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BSI Standards Publication

Aerospace series — Fibre reinforced plastics — Test method — Determination of in-plane shear properties (± 45° tensile test)

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National foreword

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A list of organizations represented on this committee can be obtained on request to its secretary.

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English Version

Aerospace series - Fibre reinforced plastics - Test method - Determination of in-plane shear properties (± 45° tensile test)

Série aérospatiale - Matières plastiques renforcées de fibres - Méthode d'essai - Détermination des propriétés en cisaillement plan (traction il ± 45°)

Luft- und Raumfahrt - Faserverstärkte Kunststoffe - Prüfverfahren - Bestimmung der Schubeigenschaften (± 45° Zugversuch)

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EUROPÄISCHES KOMITEE FÜR NORMUNG

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European foreword

This document (EN 6031:2015) has been prepared by the Aerospace and Defence Industries Association of Europe - Standardization (ASD-STAN).

After enquiries and votes carried out in accordance with the rules of this Association, this Standard has received the approval of the National Associations and the Official Services of the member countries of ASD, prior to its presentation to CEN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 2016, and conflicting national standards shall be withdrawn at the latest by May 2016.

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1 Scope

This European Standard specifies the procedure for the determination of the in-plane shear strength and modulus of fibre composites. The procedure is based on the uni-axial tensile stress-strain response of a ± 45° laminate which is symmetrically laminated about the mid-plane.

This standard is applicable to composite laminates manufactured from unidirectional tape or woven fabric reinforcement.

This standard does not give any directions necessary to meet the health and safety requirements. It is the responsibility of the user of this standard to consult and establish appropriate health and safety precautions.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 2374, *Aerospace series — Glass fibre reinforced mouldings and sandwich composites — Production of test panels*

EN 2489, *Aerospace series — Fibre reinforced plastics — Determination of the action of test fluids*

EN 2565, *Aerospace series — Preparation of carbon fibre reinforced resin panels for test purposes* 1)

EN 2743, *Aerospace series — Fibre reinforced plastics — Standard procedures for conditioning prior to testing unaged materials*

EN 2823, *Aerospace series — Fibre reinforced plastics — Test method for the determination of the effect of exposure to humid atmosphere on physical and mechanical characteristics* 1)

3 Terms and definitions

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

3.1
tensile stress at a given moment during the test
longitudinal tensile load experienced by the test specimen at a particular moment during the test, divided by the initial unit cross sectional area within the gauge length

3.2
shear stress at a given moment during the test
the shear stress is defined as the in-plane shear stress with its principal direction under ± 45° with the direction in which the tension load is applied, and its magnitude is half of the tensile stress

3.3
shear strength
the shear strength is the maximum occurring shear stress during the test. For calculation see 9.1.

1) Published as ASD-STAN Prestandard at the date of publication of this standard. http://www.asd-stan.org/

3.4
tensile strain
variation in the longitudinal or transverse distance between points within the test specimen gauge length, produced by a tensile load and expressed with respect to the initial distance between the points *(ε_0 is the longitudinal strain, its value is positive; ε_{90} is the transverse strain of a tensile specimen, its value is negative)*

3.5
shear modulus
slope of the straight line in a shear stress/strain diagram through the points corresponding with two longitudinal strain limits. Unless otherwise defined these longitudinal strains are $(\varepsilon_0)_1 = 500 \times 10^{-6}$ and $(\varepsilon_0)_2 = 2\ 500 \times 10^{-6}$ (see Figure 3). For calculation see 9.2.

4 Principle of the method

Through the use of relations derived from laminated plate theory, expressions are presented which allow the in-plane 0° shear stress-strain curve to be generated from a uniaxial tension test of a ± 45° laminate. Experimental test data from a tensile test are used for generating the shear strength and modulus.

5 Designation of the method

The designation of the used method shall be drawn up according to the following example.

Description block	**Identity block**
Fibre reinforced plastics, determination of in-plane shear properties (± 45° tensile test)	**EN6031**

Number of this standard

6 Apparatus

6.1 Tensile testing machine, accurate to within 1 %, in the load range used.

6.2 Flat face micrometer accurate to the nearest 0,01 mm.

6.3 Vernier caliper accurate to the nearest 0,1 mm.

6.4 This procedure requires load strain data in both the longitudinal and transverse directions. This is accomplished by instrumenting the specimen with longitudinal and transverse strain gauges (5 mm to 10 mm gauge length). The gauges, surface preparation, and bonding agents should be chosen to provide for optimal performance on the subject material, and suitable automatic strain recording equipment shall be employed.

If available, a bi-directional extensometer or a combination of longitudinal and a transverse extensometer can be used. The extensometers shall be accurate to within 1 % in the applied load range.

6.5 Temperature measuring equipment accurate to ± 0,2 °C at the applied test temperature.

6.6 Vacuum bag sealant material.

6.7 Timer/clock.

7 Test specimen

7.1 Test specimen description

The test specimen can consist of either unidirectional tape or woven fabric. Eight plies oriented at + 45° and – 45° to the longitudinal axis are applied: (+ 45, – 45, + 45, – 45) s. To avoid distortions and induced bending the lay-up shall be fully symmetrical.

See Figure 1 for dimensions and tolerances of test specimen.

7.2 Test specimen preparation

The specimens are cut out of plates. The coefficient of variation in thickness measurements shall be smaller than 2 % per plate.

The lay-up shall be alternatively at + 45° and – 45° and symmetrical (see 7.1). The accuracy of the orientation of the fibres shall be within ± 2,5°.

Carbon plates shall be produced according to EN 2565, glass plates in accordance with EN 2374. The process parameters such as bleeders, curing temperature and time, etc. shall be in accordance with the applicable technical specification.

All the specimens shall have a ± 45° lay-up with respect to the specimen axis. Precautions shall be taken to avoid notches, undercuts, rough or uneven surfaces after machining.

7.3 Strain gauges

If strain gauges (see 6.4) are applied for modulus determination, they shall be attached at the centre of the specimen in the longitudinal (0°) and in the transverse (90°) direction.

7.4 Tabs

The specimen shall have tabs (see Figure 1), either by using precured tabs made by two plies of fabric (lay-up ± 45°) or by co-bonding using a suitable prepreg system. The precured tabs shall be bonded on both specimen faces with an adhesive system that will meet the temperature and ageing requirements. Care should be taken that the (co-)bonding temperature does not add any undesired post cure effect to the laminate.

7.5 Number of test specimens

Five specimens shall be tested per test condition, except when otherwise specified in the applicable technical specification. If tests are carried out after ageing or at a temperature different from room temperature, care should be taken to assure that room temperature/dry reference specimens which have been machined from the same plate as the specimen under investigation are also tested.

7.6 Ageing of specimen

ln case of tests after immersion, the conditioning shall be according to EN 2489.

ln case of tests after exposure to humid atmosphere, the conditioning shall be according to EN 2823.

8 Procedure

8.1 Conditioning

The storage and testing of the as-cured specimens (see EN 2743) shall be carried out at (23 ± 2) °C, (50 ± 5) % relative humidity in accordance with EN 2743. Aged specimens shall be tested directly after the ageing procedure (a maximum of 8 h at (23 ± 2) °C is allowed).

8.2 Determination of dimensions

Measure and record before ageing and mechanical testing the thickness and width at 3 points in the non-gripping area of the specimen. Use for the thickness the micrometer (see 6.2) and for the width the vernier caliper (see 6.3) or the micrometer (see 6.2).

8.3 Tensile testing

Place test specimen into wedge action or hydraulic tension grips of the testing machine (see 6.1), in such a way that the tabs are fully clamped; see Figure 2 for details.

Alignment of the test specimen in the test machine shall be as accurate as possible, in order to avoid introducing any bending loads.

The tensile load shall be applied at a crosshead speed of 1 mm/min until 2 % longitudinal strain has been reached; the 0° and 90° strains being recorded versus the load by the strain indicator device (see 6.4) continuously throughout the test. At this point the speed is to be increased to 10 mm/min until failure (if necessary, the strain recording may revert to a longitudinal record of crosshead movement by constant chart feed only).

If strain indicators are used on both sides of the specimen, the strain in each direction is the average of the strain in that direction measured on both sides of the specimen.

NOTE It is allowed to arrange the longitudinal and transverse strain indicators in the wheatstone bridge in such a way that the $(\Delta\varepsilon_0 - \Delta\varepsilon_{90})$ is measured directly (see 9.2).

Record the maximum load carried by the specimen during the test and time to failure.

8.4 Elevated and sub-zero temperature tests

Apply a thermocouple (see 6.5) on the composite material as close as possible to the centre of the specimen and seal the thermocouple from the surrounding air by using vacuum bag sealant (see 6.6).

After a dry specimen has reached a temperature of 2 °C below the required elevated temperature or 2 °C above the required sub-zero temperature, the specimen shall be maintained at the required condition for 5 min prior to testing.

The above time for aged specimen is 1 min.

9 Presentation of the results

9.1 Shear strength (see 3.3)

$$T = 0{,}5 \times \frac{P\,\text{max.}}{w \times t}$$

where

T is the shear strength, in N/mm²;

P max. is the highest tensile load during testing, in N;

w is the average of the three width measurements per specimen, in mm;

t is the average of the three thickness measurements per specimen, in mm.

9.2 Shear modulus (see 3.5)

$$G = 0{,}5 \times \frac{\Delta P}{w \times t \times (\Delta \varepsilon_0 - \Delta \varepsilon_{90})}$$

where (see Figure 3)

G is the shear modulus, in N/mm²;

ΔP is the difference in tensile loads at $(\varepsilon_0)_2 = 2\,500 \times 10^{-6}$ and at $(\varepsilon_0)_1 = 500 \times 10^{-6}$, in N;

w is the average of the three width measurements per specimen, in mm;

t is the average of the three thickness measurements per specimen, in mm;

$\Delta\varepsilon_0$ $= (\varepsilon_0)_2 - (\varepsilon_0)_1 = 2\,000 \times 10^{-6}$;

$\Delta\varepsilon_{90}$ is the difference in transverse strains corresponding to $(\varepsilon_0)_2 = 2\,500 \times 10^{-6}$ and $(\varepsilon_0)_1 = 500 \times 10^{-6}$;

(note: $\Delta\varepsilon_{90}$ is negative).

NOTE If $\Delta\varepsilon_0 - \Delta\varepsilon_{90}$ is measured directly (see Figure 4) than:
ΔP is the difference in tensile loads at $(\varepsilon_0 - \varepsilon_{90})_2 = 4\,500 \times 10^{-6}$ and $(\varepsilon_0 - \varepsilon_{90})_1 = 900 \times 10^{-6}$
$\Delta\varepsilon_0 - \Delta\varepsilon_{90} = (\varepsilon_0 - \varepsilon_{90})_2 - (\varepsilon_0 - \varepsilon_{90})_1 = 3\,600 \times 10^{-6}$

the above strain limits shall be used unless otherwise defined.

10 Test report

The test report shall refer to this standard and shall include the following:

10.1 Complete identification of the material tested, including at least: material designation, supplier, batch number, roll number, fibre areal weight, filament count, processing details, stacking sequence, test orientation.

10.2 All details regarding specimen preparation (including when applicable: tab material, tab adhesive and curing condition of this adhesive).

10.3 The measured specimen dimensions.

10.4 Ageing and/or exposure conditions prior to the test.

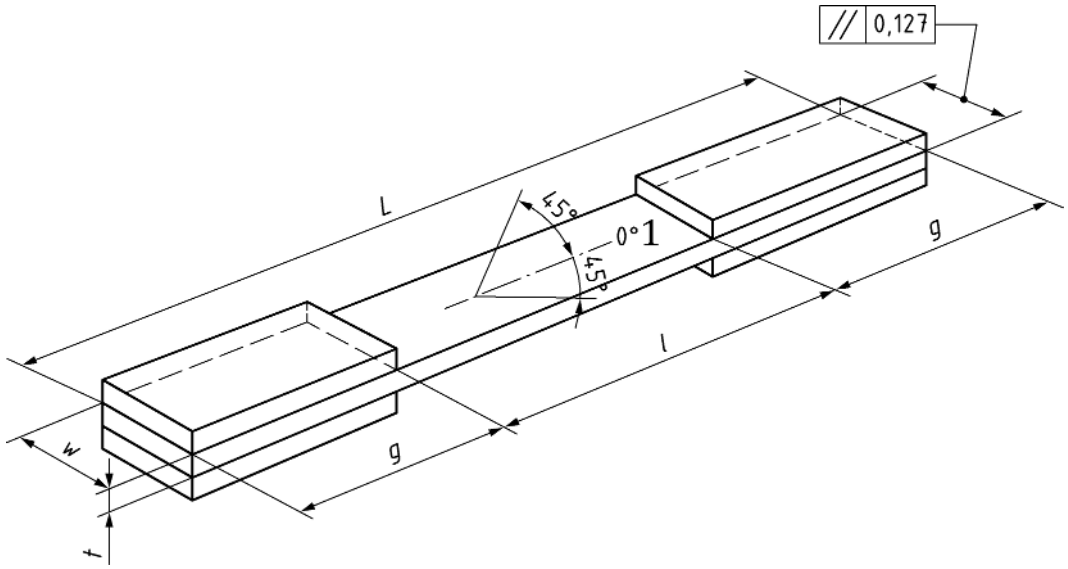
10.5 Date of test, facility and identification of individuals performing the tests.

10.6 Equipment method and test parameters used.

10.7 A typical set of load-deformation curves (both longitudinal and transverse). The individual curves shall be kept in file by the test laboratory.

10.8 Individual values, arithmetic mean and standard deviations per group of specimens of shear strength and shear modulus.

10.9 Any incident which may have affected the results and any deviation from this standard.

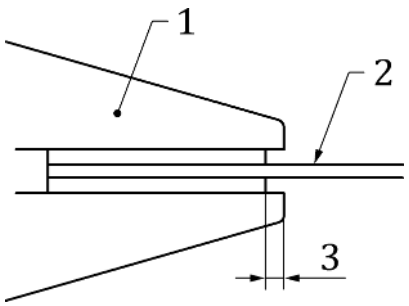


Key

1 Axis

t	8 × cured ply thickness of the used material
w	(25,00 ± 0,25) mm
l	(130 ± 1) mm
L	(230 ± 1) mm
g	(50 ± 1) mm
0°	Main specimen axis in which load is applied (0°)
± 45°	Fibre orientations
Tabs	See 7.4. Parallelism of tab faces must be maintained to within 0,08 mm across the with and length. Tabs faces must be parallel width specimen faces to within 0,04 mm.

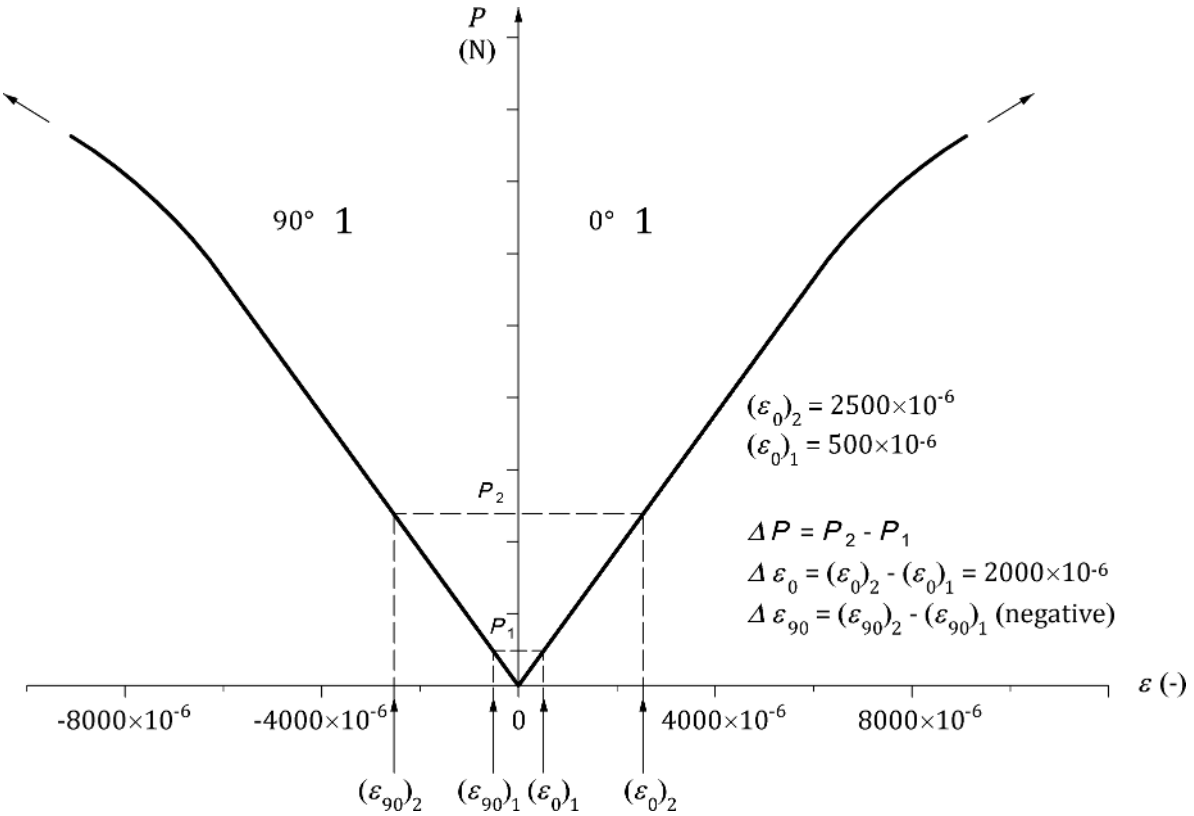
Figure 1 — Test specimen



Key

1 Grip
2 Test specimen
3 (5 to 7) mm

Figure 2 — Position of test specimen in the grips



Key

1 Direction

Figure 3 — *P* – *ε* curve for the determination of the shear modulus G

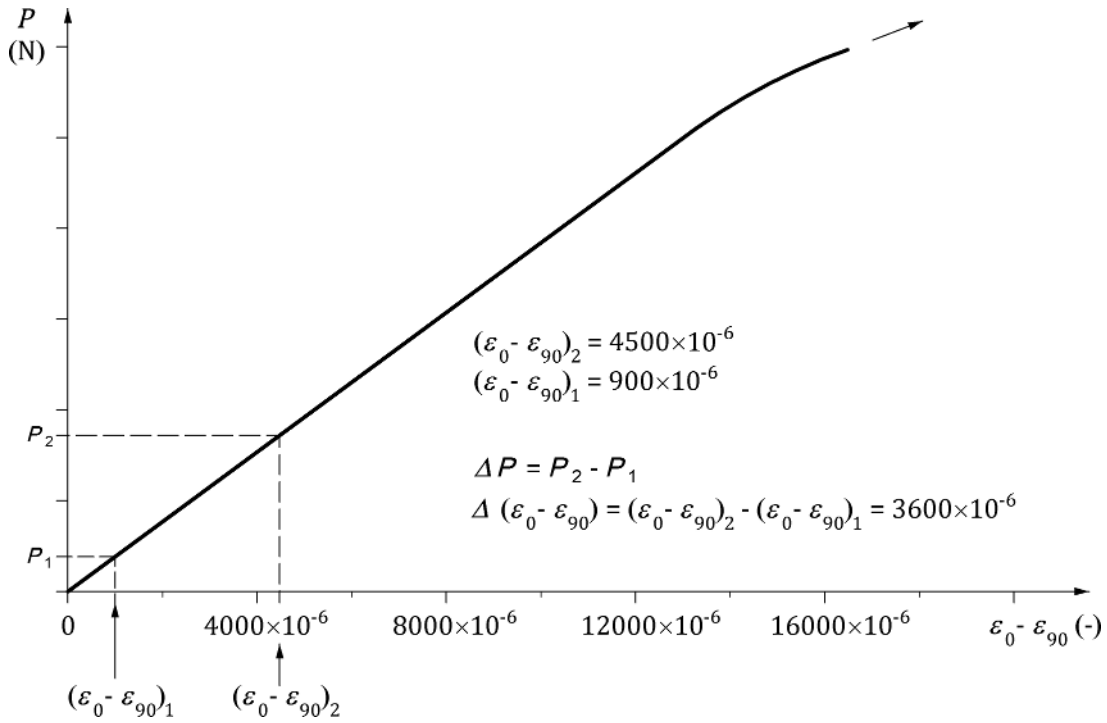


Figure 4 — $P - (\varepsilon_0 - \varepsilon_{90})_2$ curve for the determination of the shear modulus Go

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