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Plastics — Determination of fracture toughness (G_{IC} and K_{IC}) at moderately high loading rates (1 m/s)

Plastiques — Détermination de la ténacité à la rupture (G_{IC} et K_{IC}) à vitesses de charge modérément élevées (1 m/s)

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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).

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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 2, *Mechanical behaviour*.

This second edition cancels and replaces the first edition (ISO 17281:2002), which has been technically revised with the addition of Annex C.

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.

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Introduction

This document is based on a testing protocol developed by the European Structural Integrity Society (ESIS), Technical Committee 4, *Polymers, Polymer Composites and Adhesives*, who carried out the preliminary enabling research through a series of round-robin exercises which covered a range of material samples, specimen geometries, test instruments and operational conditions (see References [3] to [6]). This activity involved about 30 laboratories from 12 countries.

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Plastics — Determination of fracture toughness (G_{IC} and K_{IC}) at moderately high loading rates (1 m/s)

1 Scope

This document specifies the principles and provides guidelines for determining the fracture toughness of plastics in the crack-opening mode (Mode I) by a linear elastic fracture mechanics (LEMF) approach, at load-point displacement rates of up to 1 m/s. It supplements ISO 13586 so as to extend its applicability to loading rates somewhat higher than is the case in the scope of the latter document.

Fracture testing at high loading rates presents special problems because of the presence of dynamic effects: vibrations in the test system producing oscillations in the recorded quantities, and inertial loads producing forces on the test specimen different from the forces sensed by the test fixture. These effects need either to be controlled and, if possible, reduced by appropriate action, or else to be taken into account through proper analysis of the measured data.

The relative importance of such effects increases with increasing testing rate (decreasing test duration). At speeds of less than 0,1 m/s (loading times of greater than 10 ms) the dynamic effects may be negligible and the testing procedure given in ISO 13586 can be applied as it stands. At speeds approaching 1 m/s (loading times of the order of 1 ms) the dynamic effects may become significant but still controllable. The procedure given in ISO 13586 can still be used though with some provisos and these are contemplated in this document. At speeds of several meters per second and higher (loading times markedly shorter than 1 ms) the dynamic effects become dominant, and different approaches to fracture toughness determination are required, which are outside the scope of this document.

The general principles, methods and rules given in ISO 13586 for fracture testing at low loading rates remain valid except where expressly stated otherwise in this document.

The methods are suitable for use with the same range of materials as covered by ISO 13586, i.e.

— rigid and semi-rigid thermoplastic moulding, extrusion and casting materials;

— rigid and semi-rigid thermosetting moulding and casting materials;

and their compounds containing fibres ≤ 7,5mm in length.

In general, fibres 0,1 mm to 7,5 mm in length are known to cause heterogeneity and anisotropy, especially significant in the fracture processes. Therefore, in parallel with Annex B of ISO 13586:2018, where relevant Annex C of this document offers some guidelines to extend the application of the same testing procedure, with some reservations, to rigid and semi-rigid thermoplastic or thermosetting plastics containing such short fibres.

Although the dynamic effects occurring at high loading rates are largely dependent on the material tested as well as on the test equipment and test geometry used, the guidelines given here are valid in general, irrespective of test equipment, test geometry and material tested.

The same restrictions as to linearity of the load-displacement diagram, specimen size and notch tip sharpness apply as for ISO 13586.

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.

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ISO 13586:2018, *Plastics — Determination of fracture toughness (G_{IC} and K_{IC}) — Linear elastic fracture mechanics (LEFM) approach*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13586 apply.

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/

4 Test specimens

4.1 Specimen geometry and preparation

As for the low-rate testing case covered by ISO 13586, two test configurations are recommended, namely the three-point bending [also called single edge notch bend (SENB)] and the compact tension (denoted CT), see Figure 1.

Shape and size, preparation, notching and conditioning of test specimens shall comply with the requirements set out in Clause 4 of ISO 13586:2018.

4.2 Crack length and number of test replicates

4.2.1 Determination of K_{IC}

As in the low-rate testing case covered by ISO 13586, measuring test specimens having the same crack length is adequate for determining K_{IC}. The initial crack length a should be in the range $0{,}45 \leq a/w \leq 0{,}55$. However, in view of the lower degree of accuracy to be expected with measurements at high rates of loading as compared with low-rate testing, it is recommended that at least five replicates, with crack lengths in the range specified above, be used to determine K_{IC}, and the results averaged.

4.2.2 Determination of G_{IC}

At variance with the low-rate testing case covered by ISO 13586, a multi-specimen procedure, using a series of test specimens with identical dimensions but varying crack-length as specified below, shall be applied for determining G_{IC}.

At least 15 valid determinations shall be made, with initial crack length varying over the range $0{,}20 \leq a/w \leq 0{,}70$ for the SENB configuration and $0{,}40 \leq a/w \leq 0{,}75$ for the CT configuration. They may include the five determinations made on test specimens having initial crack lengths in the range $0{,}45 \leq a/w \leq 0{,}55$ to obtain K_{IC}. It is then suggested that, of the remaining ten test specimens to be used, six have initial crack lengths in the range $0{,}20 \leq a/w \leq 0{,}45$ and four in the range $0{,}55 \leq a/w \leq 0{,}70$ in the case of the SENB configuration and three have initial crack length in the range $0{,}40 \leq a/w \leq 0{,}45$ and seven in the range $0{,}55 \leq a/w \leq 0{,}70$ in the case of the CT configuration.

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