BSI Standards Publication

Metallic materials — Unified method of test for the determination of quasistatic fracture toughness

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National foreword

This British Standard is the UK implementation of ISO 12135:2021. It supersedes BS 7448-1:1991 and BS 7448-4:1997, which are withdrawn.

The UK participation in its preparation was entrusted to Technical Committee ISE/101/4, Toughness testing.

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

BS 7448-1:1991, *Fracture mechanics toughness tests — Part 1: Method for determination of K_{Ic}, critical CTOD and critical J values of metallic materials*, and BS 7448-4:1997, *Fracture mechanics toughness tests — Part 4: Method for determination of fracture resistance curves and initiation values for stable crack extension in metallic materials*, have not undergone revision since their publication. BSI Technical Committee ISE/101/04, which is responsible for those standards, decided to work with ISO to revise and update ISO 12135:2016 rather than update those British Standards. This approach is consistent with the decision, taken some years previously, to work with ISO to publish BS EN ISO 15653:2018, *Metallic materials — Method of test for the determination of quasistatic fracture toughness of welds*, which was based on BS 7448-2:1997, *Fracture mechanics toughness tests — Part 2: Method for determination of K_{Ic}, critical CTOD and critical J values of welds in metallic materials* (now withdrawn). BS ISO 12135:2021 now provides a unified standard, bringing together both single point and resistance curve fracture toughness testing of homogeneous metallic materials. This makes sense technically because, without prior knowledge, it is not possible to know how the test material will behave. In addition, BS ISO 12135:2021 now complements BS EN ISO 15653:2018 on weldment testing (which BS 7448-1:1991 and BS 7448-4:1997 did not).

The 2021 edition of ISO 12135, in addition to updating the 2016 edition, now incorporates many of the revisions requested by BSI Technical Committee ISE/101/04 and includes conclusions from research into fracture toughness testing since the 1990s. In general, the methods of specimen preparation and testing remain the same as in BS 7448-1:1991 and BS 7448-4:1997, with the possible exception of the fatigue precracking requirements. However, the lower limit of the initial fracture toughness testing rate has been reduced from 0,5 $MPam^{0,5}$ s^{-1} to 0,3 $MPam^{0,5}$ s^{-1}.

The main changes relate largely to the methods used to analyse the test results. These include better-defined fatigue precracking requirements, which are intended to minimize the risk of overestimating fracture toughness. When the fatigue crack front straightness requirement cannot be achieved, the application of modification techniques, described in BS EN ISO 15653:2018, is now permitted. There is a slight relaxation in the way that crack front straightness is calculated. Now, the difference between the central seven- and nine-point weighted average should not exceed 10 % a_0. In addition, the formulae for calculating crack tip opening displacement (CTOD) have been revised based on research carried out in the UK and Japan. The new formulae are still based on the concept that the specimen rotates around a hinge point located ahead of the crack tip but recognize that CTOD depends on the material yield to tensile strength ratio. The formulae in BS 7448-1:1991 and BS 7448-4:1997 tend to overestimate CTOD for materials that exhibit high strain hardening (i.e. a low yield to tensile strength ratio). This means that CTOD values for these materials calculated according to the

new formulae will be lower than when calculated according to the old formulae. However, CTOD values for low strain-hardening materials will remain largely unchanged. The formulae for calculating *J*-integral are unchanged but have been supplemented to include using crack-mouth opening displacement in addition to load-line displacement.

Furthermore, BS ISO 12135:2021 now incorporates five informative annexes that supplement or are additional to those in either BS 7448-1:1991 or BS 7448-4:1997.

Annex A describes the determination of δ_i and J_i using scanning electron microscopy.

Annex C provides detailed examples of what can be included in the test report.

Annex D contains stress intensity factor and compliance formulae.

Annex F describes the derivation of pop-in formulae.

Annex H describes in detail single-specimen methods for determining CTOD and *J*-integral *R*-curves using partial unloading compliance and electrical resistance methods.

Contractual and legal considerations

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Compliance with a British Standard cannot confer immunity from legal obligations.

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Amendments/corrigenda issued since publication

Date	Text affected
30 November 2022	Implementation of ISO corrected text August 2022: Details in ISO foreword

INTERNATIONAL ISO

Third edition
2021-07-27

Metallic materials — Unified method of test for the determination of quasistatic fracture toughness

Matériaux métalliques — Méthode unifiée d'essai pour la détermination de la ténacité quasi statique

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Contents

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).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 164, *Mechanical testing of metals*, Subcommittee SC 4, *Fatigue, fracture and toughness testing*.

This third edition cancels and replaces the second edition (ISO 12135:2016), which has been technically revised.

The main changes compared to the previous edition are as follows:

— formulae to calculate CTOD have been replaced with those based on rigid rotation assumption throughout; replacing the previous *R*-curve formulae based on CTOD from *J*. CTOD formulae for SENBs are now those based on recent research to include the material yield to tensile strength ratio in the CTOD formulae;

— the determination of *J* directly from displacement defined in terms of CMOD has been included, in addition to the methods based on load line displacement;

— where fatigue precrack straightness requirements cannot be met due to internal residual stresses, the application of modification techniques, originally developed for weld specimens, is now permitted;

— the rotation correction factor for compact specimens has been revised with a new formula;

— editorial changes have been made to improve consistency of terms and definitions used throughout the document.

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.

This corrected version of ISO 12135:2021 incorporates the following corrections:

— in Figure 6 a) the envelope tip angle was corrected from 60° to 30°;

— in 7.3.1, Formula (35) was corrected, with the addition of "Δ" before "a", to read: $J=\left[\frac{F\cdot S}{(B\cdot B_N)^{0,5}W^{1,5}}g_1\left(\frac{a_0}{W}\right)\right]^2\cdot\frac{1-\nu^2}{E}+\frac{\eta_p U_p}{B_N(W-a_0)}\cdot\left[1-\frac{\gamma_p\cdot\Delta a}{(W-a_0)}\right]$;

— in 7.3.2, Formula (38) was corrected, with the deletion of "+z", to read: $\delta=\left[\frac{F\cdot S}{(B\cdot B_N)^{0,5}W^{1,5}}g_1\left(\frac{a_0}{W}\right)\right]^2\frac{1-\nu^2}{mR_{p0,2}E}+\frac{(1-r_p)\Delta a+r_p B_N}{(1-r_p)\Delta a+r_p B_N+a_0}\cdot V_p$;

— in 7.3.2, Formula (43) was corrected, with the deletion of "+z", to read: $\delta=\left[\frac{F}{(B\cdot B_N\cdot W)^{0,5}}g_2\left(\frac{a_0}{W}\right)\right]^2\cdot\frac{1-\nu^2}{2R_{p0,2}E}+\frac{0,54\Delta a+0,46(W-a_0)}{0,54(a_0+\Delta a)+0,46W}\cdot V_p$;

— in Table C.3 the small "v" was corrected to capital "V";

— in Annex D, Formula (D.7) was corrected, with the replacement of $1-\left(\frac{a}{W}\right)^2$ with $\left(1-\frac{a}{W}\right)^2$, to read: $g_4\left(\frac{a}{W}\right)=\frac{15,8}{\left(1-\frac{a}{W}\right)^2}\left\{0,121+1,21\frac{a}{W}-0,159\left(\frac{a}{W}\right)^2-1,47\left(\frac{a}{W}\right)^3+1,30\left(\frac{a}{W}\right)^4\right\}$;

— in Annex H, Formula (H.13) was corrected, with the replacement of "g_6" with "g_4", to read: coefficient $\lambda=\frac{g_4\left(\frac{a_0}{W}\right)}{g_4\left(\frac{a_{0,est}}{W}\right)}$ and the function to read: $g_4\left(\frac{a}{W}\right)$.

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INTERNATIONAL STANDARD ISO 12135:2021

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1 Scope

This document specifies methods for determining fracture toughness in terms of K, δ, J and R-curves for homogeneous metallic materials subjected to quasistatic loading. Specimens are notched, precracked by fatigue and tested under slowly increasing displacement. The fracture toughness is determined for individual specimens at or after the onset of ductile crack extension or at the onset of ductile crack instability or unstable crack extension. In cases where cracks grow in a stable manner under ductile tearing conditions, a resistance curve describing fracture toughness as a function of crack extension is measured. In some cases in the testing of ferritic materials, unstable crack extension can occur by cleavage or ductile crack initiation and growth, interrupted by cleavage extension. The fracture toughness at crack arrest is not covered by this document. Special testing requirements and analysis procedures are necessary when testing weldments, and these are described in ISO 15653 which is complementary to this document.

Statistical variability of the results strongly depends on the fracture type, for instance, fracture toughness associated with cleavage fracture in ferritic steels can show large variation. For applications that require high reliability, a statistical approach can be used to quantify the variability in fracture toughness in the ductile-to-brittle transition region, such as that given in ASTM E1921. However, it is not the purpose of this document to specify the number of tests to be carried out nor how the results of the tests are to be applied or interpreted.

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 3785, *Metallic materials — Designation of test specimen axes in relation to product texture*

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 9513, *Metallic materials — Calibration of extensometer systems used in uniaxial testing*

3 Terms and definitions

For the purposes of this document, the following terms and definitions 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/

3.1
stress intensity factor
K
magnitude of the elastic stress-field singularity for a homogeneous, linear-elastic body

Note 1 to entry: The stress intensity factor is a function of applied force, crack length, specimen size and specimen geometry.