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Composites and reinforcements fibres — Mechanoluminescent visualization method of crack propagation for joint evaluation

Composites et fibres de renforts — Méthode de visualisation mécanoluminescente de la propagation des fissures pour l'évaluation des assemblages

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Foreword

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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

This document specifies a method for mechanoluminescent visualization of position of crack tip and crack propagation for joint evaluation of the bonded plates of carbon fibre reinforced plastics (CFRPs) to metal assemblies, with a standard specimen and under specified conditions of preparation, conditioning and testing. This method is intended for testing only those bonded plates used in bonding carbon fibre reinforced plastics (CFRPs) to metal assemblies.

The potential benefits to the users of mechanoluminescent visualization method of crack propagation for joint evaluation of the bonded plates of carbon fibre reinforced plastics (CFRPs) to metal assemblies based on this document are:

a) providing precise position and amount of crack propagation, required for quantitatively calculating evaluation of the fracture toughness energy through double cantilever beam (DCB) test for opening mode.

b) providing precise position and amount of crack propagation for end notched flexure (ENF) test and end-loaded split (ELS) test, which evaluate the fracture toughness (mode II) of crack propagation without opening against shear stress.

c) providing visual information of crack propagation behaviour that occurs around adhesive bond layer inside the joint during the adhesive evaluation test, such as tensile shear test, cross tension, etc;

d) for reliable evaluation, providing visual information of asymmetric behaviour of deformation in both adherends, originated from asymmetric flexural rigidity of both adherends, which occurs especially when joining dissimilar materials;

e) for reliable evaluation to confirm health of adherend, providing of visual information of minor damage and fracture in one or both adherends, which causes scattering in the evaluation value of adhesive strength and performance, originated from asymmetric flexural rigidity of both adherends, especially in joining dissimilar materials;

f) expanding CFRP applications to the fields of the combinations with metallic components;

g) 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;

h) demonstrating the conformity to specified conditions for type certification requirements in the engineering such as aircraft developments;

i) evaluating the procedures for maintenance, repair and overhaul (MRO) in the engineering operations such of CFRP aircrafts.

Composites and reinforcements fibres — Mechanoluminescent visualization method of crack propagation for joint evaluation

1 Scope

This document applies to the measurement of crack tip position and crack propagation on the bonding surface of carbon fibre reinforced plastic (CFRPs) and metal assemblies bonded panels.

This document does not apply to the visualization measurement of strain distribution or defects during load application to specimens.

This document does not intend to:

a) omit relevant field tests for CFRP related engineering;

b) generally specify the dimensions of test specimen to represent CFRPs related bonded or fastened structures;

c) superimpose test results for specific applications of the parameters that exceed the range of this document.

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 10365, *Adhesives — Designation of main failure patterns*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 10365 and the following 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
mechanoluminescence
ML
luminescence generated by mechanical stimulation

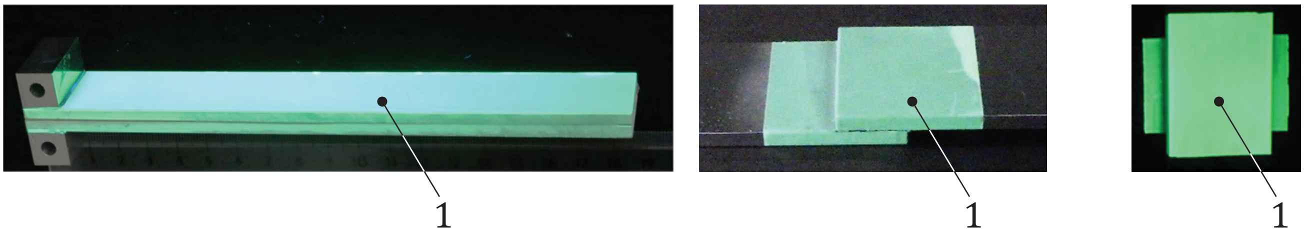
4 Principle

Mechanoluminescence (ML) intensity is proportional to the strain energy of measurement object. Therefore, at crack tip, strain is concentrated under loading, and intense mechanoluminescence can be generated reflecting the strain concentration at the crack tip to visualize the position of the crack tip.

5 Specimen preparation

5.1 Specimen

Various type of bonded plates can be used, such as double-cantilever beam (DCB) specimen, end-notch flexure (ENF) specimen, single lap shear (SLS), end-load split (ELS), double lap shear (DLS), cross tension (CT), etc. (see Figure 1).



DCB specimen   SLS specimen   CT specimen

Key

1 ML paint

Figure 1 — Examples of test specimens for mechanoluminescence visualization of crack tip and crack propagation such as DCB, SLS and CT test

5.2 Surface pre-treatment

Surface pre-treatment can be used to make fine adhesion between mechanoluminescence (ML) paint and surface of specimen, but it is not mandatory. As the method of surface pre-treatment, solvent degreasing, sanding, atmospheric pressure plasma treatment, etc. can be used. However, a method that does not affect the adhesive bonding performance and the strength of the adherend should be selected.

5.3 Preparation for mechanoluminescence paint

Mechanoluminescence (ML) paint is prepared by mixing ML material and polymer resin. It is possible to use any ML materials and polymer materials. Candidate ML material is shown in Annex A.

5.4 Method of applying mechanoluminescence paint

Mechanoluminescence (ML) paint can be apply on the surface of specimen by spraying, dipping, or brushing, etc. It is preferable that the film thickness is uniform, however, even if it is not uniform, it does not affect the crack tip monitoring mechanoluminescence.

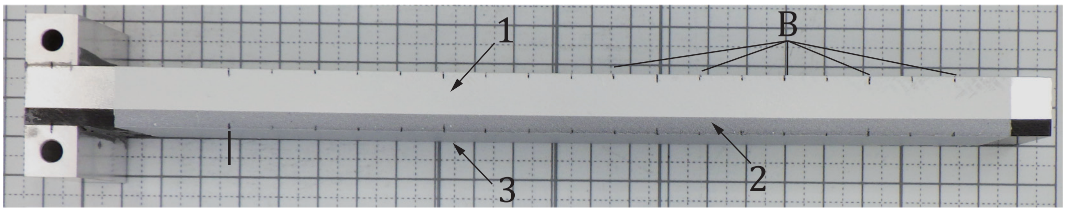
NOTE Conditions for applying mechanoluminescence paint are shown in Annex B (B.1 for DCB test, B.2 for SLS test, B.3 for CT test). Effect on quality of mechanoluminescent paint coating is described for monitoring performance of crack tip in Annex C.

5.5 Post-treatment

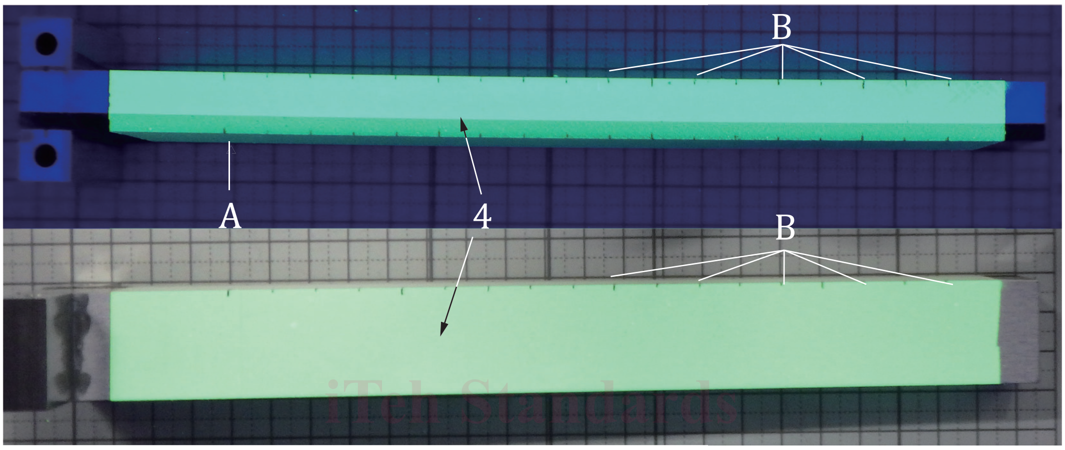
As a post-treatment, in order to cure the mechanoluminescent (ML) paint, thermosetting, photocuring, room temperature curing, etc. can be performed depending on the polymer material of the ML paint. However, condition of the post-treatment should be selected within a range of conditions that does not affect the test piece and bonding performance.

5.6 Scale labelling on specimen

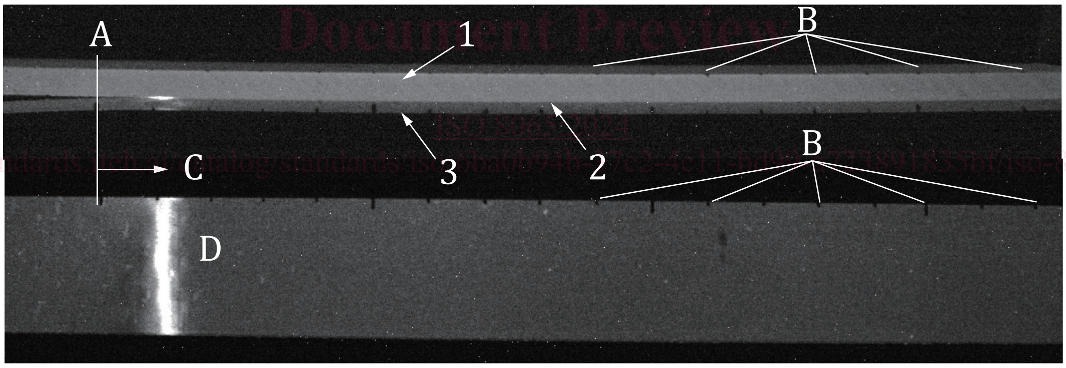
In case it is necessary to determine the length of crack propagation from initial, for example for calculating fracture energy and toughness in DCB test, ENF and c-ELS test, scale labelling from initial crack should be marked with black pen at least every 10 mm (see Figure 2). The scale labelling should be beneficial not only at only one side but also other surface. For example, the scale inside surface can be used to determine crack length and the ones on top and bottom surface should be beneficial to identify the position of mechanoluminescent (ML) line reflecting fracture front in bond line.



a) Photo in sideview



b) Side and top views under UV light



c) ML image

Key

1	metal plate	A	position of initial crack
2	adhesive layer	B	scale labelling
3	CFRTP plate	C	direction of crack propagation
4	ML paint	D	ML line

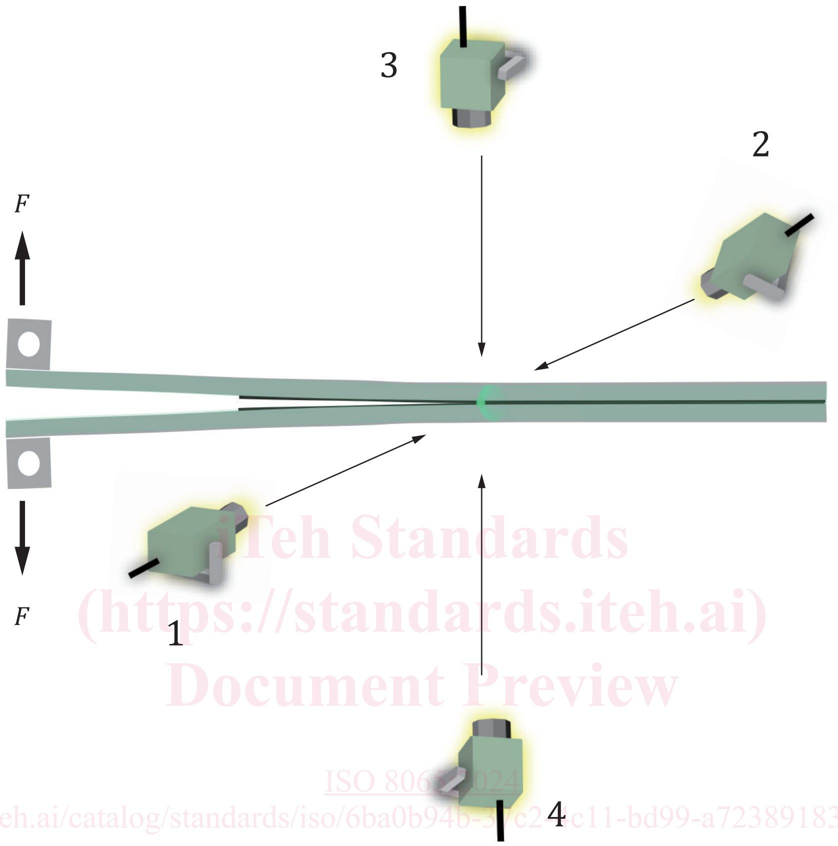
Figure 2 — Example of scale labelling for DCB testing

6 Test equipment and testing procedure

6.1 Measurement equipment for mechanoluminescence

A four-way camera setup of the test piece is recommended (see Figure 3), but at least the tip of the crack to be monitored should be set up with the camera facing the position where it can be recorded.

NOTE 4-way camera system is not mandatory. Number of cameras depends on which face of specimen you want to focus and record.



Key

1 camera 1
2 camera 2
3 camera 3
4 camera 4
F load

Figure 3 — Example of equipment for mechanoluminescence visualization of crack tip and crack propagation

6.2 Test conditions

Mechanical conditions of testing bonded samples should follow the respective joining test standards:

— ISO 22838

— ISO 22841

6.3 Recording conditions of mechanoluminescence

Recording rate, frame-per-second (fps), should be determined in consideration of the crack growth rate in each adhesion evaluation test. In addition, frame-per-second (fps), exposure time, gain, etc. are determined in consideration of the characteristics of the applied mechanoluminescent material. Specifically, the conditions can be set, in which mechanoluminescence should be recorded during crack growth from the initial crack to the end of the testing.

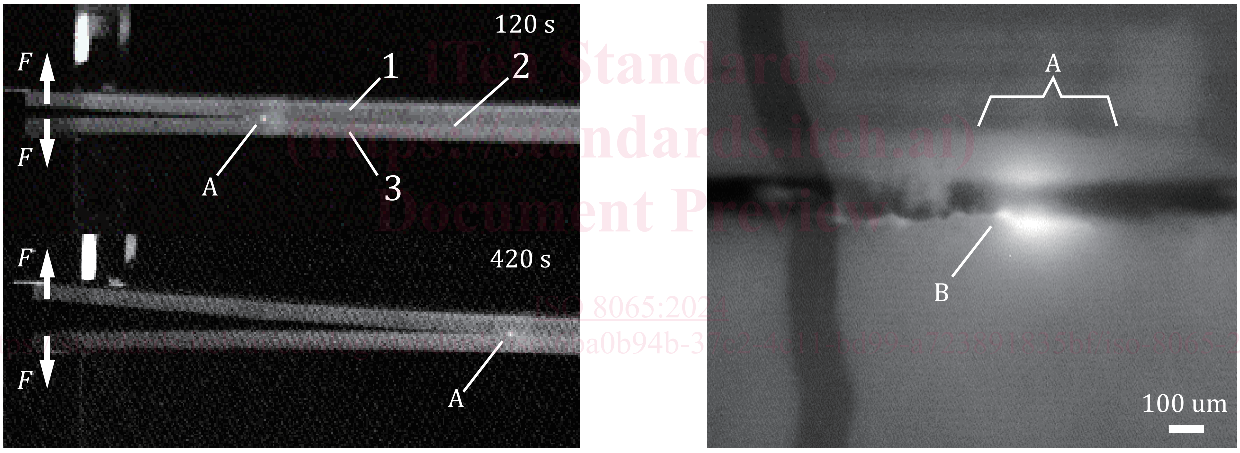
NOTE Examples of recording conditions responding to each testing are shown in Annex B (B.1 for DCB test, B.2 for SLS test, B.3 for CT test).

7 Data analysis

7.1 Position of crack tip

Position of crack tip during testing can be determined as a point with highest mechanoluminescent (ML) luminance in adhesive layer, by reading the position of the rearmost edge (see Figure 4). The ML contour image converted from raw image should be easier to identifying highest ML point reflecting position of crack tip (see Figure 5 and Annex D). From this information of crack tip position, the crack length can be calculated and used to evaluate the adhesive fracture toughness energy in DCB test, ENF test, c-ELS test, etc.

In addition, by visualizing the crack tip by mechanoluminescence, it is possible to identify the fracture origin point and propagation of the adhesive bond during joint evaluation (see Figure 6).



a) ML images at 120 and 420 s loading

b) Microscopic image at crack tip

Key

1 metal plate
2 adhesive layer
3 metal plate
A ML points
B position of crack tip
F load

Figure 4 — Example of crack tip monitoring using mechanoluminescence (DCB test)