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Plastics — Determination of tensile properties —

Part 5: Test conditions for unidirectional fibre-reinforced plastic composites

Plastiques — Détermination des propriétés en traction —

Partie 5: Conditions d'essai pour les composites plastiques renforcés de fibres unidirectionnelles

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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.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 13, *Composites and reinforcement fibres*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 249, *Plastics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This third edition cancels and replaces the second edition (ISO 527-5:2009), which has been technically revised. The main changes compared to the previous edition are as follows:

— gripping force or pressure (e.g. via torque or manometer depending on gripping system used) has been adjusted;

— a new Annex B (Use of unbonded tabs and conditions for gripping tab-less specimens using fine grip faces) has been added.

A list of all parts in the ISO 527 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Plastics — Determination of tensile properties —

Part 5:
Test conditions for unidirectional fibre-reinforced plastic composites

1 Scope

This document specifies the test conditions for the determination of the tensile properties of unidirectional fibre-reinforced plastic composites, based upon the general principles given in ISO 527-1.

NOTE Isotropic and orthotropic reinforced materials are covered by ISO 527-4.

The methods are used to investigate the tensile behaviour of the test specimens and for determining the tensile strength, tensile modulus, Poisson's ratios and other aspects of the tensile stress-strain relationship under the conditions defined.

The test method is suitable for all polymer matrix systems reinforced with unidirectional fibres and which meet the requirements, including failure mode, set out in this document.

The method is suitable for composites with either thermoplastic or thermosetting matrices, including preimpregnated materials (prepregs). The reinforcements covered include carbon fibres, glass fibres, aramid fibres and other similar fibres. The reinforcement geometries covered include unidirectional (i.e. completely aligned) fibres and rovings and unidirectional fabrics and tapes.

The method is not normally suitable for multidirectional materials composed of several unidirectional layers at different angles (see ISO 527-4).

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 527-1:2019, *Plastics — Determination of tensile properties — Part 1: General principles*

ISO 1268 (all parts), *Fibre-reinforced plastics — Methods of producing test plates*

ISO 2818, *Plastics — Preparation of test specimens by machining*

ISO 16012, *Plastics — Determination of linear dimensions of test specimens*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

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

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at https://www.electropedia.org/

3.1
gauge length
L_0
initial distance between the gauge marks on the central part of the test specimen

Note 1 to entry: It is expressed in millimetres (mm).

Note 2 to entry: The values of the gauge length that are indicated for the specimen types in the different parts of ISO 527 represent the maximum relevant gauge length.

[SOURCE: ISO 527-1:2019, 3.1]

3.2
thickness
h
smaller initial dimension of the rectangular cross-section in the central part of a test specimen

Note 1 to entry: It is expressed in millimetres (mm).

[SOURCE: ISO 527-1:2019, 3.2]

3.3
width
b_1
larger initial dimension of the rectangular cross-section in the central part of a test specimen

Note 1 to entry: It is expressed in millimetres (mm).

[SOURCE: ISO 527-1:2019, 3.3]

3.4
test speed
v
rate of separation of the gripping jaws

Note 1 to entry: It is expressed in millimetres per minute (mm/min).

[SOURCE: ISO 527-1:2019, 3.5]

3.5
stress
σ
normal force per unit area of the original cross-section within the *gauge length* (3.1)

Note 1 to entry: It is expressed in megapascals (MPa).

Note 2 to entry: In order to differentiate from the true stress related to the actual cross-section of the specimen, this stress is frequently called “engineering stress”.

Note 3 to entry: σ for type A specimens is defined as σ_1 and for type B specimens as σ_2 (see 3.9, Figure 2 and Clause 6 for definitions of these directions).

[SOURCE: ISO 527-1:2019, 3.6, modified — Domain “<engineering>” and Note 3 to entry has been added.]

3.5.1
strength
σ_m
maximum stress observed during a tensile test

Note 1 to entry: It is expressed in megapascals (MPa).

Note 2 to entry: σ_m for type A specimens is defined as σ_{m1} and for type B specimens as σ_{m2}.

[SOURCE: ISO 527-1:2019, 3.6.2]

3.6
strain
ε
increase in length per unit original length of the gauge

Note 1 to entry: For type A specimens, ε is defined as ε_1 and for type B specimens as ε_2.

Note 2 to entry: It is expressed as a dimensionless ratio, or as a percentage (%).

[SOURCE: ISO 527-1:2019, 3.7]

3.6.1
strain at strength
failure strain
ε_m
strain at which the *strength* (3.5.1) is reached

Note 1 to entry: For type A specimens, ε_m is defined as ε_{m1} and for type B specimens as ε_{m2}.

Note 2 to entry: It is expressed as a dimensionless ratio, or as a percentage (%).

[SOURCE: ISO 527-1:2019, 3.7.3]

3.7
tensile modulus
modulus of elasticity in tension
E
slope of the stress-strain curve σ(ε) in the interval between the two strains ε' = 0,05 % and ε'' = 0,25 % (see Figure 1)

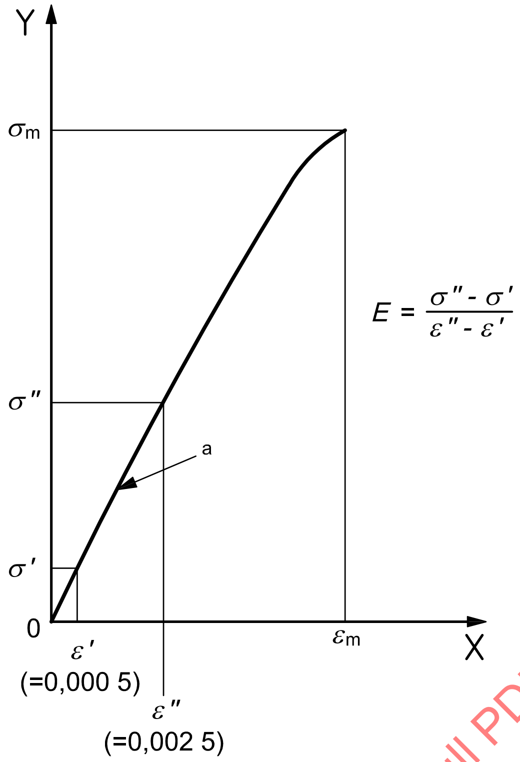
Note 1 to entry: It is expressed in megapascals (MPa).

Note 2 to entry: It may be calculated either as the chord modulus or as the slope of a linear least-squares regression line in this interval.

Note 3 to entry: This definition does not apply to films.

Note 4 to entry: E for type A specimens is defined as E_1 and for type B specimens as E_2.

[SOURCE: ISO 527-1:2019, 3.9.]



Key

X strain, ε

Y stress, σ

[a] Slope E.

Figure 1 — Stress-strain curve

3.8
Poisson's ratio
μ
negative ratio of the strain change $\Delta\varepsilon_n$, in one of the two axes normal to the direction of extension, to the corresponding strain change $\Delta\varepsilon_l$ in the direction of extension, within the linear portion of the longitudinal versus normal strain curve.

Note 1 to entry: It is expressed as a dimensionless ratio.

Note 2 to entry: Since the lateral strain change $\Delta\varepsilon_n$ is a negative number and the longitudinal strain change $\Delta\varepsilon_l$ is positive, the Poisson's ratio as defined in ISO 527-1:2019, 3.10 is a positive number.

Note 3 to entry: μ_{12} is the major Poisson's ratio of a UD composite, describing the dimensional change in 2-direction as a result of a load applied in 1-direction for type A specimens (see 3.9 and Figure 2).

Note 4 to entry: μ_{21} is the minor Poisson's ratio of a UD composite, describing the dimensional change in 1-direction as a result of a load applied in 2-direction for type B specimens (see 3.9 and Figure 2).

[SOURCE: ISO 527-1:2019, 3.10]

3.9
specimen coordinate axes
coordinate axes for the material under test, as shown in Figure 2, the direction parallel to the fibres being defined as the "1"-direction and the direction perpendicular to them (in the plane of the fibres) as the "2"-direction

Note 1 to entry: The "1"-direction is also referred to as the 0° or longitudinal direction and the "2"-direction as the 90° or transverse direction. See Figure 2.

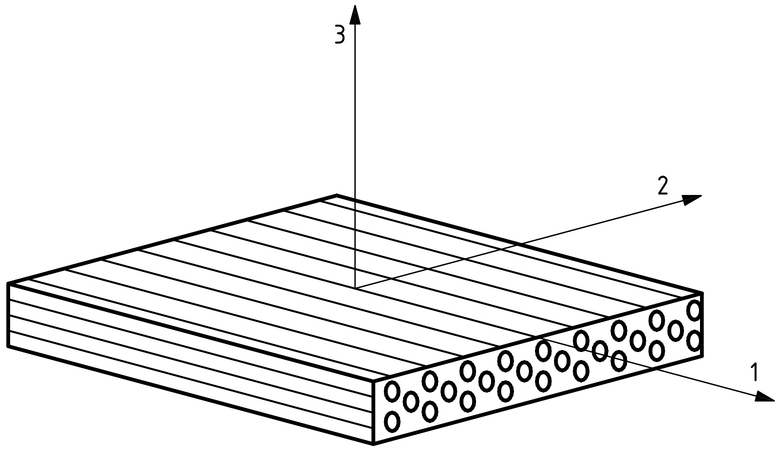


Figure 2 — Unidirectionally reinforced plastic composite showing axes of symmetry

4 Principle

According to ISO 527-1:2019, Clause 4.

5 Apparatus

The apparatus shall conform to ISO 527-1:2019, Clause 5, except for the following:.

The micrometre or its equivalent (in accordance with ISO 16012:2015, 5.5) shall read to 0,01 mm or better. It shall have a suitable-size ball ended anvil if used on irregular surfaces and a flat anvil if used on flat, smooth (e.g. machined) surfaces.

Care shall be exercised to ensure that the pressure exerted by the grips (see ISO 527-1:2019, 5.1.3) is only sufficient to prevent the specimen slipping in the grip when loaded to failure. Excessive grip pressure may cause crushing of the specimen due to the low transverse strength of these materials. Hydraulic grips which can be set at a constant grip pressure are preferred.

If strain gauges bonded to the specimen are used, the errors produced by the transverse effect on the transverse gauge will generally be much larger for anisotropic composites than for metals, which are isotropic. Accurate measurement of Poisson's ratio requires correction for this effect.

It is recommended that alignment of the specimen and loading train be checked as described in Annex A.

6 Test specimens

6.1 Shape and dimensions

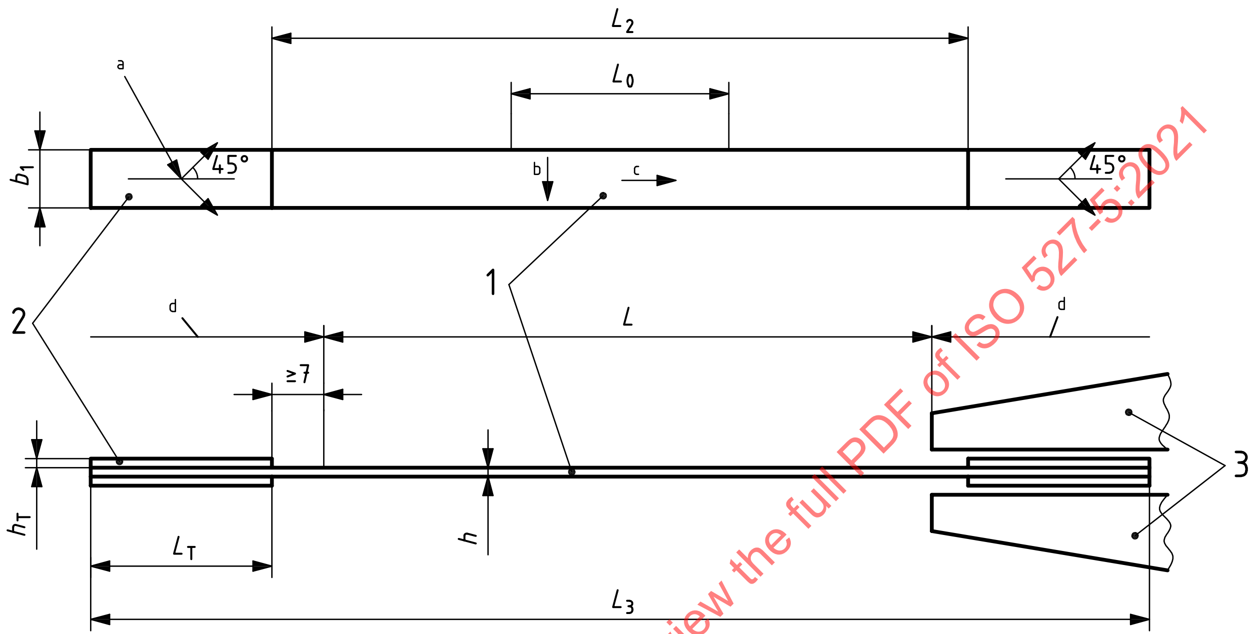
6.1.1 General

The method is performed using one of two different types of test specimen, depending on the direction of the applied stress relative to the fibre direction. Two types of test specimen are specified for use with this document, depending on the direction of test relative to the fibre direction, as detailed and illustrated in Figure 3. Type A is used for testing in direction parallel to the fibres with end tabs. Type B is used for testing in direction transverse to the fibres with end tabs. Type A and B can also be used with unbonded tabs or without tabs using fine grip faces and careful control of the gripping force (see Annex B).

To decide whether to use specimens with or without bonded tabs, initially carry out tests without using bonded tabs. If these tests are unsuccessful, i.e. if almost all specimens break in the grips (see Clause 7), perform tests on specimens with bonded end tabs.

In the following paragraphs, the specimen thicknesses are defined. If materials cannot be manufactured in the appropriate thickness because of unavoidable reasons, such as a higher area weight or manufacturing from pultrusion in a different thickness, the nearest possible thickness shall be chosen.

Dimensions in millimetres



Key

1 specimen

2 tab

3 jaws

a Tab-fibre orientation.

b Fibre direction in type B specimen.

c Fibre direction in type A specimen.

d Zone covered by jaws.

Dimensions in millimetres

		Type A	Type B
L_3	Overall length	≥ 250	≥ 250 (see Note 2)
L_2	Distance between end tabs	150 ± 1	150 ± 1
b_1	Width	15 ± 0,5	25 ± 0,5
h	Thickness	1 ± 0,2	2 ± 0,2
L_0	Gauge length (recommended for extensometers)	50 ± 1	50 ± 1
L	Initial distance between grips (nominal)	136	136
L_T	Length of end tabs	> 50	> 50 (see NOTE 2)
h_T	Thickness of end tabs	0,5 to 2	0,5 to 2

NOTE 1 Requirements on specimen quality and parallelism are given in ISO 527-1:2019, 6.4.

NOTE 2 For specimens taken from filament-wound plates prepared using ISO 1268-5, an overall specimen length of 200 mm is acceptable, with an end-tab length of 25 mm.

Figure 3 — Type A and type B specimens

6.1.2 Type A specimen (for longitudinal direction)

Type A specimens shall have a width of 15 mm ± 0,5 mm, an overall length of 250 mm and a thickness of 1 mm ± 0,2 mm or, for specimens from filament-wound test plates, a thickness of 2 mm ± 0,2 mm. The sides of each individual specimen shall be parallel to within 0,2 mm.

6.1.3 Type B specimen (for transverse direction)

Type B specimens shall have a width of 25 mm ± 0,5 mm, an overall length of 250 mm and a thickness of 2 mm ± 0,2 mm. The sides of each individual specimen shall be parallel to within 0,2 mm.

For type B specimens taken from filament-wound plates prepared using ISO 1268-5, a test specimen length of 200 mm is acceptable.

6.2 Preparation of specimens

6.2.1 General

In the case of moulding and lamination materials, prepare a test plate in accordance with the relevant part of ISO 1268 or another specified/agreed procedure. Cut individual specimens, or groups of specimens (see Annex C), from the test plate.

In the case of finished products (for example, for quality control during manufacture or on delivery), take specimens from flat areas.

Take all specimens with their axis within 0,5° of the mean fibre axis.

Parameters for machining specimens shall be as specified in ISO 2818. Further guidance on cutting out specimens is given in Annex C.

6.2.2 End tabs

The ends of the specimen type A and B shall be reinforced with end tabs, preferably made of cross-ply or fabric glass-fibre/resin laminate with the fibres at ±45° to the specimen axis. The tab thickness shall be between 0,5 mm and 2 mm, with a tab angle of 90° (i.e. not tapered).

Alternative tabbing arrangements are permissible, but shall be shown, before use, to give at least equal strength and no greater coefficient of variation (see ISO 527-1:2019, 10.5 and ISO 3534-1[1]) than the recommended tabs. Possible alternatives include tabs made from the material under test, mechanically fastened tabs, unbonded tabs made of rough materials (such as emery paper or sandpaper, and the use of roughened grip faces), and fine grip faces without tabs as described in Annex B.

If the test is carried out on untabbed specimens, the distance between the grips shall be the same as that between the tabs of tabbed specimens. Care should be given to the contact part at the edge of grip faces.

6.2.3 Application of end tabs

Bond the end tabs to the specimen with a high-stretch adhesive in accordance with Annex C.

NOTE The same procedure can be used for individual specimens and for a group of specimens.

6.3 Gauge marks

Gauge marks shall be in accordance with ISO 527-1:2019, 6.3.

6.4 Checking the specimens

Checking of specimens shall conform to ISO 527-1:2019, 6.4.

7 Number of specimens

According to ISO 527-1:2019, Clause 7, except the following.

Specimens of type B that break inside the grips or at grips edge regions are invalid. Those specimens shall be discarded and further specimens shall be tested.

8 Conditioning

Conditioning shall be in accordance with ISO 527-1:2019, Clause 8.

9 Procedure

9.1 Test atmosphere

Test atmosphere shall be in accordance with ISO 527-1:2019, 9.1.

9.2 Measurement of specimen dimensions

The measurement shall conform to ISO 527-1:2019, 9.2, except for the following: The thickness shall be measured to the nearest 0,01 mm.

9.3 Clamping

Clamping shall conform to ISO 527-1:2019, 9.3, except for the following.

Insert the end tabs so that they are 7 mm inside the grip as shown in Figure 3.

NOTE Invalid failure (see Clause 7) of the test specimen inside the grip or at the grips edge regions can often be avoided by adjusting the gripping force or pressure (e.g. via torque or manometer depending on gripping system used) so that it does not cause fracture or crushing of the test specimen. Misalignment of the specimen can also be a reason for the invalid failures described.

9.4 Prestresses

The prestress shall conform to ISO 527-1:2019, 9.4.

9.5 Setting of extensometers and strain gauges and placing of gauge marks

The strain measurement setting shall conform to ISO 527-1:2019, 9.5. Measure the gauge length to an accuracy of 1 % or better.

9.6 Test speed

The test speed for type A specimens shall be 2 mm/min and for type B specimens 1 mm/min.

9.7 Recording of data

The recording of data shall conform to ISO 527-1:2019, 9.7.

10 Calculation and expression of results

10.1 Calculation of all properties for parallel sided specimens (Type A and B)

The property calculation shall conform to ISO 527-1:2019, Clause 10, except that the definitions given in Clause 3 apply and strain values shall be reported to three significant figures.

11 Precision

See Annex B.

12 Test report

The test report shall include the following information:

a) a reference to this document, including the type of specimen and the test speed, written in the following format:

Tensile test	ISO 527-5 / A / 2
Type of specimen	A
Test speed in millimetres per minute	2

b) to q) see ISO 527-1:2019, Clause 12, b) to q), including fibre type, fibre content and fibre geometry (e.g. unidirectional tape) in 12 b);

r) failure mode and location of failure for each specimen.

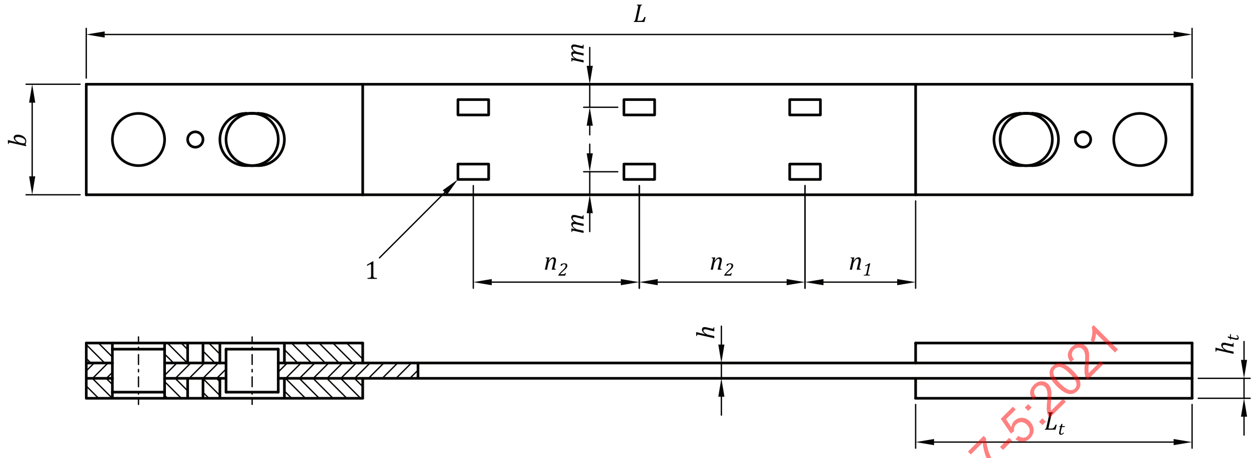
Annex A
(informative)

Alignment of specimens

It is recommended that the alignment of the tensile-testing machine be checked in accordance with ASTM E 1012[2] or ISO 23788[3], using a thin rectangular alignment gauge, instrumented with strain gauges applied at 3 planes (A, B and C) and 4 strain gauges per plane.

The result of the alignment verification depends on the dimensions of the alignment gauge being used, the positions of the strain gauges and their stiffness. Therefore, the alignment gauge only reflects the expected situation when testing with a specimen, if it is similar in shape, dimensions and material. Fibre reinforced polymer composites normally show localized deformations and are therefore not adapted to serve as material for alignment gauges. Steel of a yield stress of >800 MPa and a tensile modulus of approximately 200 GPa, free of significant internal stresses, is considered to be acceptable.

In order to avoid multiple alignment verifications related to each of the specimen shapes and dimensions being used for testing, it is acceptable to verify the testing machine and its loading train by using the alignment gauge shown in Figure A.1. This alignment gauge is in accordance with the Nadcap Audit Criteria AC7122-I and –R[4], Appendix A which is broadly used in the aerospace industry. Results for Bending and Percent Bending obtained using this gauge are higher than results obtained with alignment gauges produced in accordance with the specimen dimensions shown in this document.



Key

1 strain gauge

Symbol	Name	Dimensions in millimetres
L	Overall length	254
h	Height	3,2
b	Width	25,4
L_t	Tab length	64
h_t	Tab height	4,5
m	Strain gauge distance from specimen's edge in transverse direction	5
n_1	Strain gauge distance from tab in specimen's longitudinal direction	25
n_2	Distance between strain gauges in specimen's longitudinal direction	38

Figure A.1 — Example of a standard alignment gauge equipped with 12 strain gauges and exchangeable protection tabs

Verify the alignment situation in at least two positions of the gauge, normally turned by 180° around the centre axis of the alignment gauge. Optionally, measurements in top-down position of the alignment gauge may be required.

In accordance with ASTM E 1012 and ISO 23788 it is important to:

— zero all strain gauges in a free hanging position of the alignment gauge and note the remaining residual bending;

— measure bending (µm/m) in clamped position at zero load or a small preload.

Annex B
(informative)

Use of unbonded tabs and conditions for gripping tab-less specimens using fine grip faces

B.1 Overview

This annex describes guidance for using specimens (1) with unbonded tabs, or (2) without tabs using fine grip faces. For the latter case, consideration should be given to the gripping condition. Care should be taken to ensure that damage to the material in the gripping regions is prevented when testing specimen types with unbonded tabs or those that are tab-less. Final fracture at the edge or inside of the gripping regions, tab-debonding and damage during the tab application process are typical examples of unsatisfactory damage that may occur before and during the tests. Consideration should be given to the correct selection and use of (1) unbonded tabs made of rough materials (such as emery paper or sand paper), or (2) grip faces with fine teeth and appropriate gripping force, to avoid damage to the specimen.

B.2 Test specimens

See Clause 6, except for the description about end tabs (6.2.2 and 6.2.3). This annex permits tab-less gripping conditions as well as alternative tabbing arrangements according to 6.2.2.

B.3 Unbonded tabs

Tests with unbonded tabs are carried out as follows.

Appropriately sized sheets of emery cloth, emery paper or sandpaper are inserted between the grip face and specimen, with the rough surface in contact with the surface of the specimen. Two layers of cloth/paper are recommended.

B.4 Gripping condition without tabs using fine grip faces

— Grip faces with a fine roughness are recommended for this test condition.

— The gripping force should be controlled with care taken not to damage the surface of the specimen. Hydraulic gripping should be used for better control over gripping force.

NOTE Detailed results are given in References [5] to [7].

For thermoplastic matrix composite materials, unbonded tabs or gripping without tabs using fine grip faces give better test results for:

— tests of composite materials made of thermoplastic matrix resin which can be difficult to bond to;

— warpage in laminates is often observed for composite materials made of thermoplastic matrix. In this case, the process of bonding end tabs can cause unnecessary damage to the specimens.

B.5 Comparison of grip conditions

Three test methods are provided which can give equal strength results to tests on specimens with end tabs. These methods have been selected based on the subtraction of the standard deviation from the average strength for tests with tabs.

1) Two layers of emery papers (#400 to # 600) are inserted between the grip faces and specimen.

   Condition 1 in Table B.2 and Figure B.1.

2) Only one layer of emery paper (#400 to #600) is inserted between the grip faces and specimen, with grip faces having a similar morphology to that of the emery paper.

   Condition 2 in Table B.2 and Figure B.1.

3) No unbonded tab is used. Grip faces have a similar morphology to that of the emery paper. The pitch of the grip face serration is less than 0,25 mm, and the gripping force is carefully controlled so as to not damage the specimen.

   Condition 3 and 4 in Table B.2 and Figure B.1.

NOTE Detailed data are available in References [5] to [7].

Table B.1 — Material used for RRT

Fibre	PAN based carbon fibre
Matrix	Polyamide 6
Fibre volume fraction	Ca. 43 %
Tape thickness	0,18 mm
Moulding process	Hot press
Number of layers	7
Specimen number	5

Table B.2 — Comparison of test methods for unbonded tabs (Emery papers), and gripping condition without tabs using fine grip faces

Gripping condition	1	2	3	4	5	6	7	8	9	10	11
Force control : H = Hydlaulic M = Manual screw	M	H	M :Precise	H :Precise	H	H	M	M :Precise	H	M :Precise	M
Roughness of grip face : L = Large (> 1 mm) M = Middle (< 1 mm) F = Fine (< 0,25 mm or Carbide)	M	F	F	F	M	F	M	M	M	L	M
Abrasive paper? Y = Yes N = No	Y :double	Y	N	N	Y	N	Y	N	N	N	N