

Fibre-reinforced plastic composites — Determination of mode I interlaminar fracture toughness, G_{IC} , for unidirectionally reinforced materials

ICS 83.120

National foreword

This British Standard reproduces verbatim ISO 15024:2001 and implements it as the UK national standard.

The UK participation in its preparation was entrusted to Technical Committee PRI/42, Fibre reinforced thermosetting plastics and prepregs, which has the responsibility to:

- aid enquirers to understand the text;
- present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;
- monitor related international and European developments and promulgate them in the UK.

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

Cross-references

The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled “International Standards Correspondence Index”, or by using the “Find” facility of the BSI Standards Electronic Catalogue.

A British Standard does not purport to include all the necessary provisions of a contract. Users of British Standards are responsible for their correct application.

Compliance with a British Standard does not of itself confer immunity from legal obligations.

This British Standard, having been prepared under the direction of the Materials and Chemicals Sector Policy and Strategy Committee, was published under the authority of the Standards Policy and Strategy Committee on 30 January 2002

Summary of pages

This document comprises a front cover, an inside front cover, the ISO title page, pages ii to iv, pages 1 to 24, an inside back cover and a back cover.

The BSI copyright date displayed in this document indicates when the document was last issued.

Amendments issued since publication

Amd. No.	Date	Comments

© BSI 30 January 2002

ISBN 0 580 38868 9

**Fibre-reinforced plastic composites —
Determination of mode I interlaminar
fracture toughness, G_{IC} , for unidirectionally
reinforced materials**

*Composites plastiques renforcés de fibres — Détermination de la ténacité
à la rupture interlaminaire en mode I, G_{IC} , de matériaux composites à
matrice polymère renforcés de fibres unidirectionnelles*



Reference number
ISO 15024:2001(E)

Contents

Page

Foreword.....	iv
1 Scope	1
2 Normative references	1
3 Terms and definitions	1
4 Principle.....	2
5 Apparatus	5
6 Test specimens.....	7
7 Number of specimens	8
8 Conditioning.....	8
9 Test procedure	9
10 Calculation of G_{IC}	10
11 Precision.....	15
12 Test report	15
Annex A (normative) Preparation and bonding of the load blocks or piano hinges	17
Annex B (informative) Recommendations for testing	18
Annex C (informative) Recommended test result sheet	21
Bibliography.....	24

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 3.

The main task of technical committees is to prepare International Standards. 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.

Attention is drawn to the possibility that some of the elements of this International Standard may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

ISO 15024 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 13, *Composites and reinforcement fibres*.

Annex A forms a normative part of this International Standard. Annexes B and C are for information only.

Fibre-reinforced plastic composites — Determination of mode I interlaminar fracture toughness, G_{IC} , for unidirectionally reinforced materials

1 Scope

1.1 This International Standard specifies a method for the determination of mode I interlaminar fracture toughness (critical energy release rate), G_{IC} , of unidirectional fibre-reinforced plastic composites using a double cantilever beam (DCB) specimen.

1.2 It is applicable to carbon-fibre-reinforced and glass-fibre-reinforced thermosets and thermoplastics.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to applies. Members of ISO and IEC maintain registers of currently valid International Standards.

ISO 291:1997, *Plastics — Standard atmospheres for conditioning and testing*

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

ISO 4588:1995, *Adhesives — Guidelines for the surface preparation of metals*

ISO 5893:—¹⁾, *Rubber and plastics test equipment — Tensile, flexural and compression types (constant rate of traverse) — Description*

3 Terms and definitions

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

3.1

mode I interlaminar fracture toughness
critical energy release rate

G_{IC}

the resistance to the initiation and propagation of a delamination crack in unidirectional fibre-reinforced polymer matrix composite laminates under mode I opening load

NOTE It is measured in joules per square metre.

1) To be published. (Revision of ISO 5893:1993)

3.2

mode I crack opening

the crack-opening mode due to a load applied perpendicular to the plane of delamination using the double cantilever beam specimen shown in Figure 1

3.3

NL point

the point of deviation from linearity on the load versus displacement trace as shown in Figure 2

3.4

VIS point

the point of the onset of delamination, as determined by visual observation, at the edge of the specimen, marked on the load-displacement trace as shown in Figure 2

3.5

5 % / MAX point

the point which occurs first on loading the specimen between:

- a) the point of 5 % increase in compliance ($C_5\%$) from its initial value (C_0) as shown in Figure 2;
- b) the maximum load point as shown in Figure 2

3.6

PROP points

points of discrete delamination length increments beyond the tip of the insert or starter crack tip marked on the load-displacement trace in Figure 2, points where the crack has been arrested being excluded

3.7

delamination-resistance curve

R-curve

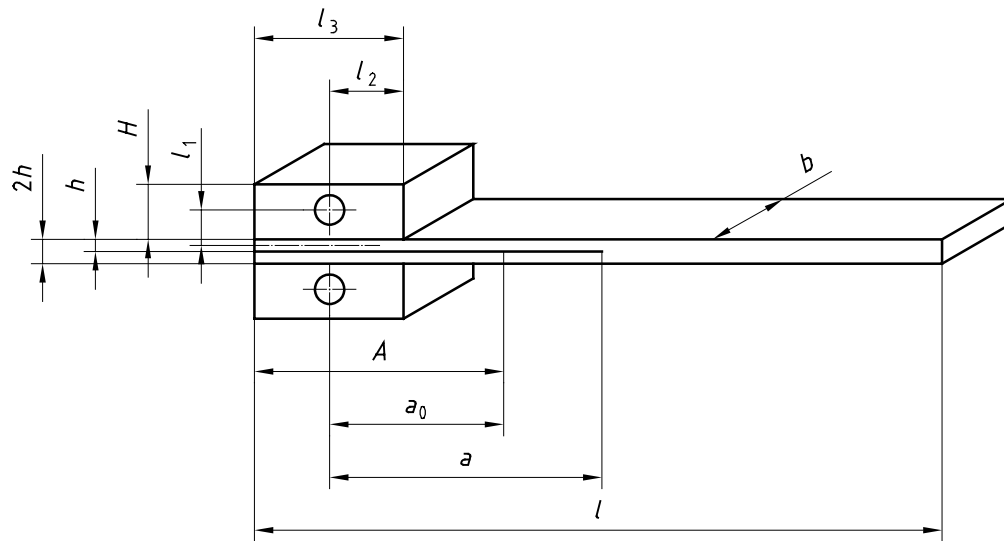
a cross-plot of G_{IC} for initiation and subsequent propagation values for mode I crack opening as a function of delamination length (see clause 10)

4 Principle

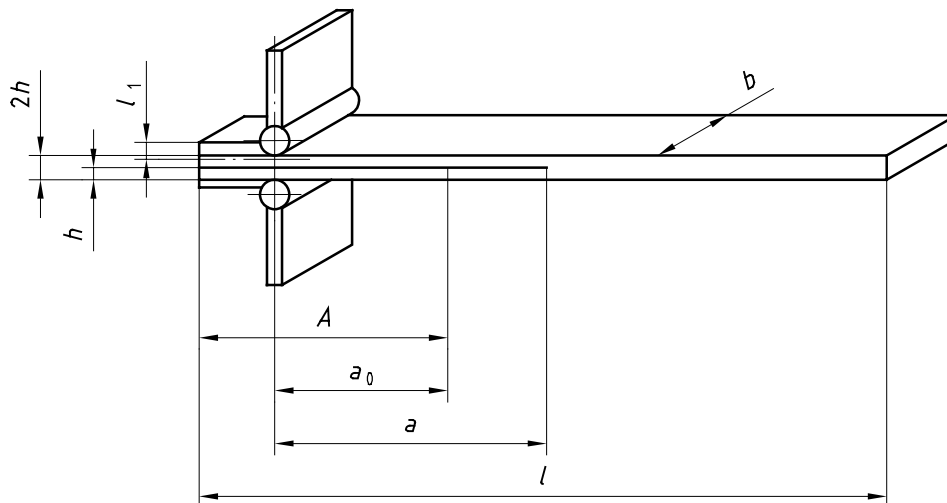
A mode I double cantilever beam (DCB) specimen, as shown in Figure 1, is used to determine G_{IC} , the critical energy release rate, or interlaminar fracture toughness, of fibre-reinforced plastic composites. The test method is limited to zero-degree unidirectional lay-ups only (see clause B.1). Data reduction yields initiation and subsequent propagation values of G_{IC} for mode I opening fracture toughness. A delamination-resistance curve, or R-curve, is generated by plotting G_{IC} on the ordinate as a function of delamination length plotted on the abscissa.

The aim of the test method is to determine initiation values for the composite material tested. Delamination typically occurs between plies of dissimilar orientation in composite structures. However, in the DCB test the delamination cracks are grown between similar zero-degree unidirectional plies, resulting in fibre bridging after the delamination crack initiates. This fibre bridging is an artifact of the DCB test and is not representative of the composite material tested. Fibre bridging is considered to be the main cause for the observed shape of the R-curve, which typically rises before reaching a roughly constant value of G_{IC} for long delamination lengths.

A crack-opening load is applied to the DCB specimen, perpendicular to the plane of delamination, through load blocks or piano hinges under displacement control at a constant rate. The DCB specimen contains a thin, non-adhesive starter film embedded at the midplane as shown in Figure 3, which is used to simulate an initial delamination. The specimen is precracked by unloading the DCB specimen immediately after the first increment of delamination growth from the insert, followed by re-loading. The onset of stable delamination growth is monitored and the delamination initiation and propagation readings are recorded. The R-curve is plotted with the initiation values from both the insert and the mode I precrack, and with the propagation from the precrack. Under certain prescribed circumstances (see 9.2.7), an alternative wedge precracking procedure can be used but is not recommended.



a) Starter delamination using load blocks



b) Starter delamination using piano hinges

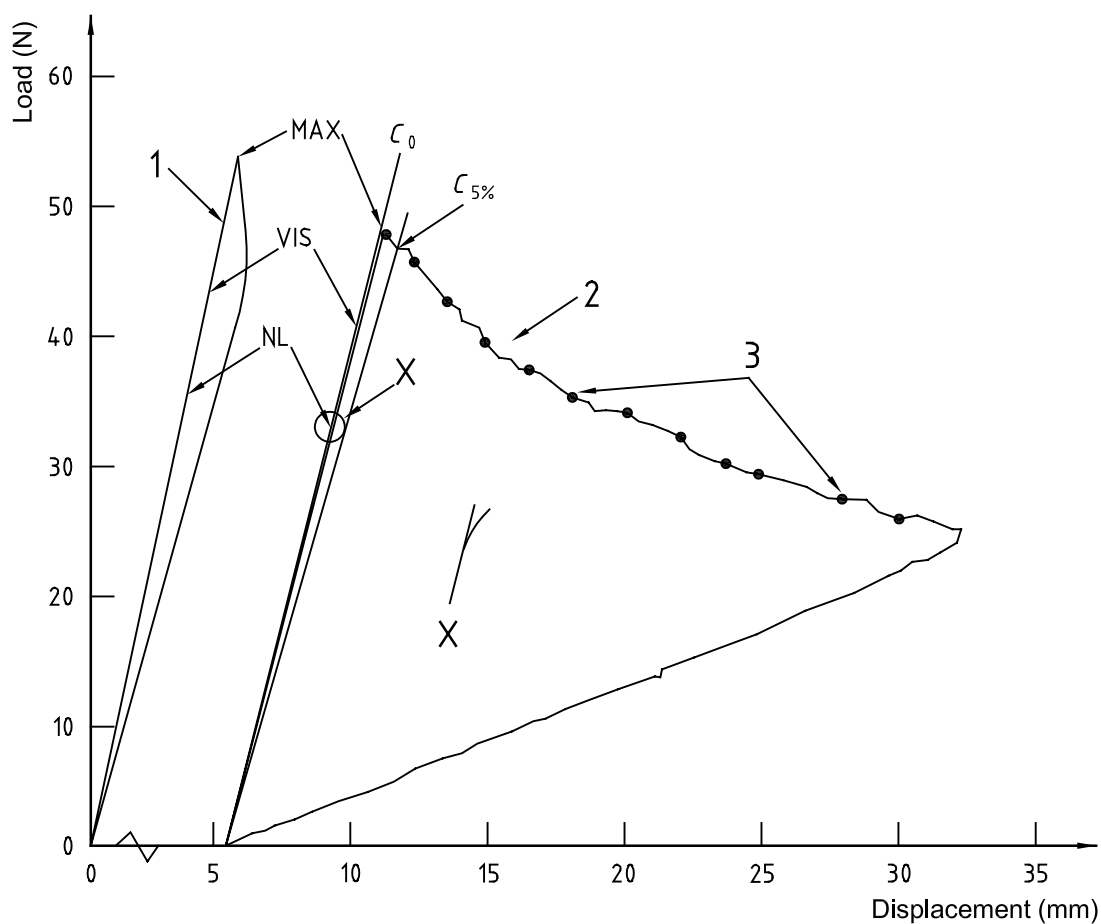
Key

b	Specimen width	l_1	Distance from centre of loading pin (or piano hinge axis) to midplane of specimen
$2h$	Specimen thickness	l_2	Distance from centre of loading pin (or piano hinge axis) to edge of load block (or piano hinge)
a_0	Initial delamination length	l_3	Block length
a	Total delamination length	H	Block thickness
A	Insert length		
l	Specimen length		

NOTE 1 Alternative loading arrangements are (a) load blocks and (b) piano hinges.

NOTE 2 The fibre orientation is parallel to the length l .

Figure 1 — Geometry for the double cantilever beam (DCB) specimen with a starter delamination



Key

- 1 Crack initiation followed by unloading
- 2 Crack propagation
- 3 Crack propagation markers

NOTE Figure shows case where 5 % values follow maximum load, and reload curve has been offset 5 mm for clarity.

Figure 2 — Load-displacement curve for a DCB test showing (1) initiation from the insert followed by unloading and (2) re-initiation from the resulting mode I precrack followed by crack propagation and unloading