# INTERNATIONAL STANDARD

# ISO 11566

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## Carbon fibre — Determination of the tensile properties of single-filament specimens



*Fibres de carbone — Détermination des propriétés en traction sur éprouvette monofilament*



Reference number
ISO 11566:1996(E)

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.



International Standard ISO 11566 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 13, *Composites and reinforcement fibres*.

Annex A forms an integral part of this International Standard.





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# Carbon fibre — Determination of the tensile properties of single-filament specimens

## 1 Scope

This International Standard specifies a method of test for the determination of the tensile properties of a single-filament specimen.

The method is applicable to single filaments of carbon fibres, taken from multifilament yarns, strands, tows, staple fibres, staple yarns, woven fabrics, braids and knits.



## 2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 291:1977, *Plastics — Standard atmospheres for conditioning and testing.*

ISO 527-1:1993, *Plastics — Determination of tensile properties — Part 1: General principles.*

ISO 10548:1994, *Carbon fibre — Determination of size content.*

ISO 10618:—[1], *Carbon fibre — Determination of tensile properties of resin-impregnated yarns.*

ISO 11567:1995, *Carbon fibre — Determination of filament diameter and cross-sectional area.*

1) To be published.

## 3 Definitions

For the purposes of this International Standard, the definitions given in ISO 527-1 apply, together with the following.

**3.1 system compliance:** That portion of the indicated extension contributed by the load train system and the specimen-gripping system.

**3.2 specimen mounting:** A thin sheet made of paper, metal or plastic with a slot whose length corresponds to the gauge length of a test specimen.

## 4 Principle

A single-filament specimen is loaded in tension at a constant speed by a suitable mechanical testing machine until failure and the force-extension curve recorded.

The tensile strength and tensile modulus of elasticity are calculated from the force-extension relationship and the specimen cross-sectional area.

The tensile modulus of elasticity is calculated by dividing the difference in stress at two defined points by the corresponding difference in strain at these points, which may be two stress levels (method A) or two strain levels (method B). The difference in strain is corrected for the system compliance. The cross-sectional area is determined independently.

The relationship between stress and strain may not be linear, hence a chord modulus has to be defined. The two methods (A and B) represent two distinct methods of defining the position of the chord and may not give identical results.

## 5 Apparatus and materials

**5.1 Tensile-testing machine,** operating at a constant crosshead speed, equipped with force- and extension-recording devices. The accuracy of the force indication shall be better than 1 % of the recorded value.

The movement of the crosshead shall be recorded in order to calculate the specimen extension. The grips shall have flat surfaces.

**5.2 Specimen mounting,** made from a thin sheet of paper, flexible metal or plastic, with slot of length 25 mm ± 0,5 mm, as shown in figure 1.

The sheet shall be as thin as possible in order to minimize misalignment of the specimen at the grips. A thickness of 0,1 mm is recommended

**5.3 Adhesive:** any epoxy resin, rosin or sealing wax which is suitable for bonding the filament firmly to the mounting.

**5.4 Adhesive tape,** to fix the filament temporarily to the mounting (no special requirements).



## 6 Test specimens

Prepare at least 20 test specimens from each elementary unit, to enable 20 measurements to be made for each result reported.

Removal of any size present makes it easier to prepare good specimens. To remove the size, use the solvent-extraction, chemical-digestion or pyrolysis methods specified in ISO 10548.

## 7 Procedure

### 7.1 Test atmosphere

Carry out the test in one of the standard atmospheres defined in ISO 291.

### 7.2 Measurement of cross-sectional area

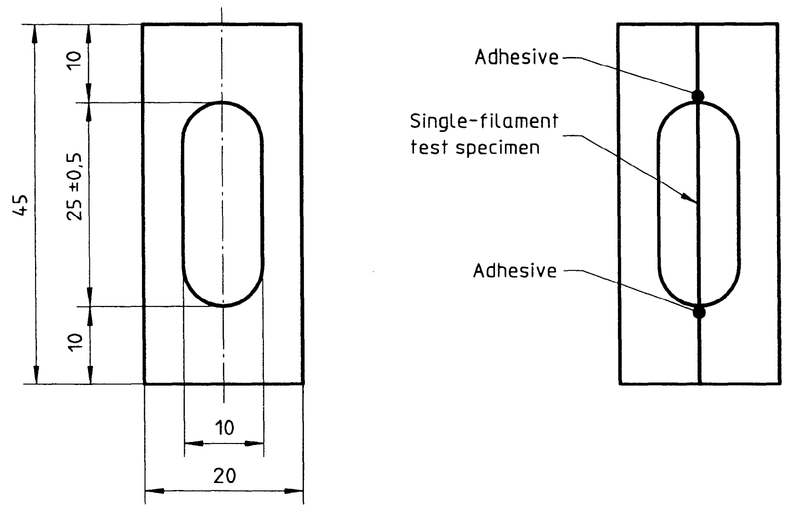
**7.2.1** Measure the cross-sectional area of the filaments independently by one of the methods given in ISO 11567 (microscopic determination for transversely cut specimens; calculation from the number of filaments, density and linear density of the yarns; calculation from the diameter as determined by optical microscopy; or calculation from the diameter as determined by laser diffractometry).

When the cross-sectional area is determined from the diameter measured by optical microscopy or laser diffractometry, the same test specimens can be used for the measurement of both cross-sectional area and tensile properties.

**7.2.2** In cases where the cross-sectional area of the fibres is known to vary widely within a given fibre bundle or tow, ensure, if judged necessary, that the tensile strength is determined on filaments for which the cross-sectional area has been measured. In this case, prepare the test specimens and determine the cross-sectional area in accordance with ISO 11567 using optical microscopy or laser diffractometry.

Take care when measuring the cross-sectional area to avoid damage to the filaments.

Dimensions in millimetres




a) Dimensions of mounting

b) Mounting with specimen bonded in place

**Figure 1 — Mounting for single-filament test specimen**

### 7.3 Tensile testing

#### 7.3.1 System compliance

The system compliance $K$ is a correction coefficient applied to the indicated extension to correct for the contribution from the load train system and the specimen-gripping system (see 3.1) and hence give the true specimen gauge-length extension. The procedure for the determination of the system compliance is given in annex A.

Determine the system compliance experimentally for each combination of test machine conditions, grip system and specimen mounting. Subtract the compliance from the indicated extension to give the true specimen gauge-length extension [see 8.2, equations (2) and (3)]. Check the compliance at regular intervals as recommended in the product specification or by the person requesting the test.

#### 7.3.2 Performing the test

**7.3.2.1** Place a single-filament specimen over the centre of the slot of a mounting (5.2). Temporarily fix one end of the specimen to the mounting with a piece of adhesive tape (5.4). Lightly stretch the specimen across the slot and fix the other end to the other end of the mounting with a piece of adhesive tape.

**7.3.2.2** Apply a drop of adhesive (5.3) to the specimen at each end of the mounting slot to bond the specimen firmly in place.

**7.3.2.3** Set the crosshead speed of the tensile-testing machine (5.1) to a value between 1 mm/min and 5 mm/min.

**7.3.2.4** Clamp the mounting in the grips so that the specimen is aligned with the loading axis of the test machine.

**7.3.2.5** Before applying the load, i.e. with the mounting unstrained, cut or burn through both sides of the mounting at mid-gauge. If burning is used, care must be taken to avoid exposing the specimen to the flame. As the filament is very fragile, the specimen breaks occasionally during this step.

**7.3.2.6** Start the recording equipment and load the test specimen to failure.

**7.3.2.7** If the test specimen fails within the grips, discard the result and repeat with a fresh specimen.

## 8 Expression of results

### 8.1 Tensile strength

For each test specimen, calculate the tensile strength $\sigma_f$, expressed in megapascals, of the filament using the equation

$$\sigma_f = \frac{F_f}{A_f} \qquad \dots (1)$$

where

$F_f$ is the maximum tensile force, in newtons;

$A_f$ is the cross-sectional area, in square millimetres, of the filament (see 7.2).

### 8.2 Tensile modulus of elasticity

#### 8.2.1 Method A (see figure 2)

In this method, the tensile modulus of elasticity $E_{f,A}$, expressed in gigapascals, is calculated using the equation



$$E_{f,A} = \frac{\left(\frac{\Delta F_A}{A_f}\right)\left(\frac{L}{\Delta L_A}\right)}{1 - K\left(\frac{\Delta F_A}{\Delta L_A}\right)} \times 10^{-3} \qquad \dots (2)$$

where

$\Delta F_A$ is the difference in force, in newtons, corresponding to load limits of 400 mN/tex and 800 mN/tex;

$A_f$ is the cross-sectional area, in square millimetres, of the filament (see 7.2);

$L$ is the gauge length, in millimetres, of the specimen;

$\Delta L_A$ is the difference in length, in millimetres, corresponding to load limits of 400 mN/tex and 800 mN/tex;

$K$ is the system compliance, in millimetres per newton, calculated in accordance with annex A.

#### 8.2.2 Method B (see figure 2)

In this method, the tensile modulus of elasticity $E_{f,B}$, expressed in gigapascals, is calculated using the equation

$$E_{f,B} = \frac{\left(\frac{\Delta F_B}{A_f}\right)\left(\frac{L}{\Delta L_B}\right)}{1 - K\left(\frac{\Delta F_B}{\Delta L_B}\right)} \times 10^{-3} \qquad \ldots (3)$$

where

$\Delta F_B$ is the difference in force, in newtons, corresponding to the strain limits selected, depending on the nominal strain at break of the fibre, as specified in table 1;

$A_f$ is the cross-sectional area, in square millimetres, of the filament (see 7.2);

$L$ is the gauge length, in millimetres, of the specimen;

$\Delta L_B$ is the difference in length, in millimetres, corrresponding to the strain limits selected, depending on the nominal strain at break of the fibre, as specified in table 1;

$K$ is the system compliance, in millimetres per newton.

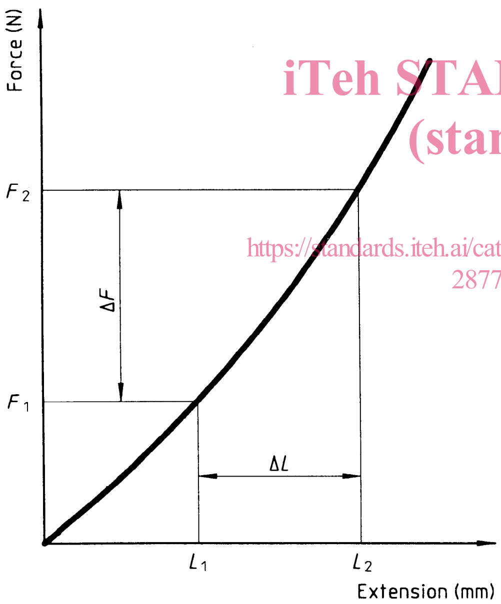



**Figure 2 — Relationship between force and extension during a tensile test**

## 9 Precision

The precision of this method is not known because interlaboratory data are not available. Interlaboratory data are being obtained and a precision statement will be added at the following revision.

**Table 1 — Selection of strain limits**

Values in percent

| Nominal strain at break, $\varepsilon$ | Strain limits |
|---|---|
| $1,2 \leqslant \varepsilon$ | 0,1 to 0,6 |
| $0,6 \leqslant \varepsilon < 1,2$ | 0,1 to 0,3 |
| $0,3 \leqslant \varepsilon < 0,6$ | 0,05 to 0,15 |

NOTE — The nominal strain at break (or percent elongation at maximum load) of commercially available products may be calculated from the nominal tensile strength and tensile modulus of elasticity values for the type of carbon fibre under test.

## 10 Test report

The test report shall include the following particulars:

a) a reference to this International Standard;

b) all details necessary for identification of the fibre sample tested;

c) the cross-sectional area of the filament and the method used to determine it;

d) the adhesive used;

e) the crosshead speed used in the tensile test;

f) the system compliance $K$;

g) the number of specimens tested, including the number of specimens discarded;

h) the individual and mean values of the tensile strength and tensile modulus of elasticity;

i) the method used to calculate the tensile modulus of elasticity, i.e. method A or B;

j) the date of the test;

k) the atmospheric conditions used in the test;

l) any deviation from the procedure specified likely to have had a bearing on the results.

# Annex A
(normative)

## Determination of system compliance

**A.1** Prepare specimen mountings (5.2) with slots of different lengths, in order to produce test specimens of different gauge lengths. These mountings shall all be of the same material and differ only in overall length and slot length. Use slot lengths such as 5 mm, 10 mm, 20 mm, 30 mm and 40 mm, preparing at least three mountings for each slot length and ensuring that, for each slot length, the length of the slot is the same to within ± 0,5 mm.

**A.2** Mount filaments on the mountings, taking care that, for each slot length, the gauge length is the same to within ± 0,5 mm, and determine the force-extension curve for each of the specimens as in 7.3.2.

**A.3** Analyse the force-extension curve as follows:

a) read $\Delta F$ and $\Delta L$ from the force-extension curve (see figure 2);

b) plot the ratio $\Delta L/\Delta F$ against the gauge length $L$, with $\Delta L/\Delta F$ as ordinate and $L$ as abscissa, as shown in figure A.1;

c) the system compliance $K$ is given, in millimetres per newton, by the value of the ordinate when the plot is extrapolated back to zero gauge length (i.e. the ordinate at the origin).



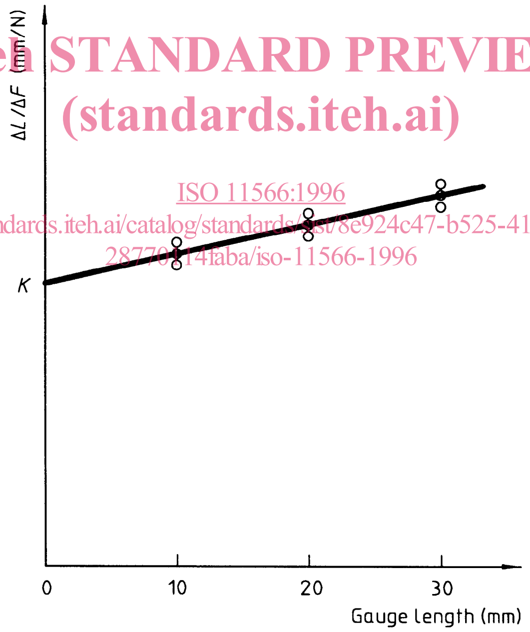



**Figure A.1 — Determination of system compliance $K$**

**ICS 59.100.20**

**Descriptors:** fibres, mineral fibres, carbon fibres, yarns, filaments, tests, tension tests, determination, tensile properties, tensile strength.

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