

INTERNATIONAL STANDARD

NORME INTERNATIONALE



Optical fibres –

Part 1-33: Measurement methods and test procedures – Stress corrosion susceptibility

Fibres optiques –

Partie 1-33: Méthodes de mesures et procédures d'essai – Résistance à la corrosion sous contrainte



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INTERNATIONAL STANDARD

NORME INTERNATIONALE



**Optical fibres –
Part 1-33: Measurement methods and test procedures – Stress corrosion
susceptibility**

**Fibres optiques –
Partie 1-33: Méthodes de mesures et procédures d'essai – Résistance à la
corrosion sous contrainte**

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OPTICAL FIBRES –

**Part 1-33: Measurement methods and test procedures –
Stress corrosion susceptibility**

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International Standard IEC 60793-1-33 has been prepared by subcommittee 86A: Fibres and cables, of IEC technical committee 86: Fibre optics.

This second edition cancels and replaces the first edition published in 2001. It constitutes a technical revision.

This edition includes the following significant technical changes with respect to the previous edition:

- a) removal of RTM;
- b) changes to scope.

The text of this International Standard is based on the following documents:

FDIS	Report on voting
86A/1803/FDIS	86A/1824/RVD

Full information on the voting for the approval of this International Standard can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

A list of all parts of the IEC 60793 series, published under the general title *Optical fibres*, can be found on the IEC website.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under "<http://webstore.iec.ch>" in the data related to the specific document. At this date, the document will be

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- withdrawn,
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INTRODUCTION

Annexes A, B, C, D, and E form an integral part of this document.

Annexes F, G, and H are for information only.

OPTICAL FIBRES –

Part 1-33: Measurement methods and test procedures – Stress corrosion susceptibility

1 Scope

This part of IEC 60793 contains descriptions of the five main test methods for the determination of stress corrosion susceptibility parameters.

The object of this document is to establish uniform requirements for the mechanical characteristic of stress corrosion susceptibility for silica-based fibres. Dynamic fatigue and static fatigue tests are used to determine the (dynamic) n_d value and (static) n_s value of stress corrosion susceptibility parameters. Currently, only the n_d -value is assessed against specification. Measured values greater than 18 per this procedure reflect the n_d -value of silica, which is approximately 20. Higher values will not translate to demonstrable enhanced fatigue resistance.

Silica fibre mechanical tests determine the fracture stress and fatigue properties under conditions that model the practical applications as closely as possible. The following test methods are used for determining stress corrosion susceptibility:

- A: Dynamic n_d value by axial tension;
- B: Dynamic n_d value by two-point bending;
- C: Static n_s value by axial tension;
- D: Static n_s value by two-point bending;
- E: Static n_s value by uniform bending.

These methods are appropriate for category A1, A2 and A3 multimode, class B single-mode fibres and class C intraconnecting single-mode fibres.

These tests provide values of the stress corrosion parameter, n , that can be used for reliability calculations according to IEC TR 62048 [18]¹.

Information common to all methods is contained in Clauses 1 to 10, and information pertaining to each individual test method appears in Annexes A, B, C, D, and E.

Annexes F and G offer considerations for dynamic and static stress corrosion susceptibility parameter calculations, respectively; Annex H offers considerations on the different stress corrosion susceptibility parameter test methods.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

No terms and definitions are listed in this document.

¹ Numbers in square brackets refer to the Bibliography.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

4 Overview of test methods

The following test methods are available:

- Dynamic n_d value by axial tension, see Annex A.
- Dynamic n_d value by two-point bending, see Annex B.
- Static n_s value by axial tension, see Annex C.
- Static n_s value by two-point bending, see Annex D.
- Static n_s value by uniform bending, see Annex E.

5 Reference test methods

At the time of this revision, no agreement could be reached in maintaining method A only as RTM in using it with some fibres equipped with modern coatings. Method A or B should be used to resolve disputes because they may be completed in a duration practical for dispute resolution.

6 Apparatus

See Annexes A, B, C, D, and E for each of the layout drawings and other equipment requirements for each of the methods.

7 Sampling and specimens

7.1 General

These measurements are statistical in nature. A number of specimens or samples from a common population are tested, each under several conditions.

Failure stress or time statistics for various sampling groups are used to calculate the stress corrosion susceptibility parameters.

7.2 Specimen length

Specimen length is contingent on the test procedure used. See Annexes A, B, C, D, and E for the length required for each test method. For tensile tests, the length ranges from 0,5 m to at most 5 m. For two-point bending tests, the actual length tested is less than 1 cm and for uniform bending tests, about 1 m.

7.3 Specimen preparation and conditioning

All of the test methods shall be performed under constant environmental conditions. Unless otherwise specified in the detail specification, the nominal temperature shall be in the range of 20 °C to 23 °C with a tolerance of ± 2 °C for the duration of the test. Unless otherwise specified in the detail specification, the nominal relative humidity (RH) shall be in the range of 40 % to 60 % with a tolerance of ± 5 % for the duration of the test.

Unless otherwise specified, all specimens shall be pre-conditioned in the test environment for a minimum period of 12 h.

A method for extrapolating such stress corrosion susceptibility parameters to service environments different from the default environment specified above has not been developed.

It has been observed that the value of n produced by these tests can change after even brief exposure of the fibre to elevated temperature and humidity. A guide for the use of these methods is documented in IEC TR 62048 [18].

The observed value of stress corrosion susceptibility parameter, n , may differ between fatigue test methods, if not performed in the same effective measuring time and effective glass area under test (see Annex H). Care should be taken in the choice of test method. This should be agreed between the customer and supplier.

8 Procedure

See Annexes A, B, C, D, and E for the individual test methods.

Each of several samples (consisting of a number of specimens) is exposed to one of a number of stress conditions. For static fatigue tests, a constant stress is applied from sample to sample and time to failure is measured. For dynamic fatigue tests, the stress rate is varied from sample to sample, and the failure stress is measured.

The following is an overview of the procedures common to all methods:

- complete pre-conditioning;
- divide the specimens into sample groups;
- apply the specified stress conditions to each sample group;
- measure time or stress at failure;
- complete calculations.

9 Calculations

The calculations for each individual test method are found in Annexes A, B, C, D, and E.

10 Results

The following information shall be reported with each test:

- fibre identification;
- test date;
- stress corrosion susceptibility parameter;
- test method.

The following information shall be provided upon request:

- specific information as required by the test method;
- relative humidity and ambient temperature;
- any special pre-conditioning.

Clauses A.5, B.5, C.5, D.5, and E.5 have results that apply to each specific method.

11 Specification information

The detail specification shall specify the following information:

- information to be reported;
- any deviations to the procedure that apply;
- failure or acceptance criteria.

Annex A (normative)

Dynamic n value, n_d , by axial tension

A.1 General

This method is designed for determining the dynamic stress corrosion susceptibility parameter (dynamic n value, n_d) of optical silica-based fibre at specified constant strain rates.

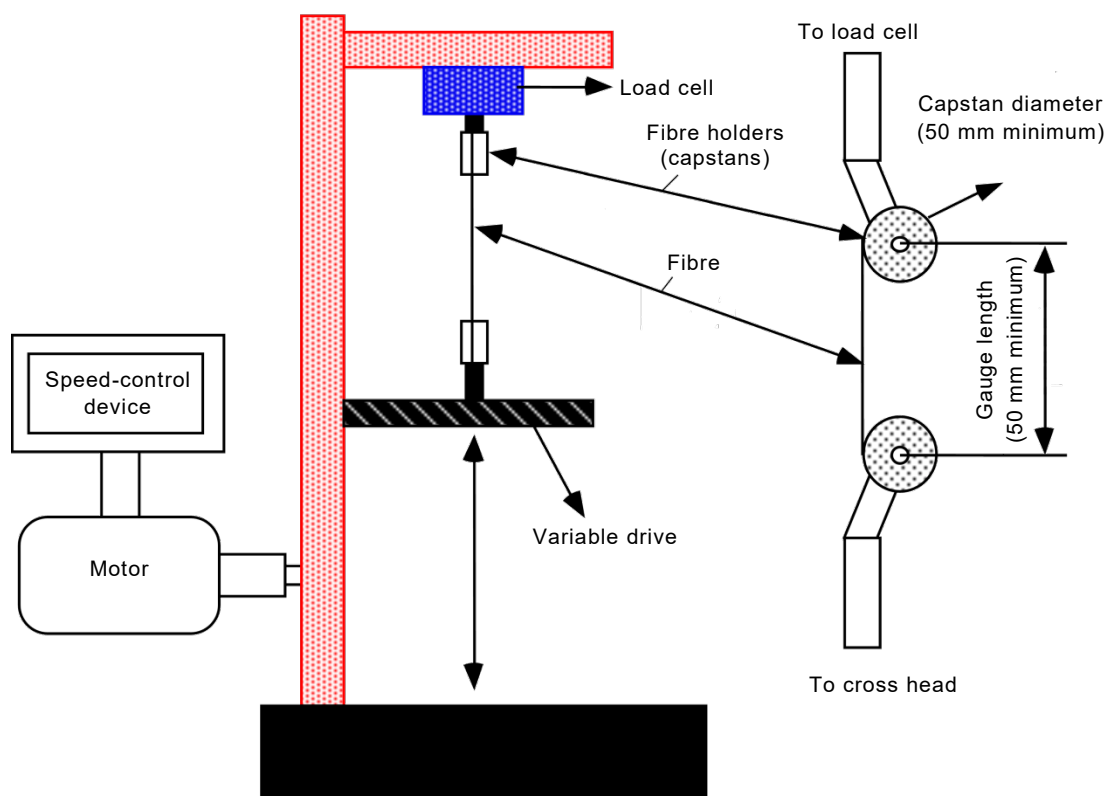
This method is intended only to be used for those optical fibres of which the median fracture stress is greater than 3 GPa at the highest specified strain rate. For fibres with median fracture stress less than 3 GPa, the conditions herein have not demonstrated sufficient precision.

This method is intended to test fatigue behaviour of fibres by varying the strain rate. The test is applicable to fibres and strain rates for which the logarithm of fracture stress versus the logarithm of strain rate behaviour is linear.

A.2 Apparatus

A.2.1 General

Clause A.2 describes the fundamental requirements of the equipment used for dynamic fracture stress testing. There are several configurations that meet these requirements. Examples are presented in Figures A.1 to A.3. Unless otherwise specified in the detail specification, use a gauge length of 500 mm for tensile test specimens.



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Figure A.1 – Schematic of translation test apparatus

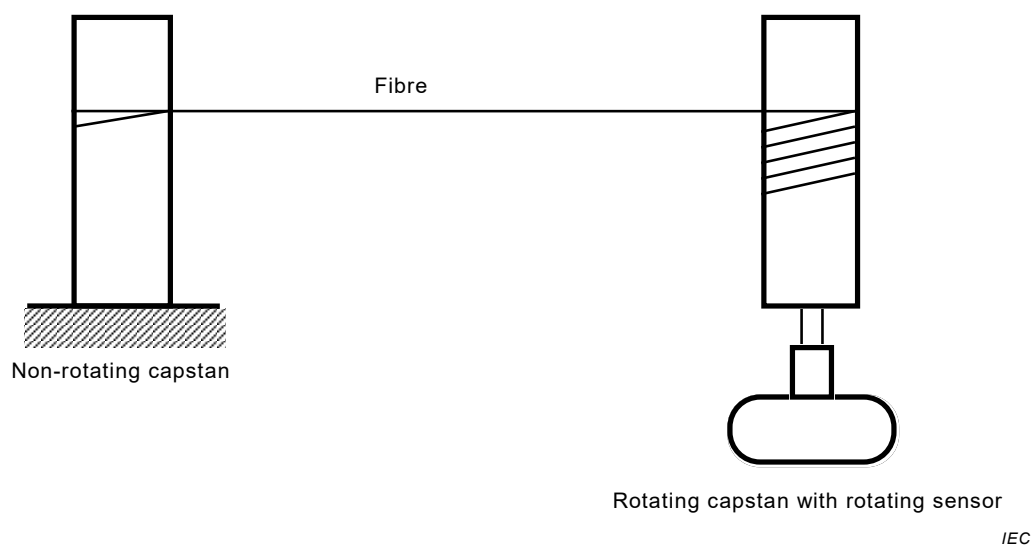


Figure A.2 – Schematic of rotational test apparatus

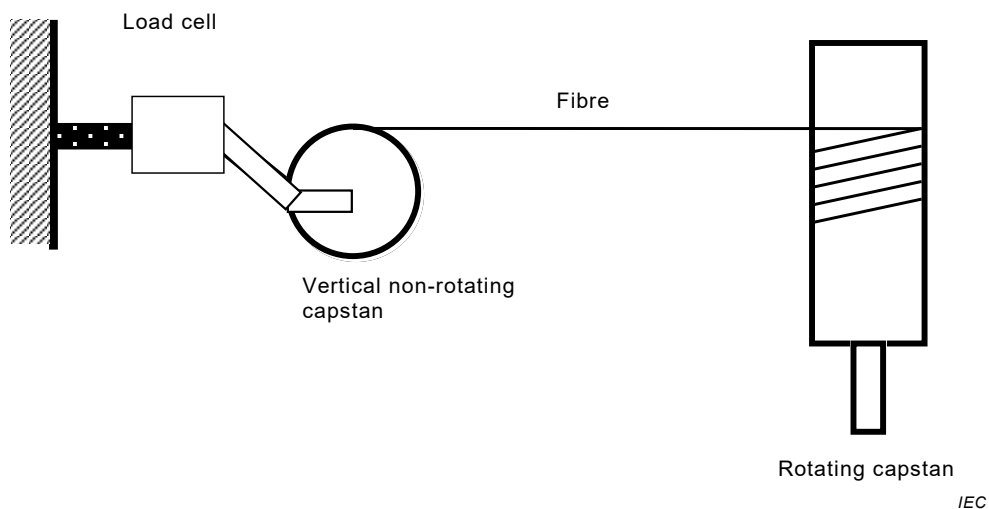


Figure A.3 – Schematic of rotational test apparatus with load cell

A.2.2 Support of the specimen

Grip the fibre length to be tested at both ends and subject the fibre to tension until fracture occurs in the gauge length section of the fibre. Minimize the fibre fracture at the grip – a sensitive aspect of this method – by providing a surface friction that prevents excessive slippage.

Do not include breaks that occur at the grip in the sample or use them in the calculations.

Use a capstan, optionally covered with an elastomeric sheath, to grip the fibre. Wrap a section of the fibre that will not be tested around the capstan several times and secure it at the end with, for example, an elastic band or masking tape. Apply sufficient fibre length at the grip in order to avoid slippage inside the coating (coating type depending aspect [19]). Wrap the fibre with no crossovers. The gauge length is the length of fibre between the axes of the gripping capstans before it is stretched.

Use a capstan and pulley diameter so that the fibre is not subjected to a bending stress that causes the fibre to break on the capstan. For typical silica-based fibres, the bending stresses shall not exceed 175 MPa when the fibre is wrapped as shown in Figures A.1 to A.3 or traverses a pulley. For example in case of 125 µm cladding diameter silica fibre (200 µm and 250 µm coating diameter), the minimum capstan diameter is then 50 mm. Provide a capstan surface tough enough that the fibre does not cut into it when fully loaded. This condition can be determined by pre-testing.

A.2.3 Stressing application

Elongate the fibre at a fixed strain rate until it breaks. The rate of elongation is expressed as percentage per minute, relative to the gauge length. Two examples are given:

- a) increase the separation between the gripping capstans by moving one or both of the capstans at a fixed rate of speed, with the starting separation equal to the gauge length (Figure A.1); or
- b) rotate one or both of the gripping capstans, to take up the fibre under test (see Figures A.2 and A.3).

The strain rate is the change in length between the two locations, in per cent, divided by the time.

If method b) is used, ensure that the fibre on the capstan does not cross over itself as it is wrapped.

If fibres are tested simultaneously, protect each fibre from adjacent fibres so that whiplash at fracture does not damage other fibres under test.

A.2.4 Fracture force measurement

Measure the tensile stress during the test and at fracture for each test fibre by a load cell, calibrated to within 0,5 % (0,005) of the fracture or maximum load, for each range of fracture stress. Calibrate the load cell while oriented in the same manner as when testing the fibre under load. For method b), use a light, low-friction pulley (or pulleys) in place of the non-rotating capstan (see Figure A.2), or the rotating capstan (see Figure A.3), when calibrating load cells with a string and calibration weight.

Use a string, attached at one end to the load-measuring device (or its capstan), to duplicate the direction of an actual test fibre with a thickness or diameter comparable to that of a test fibre. A minimum of three calibration weights are recommended for load cell calibration which bracket the typical fracture or maximum load (50 % below maximum, maximum and 50 % above maximum).

The response time of the load-measuring system shall be sufficient to report the fracture stress within 1 % of the actual value.

NOTE Frictional effects from the pulleys can lead to substantial errors in the load cell calibration of rotating capstan testers for horizontally mounted fibre.

A.2.5 Strain rate control

Determine the setting for the speed control unit by trial in order to meet the specified strain rates. Express the strain rate as a percentage of gauge length per unit time. Unless otherwise specified in the detail specification, the maximum strain rate shall be equal to or less than 100 %/min. Select the actual maximum strain rate by taking into account aspects of the test method such as equipment considerations and material properties of the samples. In addition to the maximum rate, use three additional strain rates, each reduced sequentially by roughly a power of 10 from the maximum.

It is possible to minimize test duration by using a faster strain rate in conjunction with a reduced load. For example, if a strain rate of 0,025 %/min is specified, test some specimens at the next fastest rate (0,25 %/min) to establish a range of fracture stress. Then pre-load to a level equal to or less than 80 % of the lowest fracture stress found for the initial trial specimens at the next fastest rate.

A.2.6 Stress rate characterization

The stress rate may vary with fibre type, equipment, breaking stress, fibre slippage, and strain rate. Characterize the stress rate, $\dot{\sigma}_a$, at each strain rate used in the fatigue calculation according to:

$$\sigma_a = \frac{0,2 \times \sigma_f}{t(\sigma_f) - t(0,8 \times \sigma_f)} \quad (\text{A.1})$$

where

- σ_f is the fracture stress;
- $t(\sigma_f)$ is the time to fracture;
- $t(0,8 \times \sigma_f)$ is the time at 80 % of the fracture stress.

A.3 Test sample

A.3.1 Sample size

Because of the variability of test results, test a minimum of 15 specimens for each strain rate, and drop the lowest breaking fracture stress data point for each strain rate. Alternatively, if the standard error of estimate of slope σ_f vs. $\dot{\sigma}_a$ is 0,0017 or greater (as explained in Clause F.2), test a minimum of 30 specimens for each strain rate and drop the lowest two breaking fracture stress data points for each strain rate.

A.3.2 Sample size (optional)

As explained in A.3.1, additional specimens may be required for some applications in which the confidence interval on the estimate of the dynamic (tension) stress corrosion susceptibility parameter, n_d , needs to be known. Refer to Table F.1 for various sample sizes, depending upon the expected dynamic Weibull slope, m_d . Appropriate use of the algorithm in Clause F.2 is restricted to tests in which the same sample size is specified for each strain rate.

A.4 Procedure

This procedure describes how to obtain fibre fracture stress on a given sample set tested at a given strain rate. Calculations of population statistics are presented in Clause F.2.

- 1) Set and record the gauge length (see A.2.3).
- 2) Set and record the strain rate (see A.2.5).
- 3) If method a) of A.2.3 is used, return the gripping capstans to the gauge length separation.
- 4) Load the test specimen in the grips, one end at a time. The tangent point of the fibre shall be in the same location as that for the load calibrations. Guide each specimen so that the fibre makes at least the required number of turns around the capstan without crossing over itself.
- 5) If necessary, re-set the load-measuring system.
- 6) Start the motor to stress the fibre. Record the stress vs. time until the fibre breaks. Stop the motor.
- 7) Repeat steps 3) through 6) for all fibres in the sample set.

- 8) Calculate the fibre fracture stress, σ_f , for each break. Use Equation (A.2).
- 9) Calculate the stress rate, $\dot{\sigma}_a$. Use Equation (A.1).
- 10) Complete the required population statistic calculations. Use Equations (A.3) to (A.6).

A.5 Calculations

A.5.1 Fracture stress

The following method can be used to calculate the fracture stress, σ_f , when the coating contribution is negligible (less than 5 %), such as on common 125 μm diameter fibre with a coated diameter of 250 μm (polymer coating):

$$\sigma_f = T / A_g \quad (\text{A.2})$$

where

T is the force (tension) experienced by the composite specimen at fracture;

A_g is the nominal cross-sectional area of the glass fibre.

A more complete method is given in Clause F.3 for use when the coating contribution is important.

A.5.2 Fracture stress at a given strain rate

The following steps are required to form a Weibull plot characterizing the population.

- a) Sort the fracture stresses from minimum to maximum. Assign a rank, k , to each. Rank is the order, for example first is the weakest, second is the next weakest, etc. Assign a different rank to each break, even if several breaks have the same fracture stress.
- b) Calculate the cumulative probability of failure, F_k , for each break:

$$F_k = (k - 0,5)/N, \quad k = 1, 2, \dots N \quad (\text{A.3})$$

where

N is the sample size.

- c) Graph $\ln [-\ln (1 - F_k)]$ vs $\ln (\sigma_f)$ to form the Weibull plot.
- d) Label the plot with the required information.
- e) For a given gauge length and diameter, the dynamic fatigue Weibull plot is associated with the following cumulative probability function:

$$F_k = 1 - \exp [-(\sigma_f/\sigma_0)^{m_d}] \quad (\text{A.4})$$

Let $k(P) = P \times N + 0,5$ define a rank associated with a given probability, P .

If $k(P)$ is an integer, let $\sigma_f(P) = \sigma_{fk}(P)$, the fracture stress of the $k(P)^{\text{th}}$ rank. If $k(P)$ is not an integer, let k_1 be the integer just below $k(P)$ and $k_2 = k_1 + 1$.

Then, let $\sigma_f(P) = (\sigma_{fk1} \times \sigma_{fk2})^{1/2}$.

The median fracture stress is $\sigma_f(0,5)$. The Weibull slope is:

$$m_d = \frac{2,46}{\ln [\sigma_f(0,85)] - \ln [\sigma_f(0,15)]} \quad (\text{A.5})$$

The Weibull parameter is:

$$\sigma_o = \exp \left[\frac{0,3665}{m_d} + \ln[\sigma_f(0,5)] \right] \quad (\text{A.6})$$

Graph the Weibull plot for each stress rate, and determine the median fracture stress $\sigma_f(0,5)$ for each stress rate.

A.5.3 Dynamic (tension) stress corrosion susceptibility parameter, n_d

The median fracture stress $\sigma_f(0,5)$ as defined in A.5.2, will generally vary with constant stress rate, as follows:

$$\ln \sigma_f(0,5) = \frac{\ln \sigma_a}{1 + n_d} + C \quad (\text{A.7})$$

where

C is the natural logarithm of fracture stress at a stress rate of unity as shown in Figure A.4 (intercept).

Intercept can be calculated from the following:

$$C = \bar{Y} - (S) \times \bar{X} \quad (\text{A.8})$$

where

S is the slope.

Unless otherwise specified, use the algorithm in Clause F.2 to calculate $\bar{X}$, $\bar{Y}$, the estimate of n_d , and the 95 % confidence interval for the test. Unless otherwise specified, the standard error of estimate of slope $\ln \sigma_f$ vs. $\ln \dot{\sigma}_a$ shall be less than 0,0017. Refer to Clause F.2 to determine the standard error of estimate of slope.

A.6 Results

The following data shall be provided upon request:

- strain rates;
- sample size per strain rate;
- standard error of estimate;
- $\bar{X}$ and $\bar{Y}$;
- gauge length;
- test environment;
- environmental pre-conditioning time;
- fracture stress calculation method;
- Young's modulus of fibre (if taken into account);
- Young's modulus of coating(s) (if taken into account);
- Weibull plots for all strain rates (if used);
- method of calculating the stress rate.

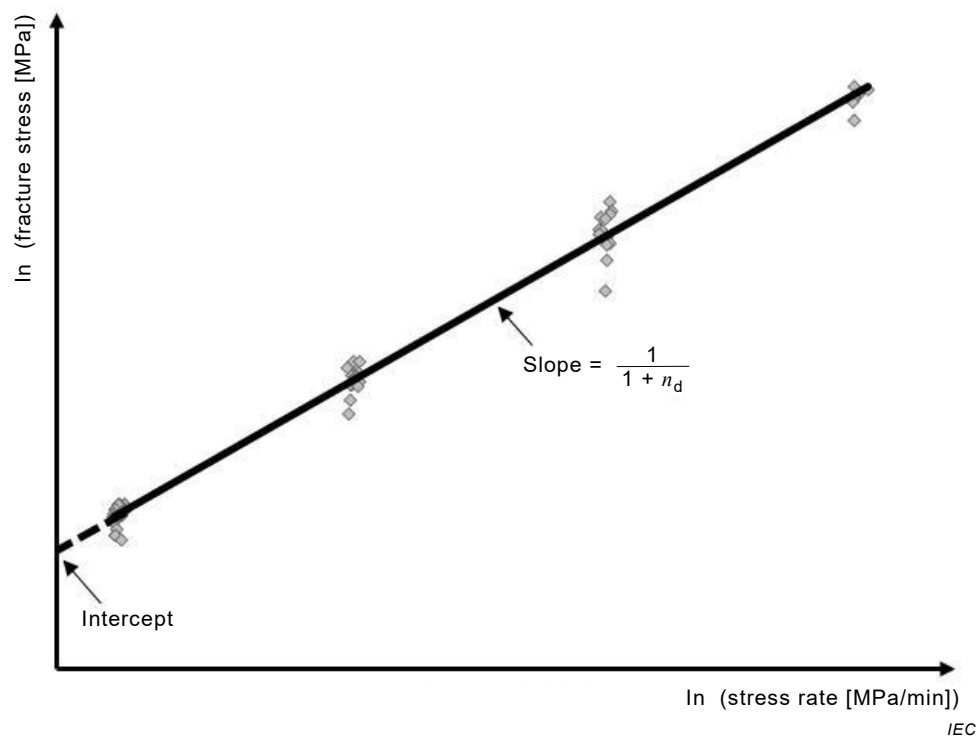


Figure A.4 – Representation of dynamic fatigue graph

Annex B (normative)

Dynamic n value, n_d , by two-point bending

B.1 General

This procedure provides a method for measuring the dynamic fatigue parameters (dynamic n value, n_d) of optical fibre in two-point bending at a constant platen velocity. This method is intended to test fatigue behaviour of fibres by varying the platen velocity. The test is applicable to fibres and platen velocities for which the logarithm of fracture stress versus the logarithm of platen velocity behaviour is linear.

B.2 Apparatus

B.2.1 General

A possible test apparatus is schematically shown in Figure B.1. This equipment is designed to measure the strain/stress required to break an optical fibre in a two-point bending geometry by measuring platen separation at fracture. This technique is readily amenable to various test environments.

B.2.2 Stepper motor control

This device allows accurate, reliable, repeatable motorized control of the linear table. A maximum step length of 1 μm shall be used. A step length of 0,1 μm could be used for higher accuracy.

B.2.3 Stepper motor-driven movable platen

The movable platen converts the stepper motor rotation to linear translation by means of a lead screw.

B.2.4 Stationary platen

This device holds the fibre against the movable platen.

B.2.5 Platen velocity

Place the fibre between two platens that are brought together by a computer controlled stepper motor at a specified constant platen velocity ($V = \text{constant}$) until the fibre breaks. Unless otherwise specified in the detail specification, use velocities 1 $\mu\text{m/s}$, 10 $\mu\text{m/s}$, 100 $\mu\text{m/s}$, 1 000 $\mu\text{m/s}$, each accurate to $\pm 10\%$.

B.2.6 Fibre fracture detecting system

One of the following techniques may be used to detect fibre fracture.

1) Method 1

Use an acoustic emission detector or transducer and computer to sense the fibre break and platen position at time of break. The computer then stops the platen and displays the platen separation at the time of the break.

2) Method 2

Incorporate a force (pressure) transducer into the stationary platen and connect it to a suitable signal conditioning equipment to measure force exerted on the fibre during the test. When the fibre breaks, the force drops to zero, providing a means of detecting the break.

3) Method 3

Launching light through a fibre during the test and monitoring the output signal is another technique for detecting fibre fracture. When the fibre breaks, the transmission is lost.

With all of the techniques above, calculate the platen separation at fracture d as:

$$d = a - b \quad (\text{B.1})$$

where

a is the platen starting position;

b is the platen travel.

B.3 Test sample

The test sample is a length of coated optical fibre approximately 30 mm to 120 mm long. The glass diameter shall be known to $\pm 1 \mu\text{m}$ and coating diameter shall be known to $\pm 5 \mu\text{m}$. Unless otherwise specified in the detail specification, the sample size for each velocity shall be at least 15 specimens.

B.4 Procedure

The following is one example of a calibration procedure.

- 1) Set the distance between the platen to zero when the faces of the platen are completely touching. When contact is made, the readout on the stepper motor controller should be zero. The platen separation value d when the fibre breaks may be verified by checking the distance with a gauge block. The zero position should be repeatable to $\pm 5 \mu\text{m}$. It is recommended the surfaces of the platen be carefully cleaned before they are run together for touching.
- 2) Unless otherwise specified in the detail specification, set the initial fibre platen opening gap to 12,00 mm including groove depths.
- 3) Before a population of fibres for a given platen velocity is tested, break an identical fibre from the same group to determine the platen separation at fibre fracture. This platen separation d is used to calculate the breaking stress (Equations (B.2), (B.3), and B.4)). An initial (starting) platen separation can be determined from Equations (B.2), (B.3), (B.4), and (B.5) using a value of stress equal to 50 % of the breaking stress. This will allow the duration of the test to be reduced and the highest platen velocities to be achieved, since the maximum stepper motor speed may limit the maximum obtainable platen velocities.

It is possible to minimize test duration by using a faster platen velocity in conjunction with a reduced velocity. For example, if a platen velocity of $1 \mu\text{m/s}$ is specified, test some specimens at the next fastest rate ($10 \mu\text{m/s}$) to establish a range of fracture stresses. Then preload to a level equal to or less than 80 % of the lowest fracture stress found for the initial trial specimens at the next fastest rate.

- 4) Carefully grasp both ends of the test specimen, bend it carefully, and insert it between the platen, then pull it upwards to position it as shown in Figure B.2. Do not touch the bent fibre (gauge length) with fingers when handling or loading fibres. The apex of the fibre should always be at the same position in the fixture. This minimizes the effect of a non-parallel platen. Fibre orientation, whether up or down, does not matter.
- 5) After the specimen has broken, brake the stepper motor to a stop and record the platen separation at the break.

- 6) Repeat steps 1) to 5) for each fibre sample at the specified load rate, and for all samples at the other specified load rates.
- 7) Calculate the fibre fracture stress, σ_f , for each break, using Equations (B.2) to (B.4).
- 8) Complete the required population statistic calculations, using Equations (B.5) and (B.6).

B.5 Calculations

B.5.1 Fracture stress

Calculate the fracture stress of each fibre by:

$$\sigma_f = E_o \times \varepsilon_f (1 + 0,5 \times \alpha' \times \varepsilon_f) \quad (\text{B.2})$$

$$\varepsilon_f = 1,198 \frac{d_f}{d - d_c + 2d_g} \quad (\text{B.3})$$

$$\alpha' = 0,75 \times \alpha - 0,25 \quad (\text{B.4})$$

where

- σ_f is the fracture stress in GPa;
- E_o is the Young's modulus of silica glass (72 GPa);
- ε_f is the fracture strain at the apex of the fibre;
- α is the correction parameter for non-linear stress/strain behaviour (typical value for α is 6);
- d_f is the glass fibre diameter in μm ;
- d is the distance between platen at fibre fracture in μm ;
- d_c is the overall fibre diameter including any coating in μm ;
- $2d_g$ is the total depth of both grooves in μm (see Figure B.2).

B.5.2 Dynamic (two-point bending) stress corrosion susceptibility parameter, n_d

The median fracture stress, $\sigma_f(0,5)$, will generally vary with constant platen velocity, V , according to:

$$\ln \sigma_f(0,5) = \frac{1}{n_d - 1} \times \ln \frac{V}{r} + C \quad (\text{B.5})$$

where

- r is the radius of glass fibre;
- C is the natural logarithm of fracture stress at a constant platen velocity of unity as shown in Figure B.3 (intercept).

C can be calculated from:

$$C = \bar{Y} - (S) \times \bar{X} \quad (\text{B.6})$$

where

- S is the slope.

Unless otherwise specified, use the algorithm in Clause F.2 to calculate $\bar{X}$, $\bar{Y}$, the estimate of n_d , and the 95 % confidence interval for the test. Unless otherwise specified, the standard error of estimate of slope $\log(\sigma_f)$ vs. $\log(V)$ shall be less than 0,001 7. Refer to Clause F.2 to determine the standard error of estimate.

B.5.3 Results

The following data shall be provided upon request:

- platen velocities;
- sample size for each platen velocity;
- the standard error of estimate;
- test environment;
- environmental pre-conditioning time;
- Young's modulus of fibre glass (if assumed other than what is given in B.5.1);
- Weibull plots for all platen velocities (if used);
- $\bar{X}$ and $\bar{Y}$;
- fibre (glass and coating) diameter.

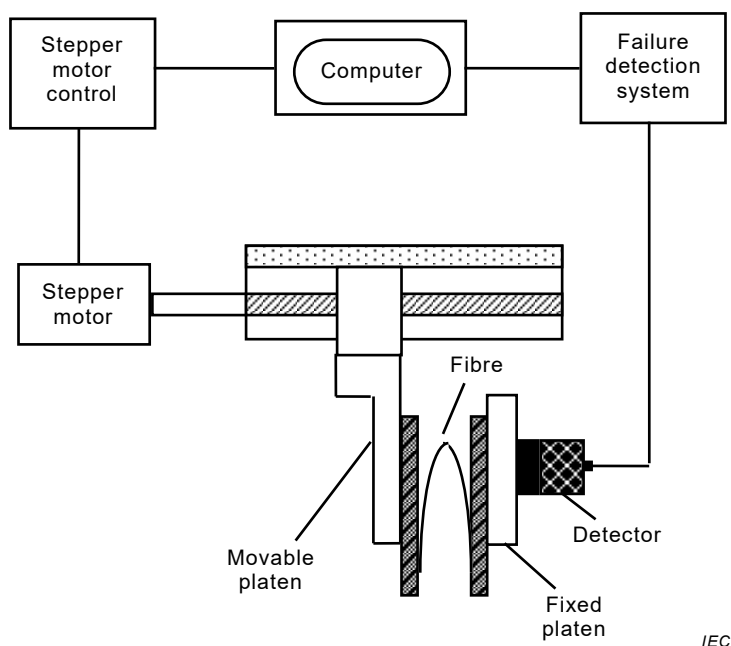


Figure B.1 – Schematic of two-point bending unit

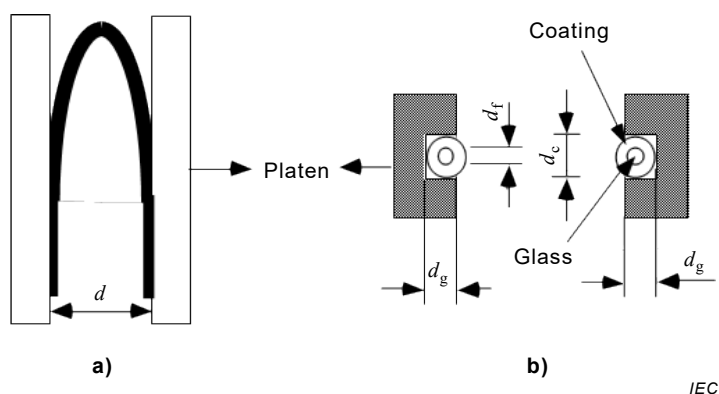


Figure B.2 – Schematic of possible dynamic fatigue (two-point bending) apparatus

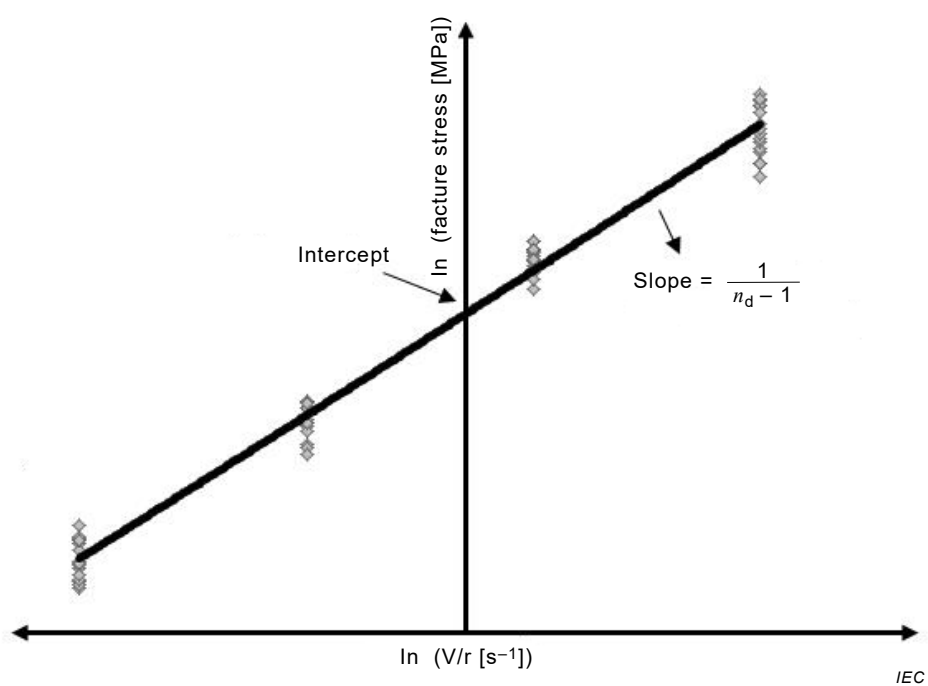


Figure B.3 – Schematic of dynamic fatigue data

Annex C (normative)

Static n value, n_s , by axial tension

C.1 General

This method is designed for determining the static fatigue parameters (static n value, n_s) of individual optical fibre lengths under tension. This method is intended to test static fatigue behaviour of fibres by varying the applied stress levels.

C.2 Apparatus

C.2.1 General

Possible arrangements of test equipment are schematically shown in Figure C.1. Each arrangement consists of a means of applying stress to a fibre and monitoring time to fracture. Unless otherwise specified in the detail specification, the gauge length, i.e. the distance between the capstans, shall be 500 mm.

C.2.2 Gripping the fibre at both ends

See A.2.2.

C.2.3 Stressing the fibre

The stress is applied on the fibre by hanging a known weight on one capstan (see Figure C.1). Several specimens are tested at a given nominal stress level. The range of actual stress levels for a given nominal level can influence the quality of the measurement. For the simple median computation method, the range of stress levels for a given nominal shall be within $\pm 0,5\%$ of the nominal. For the homologous method and the maximum likelihood estimate method, the individual stress levels for each specimen shall be recorded for use in the computation (see C.5.2).

C.2.4 Measuring time to fracture

There are many techniques to monitor time to fracture which can meet the requirements of this test method. One way to monitor the time to fracture is to set up timers underneath the hanging weights used to apply the stress on the fibre.

C.3 Test sample

Unless otherwise specified in the detail specifications, use the sample size for each nominal stress level of at least 15.

C.4 Procedure

Test a minimum of five different nominal applied stress levels, σ_a . Choose the nominal stresses such that the median times to fracture range from about 1 h to about 30 days in roughly equal distance on the logarithmic scale. The loads necessary to achieve this for standard silica-based fibres are in the range of 30 N to 50 N.

Since the time to fracture is dependent on both the fracture stress of the fibre and the fatigue parameter, the actual nominal stress levels applied and the number that are applied can be determined iteratively. Alternatively, a broad range of levels may be applied at the beginning of a measurement. Data from test sets that break too soon or take too long to break may be discarded.

Upon completion of pre-conditioning, load the fibres into the unit. Monitor and record the time to fracture for each fibre fracture. When testing a sample set for a given nominal stress level, as soon as the median specimen has broken the test may be terminated early. That is, if more than half of the samples have broken, the computation can be carried out and a median time to fracture determined before all the remaining samples fail. The standard error of the estimate shall be computed and reported for each measurement. Unless otherwise specified in the detail specification, the standard error of the estimate shall be less than 1.

C.5 Calculations

C.5.1 Fracture stress

See A.5.1.

C.5.2 Static (tension) stress corrosion susceptibility parameter, n_s

Unless otherwise specified, the following method shall be used to determine n_s . Alternatively, other methods, for example homologous or maximum likelihood estimate, can be used to determine n_s (see Clause A.5).

C.5.3 Simple median

This method does not require an assumption of linearity of the Weibull slope. Since all the data are not used, it can produce a larger standard error of the estimate than others. For each nominal stress level, σ_i , the median time to fracture, t_i , is determined. Fit the data to the following linear regression model by minimizing the sum of squared errors:

$$-n_s \ln(\sigma_i) + C = \ln(t_i) \quad (\text{C.1})$$

where

C is the intercept.

The standard error of the estimate for n_s is reported by most statistical packages. The median of $\ln(\sigma_i)$ and the median of $\ln(t_i)$ are also reported. The value of intercept in the above equation is as follows:

$$C = M[\ln(t_i)] + n_s M[\ln(\sigma_i)] \quad (\text{C.2})$$

where

M is the median value.

C.6 Results

The following data shall be provided upon request:

- fibre diameter;
- coating diameter (if it is taken into account);
- test environment;
- gauge length;