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Fibre-reinforced plastic composites — Determination of laminate through-thickness properties —

Part 1: Direct tension and compression tests

Composites plastiques renforcés de fibres — Détermination des propriétés dans l'épaisseur d'un composite stratifié —

Partie 1: Essais directs de traction et de compression

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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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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*.

A list of all parts in the ISO 20975 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.

Introduction

Through-thickness properties and the methods specified in this document for their measurement are of interest for engineering specifications and design use. The test geometries recommended are suitable for testing thermoset and thermoplastic-based fibre-reinforced composites, although some materials can be difficult to bond to the loading bars when loaded in tension. A through-thickness dimension of 40 mm is recommended.

For the tension method, consideration has been given to the possibility of out-of-plane bending and end effects influencing the measured tensile properties. Specimen geometries have therefore been specified on the basis of minimising these effects, promoting failure away from the specimen ends (i.e. type II and III) and ease of handling (i.e. machining and testing).

For the compression method, consideration has been given to the possibility of Euler buckling and end effects influencing the measured compressive properties. Specimen geometries have therefore been specified on the basis of minimising these effects, promoting failure away from the specimen ends (i.e. type III) and ease of handling (i.e. machining and testing).

Fibre-reinforced plastic composites — Determination of laminate through-thickness properties —

Part 1: Direct tension and compression tests

1 Scope

This document specifies methods for determining the through-thickness properties (i.e. strength, modulus of elasticity, Poisson's ratio and strain-to-failure) of fibre-reinforced plastic composites using either rectangular prism and/or waisted block specimens. The methods are suitable for use with a variety of aligned and non-aligned, continuous, and discontinuous fibre formats, with both thermoset and thermoplastic matrices, ranging from 20 mm to 40 mm in thickness.

Three specimen types are described in this document. These are:

— Type I - fixed rectangular cross-section along length of specimen. It is the preferred specimen for determining elastic properties.

— Type II - waisted rectangular cross-section, variable cross-section along length of specimen. It is only suitable for determining tensile strength values and is the preferred specimen for highly anisotropic and thermoplastic materials.

— Type III - waisted rectangular cross-section, fixed cross-section along the gauge-length of specimen. It is used to provide both elastic and strength property data and is the preferred specimen for generating a full stress-strain response.

Specimen types I and II are also suitable for use with unreinforced plastics but are unsuitable for use with rigid cellular materials and sandwich structures containing cellular materials.

Two testing modes are covered:

— Method A – Tension

— Method B – Compression

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 291, *Plastics — Standard atmospheres for conditioning and testing*

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

ISO 2602, *Statistical interpretation of test results — Estimation of the mean — Confidence interval*

ISO 5893, *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Specification*

ISO 7500-1, *Metallic materials — Calibration and verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Calibration and verification of the force-measuring system*

3 Terms and definitions

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

ISO and IEC maintain terminology 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
tensile stress
σ_{33T}
tensile force, carried by the test specimen at any particular moment, divided by the initial cross-sectional area of the specimen at the specimen mid-length

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

3.2
tensile failure stress or strength
σ_{33TM}
tensile stress (3.1) at the moment of failure, or when the load reaches a maximum value

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

3.3
tensile failure strain
ε_{33TM}
through-thickness strain at the tensile failure stress or strength, σ_{33TM} (3.2)

Note 1 to entry: It is expressed as a dimensionless ratio or in percent, %.

3.4
modulus of elasticity (chord) in tension
E_{33T}
chord modulus obtained from the ratio of the stress difference (σ” minus σ') and the corresponding strain difference (ε” = 0,002 5 minus ε' = 0,000 5)

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

Note 2 to entry: A ratio of the stress difference (σ” minus σ') and the corresponding strain difference (ε” minus ε') may be used if failure strain, ε_{33TM}, is less than 0,002 5. Where this is the case, ε”, and the corresponding value of σ”, should be taken as the maximum values of strain and stress, respectively, in the linear region of the stress-strain response.

3.5
compressive stress
σ_{33C}
compressive force, carried by the test specimen at any particular moment, divided by the initial cross-sectional area of the specimen at the specimen mid-length

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

3.6
compressive failure stress or strength
σ_{33CM}
compressive stress (3.5) at the moment of failure, or when the compressive load reaches a maximum value

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

3.7
compressive failure strain
ε_{33CM}
through-thickness strain at the compressive failure stress or strength, σ_{33CM} (3.6)

Note 1 to entry: It is expressed as a dimensionless ratio or in percent, %.

3.8
modulus of elasticity (chord) in compression
E_{33C}
chord modulus obtained from the ratio of the stress difference (σ” minus σ') and the corresponding strain difference (ε” = 0,002 5 minus ε' = 0,000 5),

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

Note 2 to entry: A ratio of the stress difference (σ” minus σ') and the corresponding strain difference (ε” minus ε') may be used if failure strain, ε_{33CM}, is less than 0,002 5. Where this is the case, ε”, and the corresponding value of σ”, should be taken as the maximum values of strain and stress, respectively, in the linear region of the stress-strain response.

3.9
Poisson’s ratio
ν
negative ratio of the strain, ε_n, in one of the two axes normal to the direction of loading, to the corresponding strain ε, in the direction of loading, within the initial linear portion of the longitudinal versus normal strain curve

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

3.10
specimen coordinate axes
1, 2, 3
coordinate axes for the material with the fibres preferentially aligned in one direction

Note 1 to entry: The direction parallel with the fibre axes is defined as the “1” direction, the direction perpendicular and in the same plane as the “2” direction, and the direction perpendicular to the 1-2 plane as the “3” direction. For other materials, the “1” direction is normally defined in terms of a feature associated with the production process, such as the long direction for continuous sheet processes. The “2” direction is perpendicular to the “1” direction in the same plane, and the “3” direction is perpendicular to the 1-2 plane. Results for specimens cut parallel with the “3” direction are identified by the subscript “33” (e.g. E_{33T}). See Figure 1.

Note 2 to entry: The “1” direction is also referred to as the 0 degree (0°) or longitudinal directional, the “2” direction as the 90 degree (90°) or transverse direction, and the “3” direction as the through-thickness or out-of-plane direction.

Note 3 to entry: The specimen height corresponds to the through-thickness or out-of-plane direction dimension.

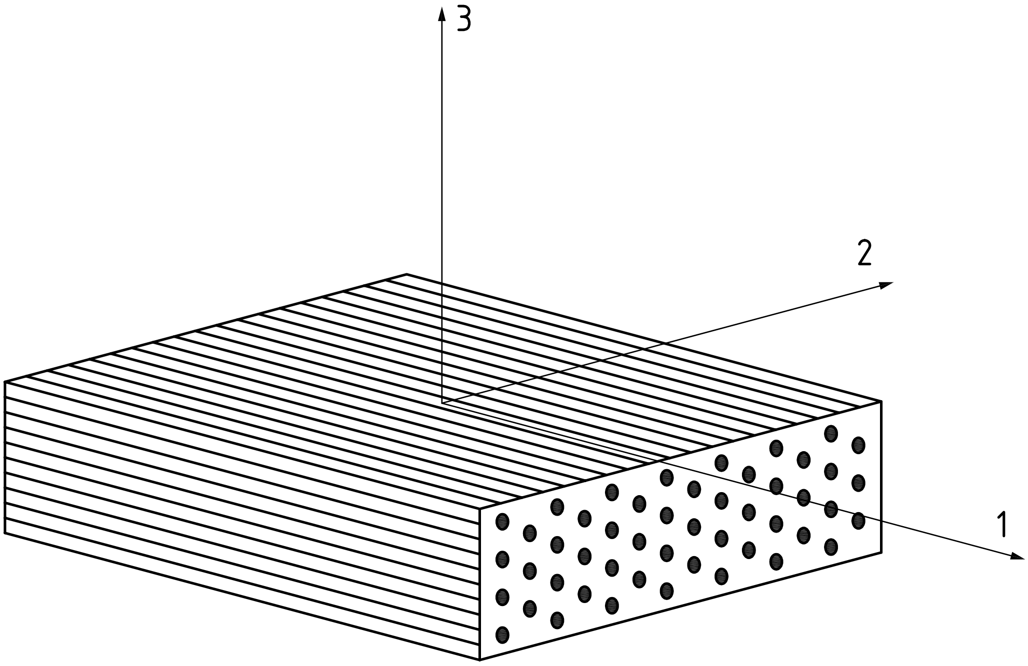

Figure 1 — Aligned fibre-reinforced composite plate element showing specimen coordinate axes

4 Principle

Test specimens are loaded along their major axis at constant speed in tension or compression until the specimen fractures [for type II (tension only) and III specimens], or for type I specimens until the specified strain limit or load is reached. The load and strain (or displacement) are measured depending on the method used.

In tension, the specimens are end-loaded via two metallic (aluminium or stainless steel) loading bars, adhesively bonded to the end of the specimen.

In compression, specimens are end-loaded between two hardened steel parallel platens. Failure of the specimens (type III only) occurs in local shear.

The procedures are performed using specimens, which can be either machined from flat areas of products, machined from semi-finished products such as mouldings, laminates and extruded or cast sheet, or made from test panels manufactured in accordance with ISO 1268.

The methods specify preferred dimensions for each type of specimen. Tests which are carried out on specimens of other dimensions or on specimens which are prepared under different conditions can produce results which are not comparable. Other factors, such as the speed of testing and the condition of the specimens can influence results. Consequently, when comparative data are required, these factors shall be carefully controlled and recorded.

5 Apparatus

5.1 Test machine

5.1.1 General

The test machine shall be in accordance with ISO 5893 as appropriate. The testing machine shall be capable of maintaining the required speed of testing (see 9.6).

5.1.2 Indicators for load and strain

The error for the indicated load shall not exceed ±1 % of applied full load, according to ISO 7500-1, and the error for the indicated strains shall not exceed ±2 %.

5.2 Strain gauges and strain acquisition

Strain shall only be determined by means of strain gauges. For maximum accuracy, the strain shall be measured on all four faces of the specimen (types I and III only). The active length of the strain gauge shall not be more than 2 mm. The gauges, surface preparation and bonding agents shall be chosen to give adequate performance on the subject materials, and suitable strain-recording equipment shall be employed. Strain-recording equipment should have 8 channels, of which 4 channels should be used to measure the axial strain on 4 surfaces and 4 channels should be used to measure the transverse strain on those surfaces.

5.3 Micrometer

Micrometer, or equivalent, reading to less than or equal to 0,01 mm, shall be used to determine the cross-sectional dimensions of the specimen at the specimen mid-length.

The shape of the anvils shall be suitable for the surface being measured (i.e. flat faces for flat, and hemispherical faces for irregular surfaces).

5.4 Loading fixtures

5.4.1 General

The loading arrangement shall load the specimen so that the requirement on allowable specimen bending in 9.10 is achieved. For tensile tests the use of hydraulic grips is recommended. The fixture in use shall be identified in accordance with Clause 12.

The main design points for all test methods and specimen types are alignment (initial and throughout the test) and the prevention of failure at the end of the specimen.

NOTE The use of hydraulic grips has been shown [1] to provide a means of achieving acceptable and repeatable alignment (see 9.10).

5.4.2 Method A - Tension loading

The tensile loading bars shall be in accordance with, or similar to, that shown in Figure 2. Load is applied direct to the end of the specimen via adhesively bonded loading bars. The loading bars shall be manufactured from either aluminium or stainless steel and the contact surfaces shall be flat and parallel to within ±0,01 mm.

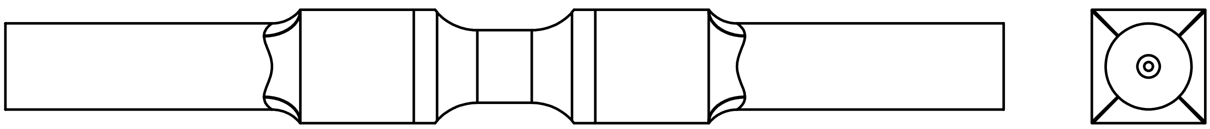

Figure 2 — Schematic of Method A — Tension loading arrangement

5.4.3 Method B - Compression loading

Compression loading shall be between hardened surfaces on the test machine platens, or a die set (see Figure 3). The contact surfaces shall be flat and parallel to within ±0,01 mm.