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Plastics — Determination of J-R curves — Fracture toughness

Plastiques — Détermination des courbes J-R — Résistance à la rupture

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Foreword

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This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 2, *Mechanical properties*.

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.

Plastics — Determination of J-R curves — Fracture toughness

1 Scope

This document specifies a method for determining the fracture toughness in term of *J* and *R* curves for plastics.

The method is suitable for use with ductile and semi-ductile polymers and polymer blends. It is not intended to be used with materials in which the crack front cannot be distinguished from additional deformation processes in advance of the crack tip. The method is unsuitable for polymers reinforced with fibres.

NOTE *J-R* curves, produced in accordance with this test method, characterizes the crack growth resistance that cannot be characterized by linear elastic fracture mechanics according to ISO 13586.

2 Normative references

The following referenced documents are indispensable for the application 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 2818, *Plastics — Preparation of test specimens by machining*

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*

ISO 13586, *Plastics — Determination of fracture toughness (GIC and KIC) — Linear elastic fracture mechanics (LEFM) approach*

ASTM D 6068, *Standard Test Method for Determining J-R Curves of Plastic Materials*

3 Terms, definitions and symbols

3.1 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 13586, ASTM D6068-96 and the following 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/

3.1.1
***J*-integral**
J
line or surface integral over a path that enclosed the crack front from one crack surface to the other, used to characterise the local stress-strain field around the crack front

Note 1 to entry: See Reference [5].

Note 2 to entry: It is expressed in Joules per square meter (kJ/m^2).

3.1.2
***J-R* curve**
J-Δa_p
plot of resistance to stable physical crack extension

3.1.3
net thickness
B_N
distance between the roots of the side grooves in side grooved specimens

Note 1 to entry: It is expressed in millimetres (mm).

3.1.4
thickness
B
side to side dimension of the test specimen

Note 1 to entry: It is expressed in millimetres (mm).

Note 2 to entry: shown in Figure 2 and Figure 3.

3.1.5
specimen width
W
larger initial dimension of the rectangular cross section of the test specimen

Note 1 to entry: It is expressed in millimetres (mm).

Note 2 to entry: shown in Figure 2 and Figure 3.

3.1.6
original crack size
a_0
physical crack size at the start of testing

Note 1 to entry: It is expressed in millimetres (mm).

Note 2 to entry: shown in Figure 2 and Figure 3.

3.1.7
original uncracked ligament
b_0
distance from the original crack front to the back edge of the specimen given as follows:

$$b_0 = W - a_0$$

Note 1 to entry: It is expressed in millimetres (mm).

3.1.8
crack size
a_p
physical crack size to the observed final crack front

Note 1 to entry: It is expressed in millimetres (mm).

Note 2 to entry: The size shall be a calculated average of several measurements along the crack front. See Figure 6 and Figure 7.

3.1.9
crack extension
Δa_p
increase in physical crack size given as:

$$\Delta a_p = a_p - a_0$$

Note 1 to entry: It is expressed in millimetres (mm).

3.1.10
specimen span
S
distance between specimen rollers

Note 1 to entry: It is expressed in millimetres (mm).

Note 2 to entry: Shown in Figure 1.

3.1.11
corrected energy
U
energy required to extend the crack

Note 1 to entry: It is expressed in Joules (J).

Note 2 to entry: See 8.1.

3.1.12
displacement
f
displacement measured by the transducer or extensometer

Note 1 to entry: It is expressed in millimetres (mm).

Note 2 to entry: see Figure 8.

3.1.13
slope
α
slope of the linear portion of the force versus displacement curve

Note 1 to entry: see Figure 8.

3.1.14
geometrical functions
η_{el}, η_{pl}
functions representing the notch depth influence

Note 1 to entry: See 8.2.4.

3.2 Symbols

l	total length of the test specimen (see Figures 2 and 3)
U_{Tel}	elastic part of total energy *UT,* determined from the area under the force versus displacement (see Figure 8)
U_{Tpl}	plastic part of total energy *UT,* determined from the area under the force versus displacement (see Figure 8)
U_T	total energy, expressed in joules (J)
U_{el}	elastic part of corrected energy *U,* required to extend the crack, in Joules (J)
U_{pl}	plastic part of corrected energy *U,* required to extend the crack, in Joules (J)
f_{el}	elastic part of displacement, expressed in millimetres (mm)
f_{pl}	plastic part of displacement, expressed in millimetres (mm)

4 Principle

This test method describes a multiple specimen technique for determining the *J-R* curves for polymeric materials. The *J-R* curves consist of plot of J versus crack extension in the region of J-controlled growth (see Figure 9). This method uses optical measurements of crack length and crack extension on the fracture surfaces after each test.

There are two options for specimen geometries - three-point bend (SENB) and pin-loaded compact tension (CT) specimens. The *J-R* curves from bend specimens represent lower bound estimation to those obtained from compact tension specimens.

The largest possible specimen with representative microstructure is recommended. The *J-R* curves tend to exhibit lower slope with increasing thickness.

The specimens are notched and tested under slowly increasing displacement.

Test carried out on specimens of different dimensions or with different notches, or specimens prepared under different conditions, may produce results that are not comparable. Other factors, such as test speed or conditioning of the specimens, can also influence the results. Consequently, when comparable data are required, these factors shall be carefully controlled and recorded.

5 Apparatus

5.1 Testing machine

5.1.1 General

The machine shall be in accordance with ISO 7500-1 and ISO 9513, and meet the specification given in 5.1.2 and 5.1.3.

5.1.2 Test speeds

The tensile-testing machine shall be capable of maintaining the test speeds as specified in Table 1.

Table 1 — Recommended test speeds

Test speed (mm/min)	**Tolerance** (%)
0,125	±20
0,25	
0,5	
1	
2	
5	
10	
20	±10
50	
100	
200	
300	
500	

5.1.3 Force indicator

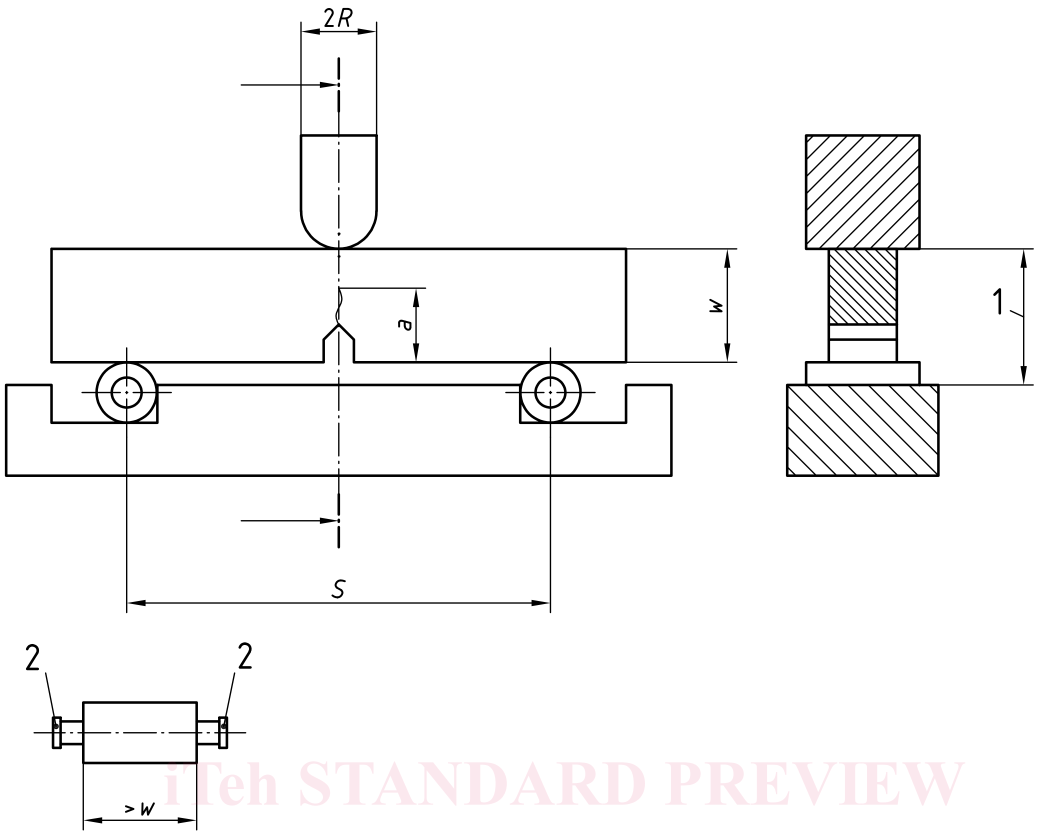
The force measurement system shall be in accordance with class 1 according to ISO 7500-1.

5.2 Displacement transducer

The displacement is recorded during the test. The transducer shall be essentially free from inertia lag at the test speeds being used. It shall measure the displacement with accuracy within the limits of class 2 of ISO 9513 or better. The effects of the transducer on the force measurements shall either be negligible (that is <1 %) or shall be compensated.

5.3 Loading rigs

A rig with either stationary or moving rollers is used for three-point-bending (SENB) tests, as shown in Figure 1. Indentation into the test specimen is minimised by the use of rollers with a larger diameter (> W/4). The measurement of the displacement shall be taken at the centre of the span, *S*.



Key

S	span between rollers	*S* = 4*W* ± 0,1*W*
R	radius	*W*/8 ≤ *R* ≤ *W*/2
1	distance monitored by displacement transducer	
2	bosses for rubber bands - for moving rollers	

NOTE Alternatively, a rig with stationary rollers according to ISO 178 can be used.

Figure 1 — Rig with two rollers and displacement transducer for three-point-bending (SENB) tests

For the compact tensile test, the test specimen is loaded by means of two pins in holes in the specimen. A clip gauge near the pins measures the displacement of the load points during the test.

6 Test specimens

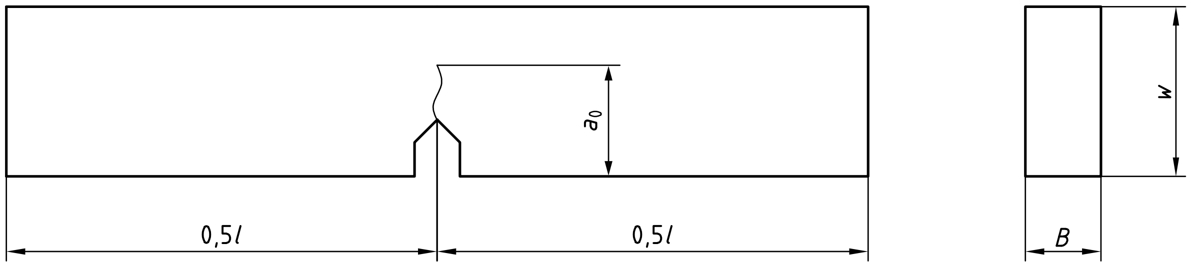
6.1 General

The largest available specimens are recommended for testing in order to obtain a larger portion of *J*-*R* curve and to obtain the most conservative estimate of crack growth resistance. The *J*-*R* curve is only appropriate for the thickness that is being evaluated.

6.2 Shape and size

Test specimens for three-point-bending tests (SENB) and for compact tensile (CT) tests shall be prepared in accordance with Figures 2 and 3, respectively. It is usually convenient to make the thickness, *B*, of the test specimens equal to the thickness of a sheet sample. Otherwise, follow the ISO 2818. All in-plane dimensions are proportional to the specimen width, *W* (see Figure 2 and Figure 3). The minimum

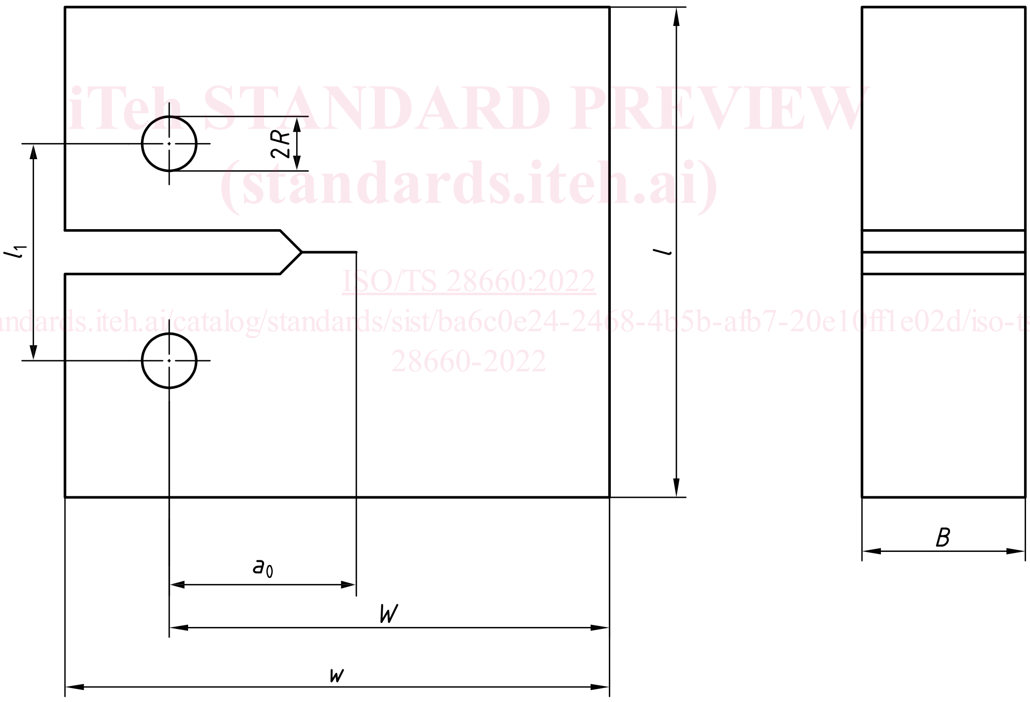
W = 25 mm (fulfil the 9.2). Unnotched test specimens are used for indentation displacement and energy corrections (see Figures 4 and 5, respectively).



Key

W	width	
l	length	l > 4,2 W
B	thickness	*W*/4 ::o *B* ::o *W*/2 prefer $B = W/2$
a_0	crack length	$0{,}45\ W \leq a_0 \leq 0{,}55\ W$

Figure 2 — Single-edge-notched bend (SENB) test specimen



Key

w	overall width	$w = 1{,}25\ W \pm 0{,}01\ W$
W	width	$l = 1{,}2W \pm 0{,}01\ W$
l	length	$l_1 = 0{,}55\ W \pm 0{,}000\ 5\ W$
l_1	distance between centres of two holes located symmetrically to the crack plane ± 0,005 *W*	$R = 0{,}125\ W \pm 0{,}005\ W$
		$W/4 \leq B \leq W/2$ prefer $B = W/2$
R	radius	$0{,}45\ W \leq a_0 \leq 0{,}55\ W$
B	thickness	
a_0	crack length	

Figure 3 — Compact tensile (CT) test specimen