

Method for

Determination of threshold stress intensity factors and fatigue crack growth rates in metallic materials

Committees responsible for this Draft for Development

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- Aluminium Federation
- British Gas plc
- British Non-ferrous Metals Federation
- British Railways Board
- British Steel Industry
- Copper Development Association
- Department of Trade and Industry (National Engineering Laboratory)
- Department of Trade and Industry (National Physical Laboratory)
- ERA Technology Ltd.
- GAMBICA (BEAMA Ltd.)
- Ministry of Defence
- Society of British Aerospace Companies Limited
- Welding Institute

The following bodies were also represented in the drafting of the standard, through subcommittees and panels:

- BCIRA
- Electricity Supply Industry in England and Wales
- Portsmouth Polytechnic
- United Kingdom Atomic Energy Authority
- University College London
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Foreword

This Draft for Development has been prepared under the authority of the Iron and Steel Standards Policy Committee and the Non-ferrous Metals Standards Policy Committee. It describes a method of determining the growth rate of a fatigue crack in metallic materials at rates below 10^{-8} m/cycle as a function of the range of its stress intensity factor, and of the threshold conditions below which the rate of crack advance rapidly becomes infinitesimally small. It is thus complementary to BS 6835 which is restricted to rates greater than or equal to 10^{-8} m/cycle.

At the low growth rates considered in this document many factors which often have only a slight influence at higher rates, for example mean stress, microstructure and environment, have a marked effect on growth rates. The reasons for this are only partially understood. Nonetheless a need is seen for a standardized test method to ensure as far as is possible at present that data drawn from different sources are comparable. However, expert advice should be sought regarding the applicability of the data generated to any particular engineering situation.

It has been assumed in the drafting of this Draft for Development that the execution of its provisions is entrusted to appropriately qualified and experienced people.

This publication is not to be regarded as a British Standard

It is being issued in the Draft for Development series of publications and is of a provisional nature for the reasons given in the foreword.

It should be applied on this provisional basis, so that information and experience of its practical application may be obtained.

A review of this Draft for Development will be carried out not later than two years after its publication. Notification of the start of the review period, with a request for the submission of comments from users of this Draft for Development, will be made in an announcement in the appropriate issue of *BSI News*. According to the replies received, the responsible BSI Committee will judge whether the Draft for Development can be converted into a British Standard or what other action should be taken.

Observations which it is felt should receive attention before the official call for comments will be welcomed. These should be sent to the Secretary of BSI Technical Committee ISM/NFM/4 at the Manchester Office, 3 York Street, Manchester M2 2AT.

Summary of pages

This document comprises a front cover, an inside front cover, pages i and ii, pages 1 to 38, an inside back cover and a back cover.

This standard has been updated (see copyright date) and may have had amendments incorporated. This will be indicated in the amendment table on the inside front cover.

1 Scope

This Draft for Development describes a method of determining the rates of growth of fatigue cracks as a function of the cyclic range of their stress intensity factors and of determining the threshold stress intensity factor ranges below which the rate of crack growth rapidly becomes infinitesimally small. It is limited to metal specimens tested in air at ambient temperature that remain predominantly elastic and to sinusoidal or triangular waveform loadings which vary in amplitude slowly and monotonically with time and which only induce macroscopic crack face displacements perpendicular to the crack plane. Crack growth rates above 10^{-8} m/cycle are not covered and the method is restricted to cases where the crack advances on a nominally straight front across the thickness of the specimen.

NOTE 1 Growth rates in air, particularly at the low rates considered in this document, can be influenced by humidity, waveform and testing frequency. Test conditions may therefore need to be selected to match the service conditions as closely as possible.

NOTE 2 The titles of the publications referred to in this Draft for Development are listed on the inside back cover.

2 Definitions

For the purposes of this Draft for Development, the following definitions apply.

2.1 force

force applied to the specimen, considered positive when its direction is such as to cause the crack faces to move apart

2.2 range

difference between the maximum and minimum values of a variable

2.3 reference plane

plane perpendicular to the intended direction of crack extension, used as a datum for the measurement of crack length, and located as shown in Figure 1 to Figure 5 inclusive

2.4 crack length

distance from the tip of the crack to the reference plane

2.5 specimen width

distance from the reference plane to the surface of the specimen in the direction of crack extension

2.6 specimen thickness

dimension of the specimen parallel to the line of the notch tip

2.7 notch length

distance from the tip of the notch to the reference plane

2.8 stress intensity factor

factor proportional to the magnitude of the stresses near to the tip of a crack in an elastic body

NOTE It has been found that stress intensity factors, calculated assuming that specimens respond purely elastically, correlate the behaviour of real cracked bodies provided that the size of the zone of plasticity at the crack tip is small compared to the crack length and the length of the uncracked ligament.

2.9 stress intensity factor function

function relating the stress intensity factor of a crack to the force, the crack length and the width and thickness of the specimen

2.10 fatigue crack growth rate

average crack extension per cycle of force

2.11 resolution

minimum change in crack length detectable with the system in use

2.12 normalized stress intensity factor gradient

rate of change of stress intensity factor with crack length divided by the prevailing stress intensity factor

2.13 fatigue crack growth threshold

highest value of the stress intensity factor range at which the rate of growth does not exceed 10^{-11} m/cycle over a period of not less than 5×10^6 cycles nor a period less than the resolution, measured in millimetres, divided by 10^{-8}

NOTE For example where the resolution is 10^{-1} mm: $10^{-1}/10^{-8} = 10^7$, therefore 10^7 cycles must be applied to confirm that the threshold has been reached.

3 Main symbols

For the purposes of this Draft for Development the following main symbols apply.

a	is the crack length (in mm)
a_i	is the crack length at the end of initiation (in mm)
a_o	is the minimum geometrical precrack length (see 9.1.2) (in mm)
a_s	is the actual precrack length (in mm)
B	is the specimen thickness (see Figure 1 to Figure 4) (in mm)
C_k	is the normalized stress intensity factor gradient (in mm^{-1})
D	is the loading hole diameter (in mm)
da/dN	is the fatigue crack growth per cycle (in m/cycle)
E	is Young's modulus (in MN/m^2)
F, F_1	are the distances between the loading hole centres and the notch centre line (see Figure 3 and Figure 4) (in mm)
H	is the half-height of the specimen (see Figure 3) (in mm)
K	is the stress intensity factor (in $\text{MN/m}^{1.5}$) (see clause 7)
$K_{\max}$	is the maximum value of K during a loading cycle (in $\text{MN/m}^{1.5}$)
$K_{\min}$	is the minimum value of K during a loading cycle (in $\text{MN/m}^{1.5}$)
K_i	is the value of $K_{\max}$ when $a = a_i$ and $P_{\max} = P_i$ (in $\text{MN/m}^{1.5}$)
K_s	is the value of $K_{\max}$ estimated to give $da/dN = 10^{-8}$ m/cycle when $R = R_s$ (in $\text{MN/m}^{1.5}$).
K_{th}	is the value of $K_{\max}$ when $\Delta K = \Delta K_{th}$ (in $\text{MN/m}^{1.5}$)
ΔK	is the stress intensity factor range $K_{\max} - K_{\min}$ (in $\text{MN/m}^{1.5}$)
ΔK_{th}	is the fatigue crack growth threshold (in $\text{MN/m}^{1.5}$)
K_{lc}	is the plane strain fracture toughness determined in accordance with BS 5447 (in $\text{MN/m}^{1.5}$)
L	is the overall specimen length (in mm)
L_1, L_2	are the distances between the inner and outer loading points on a bend specimen (in mm)

L_3	is the distance between the inner loading points on a four-point bend specimen (in mm)
M	is the notch length (see Figure 5) (in mm)
n	is the notch width (see Figure 5) (in mm)
N	is the number of loading cycles
P	is the force applied to the specimen (in kN)
$P_{\max}$	is the cyclic maximum value of P (in kN)
$P_{\min}$	is the cyclic minimum value of P (in kN)
P_i	is the value of $P_{\max}$ used to initiate a crack (in kN)
P_s	is the value of $P_{\max}$ giving $K_{\max} = K_s$ when $a = a_s$ (in kN)
ΔP	is the force range $P_{\max} - P_{\min}$ (in kN)
q	is the resolution of the crack length measuring system (in mm).
R	is the force ratio $P_{\min}/P_{\max}$
R_a	is as defined in BS 1134
R_p	is a dimension equal to $100 (K_{\max}/\sigma_Y)^2$ (in mm)
R_s	is the value of R at the end of precracking
R_t	is the target value of R at threshold in constant $K_{\max}$ testing (see 9.2)
S_p	is the value of $(W - a)$ at which net section yielding is expected (in mm)
W	is the specimen width (see Figure 1 to Figure 4)
Y	is the stress intensity factor function
σ_Y	is the yield strength or 0.2 % proof strength of a metal, determined in accordance with BS 18 (in MN/m^2)
σ_f	is the arithmetic mean of σ_Y and the tensile strength, determined in accordance with BS 18 (in MN/m^2)

4 Principle

4.1 General

Two methods are described, method A and method B, both of which involve the use of a notched specimen.

4.2 Method A

A fatigue crack is induced at the root of the notch by cyclic loading and its growth monitored by a suitable method. As the crack grows, the maximum and minimum force applied to the specimen are varied in a controlled manner so that ΔK tends to the initial test value of interest and R to its required value. This continues until the crack is of sufficient length for the influence of the notch to be negligible.

The force range is then reduced smoothly in a controlled manner until the rate of growth becomes infinitesimally small. During this process, the crack length and the force maxima and minima are recorded as a function of the number of cycles of force applied. These data are then analysed to provide values of da/dN as a function of ΔK and a value of ΔK_{th} .

4.3 Method B

This method is used when values of ΔK_{th} alone are required at high, positive values of R . Again a notched specimen is used in which a fatigue crack is induced by cyclic loading and grown to such a length that the influence of the notch is negligible. K_{max} is then kept constant and K_{min} raised in a controlled manner until $\Delta K = \Delta K_{th}$.

NOTE 1 The methods described in this Draft for Development rely on the smooth variation of the applied forces during testing in interactive response to crack length changes such that alterations to the force range do not exceed 2 %. Practically, this necessitates the use of a computer controlled test machine.

NOTE 2 Crack growth rates presented in terms of ΔK are generally independent of the geometry of the specimen used except that they may be influenced by specimen thickness. However, variations with thickness are not expected within the range of thicknesses covered by this Draft for Development.

NOTE 3 Thresholds, and near threshold growth rates, are strongly dependent on mean stress, as characterized by R . Residual stresses within specimens can thus markedly affect the observed behaviour in tests such as these. Thermal stress relief should therefore be considered prior to testing, but if this is not acceptable, the possibility of an effect should be recognized in the interpretation of the results. In particular, the presence of residual stresses can lead to an apparent dependence of ΔK_{th} on specimen dimensions.

5 Test equipment

5.1 Testing machine

The testing machine shall be verified in accordance with grade 1.0 of BS 1610-1 throughout the full range of forces to be used in the test.

NOTE 1 The required values of force frequently fall by a factor of 10 or more during the course of the tests described here. Difficulties in meeting these force accuracy requirements may be encountered if the load cell capacity is markedly in excess of the maximum force required.

The machine's control system shall be able to maintain the indicated values of both P_{max} and ΔP , to within 1 % of the values determined by clause 9.

NOTE 2 With some testing systems significant inertial forces, additional to those applied to the specimen, may be applied to the force measuring system under dynamic conditions. Correction should be made for this if necessary.

Test fixtures shall comply with Appendix A. Lubricants shall be used on all the interfaces between the specimen and the loading system at which movement is required.

5.2 Crack length measurement

A method of crack length measurement which provides an electrical analogue or digital output shall be used. Suitable techniques are described in Appendix B.

Crack lengths shall be measured to within 0.01 W . Changes in crack length shall be resolved to within 0.1 mm.

5.3 Cycle counting

The number of applied load cycles shall be accurately counted. If a digital device is used the unit of counting shall not exceed 1 000 cycles. Alternatively, computer control software can command and count individual cycles. Calculation based on measurement of frequency and elapsed time is not permitted.

6 Specimens

6.1 Geometry

One of the following types of specimen shall be used:

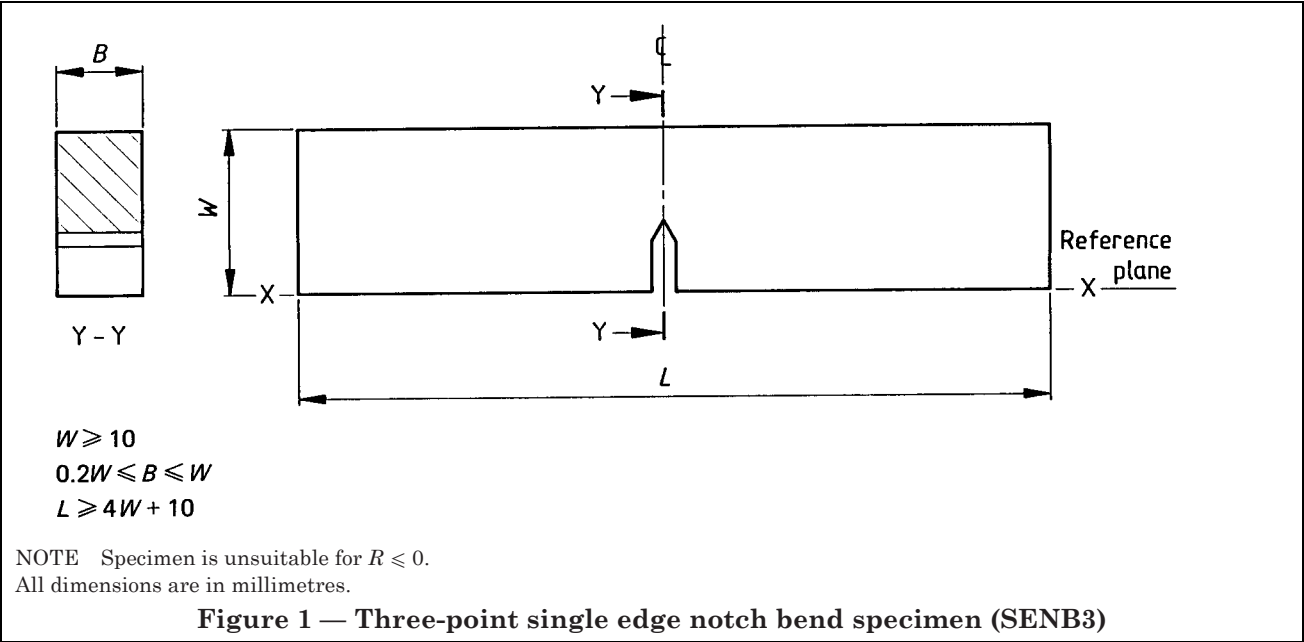
- three-point single edge notch bend (SENB3);
- four-point single edge notch bend (SENB4);
- compact tension (CT);
- centre-cracked tension (CCT).

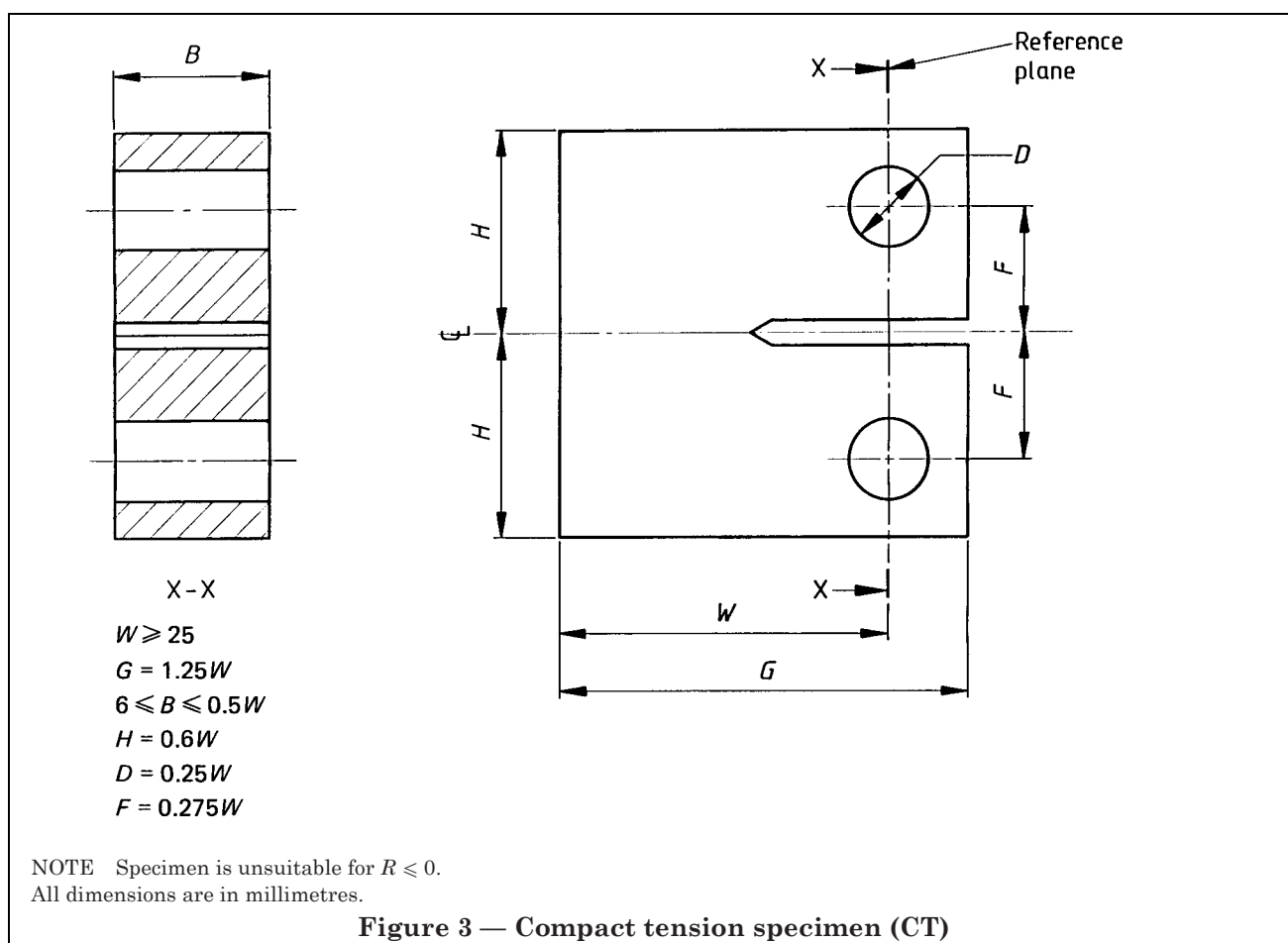
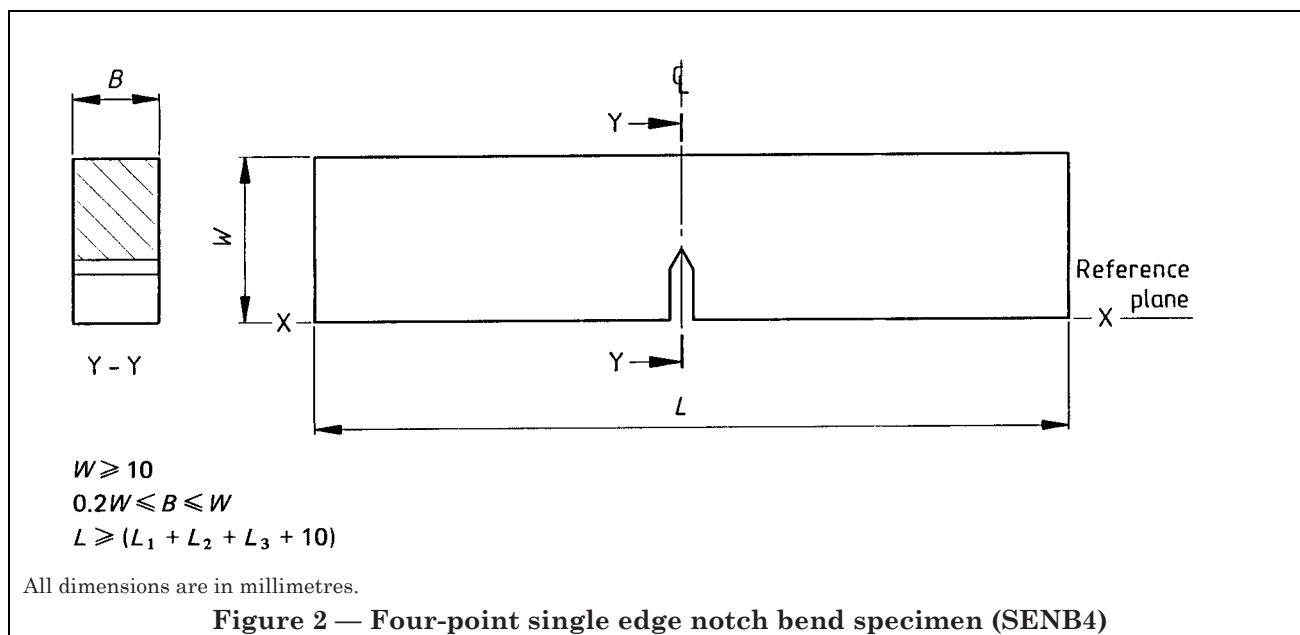
The geometries of the specimens shall be as given in Table 1 and shown in Figure 1 to Figure 5.

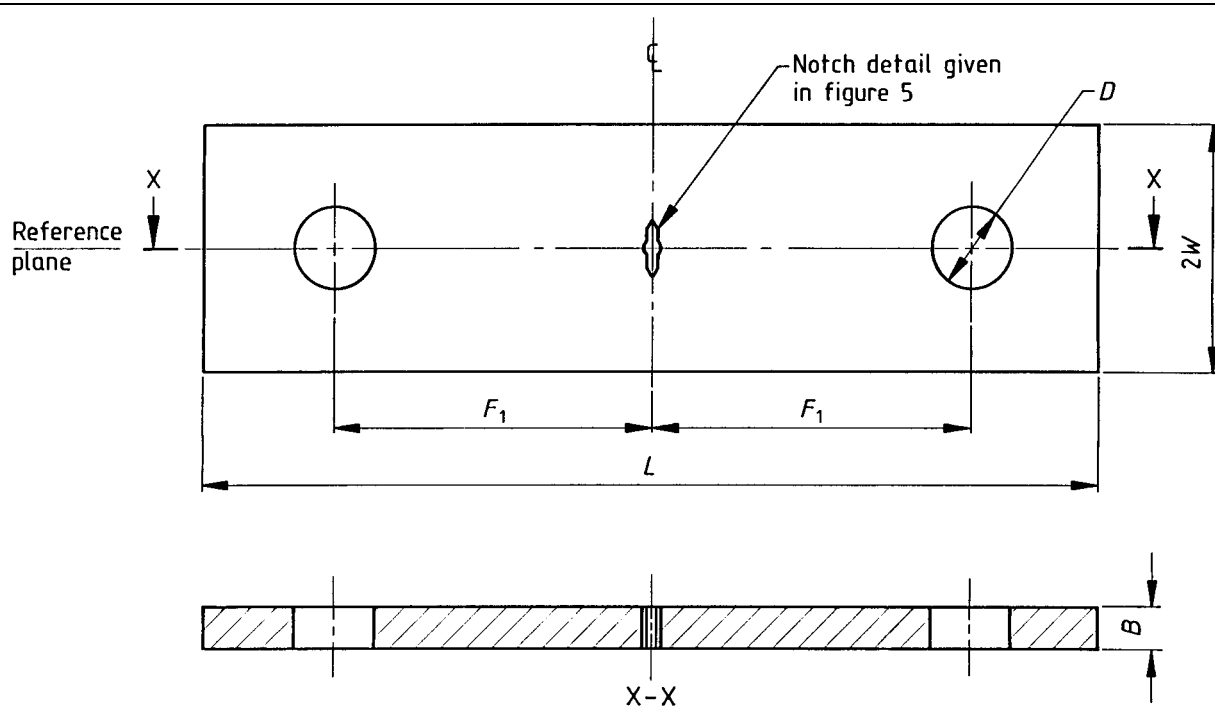
NOTE Guidance on the minimum sizes of specimen required to generate data according to this method are given in Appendix D.

Table 1 — Toleranced dimensions of specimens

Dimension	Tolerances	Surface finish, squareness and parallelism
L G H F_1	$\pm 0.01 W$	Surfaces shall be perpendicular and parallel as applicable to within $0.002 W$ (Total indicator reading) Surface finish of faces perpendicular to the line of the notch root to be $0.8 \mu m R_a$
F	$\pm 0.004 W$	Notch to be equidistant about centre line to within $0.01 W$
D	$\pm 0.004 W$	Holes to be square to faces within $\pm 0.0075 W$ and parallel within $\pm 0.0005 W$. Surface finish $0.4 \mu m R_a$







$$W \geq 10$$

$$2.0 \leq B \leq W$$

For pin loaded specimens (see Appendix A)

$$D = 0.67W$$

$$L = 6W$$

$$F_1 = 2W$$

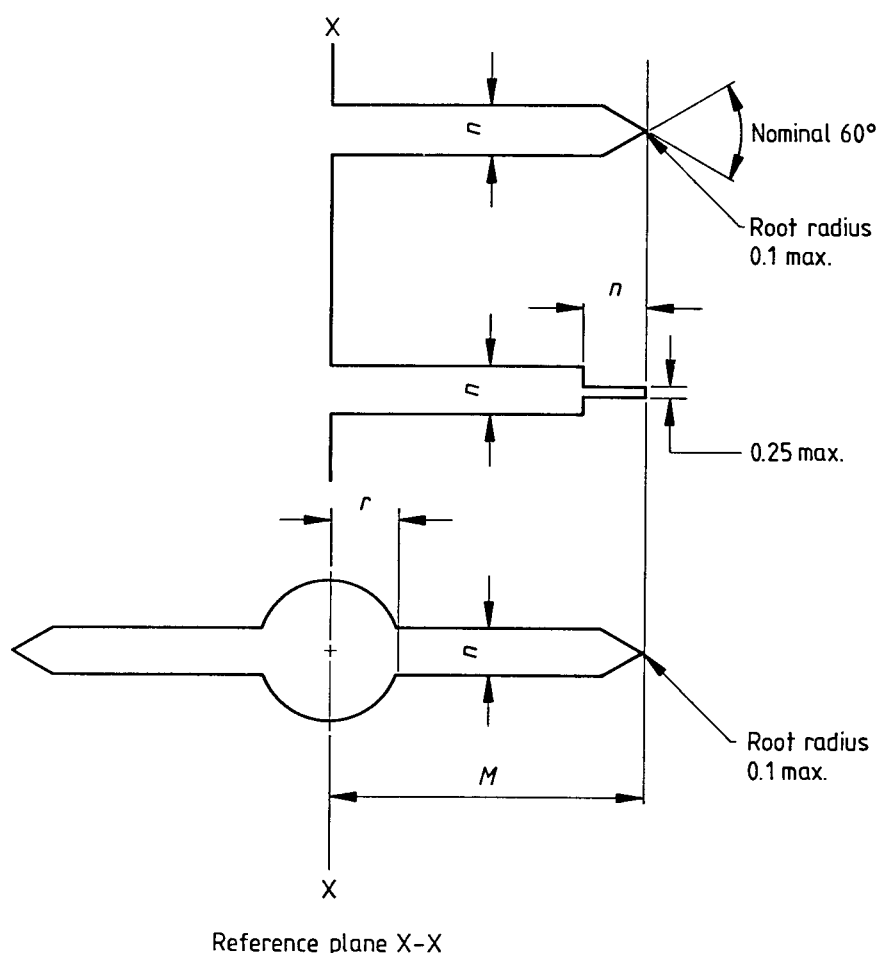
For friction gripped specimens, the pin loading holes are not required and the overall length is determined by the loading arrangement (see Appendix A).

NOTE 1 Specimen geometry is to be symmetrical about the reference plane and the notch centre line.

NOTE 2 Pin-loaded specimen is unsuitable for $R \leq 0$.

All dimensions are in millimetres.

Figure 4 — Centre-cracked tension specimen (CCT)



NOTE 1 Notch width n should be minimized.

NOTE 2 A hole of radius $r \leq 0.05W$ is allowed for ease of notch manufacture in CCT.

NOTE 3 The minimum notch length, M shall be $0.2W$ ($0.1W$ for CCT).

All dimensions are in millimetres.

Figure 5 — Permitted notch geometries

6.2 Specimen preparation

6.2.1 Marking out and extraction. The notch direction and material identity shall be clearly shown. Sufficient allowance shall be made to enable all material affected by the process of cutting out to be removed during subsequent machining. In all cases the blank shall be not less than 2 mm oversize.

NOTE Cold or semi-cold methods should be used to extract the blank, e.g. sawing or spark erosion to minimize the amount of machining subsequently required.

6.2.2 Machining. All cutting tools shall be sharp. Ensure that the tool used to finish the notch retains its required geometry (see Figure 5).

Finishing shall either be by grinding or milling. When finishing by grinding, the stone shall be dressed and cleaned prior to the final pass.

During the removal of the final 1 mm of metal from any face the depth of cut shall not exceed 0.5 mm. On those faces where a surface finish of $1.6 \mu\text{m } R_a$ or better is required the following restrictions shall also apply.

a) *Steels and aluminium alloys.* The finishing pass depth shall not exceed 0.25 mm.

NOTE High-speed steel milling cutters are generally satisfactory for notching steels having a tensile strength up to 800 MN/m^2 .

b) *Titanium alloys.* The final 0.25 mm shall be removed in passes of steadily decreasing depth, the final pass depth shall not exceed 0.01 mm.

NOTE 1 The following sequence would be suitable: 0.13, 0.06, 0.03, 0.02 and 0.01 mm.

NOTE 2 Grinding is generally necessary for alloys having a tensile strength in excess of $1\,000 \text{ MN/m}^2$.

c) *Nickel alloys*. The requirements shall be as for titanium in item b), except that the final pass shall not exceed 0.025 mm in depth.

d) *Other metals*. The method of machining shall be such that surface deformation and generation of residual stresses are minimized.

6.3 Final dimensions

The dimensions B , W , M and n shall be measured to within 0.1 mm and the measured values used in all calculations.

6.4 Heat treatment

No heat treatment operation shall take place once a fatigue crack has been initiated.

7 Stress intensity factors

Stress intensity factors shall be calculated as follows:

$$K = \frac{PY}{B} \sqrt{\left(\frac{1000}{W}\right)} \quad \text{for } P > 0$$

$$K = 0 \quad \text{for } P \leq 0$$

The values of Y appropriate to the specimen geometry given in Appendix C shall be used.

NOTE Even though when P is negative K is zero, it is possible that negative loading will have an influence on the rate of growth of a crack.

8 Crack length

Where surface measurements are used to determine crack length, they shall be made on both faces of the specimen and the arithmetic average value of crack length used to calculate K . During the determination of growth rate (see 9.1.3) the surface crack lengths shall not differ by more than 0.1 a .

9 Test procedure

CAUTION. The specimen may break during the test. Suitable precautions should be taken to protect personnel and equipment in this eventuality, e.g. guards to prevent parts of the specimen flying out and a limit on actuator travel.

NOTE Example flow charts for initiation, precracking and threshold testing are given in Appendix E. Worked examples of notional tests are given in Appendix F.

9.1 Constant R method

9.1.1 *Crack initiation*. For crack initiation undertake the following.

a) Insert the specimen into the testing machine (see 5.1) and attach any apparatus required for crack length monitoring (see 5.2).

b) Assuming the notch to behave as a crack of length M , initiate a crack with cyclic forces such that $K_{\max}$ numerically equals $10^{-4}E \text{ MN/m}^{1.5}$, where E is measured in MN/m^2 , $R \leq 0.1$.

NOTE 1 It is not essential that these cyclic forces are established immediately, but they should not be exceeded.

NOTE 2 Crack initiation and the generation of a straight crack front may be encouraged by the prior application of a negative load of equal magnitude to the positive load needed to produce the value of $K_{\max}$ given above.

c) Maintain these cyclic forces constant until the crack length equals a_i , where a_i is the greater of $(M + 0.5 \text{ mm})$ and $M + R_p$ and where R_p is calculated from $K_{\max}$ in item b).

9.1.2 *Precracking*. When the crack length equals a_i , proceed as follows.

a) Calculate K_i , the value of $K_{\max}$ at a crack length of a_i when $P_{\max} = P_i$.

b) Estimate the value of ΔK required to give a growth rate of 10^{-8} m/cycle at the R value of interest (R_s).

NOTE 1 The following figures are given for guidance.

1) steels, nickel, titanium and copper alloys;

$\Delta K = 13 \text{ MN/m}^{1.5}$.

2) aluminium alloys; $\Delta K = 6 \text{ MN/m}^{1.5}$.

In specific cases, the actual value could differ from these figures by a factor of 1.5. Where doubt exists, it is recommended that a high value within this range is used to reduce the risk that at the end of precracking, da/dN is less than 10^{-8} m/cycle and thus that part of the range of da/dN is not covered.

c) Calculate K_s , the value of $K_{\max}$ when ΔK and R are as in item b).

d) Cyclically load the specimen so that $K_{\max}$ varies linearly with crack length according to the formula:

$$K_{\max} = \frac{K_i + (K_s - K_i)(a - a_i)}{(a_s - a_i)}$$

Vary $P_{\min}$ linearly with crack length according to the formula:

$$P_{\min} = \frac{RP_i + (R_s \cdot P_s - R \cdot P_i)(a - a_i)}{(a_s - a_i)}$$

where

a_s is the greater of a_0 and $1\,000 (K_s/\sigma_Y)^2$

a_0 is the greater of $(M + n)$ and $(M + 0.05W)$

R has the value used during crack initiation (9.1.1).

NOTE 2 This ensures that $P_{\min}$ changes continuously (see Figure 15).

e) Continue until $a = a_s$.

9.1.3 Determination of threshold ΔK and growth rate data. When $a = a_s$ [see 9.1.2 e)] proceed as follows.

- a) Cyclically load the specimen, smoothly varying $K_{\max}$ with crack length according to

$$K_{\max} = K_s \exp [C_k (a - a_s)]$$

where $C_k = -0.1 \text{ mm}^{-1}$ and a and a_s are in millimetres.

- b) Vary $P_{\min}$ so that R remains constant and equal to R_s .

- c) Record a , $P_{\max}$, $P_{\min}$ and the number of elapsed cycles either continuously or at nominal intervals of indicated crack extension of the greater of $5q$ or $0.01W$ whichever is greater. Also record these parameters at test interruptions and at test termination.

- d) Terminate the test when there is no evidence of crack extension over a period of cycles of $q/10^{-8}$ (q in mm) or 5×10^6 whichever is greater. Mark the crack front position and fracture the specimen.

9.2 Constant $K_{\max}$ method

9.2.1 General. This method is useful for establishing values of the fatigue crack growth threshold at high, positive R values. Once a precrack of the requisite minimum size has been produced $K_{\max}$ is maintained constant and $K_{\min}$ increased steadily with increase in crack length until $\Delta K = \Delta K_{\text{th}}$; the value of R at this point is not pre-determined and due to the continuous variation of R during the test, useful growth rate data are not generated.

9.2.2 Initiation and precracking. The following is the procedure for initiation and precracking.

- a) Insert the specimen into the testing machine and attach any apparatus required for crack length monitoring.
- b) Calculate a value of $K_{\max}$ for the commencement of threshold testing, K_s , from the estimated K_{th} and the target R value, R_t , as

$$K_s = \frac{\Delta K_{\text{th}}}{1 - R_t}$$

- c) Calculate R_s from

$$R_s = 1 - \left[\frac{(1 - R_t)}{\exp \{C_k \times (0.75W - a_s)\}} \right]^i$$

where $C_k = -0.28 \text{ mm}^{-1}$; W and a_s are in millimetres; a_s is the greater of a_0 and $1\,000 (K_s/\sigma_Y)^2$, a_0 being the greater of $M + n$ and $M + 0.05W$.

If R_s as calculated above is less than 0.1, then set $R_s = 0.1$.

NOTE $K_s(1 - R_s)$, which equals ΔK at the beginning of the determination (9.2.2) can be less than ΔK_{th} at $R = R_s$, in which case this test method is inapplicable. This should be checked before attempting to test according to this method.

- d) If $K_s < E \times 10^{-4}$, then proceed as in 9.1.1 and 9.1.2; otherwise proceed as follows:

- e) Assuming the notch to behave as a crack of length M , cyclically load the specimen such that $K_{\max}$ equals K_s and $K_{\min}$ equals $R_s \cdot K_s$ until a reaches a_s , as defined in item c).

9.2.3 Determination of ΔK_{th} . When a reaches a_s proceed as follows:

- a) Cyclically load the specimen smoothly varying $K_{\min}$ with crack length according to

$$K_{\min} = K_s [1 - (1 - R_s) \exp \{C_k \cdot (a - a_s)\}]$$

where $C_k = -0.28 \text{ mm}^{-1}$ and a , a_s are in millimetres.

- b) Vary $P_{\max}$ so that $K_{\max}$ remains constant and equal to K_s .

- c) Terminate the test when there is no evidence of crack extension over a period of cycles of $q/10^{-8}$ (q in mm) or 5×10^6 whichever is greater. Record a , $P_{\max}$, $P_{\min}$ and the number of elapsed cycles. Mark the crack front and fracture the specimen.

9.3 Post test examination

- a) Measure the length of the fatigue crack after testing on the fracture surfaces at both edges and at points 0.25, 0.5 and 0.75 B from one edge. The maximum and minimum values of crack length shall not differ by more than $0.1a$ or $B/2$ whichever is less.

- b) Measure the deviation of the fatigue crack on either side of the specimen from the plane of symmetry containing the notch. The fatigue crack shall lie within a corridor defined by planes $0.05W$ on either side of the specimen plane of symmetry containing the notch tip.

10 Data analysis

10.1 Validity

If during the test the following criteria are not met then the subsequent data become invalid.

- a) a/W exceeds 0.75;
- b) a/W exceeds $\{1 - (S_p/W)\}$;

where S_p is calculated as follows:

- 1) for CCT specimens:

$$S_p = \frac{1\,000}{2\sigma_f} \times \frac{P_{\max}}{B}$$

2) for SENB3, SENB4 and CT specimens:

$$S_p = \sqrt{\left(\frac{1000}{0.63} \times \frac{P_{\max} \cdot L_m}{\sigma_f \cdot B}\right)}$$

where L_m has the following values:

- i) $2W$ for SENB3 specimens;
 - ii) L_1 for SENB4 specimens (see Figure 7);
 - iii) $W + a$ for CT specimens.
- c) the instantaneous value of $10R_p$ exceeds a or $4B$;
- d) the forces fall outside the certified range (see 5.1).

10.2 Threshold value

Calculate the value of ΔK_{th} from the average of the five crack lengths measured in 9.3 and the force range at test termination. Also calculate the associated value of R .

10.3 Crack growth rate data (Constant R method only)

Where the record of a as a function of N is continuous, sample the record at nominal crack length increments of the greater of $5q$ or $0.01W$ to provide pairs of values of a and N . Otherwise, the a (N) record will consist of individual pairs of values.

a) Calculate da/dN at each crack length, a_j , from

$$\frac{da_j}{dN} = \frac{(a_{j+1}) - (a_{j-1})}{(N_{j+1}) - (N_{j-1})}$$

where

- a_{j+1} is the crack length of the next record;
- a_{j-1} is the crack length of the previous record;
- N_{j+1} is the cycle count of the next record;
- N_{j-1} is the cycle count of the previous record.

b) Calculate the associated value of ΔK from a_j and the associated force range.

e) for each pair of values of a and N considered in clause 10, tabulate the following:

- a (in mm), N , da/dN (in m/cycle),
- ΔK (in $\text{MN}/\text{m}^{1.5}$);

f) record the value of ΔK_{th} ($\text{MN}/\text{m}^{1.5}$) and R at threshold, the associated crack length, the associated Δp and the number of cycles without evidence of crack extension.

11.2 Additional information

The following information is often valuable and is recommended for inclusion in the test report:

- a) material composition, heat treatment and mechanical properties;
- b) product size and form, e.g. casting, plate;
- c) crack plane orientation and propagation direction (see Appendix D of BS 5447:1977);
- d) method of stress relief (if any) and information on the residual stress distribution (if measured);
- e) temperature and relative humidity range;
- f) test machine capacity and force scale used, crack length measurement technique and resolution and crack length measurement interval.

11 Test report

11.1 Required information

The test report shall contain the following information:

- a) a reference to this Draft for Development, i.e. DD 186;
- b) the specimen type (see Appendix A); dimensions B , W (in mm);
- c) waveform and frequency;
- d) C_k , K_s , R_s , and the threshold test method (9.1 or 9.2);