0.9999	0.0341	3319325	0.9975	27404	2000	800	1.5890	0.0459	2959	2459	0.0000	0.0000
21	60	0.1004	1175860	0.9999	0.0359	3186526	0.9971	27625	2099	796	1.5939	0.0508	2947	2427	0.0000	0.0000
22	60	0.1057	1156785	0.9999	0.0379	3244890	0.9975	28049	2232	839	1.5989	0.0558	3098	2551	0.0000	0.0000
23	63	0.1110	1130080	0.9998	0.0399	3067891	0.9977	28501	2361	896	1.6060	0.0629	3291	2709	0.0000	0.0000
24	60	0.1156	1118156	0.9999	0.0416	3085430	0.9970	27511	2503	945	1.6092	0.0661	3409	2859	0.0000	0.0000
25	61	0.1206	1091045	0.9998	0.0442	3029391	0.9973	28574	2611	993	1.6166	0.0735	3596	2984	0.0000	0.0000
26	66	0.1252	1069207	0.9997	0.0458	2936597	0.9969	28599	2725	1039	1.6227	0.0795	3740	3111	0.0000	0.0000
27	67	0.1292	1057094	0.9998	0.0476	2859142	0.9980	28620	2821	1074	1.6261	0.0829	3855	3215	0.0000	0.0000
28	63	0.1347	1041935	0.9998	0.0490	2900105	0.9977	27730	2994	1137	1.6304	0.0873	4017	3405	0.0000	0.0000
29	67	0.1394	1005748	0.9997	0.0516	2787984	0.9983	28165	3103	1191	1.6409	0.0978	4195	3533	0.0000	0.0000
30	61	0.1451	999857	0.9999	0.0529	2762932	0.9983	26819	3273	1253	1.6426	0.0995	4340	3735	0.0000	0.0000
31	70	0.1496	971391	0.9997	0.0555	2658105	0.9980	27961	3362	1291	1.6511	0.1080	4500	3818	0.0000	0.0000
32	74	0.1550	948416	0.9996	0.0576	2620783	0.9975	27661	3498	1344	1.6581	0.1150	4647	3958	0.0000	0.0000
33	61	0.1620	934070	0.9999	0.0598	2685481	0.9975	25631	3727	1435	1.6626	0.1195	4854	4250	0.0000	0.0000

Specimen SEN-9

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	57	0.0041	5820876	1.0000	0.0026	8377966	0.9999	25458	1	−0	1.0467	0.0134	67	−0	0.0000	0.0000
2	43	0.0042	5892000	0.9999	0.0023	8263827	0.9995	25499	−2	−2	1.0423	0.0090	64	−3	0.0000	0.0000
3	70	0.0074	5983493	1.0000	0.0043	8665973	1.0000	39323	31	2	1.0368	0.0035	161	5	0.0000	0.0000
4	81	0.0105	6033523	1.0000	0.0064	8819825	0.9999	49930	97	45	1.0338	0.0005	339	91	0.0000	0.0000
5	93	0.0123	6073684	1.0000	0.0068	8660561	0.9999	52773	173	71	1.0314	−0.0019	418	143	0.0000	0.0000
6	87	0.0139	6045995	1.0000	0.0077	8662960	0.9999	56502	231	94	1.0330	−0.0002	508	190	0.0000	0.0000
7	82	0.0157	6175700	1.0000	0.0084	8718228	0.9999	57322	324	130	1.0254	−0.0078	579	260	0.0000	0.0000
8	75	0.0177	6140434	0.9999	0.0101	8688816	0.9999	60857	423	188	1.0275	−0.0058	739	377	0.0000	0.0000
9	90	0.0201	6052324	0.9999	0.0109	8635654	1.0000	62882	546	248	1.0327	−0.0006	890	497	0.0000	0.0000
10	84	0.0226	6072886	0.9999	0.0125	8821430	0.9999	64414	680	311	1.0315	−0.0018	1035	624	0.0000	0.0000
11	65	0.0252	6066690	0.9999	0.0131	8765622	0.9999	65234	845	379	1.0318	−0.0015	1181	759	0.0000	0.0000
12	51	0.0286	5969952	0.9998	0.0151	8825389	0.9998	67713	1041	478	1.0376	0.0043	1422	960	0.0000	0.0000
13	48	0.0324	5973922	0.9999	0.0169	8735941	0.9999	69203	1270	590	1.0373	0.0041	1670	1187	0.0000	0.0000
14	50	0.0378	5932219	0.9999	0.0186	8706343	0.9999	69130	1650	729	1.0399	0.0066	1957	1471	0.0000	0.0000
15	69	0.0417	5810894	0.9997	0.0206	8541882	0.9999	71648	1892	845	1.0473	0.0140	2230	1696	0.0000	0.0000
16	67	0.0458	5818106	0.9998	0.0231	8399419	0.9998	73031	2158	975	1.0468	0.0136	2517	1962	0.0000	0.0000
17	82	0.0500	5661098	0.9997	0.0248	8536582	0.9998	73727	2456	1101	1.0567	0.0234	2784	2200	0.0000	0.0000
18	70	0.0534	5658561	0.9997	0.0262	8228313	0.9999	74407	2676	1217	1.0568	0.0236	3034	2439	0.0000	0.0000
19	84	0.0569	5545916	0.9997	0.0282	8267812	0.9998	74950	2931	1308	1.0641	0.0308	3227	2610	0.0000	0.0000
20	55	0.0603	5474049	0.9995	0.0291	8286485	0.9999	75898	3153	1408	1.0688	0.0355	3448	2806	0.0000	0.0000
21	30	0.0638	5605029	0.9999	0.0303	8269452	0.9999	72090	3456	1538	1.0603	0.0270	3662	3098	0.0000	0.0000
22	61	0.0678	5273052	0.9996	0.0325	8173204	0.9998	76284	3726	1668	1.0823	0.0490	3977	3299	0.0000	0.0000
23	42	0.0714	5358565	0.9999	0.0337	8320051	0.9998	73810	3970	1774	1.0765	0.0432	4165	3542	0.0000	0.0000
24	67	0.0763	5044710	0.9995	0.0361	7903071	0.9996	76381	4324	1945	1.0982	0.0650	4535	3820	0.0000	0.0000
25	60	0.0811	5019737	0.9997	0.0384	7822509	0.9997	76828	4616	2081	1.1000	0.0668	4829	4101	0.0000	0.0000
26	51	0.0851	4968394	0.9998	0.0396	7931650	0.9999	73863	4960	2193	1.1038	0.0705	5005	4325	0.0000	0.0000
27	48	0.0891	4846393	0.9998	0.0413	7925313	0.9998	74431	5246	2329	1.1127	0.0794	5286	4575	0.0000	0.0000
28	63	0.0936	4655629	0.9995	0.0435	7580592	0.9998	76309	5537	2479	1.1272	0.0939	5613	4830	0.0000	0.0000
29	49	0.0993	4561200	0.9998	0.0465	7604264	0.9995	76249	5921	2665	1.1346	0.1013	5996	5195	0.0000	0.0000
30	31	0.1059	4449850	0.9999	0.0486	7447062	0.9998	69136	6512	2900	1.1435	0.1103	6335	5658	0.0000	0.0000
31	44	0.1114	4241703	0.9999	0.0511	7195850	0.9998	72754	6833	3043	1.1608	0.1275	6662	5870	0.0000	0.0000
32	52	0.1159	4087774	0.9995	0.0532	7099207	0.9996	74143	7084	3164	1.1741	0.1408	6914	6056	0.0000	0.0000

Specimen SEN-10

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	35	0.0063	1426629	1.0000	0.0031	3374840	0.9976	10188	−3	−0	1.5338	−0.0047	56	1	0.0000	0.0000
2	67	0.0105	1439917	0.9999	0.0047	3618585	0.9986	14983	9	4	1.5308	−0.0077	131	13	0.0000	0.0000
3	42	0.0173	1403117	1.0000	0.0073	3351691	0.9995	20183	68	32	1.5390	0.0005	322	100	0.0000	0.0000
4	55	0.0245	1404206	0.9999	0.0103	3385078	0.9987	23169	171	67	1.5388	0.0003	500	209	0.0000	0.0000
5	86	0.0343	1347951	0.9997	0.0141	3291286	0.9989	25052	378	149	1.5516	0.0131	816	457	0.0000	0.0000
6	79	0.0396	1358997	0.9998	0.0159	3454909	0.9983	25621	483	191	1.5491	0.0106	962	590	0.0000	0.0000
7	74	0.0455	1345948	0.9998	0.0182	3445719	0.9978	26148	630	257	1.5521	0.0136	1186	794	0.0000	0.0000
8	68	0.0505	1327835	0.9998	0.0203	3270237	0.9992	26382	752	304	1.5563	0.0178	1341	936	0.0000	0.0000
9	65	0.0569	1314433	0.9999	0.0222	3354514	0.9985	26026	920	355	1.5595	0.0210	1493	1093	0.0000	0.0000
10	68	0.0636	1271962	0.9998	0.0248	3415065	0.9994	26314	1087	427	1.5697	0.0312	1728	1302	0.0000	0.0000
11	81	0.0699	1242330	0.9998	0.0272	3158322	0.9990	26656	1233	492	1.5770	0.0385	1945	1495	0.0000	0.0000
12	81	0.0757	1231984	0.9998	0.0298	3103330	0.9972	26702	1371	534	1.5796	0.0411	2083	1626	0.0000	0.0000
13	75	0.0819	1200225	0.9997	0.0315	3059812	0.9984	26401	1540	591	1.5876	0.0491	2252	1790	0.0000	0.0000
14	81	0.0889	1171899	0.9998	0.0341	3066204	0.9987	26315	1712	657	1.5949	0.0564	2456	1983	0.0000	0.0000
15	84	0.0955	1158539	0.9997	0.0368	2955039	0.9987	26549	1870	726	1.5984	0.0599	2688	2199	0.0000	0.0000
16	79	0.1017	1130203	0.9999	0.0388	2961791	0.9971	25725	2045	781	1.6059	0.0674	2830	2356	0.0000	0.0000
17	48	0.1085	1098333	0.9997	0.0413	2923681	0.9980	25851	2205	847	1.6146	0.0761	3039	2542	0.0000	0.0000
18	62	0.1149	1068097	0.9998	0.0443	2786389	0.9987	26015	2351	909	1.6230	0.0844	3237	2715	0.0000	0.0000
19	67	0.1225	1031632	0.9996	0.0467	2775242	0.9987	25767	2538	973	1.6333	0.0948	3421	2886	0.0000	0.0000
20	58	0.1289	999059	0.9999	0.0486	2726544	0.9975	24419	2712	1034	1.6428	0.1043	3554	3052	0.0000	0.0000
21	65	0.1336	951056	0.9997	0.0510	2592549	0.9990	24732	2803	1075	1.6573	0.1188	3669	3119	0.0000	0.0000
22	82	0.1392	907319	0.9997	0.0526	2498056	0.9981	23842	2931	1120	1.6710	0.1325	3751	3208	0.0000	0.0000
23	53	0.1427	892984	0.9999	0.0534	2619626	0.9978	22507	3018	1146	1.6756	0.1371	3769	3274	0.0000	0.0000
24	50	0.1468	857420	0.9998	0.0549	2606002	0.9968	21691	3122	1198	1.6873	0.1488	3883	3398	0.0000	0.0000

Specimen SE5D

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	59	0.0012	13217300	0.9997	0.0012	13217300	0.9997	20233	−1	−3	0.8873	−0.0441	6	−8	0.0000	0.0000
2	81	0.0021	12877550	0.9999	0.0020	12877550	0.9999	30185	1	3	0.9030	−0.0284	30	−2	0.0000	0.0000
3	79	0.0029	12759120	0.9999	0.0028	12759120	0.9999	40124	2	4	0.9085	−0.0229	56	−1	0.0000	0.0000
4	112	0.0039	12861940	0.9999	0.0035	12861940	0.9999	50166	11	13	0.9037	−0.0277	95	7	0.0000	0.0000
5	65	0.0063	12385390	0.9998	0.0062	12385390	0.9998	58251	109	111	0.9261	−0.0053	242	115	0.0000	0.0000
6	95	0.0079	12366440	0.9998	0.0078	12366440	0.9998	59859	188	190	0.9270	−0.0044	332	198	0.0000	0.0000
7	98	0.0098	12317090	0.9998	0.0098	12317090	0.9998	61242	294	296	0.9293	−0.0021	453	311	0.0000	0.0000
8	68	0.0121	12208190	0.9999	0.0118	12208190	0.9999	62918	426	428	0.9345	0.0031	610	458	0.0000	0.0000
9	78	0.0139	12104860	0.9998	0.0133	12104860	0.9998	64024	534	535	0.9395	0.0080	742	581	0.0000	0.0000
10	87	0.0150	12094380	0.9998	0.0145	12094380	0.9998	64854	598	600	0.9400	0.0085	817	653	0.0000	0.0000
11	74	0.0169	12019200	0.9997	0.0166	12019200	0.9997	65575	718	720	0.9436	0.0121	962	791	0.0000	0.0000
12	125	0.0187	11879540	0.9998	0.0186	11879540	0.9998	66306	833	835	0.9503	0.0189	1115	936	0.0000	0.0000
13	58	0.0215	11806250	0.9997	0.0211	11806250	0.9997	67358	1006	1008	0.9538	0.0224	1329	1143	0.0000	0.0000
14	72	0.0236	11728880	0.9998	0.0232	11728880	0.9998	68079	1145	1146	0.9575	0.0261	1508	1315	0.0000	0.0000
15	67	0.0252	11766620	0.9998	0.0244	11766620	0.9998	66877	1256	1258	0.9557	0.0243	1621	1436	0.0000	0.0000
16	83	0.0275	11532490	0.9997	0.0269	11532490	0.9997	69042	1405	1407	0.9671	0.0356	1867	1661	0.0000	0.0000
17	79	0.0296	11547490	0.9998	0.0289	11547490	0.9998	69327	1539	1541	0.9663	0.0349	2024	1817	0.0000	0.0000
18	77	0.0315	11466600	0.9997	0.0308	11466600	0.9997	69500	1674	1675	0.9703	0.0388	2211	2000	0.0000	0.0000
19	78	0.0334	11491190	0.9998	0.0328	11491190	0.9998	69770	1801	1803	0.9691	0.0377	2358	2146	0.0000	0.0000
20	76	0.0354	11292960	0.9998	0.0347	11292960	0.9998	69623	1941	1943	0.9787	0.0473	2600	2381	0.0000	0.0000
21	81	0.0372	11258180	0.9998	0.0364	11258180	0.9998	68336	2066	2068	0.9804	0.0490	2761	2549	0.0000	0.0000
22	75	0.0393	11123090	0.9998	0.0389	11123090	0.9998	69526	2200	2202	0.9870	0.0556	2995	2770	0.0000	0.0000
23	77	0.0415	11006470	0.9997	0.0411	11006470	0.9997	69271	2354	2356	0.9927	0.0613	3249	3021	0.0000	0.0000
24	50	0.0440	10940630	0.9997	0.0434	10940630	0.9997	69039	2519	2520	0.9959	0.0645	3499	3269	0.0000	0.0000
25	57	0.0467	10744210	0.9998	0.0458	10744210	0.9998	67327	2713	2715	1.0055	0.0741	3867	3640	0.0000	0.0000

Specimen SE6D

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{pl}$ (in-lb)	LL $Area_{pl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	15	0.0006	15094600	0.9996	0.0010	15094600	0.9996	11414	-1	-4	0.8057	-0.0932	-3	-7	0.0000	0.0000
2	64	0.0013	14031350	0.9997	0.0022	14031350	0.9997	21357	2	13	0.8508	-0.0481	22	8	0.0000	0.0000
3	54	0.0020	13652480	0.9999	0.0036	13652480	0.9999	30292	0	26	0.8676	-0.0313	49	21	0.0000	0.0000
4	92	0.0026	13468390	1.0000	0.0047	13468390	1.0000	38972	-1	43	0.8759	-0.0230	85	36	0.0000	0.0000
5	85	0.0034	13417840	0.9999	0.0061	13417840	0.9999	47682	3	75	0.8782	-0.0207	138	65	0.0000	0.0000
6	64	0.0041	13327650	0.9999	0.0067	13327650	0.9999	53080	19	106	0.8823	-0.0166	187	95	0.0000	0.0000
7	91	0.0053	13321040	0.9999	0.0085	13321040	0.9999	56962	65	169	0.8826	-0.0163	258	152	0.0000	0.0000
8	102	0.0069	13147840	0.9998	0.0095	13147840	0.9998	59204	149	268	0.8905	-0.0084	366	249	0.0000	0.0000
9	66	0.0092	13010490	0.9998	0.0128	13010490	0.9998	61220	274	407	0.8968	-0.0021	515	387	0.0000	0.0000
10	54	0.0119	12806640	0.9998	0.0150	12806640	0.9998	63345	432	583	0.9063	0.0074	712	571	0.0000	0.0000
11	61	0.0137	12739890	0.9997	0.0177	12739890	0.9997	64530	534	696	0.9094	0.0105	835	688	0.0000	0.0000
12	80	0.0157	12661280	0.9998	0.0191	12661280	0.9998	65555	658	832	0.9131	0.0142	984	830	0.0000	0.0000
13	58	0.0168	12645020	0.9997	0.0203	12645020	0.9997	66385	727	909	0.9138	0.0149	1068	910	0.0000	0.0000
14	67	0.0187	12488810	0.9998	0.0222	12488810	0.9998	67060	849	1032	0.9212	0.0223	1218	1053	0.0000	0.0000
15	74	0.0205	12569750	0.9998	0.0250	12569750	0.9998	67835	958	1148	0.9174	0.0185	1328	1161	0.0000	0.0000
16	68	0.0227	12374700	0.9997	0.0264	12374700	0.9997	68454	1106	1303	0.9266	0.0277	1525	1350	0.0000	0.0000
17	73	0.0245	12364260	0.9998	0.0291	12364260	0.9998	69198	1224	1426	0.9271	0.0282	1660	1480	0.0000	0.0000
18	90	0.0266	12151870	0.9995	0.0311	12151870	0.9995	69547	1366	1567	0.9372	0.0383	1859	1671	0.0000	0.0000
19	67	0.0286	12223770	0.9996	0.0324	12223770	0.9996	70158	1500	1708	0.9338	0.0349	1996	1807	0.0000	0.0000
20	54	0.0311	12043850	0.9997	0.0351	12043850	0.9997	70516	1671	1888	0.9424	0.0435	2241	2045	0.0000	0.0000
21	50	0.0332	12108390	0.9998	0.0369	12108390	0.9998	69629	1823	2029	0.9393	0.0404	2372	2183	0.0000	0.0000
22	63	0.0355	11779500	0.9998	0.0400	11779500	0.9998	70825	1981	2199	0.9551	0.0562	2677	2470	0.0000	0.0000
23	54	0.0378	11742170	0.9997	0.0417	11742170	0.9997	70756	2127	2355	0.9569	0.0580	2869	2661	0.0000	0.0000
24	53	0.0391	11710760	0.9998	0.0437	11710760	0.9998	70458	2223	2453	0.9584	0.0595	2993	2785	0.0000	0.0000
25	42	0.0415	11706330	0.9998	0.0459	11706330	0.9998	69715	2391	2647	0.9586	0.0597	3214	3011	0.0000	0.0000
26	49	0.0426	11489360	0.9999	0.0472	11489360	0.9999	69458	2467	2706	0.9691	0.0702	3377	3167	0.0000	0.0000
27	43	0.0439	11547260	0.9999	0.0485	11547260	0.9999	69187	2554	2799	0.9663	0.0674	3460	3254	0.0000	0.0000
28	35	0.0453	11499590	0.9999	0.0502	11499590	0.9999	68598	2648	2888	0.9687	0.0698	3584	3380	0.0000	0.0000
29	51	0.0472	11194350	0.9998	0.0509	11194350	0.9998	65928	2790	3008	0.9835	0.0846	3876	3677	0.0000	0.0000
30	88	0.0483	11074370	0.9998	0.0530	11074370	0.9998	67471	2845	3081	0.9894	0.0905	4047	3833	0.0000	0.0000
31	45	0.0501	11031720	0.9999	0.0537	11031720	0.9999	60361	3004	3214	0.9915	0.0926	4203	4030	0.0000	0.0000
32	43	0.0518	10940100	0.9999	0.0553	10940100	0.9999	58104	3118	3322	0.9959	0.0970	4391	4228	0.0000	0.0000

Specimen SE7D

JRA file output using Common Method equations

Unload No.	No. of Data Points	COD (in.)	COD Slope (lb/in)	COD Corr.	Loadline Disp. (in.)	Loadline Slope (lb/in)	Loadline Corr.	Load (lb.)	COD $Area_{bl}$ (in-lb)	LL $Area_{bl}$ (in-lb)	Crack Length (in.)	Crack Extension (in.)	J (in-lb/in^2)	J Plastic (in-lb/in^2)	CTOD (in.)	CTOD Plastic (in.)
1	54	0.0022	14160080	0.9999	0.0022	14160080	0.9999	30042	−2	6	0.8452	−0.0104	38	12	0.0000	0.0000
2	71	0.0030	14143480	0.9999	0.0034	14143480	0.9999	40386	2	38	0.8459	−0.0096	87	39	0.0000	0.0000
3	66	0.0038	14154300	0.9999	0.0043	14154300	0.9999	50103	7	65	0.8455	−0.0101	135	62	0.0000	0.0000
4	114	0.0050	14062170	0.9999	0.0065	14062170	0.9999	60054	36	119	0.8495	−0.0061	215	108	0.0000	0.0000
5	55	0.0062	14234490	0.9998	0.0076	14234490	0.9998	63831	94	199	0.8420	−0.0136	290	172	0.0000	0.0000
6	79	0.0077	13832250	0.9998	0.0098	13832250	0.9998	65508	189	313	0.8596	0.0040	410	279	0.0000	0.0000
7	100	0.0098	13809030	0.9997	0.0113	13809030	0.9997	67216	309	435	0.8606	0.0051	524	385	0.0000	0.0000
8	55	0.0123	13819300	0.9999	0.0142	13819300	0.9999	69402	470	612	0.8602	0.0046	685	538	0.0000	0.0000
9	72	0.0150	13653320	0.9998	0.0176	13653320	0.9998	71147	648	822	0.8676	0.0120	892	734	0.0000	0.0000
10	95	0.0181	13656640	0.9999	0.0203	13656640	0.9999	72519	861	1035	0.8674	0.0118	1086	922	0.0000	0.0000
11	70	0.0215	13452440	0.9996	0.0239	13452440	0.9996	74588	1100	1286	0.8766	0.0210	1347	1169	0.0000	0.0000
12	86	0.0245	13307010	0.9996	0.0274	13307010	0.9996	75698	1315	1512	0.8832	0.0276	1582	1395	0.0000	0.0000
13	55	0.0276	13349540	0.9999	0.0295	13349540	0.9999	75633	1550	1739	0.8813	0.0257	1782	1597	0.0000	0.0000
14	74	0.0308	13029010	0.9996	0.0335	13029010	0.9996	77742	1788	2006	0.8960	0.0404	2112	1907	0.0000	0.0000
15	51	0.0338	12949110	0.9996	0.0361	12949110	0.9996	78234	2003	2227	0.8997	0.0441	2346	2136	0.0000	0.0000
16	51	0.0366	12738340	0.9997	0.0388	12738340	0.9997	78583	2220	2440	0.9095	0.0539	2616	2397	0.0000	0.0000
17	62	0.0396	12704660	0.9998	0.0416	12704660	0.9998	76563	2461	2658	0.9111	0.0555	2832	2623	0.0000	0.0000
18	52	0.0428	12512870	0.9997	0.0449	12512870	0.9997	78387	2697	2913	0.9201	0.0645	3167	2942	0.0000	0.0000
19	38	0.0462	12520820	0.9998	0.0481	12520820	0.9998	75024	2979	3178	0.9197	0.0641	3416	3210	0.0000	0.0000
20	57	0.0494	12169210	0.9996	0.0517	12169210	0.9996	77752	3220	3445	0.9364	0.0808	3866	3632	0.0000	0.0000
21	36	0.0515	12184750	0.9996	0.0537	12184750	0.9996	74848	3383	3590	0.9356	0.0801	3998	3782	0.0000	0.0000
22	53	0.0555	11644910	0.9997	0.0575	11644910	0.9997	73833	3694	3905	0.9616	0.1060	4653	4423	0.0000	0.0000

INITIAL DISTRIBUTION

OUTSIDE CENTER

Copies

1 DDRE/Lib

1 CNO/OP 098T

2 OCNR
  1 1132 (Rajapakse)
  1 1132 (Vasudivan)
  1 0225
  1 432S
  1 Lib

1 NAVPGSCOL

1 USNROTCU
  NAVADMINU MIT

2 NRL
  1 Code 6380
  1 Code 6384

8 NAVSEA
  1 (SEA05M)
  1 (SEA05M2)
  1 (SEA05P)
  1 (SEA05P1)
  1 (SEA05P2)
  1 (SEA05P3)
  2 (SEA08S)

2 DTIC

5 USNRC
  1 (M. Mayfield)
  2 (Dr. S.N. Malik)
  1 (A. Hiser)
  1 (Dr. E.M. Hackett)

1 DOE, Oak Ridge

2 NIST, Boulder
  1 Lib
  1 (J. Berger)

4 NIST, Washington
  1 Lib
  1 (R. Fields)
  1 (R. DeWitt)
  1 (J.T. Fong)

1 Brown Univ.
  1 (Dr. C.F. Shih)

1 Univ. of Illinois
  1 (Dr. R.H. Dodds, Jr.)

1 Texas A&M Univ.
  1 (Dr. T.L. Anderson)

2 NASA/Langley
  1 Lib
  1 (Dr. J.C. Newman)

1 Hibbit, Karlsson and Sorenson, Inc.

CENTER DISTRIBUTION

Copies

1	0115
1	60
1	60A
1	60D
1	601
1	602
1	603
1	65
2	65.4
1	66
2	66.3
1	68.
1	68.3
5	61
1	612
1	613
12	614
5	614 (R. Link)
1	615
1	3421
1	3422

NAVSSES

1	62
1	624
1	625

REPORT DOCUMENTATION PAGE

Form Approved OMB No. 0704-0188

1. AGENCY USE ONLY *(Leave blank)*

2. REPORT DATE
DECEMBER 1993

3. REPORT TYPE AND DATES COVERED
Final June 1992-Nov 1993

4. TITLE AND SUBTITLE
Effects of Tensile Loading on Upper Shelf Fracture Toughness

5. FUNDING NUMBERS
WU 9316140653

6. AUTHOR(S)
James A. Joyce and Richard E. Link

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Carderock Division, Naval Surface Warfare Center
Metals and Welding Division, Code 61
Annapolis, MD 21402

8. PERFORMING ORGANIZATION REPORT NUMBER
CDRKNSWC/SSM-61-93/023

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
US Nuclear Regulatory Commission
Division of Engineering
Washington, DC 20555

10. SPONSORING/MONITORING AGENCY REPORT NUMBER
NUREG/CR-6051

11. SUPPLEMENTARY NOTES

12a. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public relese; distribution is Unlimited

12b. DISTRIBUTION CODE
Statement A

13. ABSTRACT *(Maximum 200 words)*

The objective of this work is to develop some upper shelf, elastic-plastic experimental results to attempt to investigate the applicability of the Q and T stress parameters to the correlation of upper shelf initiation toughness and J resistance curves. The first objective was to obtain upper shelf J resistance curves, J_{Ic}, and tearing resistance, T_{mat}, results for a range of applied constraint. The J-Q and J-T stress loci were developed and compared with the expectations of the O'Dowd and Shih and the Betégon and Hancock analyses. Constraint was varied by changing the crack length and also by changing the mode of loading from bending to predominantly tensile.

The principle conclusions of this work are that J_{Ic} does not appear to be dependent on T stress or Q while the material tearing resistance is dependent on T stress and Q, with the tearing modulus increasing as constraint decreases.

14. SUBJECT TERMS
J-integral, constraint, T stress, J-Q methodology, tearing modulus, geometry effects

15. NUMBER OF PAGES

16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	18. SECURITY CLASSIFICATION OF THIS PAGE	19. SECURITY CLASSIFICATION OF ABSTRACT	20. LIMITATION OF ABSTRACT
Unclassified	Unclassified	Unclassified	Same as Report