
**Composites and reinforcements
fibres — Determination of the fracture
energy of bonded plates of carbon
fibre reinforced plastics (CFRPs) and
metal using double cantilever beam
specimens**





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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).

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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*.

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

The potential benefits to the users of CFRP/metal assemblies of implementing the adhesive fracture energy of DCB specimen based on this document are:

- a) expanding CFRP applications to the fields where it could be used in combination with metallic components;
- b) the detection or the prevention of physical properties loss — such as ion migration and time-related degradation in sealant film, injected calking layer and glass fibre reinforced plastics (GFRPs) layer;
- c) demonstrating the conformity to specified conditions for type certification requirements in the engineering such as aircraft developments;
- d) evaluating the procedures for maintenance, repair and overhaul (MRO) in the engineering operations such as CFRP in aerospace, or in constructions such as steel bridges and industrial applications (e.g. pipework repair, etc.)

Composites and reinforcements fibres — Determination of the fracture energy of bonded plates of carbon fibre reinforced plastics (CFRPs) and metal using double cantilever beam specimens

SAFETY STATEMENT — Persons using this document should be familiar with normal laboratory practice, if applicable. This document does not purport to address all of the safety problems, if any, associated with its use. It is the responsibility of the user to establish appropriate safety and health practices. It is recognized that some of the materials permitted in this document might have a negative environmental impact. As technological advances lead to more acceptable alternatives for such materials, they will be eliminated to the greatest extent possible. At the end of the test, care should be taken to dispose of all waste in an appropriate manner.

1 Scope

This document specifies the test method for the determination of adhesive fracture energy of adhesively bonded plates of carbon fibre reinforced plastic (CFRP) and metal using a double cantilever beam (DCB) specimen. The test method is also applicable to bonded joints between metals and other composite materials, such as glass fibre reinforced plastics.

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 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*

ISO 10365, *Adhesives — Designation of main failure patterns*

ISO 25217, *Adhesives — Determination of the mode 1 adhesive fracture energy of structural adhesive joints using double cantilever beam and tapered double cantilever beam specimens*

3 Terms, definitions and symbols

3.1 Terms and definitions

No terms and definitions are listed in this document.

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 <http://www.electropedia.org/>

3.2 Symbols

A	insert film length (mm), i.e. the distance between the end of the specimen and the tip of the insert film (see Figure 1)
a	crack length (mm), i.e. the distance between the load-line (intersection of plane through pin-hole centres and plane of crack) and the tip of the precrack or crack on the edge of the specimen (see Figure 1)
a_p	pre-crack length (mm), measured from the load-line to the tip of the precrack (see Figure 1)
a_0	insert film length (mm) between the load-line and the tip of the insert film (see Figure 1)
Δa_i	crack growth at i -th load step in the stick-slip behaviour of the crack propagation (see Figure 1)
b	width of the specimen (mm) (see Figure 1)
C	compliance δ/P of the specimen (mm/N)
C_0	initial compliance of the specimen, neglecting start-up effects, e.g. due to play in the specimen fixture (mm/N) (see Figure 2)
$C_{0+5\%}$	initial compliance of the specimen, C_0 , raised by a factor 1,05 (mm/N) (see Figure 2)
E_f	flexural modulus of the arms of the substrate beam, calculated from the crack propagation using DCB test (GPa)
E_1	flexural modulus of the carbon fibre reinforces plastic (CFRP) beam in DCB specimen (GPa)
E_2	flexural modulus of the metal beam in DCB specimen (GPa)
$(EI)_{eq}$	equivalent stiffness (N·m ²) (see Figure 7)
F	large-displacement correction
G_C	adhesive fracture energy for the applied opening mode (J/m ²)
H	height of the load-block (mm) (see Figure 1)
h_1	thickness of the carbon fibre reinforces plastic (CFRP) beam (mm) in DCB specimen (see Figure 1)
h_2	thickness of the metal beam (mm) in DCB specimen (see Figure 1)
h_a	thickness of the adhesive layer (mm) (see Figure 1)
I_1	moment of inertia of area in CFRP (m ⁴)
I_2	moment of inertia of area in metal (m ⁴)
l	total length of the specimen (mm) (see Figure 1)
l_1	distance from the centre of the loading pin to the mid-plane of the arm of the substrate beam to which the load-block is attached (mm) (see Figure 1)
l_2	distance between the centre of the pin-hole in the load-block and the edge of the load-block, measured towards the tip of the insert (starter film) or the tip of the precrack (mm) (see Figure 1)
l_3	total length of the load-block (mm) (see Figure 1)

MAX/5 %	either the maximum load on the load-displacement curve or the point of intersection of a straight line with the load-displacement curve with the slope of the straight line corresponding to C_{0+5} % (see Figure 2)
N	load-block correction
NL	onset of nonlinearity on the load-displacement curve (see Figure 2)
P	load measured by the load-cell of the test machine (N)
$P(\delta)$	is the experimentally obtained load value indicating the maximum extent of the portion of load-displacement curve, from the origin O to the point A in Figure 3
$P_1(\delta)$	is a linearly increasing load value indicated by the dashed line a in Figure 3 , and it is calculated by Formula (8) :
PROP	increments of the crack length during stable crack growth (propagation) that are marked on the load-displacement curve (see Figure 2)
VIS	onset of visually recognizable crack growth at the edge of the specimen that is marked on the load-displacement curve (see Figure 2)
Δ	crack-length correction for a beam that is not perfectly built-in (mm) (see Figure 7)
δ	displacement of the cross-head of the test machine (mm)
ρ	radius of curvature of the bonded plate specimen (m) (see Figure 6)

4 Principle

A double cantilever beam (DCB) specimen is used to determine the adhesive fracture energy of structural bonded joint between a metal and CFRP components

Resistance to both crack initiation and propagation is determined. The resistance to crack initiation is determined from both a non-adhesive insert placed in the adhesive layer and from a precrack. The resistance to crack propagation is determined from the precrack. The adhesive fracture energy versus applied opening load is estimated and a resistance-curve (R-curve), i.e. a plot of the value of the adhesive fracture energy versus crack length, is determined.

In the case where the CFRP/metal interlaminar toughness and interface are significantly tough, the plastic deformation of the metal beam preferentially occurs during the crack propagation. This causes the overestimation of fracture energy values. In such cases, double cantilever beam specimens with dissimilar thicknesses shall be used. An appropriate ratio of the two beams thickness (h_1/h_2) shall be determined such that the plastic deformation of the metal beams during the crack propagation is avoided.

5 Apparatus

5.1 Tensile-testing machine, capable of maintaining a crosshead displacement speed between 0,125 mm/min and 10 mm/min accurate to ± 20 % and higher speeds accurate to ± 10 %. The test tensile testing machine shall be equipped with a fixture to introduce the load to the pins inserted into the loading-blocks. Measurement of test system compliance is described in [Annex C](#) and [Figure C.1](#).

The tensile testing machine shall comply with ISO 7500-1 and the force measurement system shall comply with ISO 7500-1:2018, class 1.

The opening displacement of the test specimen shall be deduced from the position of the test machine cross-head. The test machine shall be equipped with means for recording the complete load versus displacement curves (loading and unloading) during the test.