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**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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## 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](http://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](http://www.iso.org/patents)).

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For an explanation on 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 the following URL: [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

The committee responsible for this document is ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 4, *Toughness testing — Fracture (F), Pendulum (P), Tear (T)*.

This second edition cancels and replaces the first edition (ISO 12135:2002), which has been technically revised. It also incorporates the Technical Corrigendum ISO 12135:2002/Cor 1:2008.

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

## 1 Scope

This document specifies methods for determining fracture toughness in terms of  $K$ ,  $\delta$ ,  $J$  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 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. 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 most cases, statistical variability of the results is modest and reporting the average of three or more test results is acceptable. In cases of cleavage fracture of ferritic materials in the ductile-to-brittle transition region, variability can be large and additional tests may be required to quantify statistical variability. Special testing requirements and analysis procedures are necessary when testing weldments and these are described in ISO 15653 which is complementary to this document.

When fracture occurs by cleavage or when cleavage is preceded by limited ductile crack extension, it may be useful to establish the reference temperature for the material by conducting testing and analysis in accordance with ASTM E1921.<sup>[2]</sup>

## 2 Normative references

ISO 12135:2016

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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:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

### 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.

**3.2**  
**crack-tip opening displacement**

$\delta$

<rotation point equation> relative displacement of the crack surfaces normal to the original (undeformed) crack plane at the tip of the fatigue precrack, evaluated using the rotation point formula

**3.3**  
**crack-tip opening displacement**

$\delta_j$

<from  $J$ > estimate of the crack-tip opening displacement, obtained from  $J$

**3.4**  
 **$J$ -integral**

line or surface integral that encloses the crack front from one crack surface to the other and characterizes the local stress-strain field at the crack tip

**3.5**

$J$

loading parameter, equivalent to the  $J$ -integral, specific values of which, experimentally determined by this method of test ( $J_c, J_i, J_w, \dots$ ), characterize fracture toughness under elastic-plastic conditions

**3.6**  
**stable crack extension**

crack extension which stops or would stop when the applied displacement is held constant as a test progresses under displacement control

**3.7**  
**unstable crack extension**

abrupt crack extension occurring with or without prior stable crack extension

**3.8**  
**pop-in**

abrupt discontinuity in the force versus displacement record, featured as a sudden increase in displacement and, generally, a decrease in force followed by an increase in force

Note 1 to entry: Displacement and force subsequently increase beyond their values at pop-in.

Note 2 to entry: When conducting tests by this method, pop-ins may result from unstable crack extension in the plane of the precrack and are to be distinguished from discontinuity indications arising from: i) delaminations or splits normal to the precrack plane; ii) roller or pin slippage in bend or compact specimen load trains, respectively; iii) improper seating of displacement gauges in knife edges; iv) ice cracking in low-temperature testing; v) electrical interference in the instrument circuitry of force and displacement measuring and recording devices.

**3.9**  
**crack extension resistance curves**

$R$ -curves

variation in  $\delta_j$  or  $J$  with stable crack extension

## 4 Symbols and designations

See [Table 1](#).



Table 1 — Symbols and their designations

Symbol	Unit	Designation
$a$	mm	Nominal crack length (for the purposes of fatigue precracking, an assigned value less than $a_0$ )
$a_f$	mm	Final crack length ( $a_0 + \Delta a$ )
$a_i$	mm	Instantaneous crack length
$a_m$	mm	Length of machined notch
$a_0$	mm	Initial crack length
$A_p$	J	Plastic component of the area under the force vs. notch opening displacement diagram (Figure 17)
$\Delta a$	mm	Stable crack extension including blunting
$\Delta a_{\max}$	mm	Crack extension limit for $\delta$ or $J$ controlled crack extension
$B$	mm	Specimen thickness
$B_N$	mm	Specimen net thickness between side grooves
$C$	m/N	Specimen elastic compliance
$E$	GPa	Modulus of elasticity at the pertinent temperature
$F$	kN	Applied force
$F_c$	kN	Applied force at the onset of unstable crack extension or pop-in when $\Delta a$ is less than 0,2 mm offset from the construction line (Figure 2)
$F_d$	kN	Force value corresponding to the intersection of the test record with the secant line (Figure 16)
$F_f$	kN	Maximum fatigue precracking force
$F_m$	kN	Maximum force for a test which exhibits a maximum force plateau preceding fracture with no significant prior pop-ins (Figure 2)
$F_Q$	kN	Provisional force value used for the calculation of $K_Q$
$F_u$	kN	Applied force at the onset of unstable crack extension or pop-in when $\Delta a$ is equal to or greater than 0,2 mm offset from the construction line (Figure 2)
$J$	MJ/m <sup>2</sup>	Experimental equivalent to the $J$ -integral
$J_{c(B)}$	MJ/m <sup>2</sup>	Size sensitive fracture resistance $J$ at onset of unstable crack extension or pop-in when stable crack extension is less than 0,2 mm offset from the construction line ( $B$ = specimen thickness in mm)
$J_g$	MJ/m <sup>2</sup>	$J$ at upper limit of $J$ -controlled crack extension
$J_i$	MJ/m <sup>2</sup>	Size-insensitive fracture resistance $J$ at initiation of stable crack extension
$J_{m(B)}$	MJ/m <sup>2</sup>	Size sensitive fracture resistance $J$ at the first attainment of a maximum force plateau for fully plastic behaviour ( $B$ = specimen thickness in mm)
$J_{\max}$	MJ/m <sup>2</sup>	Limit of $J$ - $R$ material behaviour defined by this method of test
$J_{u(B)}$	MJ/m <sup>2</sup>	Size sensitive fracture resistance $J$ at the onset of unstable crack extension or pop-in when the event is preceded by stable crack extension equal to or greater than 0,2 mm offset from the construction line ( $B$ = specimen thickness in mm)
$J_{uc(B)}$	MJ/m <sup>2</sup>	Size sensitive fracture resistance $J$ at the onset of unstable crack extension or pop-in when stable crack extension cannot be measured ( $B$ = specimen thickness in mm)
$J_o$	MJ/m <sup>2</sup>	$J$ uncorrected for stable crack extension
$J_{0,2BL}$	MJ/m <sup>2</sup>	Size insensitive fracture resistance $J$ at 0,2 mm stable crack extension offset from the construction line
$J_{0,2BL(B)}$	MJ/m <sup>2</sup>	Size sensitive fracture resistance $J$ at 0,2 mm stable crack extension offset from the construction line ( $B$ = specimen thickness in mm)

NOTE 1 This is not a complete list of parameters. Only the main parameters are given here, other parameters are referred to in the text.

NOTE 2 The values of all parameters used in calculations are assumed to be those measured or calculated for the temperature of the test, unless otherwise specified.

Table 1 (continued)

Symbol	Unit	Designation
$K$	MPa $\sqrt{\text{m}}$	Stress intensity factor
$K_f$	MPa $\sqrt{\text{m}}$	Maximum value of $K$ during the final stages of fatigue precracking
$K_{Ic}$	MPa $\sqrt{\text{m}}$	Plane strain linear elastic fracture toughness
$K_{J0,2BL}$	MPa $\sqrt{\text{m}}$	Plane strain linear elastic fracture toughness equivalent to $J_{0,2BL}$
$K_Q$	MPa $\sqrt{\text{m}}$	A provisional value of $K_{Ic}$
$q$	mm	Load-point displacement
$R_m$	MPa	Ultimate tensile strength perpendicular to crack plane at the test temperature
$R_{p0,2}$	MPa	0,2 % offset yield strength perpendicular to crack plane at the test temperature
$S$	mm	Span between outer loading points in a three-point bend test
$T$	°C	Test temperature
$U$	J	Area under plot of force $F$ versus specimen load-point displacement $q$ at the load-line
$U_e$	J	Elastic component of $U$
$U_p$	J	Plastic component of $U$
$V$	mm	Notch-opening displacement
$V_e$	mm	Elastic component of $V$
$V_p$	mm	Plastic component of $V$
$W$	mm	Width of the test specimen
$z$	mm	For bend and straight-notch compact specimens, the initial distance of the notch opening gauge measurement position from the notched edge of the specimen, either further from the crack tip [ $+z$ in Figure 8 b)] or closer to the crack tip [ $-z$ ]; or, for a stepped-notch compact specimen, the initial distance of the notch opening gauge measurement position either beyond ( $+z$ ) or before ( $-z$ ) the initial load-line
$\delta$	mm	Crack-tip opening displacement (CTOD) evaluated using the rotation point formula
$\delta_j$	mm	Crack-tip opening displacement (CTOD) evaluated from $J$
$\delta_{c(B)}$	mm	Size sensitive fracture resistance $\delta$ at the onset of unstable crack extension or pop-in when stable crack extension is less than 0,2 mm crack offset from the construction line ( $B$ = specimen thickness in mm)
$\delta_g$	mm	$\delta$ at the limit of $\delta$ -controlled crack extension
$\delta_{ji}$	mm	Fracture resistance $\delta_j$ at initiation of stable crack extension
$\delta_{m(B)}$	mm	Size sensitive fracture resistance $\delta$ at the first attainment of a maximum force plateau for fully plastic behaviour ( $B$ = specimen thickness in mm)
$\delta_{j,max}$	mm	Limit of $\delta_j$ - $R$ defined by this method of test
$\delta_{u(B)}$	mm	Size sensitive fracture resistance $\delta$ at the onset of unstable crack extension or pop-in when the event is preceded by stable crack extension equal to or greater than 0,2 mm offset from the construction line ( $B$ = specimen thickness in mm)
$\delta_{uc(B)}$	mm	Size sensitive fracture resistance $\delta$ at the onset of unstable crack extension or pop-in when stable crack extension $\Delta a$ cannot be measured ( $B$ = specimen thickness in mm)
$\delta_o$	mm	$\delta$ uncorrected for stable crack extension

NOTE 1 This is not a complete list of parameters. Only the main parameters are given here, other parameters are referred to in the text.

NOTE 2 The values of all parameters used in calculations are assumed to be those measured or calculated for the temperature of the test, unless otherwise specified.

Table 1 (continued)

Symbol	Unit	Designation
$\delta_{J0,2BL}$	mm	Size insensitive fracture resistance $\delta_J$ at 0,2 mm crack extension offset from construction line
$\delta_{J0,2BL(B)}$	mm	Size sensitive fracture resistance $\delta_J$ at 0,2 mm stable crack extension offset from construction line ( $B$ = specimen thickness in mm)
$\nu$	—	Poisson's ratio

NOTE 1 This is not a complete list of parameters. Only the main parameters are given here, other parameters are referred to in the text.

NOTE 2 The values of all parameters used in calculations are assumed to be those measured or calculated for the temperature of the test, unless otherwise specified.

## 5 General requirements

### 5.1 General

The fracture toughness of metallic materials can be characterized in terms of either specific (single point) values (see [Clause 6](#)), or a continuous curve relating fracture resistance to crack extension over a limited range of crack extension (see [Clause 7](#)). The procedures and parameters used to determine fracture toughness vary depending upon the level of plasticity realized in the test specimen during the test. Under any given set of conditions, however, any one of the fatigue-precracked test specimen configurations specified in this method may be used to measure any of the fracture toughness parameters considered. In all cases, tests are performed by applying slowly increasing displacements to the test specimen and measuring the forces and displacements realized during the test. The forces and displacements are then used in conjunction with certain pre-test and post-test specimen measurements to determine the fracture toughness that characterizes the material's resistance to crack extension. Details of the test specimens and general information relevant to the determination of all fracture parameters are given in this method. A flow-chart illustrating the way this method can be used is presented in [Figure 1](#). Characteristic types of force versus displacement records obtained in fracture toughness tests are shown in [Figure 2](#).

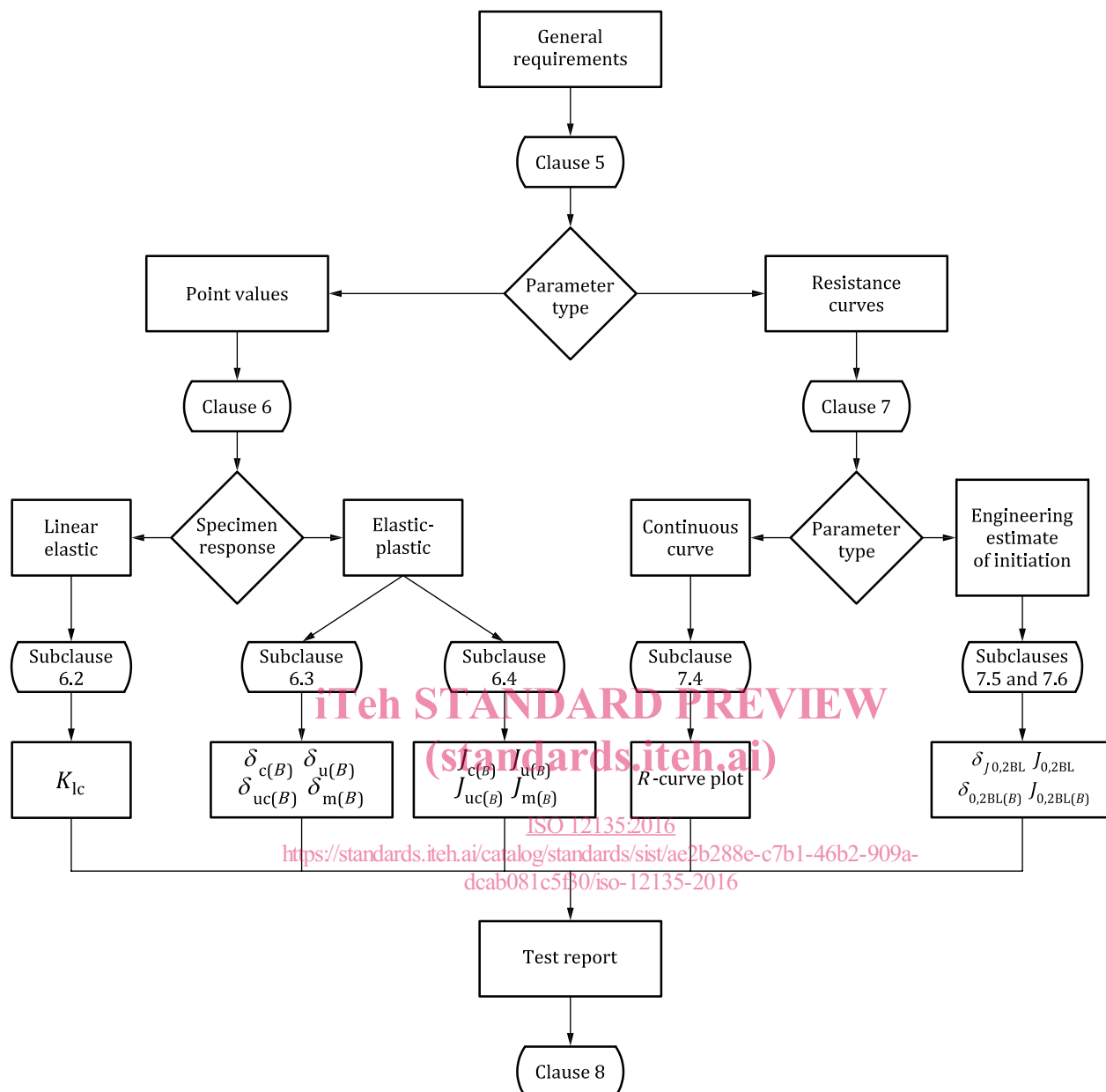
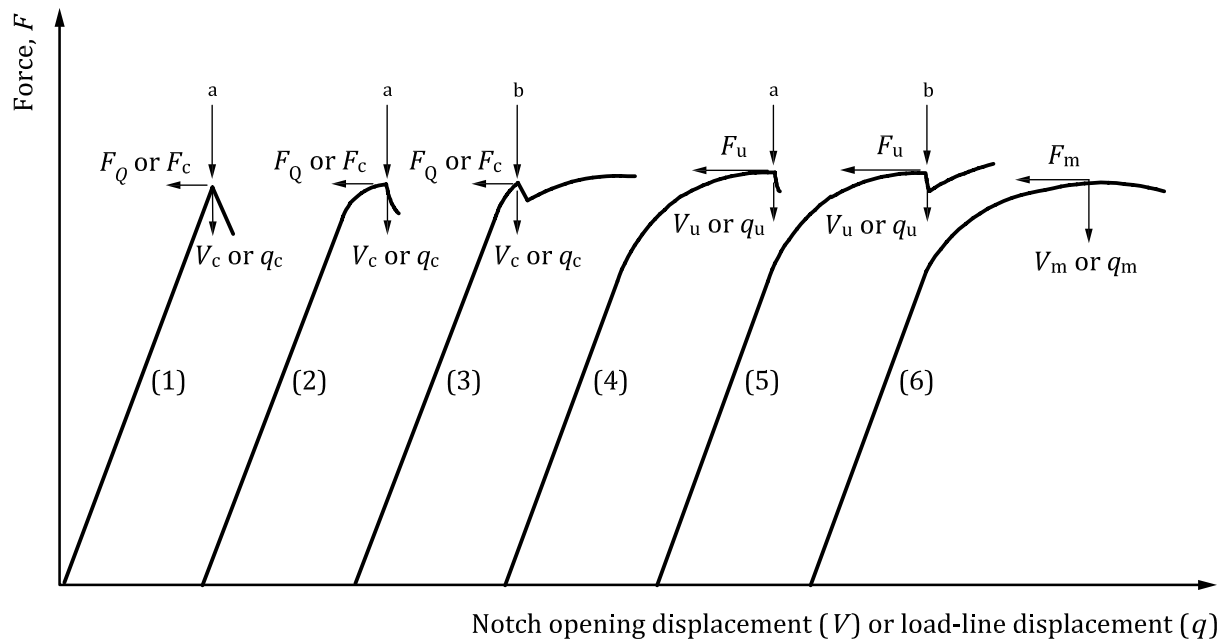


Figure 1 — General flowchart showing how to use the standard method of test

**Key**

a Fracture.

b Pop-in.

NOTE 1  $F_c$ ,  $F_u$  and  $F_m$  correspond to either  $\delta_c$ ,  $\delta_u$  and  $\delta_m$  respectively, or  $J_c$ ,  $J_u$  and  $J_m$  respectively.

NOTE 2 Pop-in behaviour is a function of the testing machine/specimen compliance and the recorder response rate.

**Figure 2 — Characteristics types of force versus displacement records in fracture tests**

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**5.2 Fracture parameters**

Specific (point) values of fracture toughness are determined from individual specimens to define the onset of unstable crack extension or describe stable crack extension.

NOTE  $K_{Ic}$  characterizes the resistance to extension of a sharp crack so that i) the state of stress near the crack front closely approximates plane strain, and ii) the crack tip plastic zone is small compared with the specimen crack size, thickness and ligament ahead of the crack.

$K_{Ic}$  is considered a size-insensitive measurement of fracture toughness under the above conditions. Certain test criteria shall be met in order to qualify measurements of  $K_{Ic}$ .

The parameters  $\delta_c$ ,  $J_c$ ,  $\delta_u$ ,  $J_u$ ,  $\delta_{uc}$  and  $J_{uc}$  also characterize the resistance of a material to unstable extension of a sharp crack. However, these measurements are regarded as size-sensitive and as such characterize only the specimen thickness tested. The specimen thickness is thus noted in millimetre units in parentheses appended to the parameter symbol when reporting a test result.

When stable crack extension is extensive, test procedure and fracture toughness measurement shall be performed as specified in [Clause 7](#). Stable crack extension is characterized either in terms of crack tip opening displacement  $\delta_{J0,2BL}$  and fracture toughness  $J_{0,2BL}$  parameters, or of a continuous  $\delta_j$ - and  $J$ -resistance curve. The values  $\delta_{J0,2BL}$  and  $J_{0,2BL}$ , regarded as specimen size insensitive, are engineering estimates of the onset of stable crack extension, not to be confused with the actual initiation toughness  $\delta_{ji}$  and  $J_i$ . Measurement of  $\delta_{ji}$  and  $J_i$  is described in [Annex A](#).

Two procedures are available for determining  $\delta_{0,2BL}$  and  $J_{0,2BL}$ . The multiple specimen procedure requires several nominally identical specimens to be monotonically loaded, each to different amounts of displacement. Measurements of force and displacement are made and recorded. Specimen crack fronts are marked (e.g. by heat tinting or post-test fatiguing) after testing, thus enabling measurement of stable crack extension on the specimen halves after each specimen is broken open. Post-test cooling

of ferritic material specimens to ensure brittle behaviour may be helpful in preserving crack front markings prior to breaking open the specimens.

A minimum of six specimens is required by the multiple-specimen method. When material availability is limited, a single-specimen procedure based on either unloading compliance or the potential drop technique may be used. There is no restriction on the single-specimen procedure providing sufficient accuracy can be demonstrated. In all cases, certain criteria are to be met before  $\delta_{J0,2BL}$  or  $J_{0,2BL}$  values and  $\delta_J$ - or  $J$ -resistance curves are qualified by this standard method of test.

### 5.3 Fracture toughness symbols

Fracture toughness symbols identified in this document are given in [Table 2](#).

**Table 2 — Fracture toughness symbols**

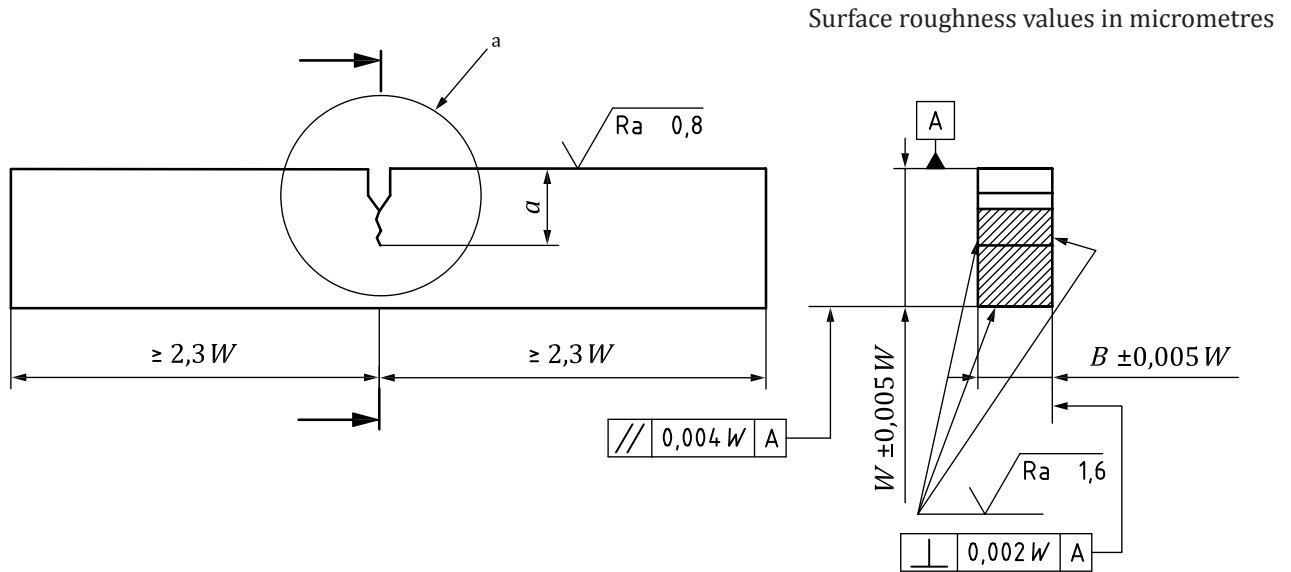
Parameter	Size insensitive quantities	Size sensitive quantities (specific to thickness $B$ tested)	Qualifying limits to $R$ -curves
$K$	$K_{Ic}$ $K_{J0,2BL}$		
$\delta, \delta_J$	$\delta_{Ji}$ $\delta_{J0,2BL}$	$\delta_{c(B)}$ $\delta_{J0,2BL(B)}$ $\delta_{u(B)}, \delta_{uc(B)}, \delta_{m(B)}$	$\delta_{J,g}, \delta_{J,g}(\Delta a_{max})$
$J$	$J_i$ $J_{0,2BL}$	$J_{c(B)}$ $J_{0,2BL(B)}$ $J_{u(B)}, J_{uc(B)}, J_{m(B)}$	$J_g, J_g(\Delta a_{max})$

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### 5.4 Test specimens

#### 5.4.1 Specimen configuration and size

Dimensions and tolerances of specimens shall conform to [Figures 3](#) to [5](#).



**Key**

a See Figures 6 to 8 and 5.4.2.3.

NOTE 1 Integral or attachable knife edges for clip gauge attachment may be used (see Figures 8 and 9).

NOTE 2 For starter notch and fatigue crack configuration, see Figure 6.

NOTE 3  $1,0 \leq W/B \leq 4,0$  ( $W/B = 2$  preferred).

NOTE 4  $0,45 \leq a/W \leq 0,70$ . For  $K_{Ic}$  determination,  $0,45 \leq a/W \leq 0,55$ .

The intersection of the crack starter notch tips with the two specimen surfaces shall be equally distant from the top and bottom edges of the specimen to within  $0,005 W$ .

**Figure 3 — Proportional dimensions and tolerances for bend specimen**