THE GEOMETRY DEPENDENCE AND SIGNIFICANCE OF MAXIMUM LOAD TOUGHNESS VALUES

O. L. Towers and S. J. Garwood

The Welding Institute, Abington Hall, Abington,
Cambridgeshire CB1 6AL, UK

ABSTRACT

Current defect assessment procedures are largely based on the concepts used to describe cleavage fracture in ferritic steels and void coalescence, or tearing, where linear elastic fracture mechanics is applicable. These procedures, with the use of toughness values which describe the point of initiation of tearing, provide extremely conservative predictions of critical flaw sizes when compared with service experience with materials of high tearing resistance. This paper attempts to show that under specified conditions it is possible to use the geometry dependent toughness value derived from the maximum load deflection in laboratory bend tests to provide a more realistic but safe flaw size evaluation.

KEYWORDS

Cracks; fracture toughness; ductile fracture; initiation toughness; propagation toughness; R curve; crack opening displacement; J integral; specimen geometry.

INTRODUCTION

Considerable experience has been gained in the assessment of defects where the failure is by a cleavage mechanism in ferritic steels and where linear elastic fracture mechanics (LEFM) is applicable, i.e. for some high strength steels and low toughness aluminium alloys. Assessment procedures are in the early stages of development, however, where defect growth occurs by a void coalescence, or tearing, micromechanism accompanied by extensive plasticity remote from the crack tip. This behaviour is apparent in structural steels at temperatures above the brittle ductile transition region, austenitic steels and high toughness aluminium alloys.

The first approach to the problem of defect assessment in ductile tearing situations has been to use the fracture toughness corresponding to initiation of tearing, and at the same time ensure adherence to a specimen size requirement. This approach is the basis of the test procedure recently proposed by Clarke and co-workers (1979). Use of the toughness value corresponding to initiation of tearing can, however, give considerable underestimates of the increasing toughness of the material during stable ductile crack growth. This resistance curve ('R curve') effect has led to need for better quantification of driving force curve/R curve analyses, which are necessary to predict conditions of ductile instability. Although analyses of this type have successfully been carried out for LEFM, or near LEFM, conditions; where plasticity is more extensive analyses have proved extremely arduous and the relevant parameters to be calculated are still somewhat uncertain.

In order to avoid the complicated driving force curve/R curve analysis route, it was suggested by Towers and Garwood (1980) that the maximum load toughness should be measured in a testpiece geometry which was known, or could be shown, to produce conservative values relative to structural situations. This toughness at maximum load has long been realised as having the attraction of equivalence to a ductile instability where the load level is maintained, i.e. deadweight loading or load control. Load control would apply to such structures as gas pressurised pipelines, storage tanks, etc, whereas other structures with high levels of redundancy would approach the less severe conditions of displacement control. Despite the obvious attraction of maximum load toughness, the geometry dependence of this parameter has tended to restrict interest to the initiation of tearing toughness which is less geometry sensitive, but over conservative when related to actual ductile instability levels. Towers and Garwood (1980), to some extent accounted for the geometry dependence of maximum load as measured in compact tension (CT) on three point loaded single edge notch bend (SENB3) testpiece configurations. They argued that maximum load toughnesses obtained in these CT and SENB3 configurations would be conservative relative to the structurally more relevant centre cracked tension (CCT) configuration.

This paper deals with the conditions which need to be satisfied to ensure the safe application of laboratory measured maximum load toughness values in the description of structural situations.

CONDITIONS GOVERNING THE USE OF LABORATORY MEASURED MAXIMUM LOAD TOUGHNESSES FOR STRUCTURAL ASSESSMENTS

1. The load controlled instability point, or maximum load point under displacement control, of the structure should occur at a higher toughness than that in the laboratory specimen.

2. Material taken from the critical areas in the structure, or material simulating the worst conditions present in the structure, should be sampled in the laboratory specimen.

3. Any possibility of cleavage fracture should be accounted for.

4. Time dependent effects should be known to be negligible or should be accounted for.

5. Any adverse effects of a plastic strain history should be allowed for either in analysis or in laboratory measurement.

These five conditions are discussed below.

Relationships between Laboratory Determinations of Maximum Load and Structural Ductile Instability

In order to establish the maximum load point, or for load controlled situations, the instability point, it is necessary to compare the load controlled driving force curves of the loading system with the resistance (R) curve of the material. The maximum load point is the point of tangency between these curves. This is shown schematically in Fig. 1 along with the corresponding schematic load versus

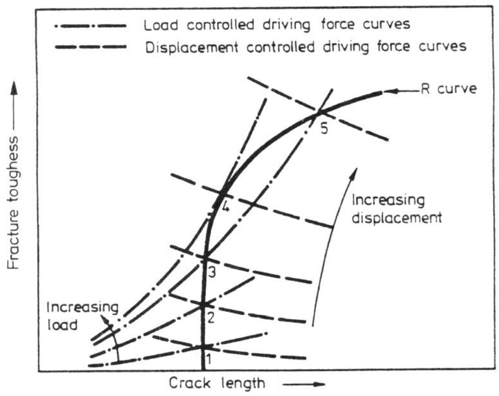

Fig.1. Instability and maximum load equivalence using the R curve concept.

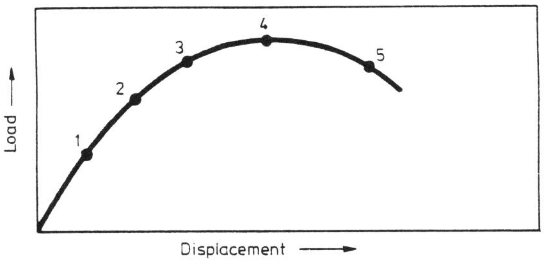

Fig.2. Typical load/displacement curve from laboratory test.

displacement trace in Fig. 2. The maximum load point can be seen as point 4 in these figures. Figures 1 and 2 also serve to demonstrate the load controlled instability point/maximum load point equivalence, as it can be seen that a point 5, which is past the instability point 4 on the R curve, corresponds to a lower load than point 4, although the displacement will have increased under displacement control without instability occurring.

Driving force geometry dependence. If it is assumed that the R curve is geometry independent (discussed later) and that LEFM is applicable (which makes derivation simple) the variation of maximum load toughness with specimen geometry and loading configuration can be observed by studying the driving force curves.

In Fig. 3, linear elastic driving force curves are shown for the CT, SENB3 and CCT specimen configurations and also for the tensile loaded infinite plate with a central crack of length 2a.

With reference to Fig. 3, Towers and Garwood (1980), argued that the laboratory specimens with a high bending loading component, i.e. CT and SENB3, would result in lower maximum load toughness values than the more structurally relevant predominantly tensile loaded, CCT and infinite plate geometries. In its present form this argument depends on the half crack length, a, in the CCT and infinite plate geometries being the same or greater than the crack length in the CT or SENB3 specimen. This is likely to be the case if the CT or SENB3 crack length is equal to the plate thickness, i.e. for the 'preferred testpiece' of BS5762:1979 'Methods for crack opening displacement (COD) testing'. The above

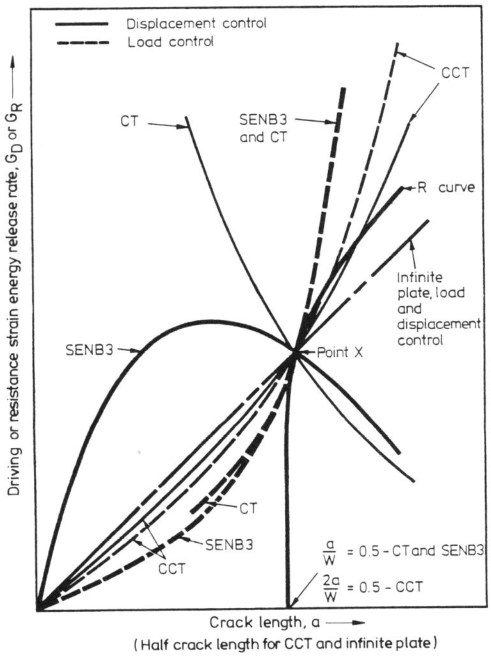

Fig.3. Typical elastic driving force curves, G_D v. a, for four geometries.

argument, however, suffers from a serious drawback in that it is based on an LEFM analysis and although elastic-plastic analyses have been attempted, i.e. Towers and Garwood (1979) and Shih (1979), the relevant parameters are, as mentioned in the introduction, still somewhat uncertain.

It was originally argued by Towers and Garwood (1980), that similar trends to those shown in Fig. 3 could be expected even under elastic-plastic conditions. The validity of this empirical argument has been questioned by Turner (1979). The plastic constraint effect used as a basis for the empirical argument, however, significantly affects the R curves, as discussed below, and is expected to override any variability in the driving force curves.

R curve geometry dependence. The geometry dependence of R curves has been observed in many investigations, e.g. Adams, Munro and Neale (1977); Tanaka and Harrison (1978); Garwood (1980); Garwood and Archer (1980). The main reason for this dependence appears to be variation of plastic constraint caused either by plane stress/ plane strain effects or by variation in configuration of load application. The latter three of the above investigations demonstrated that the greater was the plastic constraint, the shallower were the J integral or COD R curves. The investigation of Adams, Munro and Neale (1977) demonstrated the same effect on the stress intensity factor, K, R curve provided K was plotted against the actual crack length, (as opposed to the plastic zone corrected crack length).

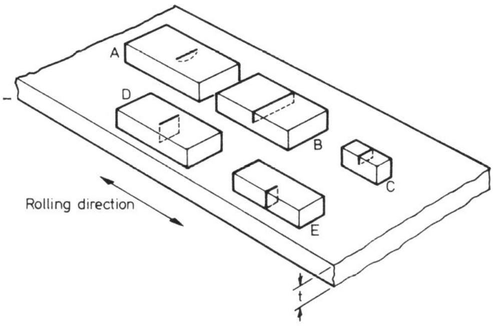

Fig.4. Five types of specimen extracted from 110mm thick A533B.

Some tests were carried out recently at The Welding Institute on A533B steel tested at +70^{o}C using SENB3, CCT and tension test-pieces both with semi-elliptical surface notches and with single edge notches, as reported by Garwood (1980). Typical specimen configurations are shown in Fig. 4.

It can be seen in Fig. 5 that SENB3 through thickness notched specimens, E in Fig. 4, resulted in significantly shallower R curves than CCT specimens, D in Fig. 4, because of the greater plastic constraint of the bend loading configuration. For the semi-elliptical surface notches and single edge notches, A and B in Fig. 4, however, the R curves were in some cases lower than those relating to the surface notched SENB3, C, as depicted in Fig. 6.

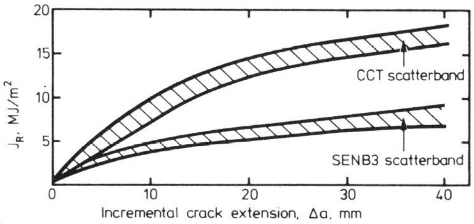

Fig.5. Resistance curve comparison, SENB3 with CCT.

This latter effect can be simply explained in terms of constraint since the surface notched SENB3 specimens, C, had specimen thicknesses substantially less than those of specimens A and B. This difference of specimen thickness counteracted with the difference in loading configuration to produce the small differences seen in Fig. 6. Specimen thickness obviously merits careful consideration and is discussed later.

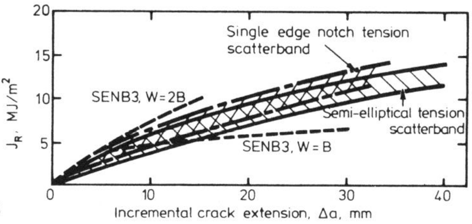

Fig.6. Resistance curve comparison, SENB3 with semi-elliptical and single edge notch tension specimens.

TABLE 1 SENB3/CCT Maximum Load Toughness Comparison

Configuration	Orientation (see Fig. 4)	Specimen thickness B (= t in Fig. 4), mm	Specimen width W, mm	$\frac{a_o^*}{W}$ - SENB3 $\frac{2a_o^*}{W}$ - CCT	Maximum load toughness J_{max}, MJ/m^2	
SENB3$^+$ 'preferred testpiece' of BS5762:1979	E	102	258	0.42	2.90	mean 2.67
		101	255	0.41	2.28	
		113	254	0.44	2.82	
CCT	D	113	508	0.42	6.85	mean 7.06
		110	508	0.52	6.56	
		112	508	0.27	7.78	

* a_o is SENB3 crack length or CCT half crack length before tearing, i.e. of the fatigue crack.

\+ The specimen dimensions do not comply strictly with those specified for the 'preferred testpiece', as W ≠ 2B and the value of a_o/W does not fall between 0.45 and 0.55.

On the basis of the results shown in Fig. 5, Garwood (1980) concluded that R curves determined from full thickness SENB3 specimens, of the 'preferred testpiece' configuration of BS5762:1979, would give conservative estimates of structural R curves for through thickness defects, which is in agreement with another investigation, reported by Garwood and Archer (1980), on API 5LX 65 pipeline steel. In the present context it is obviously of interest to compare the maximum load toughnesses obtained from the two geometries. A comparison for the A533B data presented by Garwood (1980) is given in Table 1, where it can be seen that the mean maximum load toughness for the three SENB3 specimens is 38% of the mean maximum load toughness for the three CCT specimens. Obviously, therefore, the above conclusion concerning the R curves also applies to the maximum load toughnesses in this case.

A similar comparison for the A533B surface notched data presented by Garwood (1980) is given in Table 2, where it can be seen that, despite the uncertainties of specimen thickness, specimens with dimensions close to those specified for the 'subsidiary testpiece' configuration of BS5762:1979 resulted in a mean maximum load toughness which was lower than the mean maximum load toughnesses obtained in the two more structually related specimens.

It is thus demonstrated in Tables 1 and 2 that, despite the uncertainties surrounding elastic-plastic driving force curves, lower and, therefore, conservative maximum load toughness values are obtained in SENB3 than in CCT and other more structurally relevant configurations for this material and for these particular testing conditions.

Material Sampling and Notch Position

To ensure a safe approach to analysis of the structure, the region sampled in the laboratory specimen has to have a similar toughness to that of the region of interest in the structure. As an example of the importance of the notch orientation with respect to tearing behaviour, Fig. 7 shows R curves measured in two different orientations on API 5LX pipe, as reported by Garwood and Archer (1980).

In depth experience has yet to be gained in the variation of tearing behaviour with notch orientation and crack tip locality, particularly in complicated situations such as weldments.

TABLE 2 SENB3/Single Edge Notch in Tension/Semi-Elliptical Surface Notch in Tension Maximum Load Toughness Comparison

Configuration	Orientation (see Fig. 4)	Plate thickness (t), mm	B or W,++ mm	$\frac{a_o}{t}$	$\frac{a_o}{c_o}$ **	Maximum load toughness J_{max}, MJ/m²		$25\frac{J_{max}}{\sigma_y^*}$, mm
SENB3+ 'subsidiary testpiece' of BS5762:1979	C	109	114	0.32	-	2.90	mean 2.60	156
		100	124	0.44	-	2.24		120
		104	124	0.44	-	2.66		143
Single edge notch in tension	B	110	508	0.34	-	2.72	mean 3.20	-
		110	509	0.30	-	3.13		-
		110	508	0.47	-	3.75		-
Semi-elliptical surface notch in tension	A	110	508	0.21	0.30	3.61	mean 4.86	-
		113	510	0.34	0.32	5.04		-
		113	508	0.50	0.34	5.92		-

* Yield stress, σ_y, taken as 465 N/mm², Garwood (1980).

\+ The specimen dimensions do not comply strictly with those specified for the 'subsidiary testpiece', as B ≠ t.

++ B or W refer to the SENB3 specimen thickness, B, and the specimen width for the other two test geometries.

** a_o and c_o refer to the original fatigue crack depth and half length respectively.

Cleavage Fracture

To obtain data for the design of ferritic steel structures against cleavage fracture, it has long been policy at The Welding Institute to test SENB3 specimens of full plate thickness, using either the 'preferred testpiece' or the 'subsidiary testpiece' of BS5762:1979 (previously DD19:1972 - with the same title as BS5762) to represent through thickness and surface cracks respectively. Conservative assessment then relies on the COD design curve approach which has been outlined by Harrison and co-workers (1979). A recent analysis by Kamath (1980) has shown that this approach will 'predict an allowable crack size which has a 96.7% probability of being less than or equal to the critical crack size in the wide plate test'. One drawback of the data applied in this analysis is the lack of justification for the 'subsidiary testpiece' specimen thickness, and a research programme is being instigated to examine the effect of specimen thickness on the cleavage and tearing behaviour of surface notched specimens. It is interesting to record, however, that

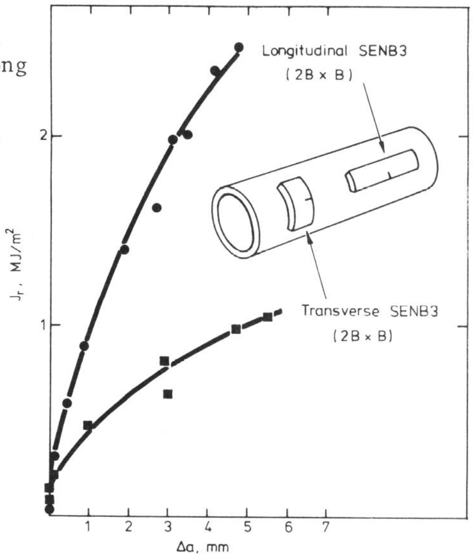

Fig.7. Orientation effects on R curves for API-5LX65.

Kamath (1980) included both: results from square section specimens, and some maximum load COD values in his analysis.

Time Dependent Behaviour

Tearing has been shown to be time dependent in many investigations, e.g. Fearnehough and Jones (1978), Green and Knott (1975) and Tsuru and Garwood (1979). This time dependence appears to take the form of lower maximum loads being sustained by the cracked specimen or structure for lower loading rates, as shown schematically in Fig. 8.

It is crucial that this effect, which appears to occur only when tearing has initiated, is accounted for if maximum load toughnesses, or any post initiation measures of tearing resistance, are to be used for defect assessment.

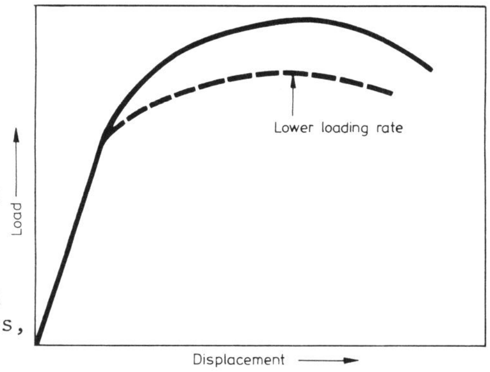

Fig.8. Load/displacement trace illustrating time dependence.

The data presented by Green and Knott (1975) and by Tsuru and Garwood (1979) indicate that there is a threshold value of COD below which, if specimens are loaded up to a given COD and held at load, no time dependent crack growth occurs. The same data indicate that this threshold can be as little as 60% of the δ_{max} (maximum load COD) measured in a normal laboratory test. In the case of Tsuru and Garwood's (1979) data this threshold COD corresponds to a load which is approximately 95% of the load achieved in the normal laboratory test. This would support Burdekin's (1979) suggestion of the COD at 95% of the maximum load as being the critical value of interest. This COD at 95% of the maximum load, however, seems unduly pessimistic when long maximum load plateaux are experienced and initiation occurs close to the maximum load value.

Further research is required into this time dependent aspect of maximum load toughness, particularly for a wider variety of materials, e.g. cleaner plate materials and weldments.

Plastic Strain History

One aspect of the use of maximum load toughness is the degree of plasticity associated with the achievement of maximum load for materials of high tearing resistance. If a specimen exhibiting extensive plasticity is loaded to a value just below the expected maximum load, unloaded, and re-tested assuming it is a new specimen, then a smaller maximum load toughness value would be recorded than that which would have been measured if the initial loading had been taken to maximum load. A similar effect would be experienced, and has been observed by, for example, Green, Smith and Knott (1973), had the material been plastically strained prior to notching. This aspect, which is relevant to any fracture toughness measurements made after significant plasticity, is not normally important in structural situations since the plasticity preceding fracture is usually induced by displacement controlled loadings, caused, for instance, by residual fabrication stresses and thermal stresses. These loadings will have been relaxed by plasticity, hence the required toughness on reloading will be correspondingly lower.

The two situations where a plastic strain history may be deleterious are:

a. Where the defect tolerance of the structure has been assessed on the basis of the tearing resistance of unstrained material; without taking due account of plastic strains occurring, for instance, during fabrication.

b. Where impact loading causing plasticity is to be repeatedly applied, i.e. plastic work has to be absorbed on each load application (for ferritic steels, of course, cleavage fracture would be of primary concern for impact loading).

DEPENDENCE OF MAXIMUM LOAD TOUGHNESS ON BEND SPECIMEN DESIGN AND SIZE

The following discussion mainly refers to SENB3 specimens, but the trends discussed are expected to be similar for CT and four point loaded single edge notch bend (SENB4) specimens. Distinct differences which should be borne in mind, however, are the presence of tensile loading in the CT specimen (the extent of which, relative to the induced bending loading, will depend on crack length) and the presence of a single back surface loading pin, in front of the crack, in the SENB3 specimen. (Note: the relative behaviour of the SENB3 and SENB4 geometries is discussed elsewhere in this conference by Green and Willoughby (1980)).

The testing of SENB3 'preferred testpieces' of BS5762:1979 to represent through thickness cracks and SENB3 'subsidiary testpieces' of BS5762:1979 to represent surface cracks has already been referred to in discussing the possibility of cleavage fracture. It is obviously advantageous to adopt the same policy in assessing tearing resistance and the results given in Tables 1 and 2 infer this. One note of caution, however, concerns the use of the 'preferred testpiece'. It has been recommended in the past that where cleavage fracture occurs, the 'preferred testpiece' be tested in order to obtain lower bound fracture toughness to apply to any orientation of crack in the structure. Where fracture occurs by a tearing mechanism it is possible that the relative properties of the various orientations and positions of cracks in plate material and, more specifically, in weldments will differ from those experienced for cleavage fracture. Hence, if tearing resistance is of concern, it is presently recommended that the policy of "'preferred testpiece' for through thickness cracks, 'subsidiary testpiece' for surface cracks" be adhered to. One uncertainty in this policy, which has already been mentioned in connection with cleavage fracture and with the results given in Table 2, is concerned with the specimen thickness of the 'subsidiary testpiece'. This variable is discussed both with reference to the sidegrooving method for ensuring lateral constraint and to a specimen thickness size criterion in the following sub-sections.

On the subject of overall specimen size, there has been increasing interest, particularly in the USA, in testing bend specimens of substantially smaller section than the plate or section thicknesses of structural interest. This variation of overall size, which is avoided in the aforementioned policy by using testpieces of the full structural section thickness, is supposedly accommodated for by the use of minimum restrictions on the various specimen dimensions of thickness, crack length and ligament length. In the recent J_{Ic} testing procedure of Clarke and co-workers (1979), a restriction of $25J/\sigma_Y$ is placed on these dimensions (where J is the J integral and σ_Y is the effective yield strength). Although this restriction may be sufficient to prevent dependence of initiation toughness, J_{Ic}, on crack length and ligament length; maximum load toughness is expected to be highly dependent on ligament size and, therefore, crack length for a given specimen width. This dependence, which is discussed in more detail later, makes the maximum load toughness results obtained from test specimens of size less than the section thickness of little practical use, although they are likely to be conservative relative to the structure provided a specimen thickness requirement is adhered to.

Specimen Thickness

It has been stressed that the specimen thickness has to be of a sufficient size to represent the constraint possible in the structure. Using the subsidiary testpiece of BS5762:1979 to model surface flaws a minimum specimen thickness should, ideally, be adhered to. A $25J/\sigma_Y$ minimum specimen thickness is suggested as a guideline, based on the J_{Ic} testing procedure of Clarke and co-workers (1979). (In terms of COD this requirement approximately corresponds to a specimen thickness of 50δ, where δ = COD and assuming that $J = 2\sigma_Y\delta$).

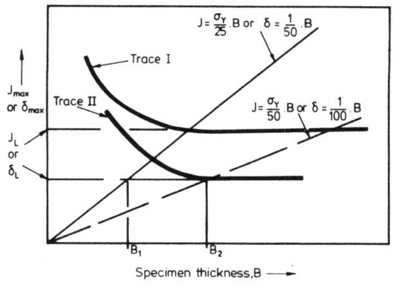

Fig.9. Variation of J_{max} or δ_{max} with specimen thickness, B.

In Fig. 9 two traces show the variations of maximum load toughness, J_{max} or δ_{max}, with specimen thickness, B, for a constant crack length and specimen width (equal to the plate thickness). The trend shown in Fig. 9 of decreasing δ_{max} with increasing B has been observed experimentally by Green and Knott (1975). Also shown in Fig. 9 are two specimen thickness criteria, one being the $25J/\sigma_Y$ criterion presently proposed, and the other being twice as severe. If the variation of maximum load toughness with B is of the form shown in trace I in Fig.. 9, a lower limit value of maximum load toughness is reached (labelled J_L or δ_L) when the $25J/\sigma_Y$ or 50δ criterion is satisfied. If, however, the variation of maximum load toughness is similar to trace II, a specimen thickness of $50J/\sigma_J$ or 100δ would be necessary to ensure a J_L or δ_L value of maximum load toughness.

Based on Green and Knott's (1975) results, the value of δ_{max} at B = 50δ is 7% higher than that at B = 100δ, indicating only slight non-conservatism of the 50δ criterion relative to the 100δ criterion for that particular material and plate thickness. Further work is necessary to establish a comprehensive specimen thickness criterion for a wide range of materials and plate thicknesses.

An aspect of the variations of maximum load toughness with B shown in Fig. 9 is that, if the B = $25J/\sigma_Y$ or 50δ criterion is sufficiently severe, in a test where a maximum load toughness exceeds the restriction of this criterion, a value of toughness of $J = B\sigma_Y/25$ or $\delta = B/50$ could be safely assumed for analysis. If the criterion is not sufficiently severe, as for trace II, a possible area of non-conservatism will occur between B_1 and B_2, as shown in Fig. 9. This $B\sigma_Y/25$ value for J, or B/50 value for δ, should obviously never be used if the actual test values of J_{max} or δ_{max} are lower.

Sidegrooves

An alternative to a specimen thickness criterion for ensuring sufficient constraint along the notch is to machine sidegrooves into the specimens. The increased constraint has been observed to cause shallower R curves, e.g. by Andrews and Shih (1979), Garwood and Turner (1977) and Green and Willoughby (1980). Unfortunately, this effect has not been demonstrated conclusively, as one method of analysis used by Andrews and Shih (1979) resulted in shallower R curves caused by sidegrooves, whereas another showed no effect. Also, there is some uncertainty concerning the specimen thickness values to employ in calculating J values.

Further research is required to quantify the effect of sidegrooving.

Crack Length

Although R curves are generally considered to be insensitive to notch depth, a distinct variation of maximum load toughness with ligament depth and, therefore notch depth, is intuitively expected. Indeed, a model proposed by Chipperfield (1977) predicted a linear variation of maximum load COD with ligament depth. The variation observed for SENB3 specimens in BS4360 50D material tested at 0°C is shown in Fig. 10. Figure 10 demonstrates an almost linear variation of maximum load COD with crack length to width ratio (a/W) and, therefore ligament depth, despite the data not necessarily complying to the 'plain strain' restrictions specified by Chipperfield (1977).

For a fixed specimen thickness, Fig. 10 demonstrates that the larger the a/W ratio chosen, the lower the J_{max} or δ_{max} value measured. For this reason, when testing laboratory specimens intended to represent surface cracks in the structure, maximum load toughnesses should be measured using specimens with cracks of depth equal to or greater than those in the structure. A suitable laboratory specimen for this measurement is the 'subsidiary testpiece' of BS5762:1979 for which the notch length is determined 'by agreement'. In assessing the resistance of surface cracks to cleavage fracture, however, it has been established practice to test the 'subsidiary testpiece' of BS5762:1979 with an a/W ratio in the range 0.3 to 0.5. This range of crack lengths has evolved from experience gained in establishing conservative measurements of resistance to cleavage for any crack depth in the structure. Although this 0.3 to 0.5 range of a/W may conflict with the notch depth required to assess the resistance to tearing of a deeper crack in the structure, in practice for a material of high tearing resistance a limit load criterion will suffice. For materials with a relatively low resistance to tearing, however, a laboratory specimen with a very deep crack would have to be used to obtain a maximum load toughness value for use in analysis.

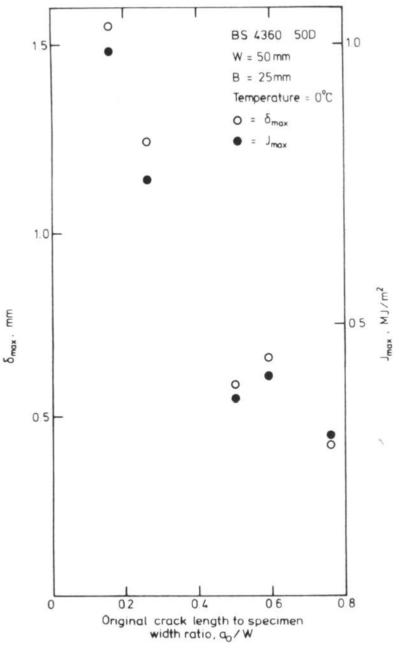

Fig.10. Measured variation of maximum load toughness with crack length (courtesy of M.S. Kamath).

Despite the observed variation of maximum load toughness with crack length; for the analysis of through thickness cracks it is recommended that the 'preferred testpiece' of BS5762:1979 is used as a laboratory specimen with the associated 0.45 to 0.55 limits on a/W. This recommendation is based on the experience that this configuration and notch depth will be the most sensitive to cleavage fracture, (very deep and very shallow cracks lead to loss of constraint). Also, although the minimum possible maximum load toughness will not be measured with this crack length, laboratory measured maximum load toughnesses will be substantially lower than those in structures where the crack size is extremely small relative to the section width.

CONCLUSIONS

It is proposed that the toughness correspond to the maximum load point experienced in laboratory fracture toughness tests when stable tearing, or microvoid coalescence, occurs can be used safely as a design fracture toughness parameter. The loading system energies in both the laboratory test and the structure would be unimportant, as maximum load toughness corresponds to instability in load control. The conditions necessary for this maximum load toughness value to be used safely in fracture assessment methods have been listed and discussed.

It is argued that maximum load toughness obtained in the 'preferred testpiece' of BS5762:1979 'Methods for crack opening displacement (COD) testing' would be conservative compared with through thickness cracks in a tension loaded plate, provided that the specimen thickness is the full plate thickness and the crack in the specimen is shorter than or equal to the half length of the crack in the tension loaded plate. It is also considered that maximum load toughness obtained in the 'subsidiary testpieces' of BS5762:1979 would be conservative compared with surface cracks in a tension loaded plate, provided that the laboratory specimen crack length is sufficient and that a specimen thickness criterion is met. A specimen thickness criterion of $B = 25J/\sigma_Y$, which corresponds approximately in COD terms to $B = 50\delta$, is suggested as an initial guideline.

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