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Plastics — Determination of Charpy impact properties —

Part 2:
Instrumented impact test

Plastiques — Détermination des caractéristiques au choc Charpy —

Partie 2: Essai de choc instrumenté

Reference number
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Contents

Page

Foreword

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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 on 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 the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 2, *Mechanical properties*, in collaboration with the European Committee for Standardization (CEN) Technical Committee CEN/TC 249, *Plastics*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

This second edition cancels and replaces the first edition (ISO 179-2:1997), which has been technically revised. It also incorporates the Technical Corrigendum ISO 179-2:1997/Cor 1:1998 and the Amendment ISO 179-2:1997/Amd 1:2011.

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

— references to ISO 13802:2015 have been updated;

— force calibration requirements have been clarified;

— a new subclause for the determination of test speed when using falling mass instruments has been added (see 5.1.6).

A list of all parts of the ISO 179 series can be found on the ISO website.

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 Charpy impact properties —

Part 2:
Instrumented impact test

1 Scope

1.1 This document specifies a method for determining Charpy impact properties of plastics from force-deflection diagrams. Different types of rod-shaped test specimens and test configurations, as well as test parameters depending on the type of material, the type of test specimen and the type of notch, are defined in ISO 179-1.

Dynamic effects such as load-cell/striker resonance, test specimen resonance and initial-contact/inertia peaks are described in this document (see Figure 1, Curve b, and Annex A).

1.2 ISO 179-1 is suitable for characterizing the impact behaviour by the impact strength only and for using apparatus whose potential energy is matched approximately to the particular energy to break to be measured (see ISO 13802:2015, Annex E). This document is used to record a force-deflection or force-time diagram for detailed characterization of the impact behaviour, and for developing automatic apparatus, i.e. avoiding the need to match energy.

The method described in this document is also suitable for:

— acquiring more and different materials characteristics under impact conditions;

— supervising the Charpy test procedure, as this instrumentation allows detection of typical operational mistakes, such as the specimen not being in close contact with the supports;

— automatically detecting the type of break;

— pendulum type instruments to avoid frequent changes of pendulum hammers;

— measuring fracture mechanical properties described in other ISO standards.

1.3 For the range of materials which can be tested by this method, see ISO 179-1:2010, Clause 1.

1.4 For the general comparability of test results, see ISO 179-1:2010, Clause 1.

1.5 Information on the typical behaviour of materials can be obtained by testing at different temperatures, by varying the notch radius and/or specimen thickness and by testing specimens prepared under different conditions.

It is not the purpose of this document to give an interpretation of the mechanism occurring at every point on the force-deflection diagram. These interpretations are a task for on-going scientific research.

1.6 The test results obtained with this method are comparable only if the conditions of test specimen preparation, as well as the test conditions, are the same. The impact behaviour of finished products cannot, therefore, be predicted directly from this test.

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 179-1:2010, *Plastics — Determination of Charpy impact properties — Part 1: Non-instrumented impact test*

ISO 291, *Plastics — Standard atmospheres for conditioning and testing*

ISO 2602, *Statistical interpretation of test results — Estimation of the mean — Confidence interval*

ISO 16012, *Plastics — Determination of linear dimensions of test specimens*

ISO 13802:2015, *Plastics — Verification of pendulum impact-testing machines — Charpy, Izod and tensile impact-testing*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 179-1 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
impact velocity
v_I
velocity of the striker relative to the test specimen supports at the moment of impact

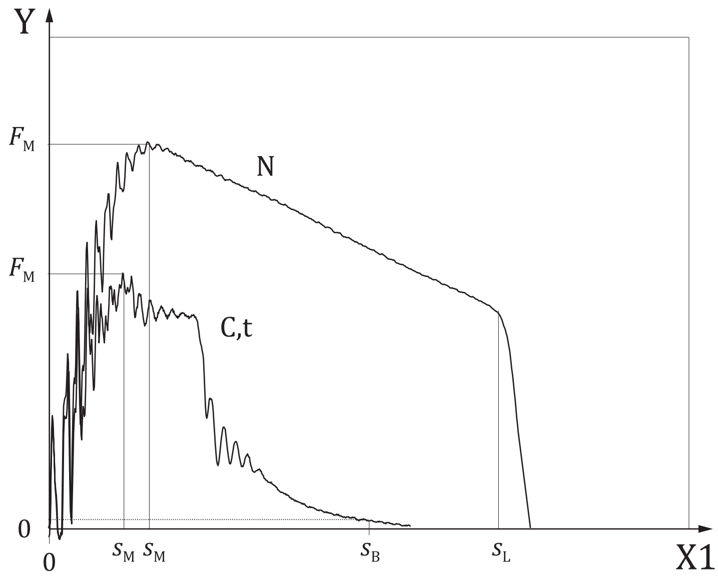
Note 1 to entry: It is expressed in metres per second (m/s).

3.2
inertial peak
first peak in a force-time or force-deflection diagram

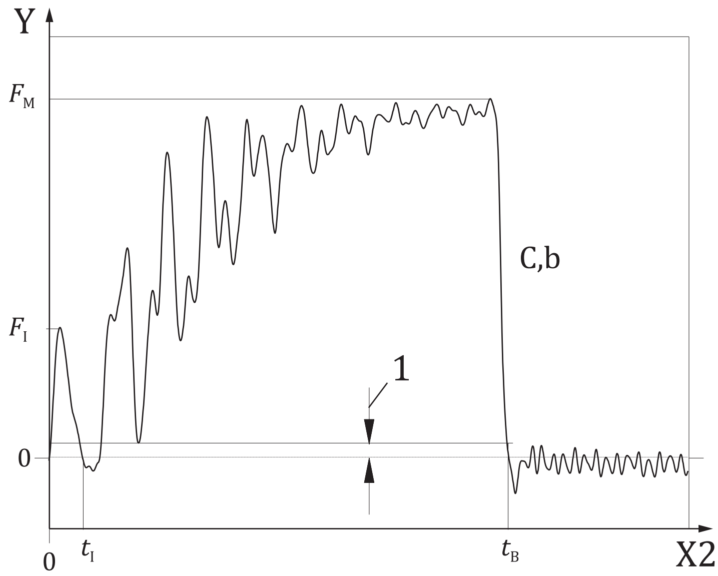
Note 1 to entry: Inertial peak arises from the inertia of that part of the test specimen accelerated after the first contact with the striker (see Figure 1, Curve b, and Annex A).

3.3
impact force
F
force exerted by the striking edge on the test specimen in the direction of impact

Note 1 to entry: It is expressed in newtons (N).



a) Force-deflection (N and C,t)



b) Force-time (C,b)

Key

X1 deflection (s) after impact in millimetres

X2 time after impact in milliseconds, ms

Y force (F) in newtons, N

F_M maximum impact force

F_I peak force of inertial peak

s_M deflection at maximum impact force F_M

s_L limiting deflection, beginning off pull-through

t_B time at break

s_B deflection at break

N no break, specimen pulled through

C,t complete break, tough

C,b complete break, brittle

1 5% of the maximum impact force

NOTE For the types of failure, see Figure 2.

Figure 1 — Typical force-deflection and force-time curves

3.4
deflection
s
displacement of the striker relative to the test specimen supports after impact, starting at first contact between striker and test specimen

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

3.5
impact energy
W
energy expended in accelerating, deforming and breaking the test specimen during the *deflection* (3.4)

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

3.6
maximum impact force
F_M
maximum value of the *impact force* (3.3) in a force-time or force-deflection diagram

Note 1 to entry: See Figure 1.

Note 2 to entry: It is expressed in newtons (N).

3.7
deflection at maximum impact force
s_M
deflection (3.4) at which the *maximum impact force* (3.6) occurs

Note 1 to entry: See Figure 1.

Note 2 to entry: It is expressed in millimetres (mm).

3.8
energy to maximum impact force
W_M
energy expended up to the *deflection at maximum impact force* (3.7)

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

3.9
deflection at break
s_B
deflection (3.4) at which the impact force is reduced to less than or equal to 5 % of the *maximum impact force* (3.6)

Note 1 to entry: See Figure 1.

Note 2 to entry: It is expressed in millimetres (mm).

3.10
impact energy at break
W_B
impact energy (3.5) up to the *deflection at break* (3.9)

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

3.11
Charpy impact strength
Charpy notched impact strength
a_{cU} (a_{cN})
impact energy at break (3.10) relative to the initial central cross-sectional area A (A_N) of the unnotched (notched) specimen

Note 1 to entry: It is expressed in kilojoules per square metre (kJ/m^2).

Note 2 to entry: See 8.4 and ISO 179-1:2010, 3.1 and 3.2.

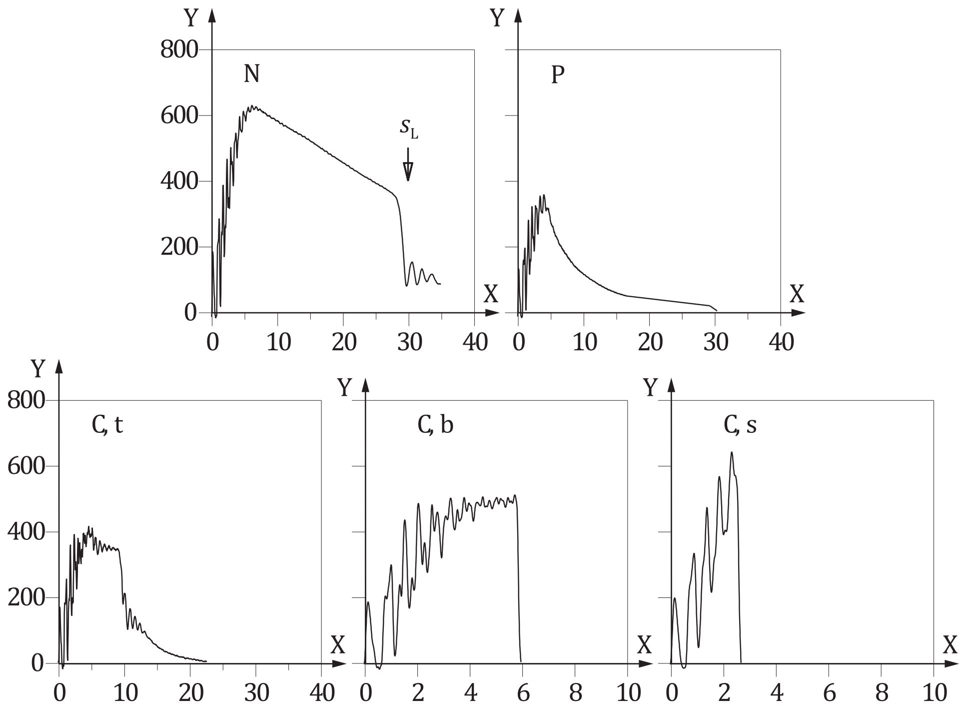
3.12
type of failure
type of deformation behaviour of the material under test up to and including the breaking event

Note 1 to entry: Failure types are: *complete break* (3.13), *hinge break* (3.14), *partial break* (3.15), *non-break* (3.16). See Figure 2.

Note 2 to entry: Types t, b and s represent subgroups of the complete break C and hinge break H defined below. For these types, values of the impact energy at break W_B, and thus for the Charpy impact strength, may be averaged to give a common mean value. For specimens giving a partial break P and for materials exhibiting interlaminar shear fracture, see ISO 179-1:2010, 7.7. For specimens showing more than one failure type, see ISO 179-1:2010, 7.7 and ISO 179-1:2010, Clause 10 l).

Note 3 to entry: As can be seen from Figure 2, the deflection and the impact energy at maximum force are identical to the deflection and impact energy at break in the case of splintering failure (see Curve s) and brittle failure (see Curve b), where unstable cracking takes place at the maximum impact force.

Note 4 to entry: Usually, complete and hinge breaks cannot be differentiated in an automatic assessment based on the force-time or force deflection-curve.



Key

N *no break* (3.16)

P *partial break* (3.15)

C *complete break* (3.13)

s_L deflection limit; beginning of pull-through

x deflection s after impact in millimetres

y impact force in newtons, N

NOTE 1 Due to the different modes of deformation, force-deformation curves obtained using this document show features which are different from those obtained using ISO 6603-2[1]. In particular, the first damage event in instrumented puncture tests frequently appears as a slight sudden force decrease (crack initiation), followed by a gradual force increase. Force increases after crack initiation are never observed in instrumented three-point-bending impact tests. Furthermore, inertial effects are not as pronounced in plate impact tests as they are in bending impacts tests (see Annex A).

NOTE 2 The distinction between break types P and C,t is difficult. As there is some extent of unstable crack growth in the F-s-diagram labelled C,t, the breaking behaviour was rated as less ductile than in case P when drafting the document. Therefore, the letter "t" was used instead of "d", which could be associated with ductile behaviour and would better apply to break types N and P.

NOTE 3 This document can be applied to automatic testing routines. For this it is also necessary to automatically assign the types of break by a suitable assessment of the force-time or force deflection traces observed. The table below is an example of assessment rules that have been used successfully. Both rules are to be met for assignment.

Type of break	Rule for deflection	Rule for force
Non break	$s_B \geq s_L$ s_L = 31mm	$F(s_L)$ $c*F_M$ The factor c was determined experimentally and set to c = 0,3
Partial break	$s_B \geq s_L$	$F_0 \leq F(s_L) \leq c*F_M$ F_0 is the level of force at which the test is considered to be finished, e.g. $F_0 = 0{,}05*F_M$
Complete break	Type s: $(s_B - s_M) \leq$ 1mm	
	Type b: $(s_B - s_D) \leq$ 2mm	
	Type t: $(s_B - s_D) \geq$ 2mm s_D is the deflection after s_M, where the steepest decline of the F-s-curve occurs	

Figure 2 — Typical force-deflection curves showing different failure modes for Type 1 specimens tested edgewise

3.13
complete break

C

break where the specimen separates into two or more pieces, subdivided in the following behaviours:

Note 1 to entry: See Figure 2.

3.13.1
tough break

t

yielding followed by stable cracking, resulting in a force at the deflection limit s_L which is less than or equal to 5 % of the maximum force

3.13.2
brittle break

b

yielding followed by unstable cracking

3.13.3
splintering break
s
unstable cracking followed by splintering

3.14
hinge break
H
incomplete break, such that one part of the specimen cannot support itself above the horizontal when the other part is held vertically (less than 90° included angle)

3.15
partial break
P
incomplete break that does not meet the definition for a hinge or complete break

Note 1 to entry: For automatic detection resulting in a force at the deflection limit s_L which is greater than 5 % of the maximum force.

3.16
non-break
N
yielding followed by plastic deformation up to the deflection limit, s_L

Note 1 to entry: The test specimen shows extended plastic deformation but no visible fracture surfaces.

4 Principle

A rod-shaped test specimen, supported near its ends as a horizontal beam, is impacted perpendicularly, with the line of impact midway between the supports, and bent at a high, nominally constant velocity. During the impact, the impact force is recorded as a function of time and/or deflection. Depending on the method of evaluation, the deflection of the specimen may be either measured directly by suitable measuring devices or, in the case of energy carriers which give a frictionless impact, calculated from the initial velocity and the force as a function of time. The force-deflection diagram obtained in these tests describes the high-bending-rate impact behaviour of the specimen from which several aspects of the material properties may be inferred.

5 Apparatus

5.1 Test machine

5.1.1 Basic components

The basic components of the test machine are the energy carrier, the striker and the frame with its specimen supports. The energy carrier may be of the inertial type (e.g. a pendulum or free-falling dart, which may be spring- or pneumatically assisted before impact) or of the hydraulic type.

The test machine shall ensure that the specimen is bent by the impact at a nominally constant velocity perpendicular to the specimen length. The force exerted on the specimen shall be measurable, and its deflection in the direction of impact shall be derivable or measurable.

If the test machine is of the pendulum type it shall be verified according to ISO 13802:2015, Clause 6 and Annex A, as applicable.

5.1.2 Energy carrier

For the low-energy pendulum types specified in ISO 179-1 (see also ISO 13802:2015, Annex A), the impact velocity, v_I, is (2,90 ± 0,15) m/s and for the high-energy types it is (3,8 ± 0,2) m/s. For the purposes of comparing impact strength data obtained using this method with data obtained in accordance with ISO 179-1, the impact velocity used in this document shall be (2,90 ± 0,15) m/s, although it may be desirable to also use the impact velocity v_I = (3,8 ± 0,2) m/s.

NOTE 1 The height of the inertial peak F_I (see Figure 1, Curve b), and also the amplitudes of the subsequent vibrations of the specimen, increase with increasing impact velocity. For basic information about these vibrations, see Annex A and References [1] and [3]. For further information about the interpretation of the inertial peak and the damping of vibrations, see Annex A.

NOTE 2 For special applications, e.g. testing precracked test specimens to obtain data on fracture properties, it is useful to use a lower impact velocity of, for example, 1 m/s ± 0,05 m/s to reduce the vibrations mentioned in NOTE 1.

To avoid obtaining results which cannot be compared due to the viscoelastic behaviour of the material under test, the decrease of velocity during impact shall not exceed 10 % if the energy carrier is rated to less than 50 J at the speed being selected for testing. These mass carriers allow measurements between 0 % and 20 % of their nominal work capacity, E.

For the sake of extending the application range of pendulum impact instruments, in case of energy carriers larger or equal to 50 J at the speed selected for testing, a range of 0 % to 80 % of its nominal work capacity is permitted, this leading to a decrease of speed of 55 % in extreme cases.

The hydraulic-type energy carrier is a high-speed impact-testing machine with suitable attachments.

In the case of gravitationally accelerated energy carriers, the above impact velocities correspond to drop heights of (43 ± 5) cm and (74 ± 7) cm, respectively, the latter representing an increase by a factor of 1,54 in the kinetic energy E at impact if the same energy carrier is used at both impact velocities.

The maximum permitted decrease in velocity during impact specified above means that for energy carriers smaller than 50 J the kinetic energy E in joules, at impact shall satisfy the condition given as Formula (1):

$$E/W^* \geq 5 \qquad (1)$$

where W^* is the highest value, in joules, of the energy to be measured (see ISO 13802:2015, Annex D, and NOTE 2 above).

This condition is in accordance with the conditions given in ISO 179-1:2010, 7.3 (see ISO 13802:2015, Annex D). It ensures that the change in velocity during impact is comparable to that in conventional impact testing, and consequently the values of impact strength are comparable. This is important, because plastics are bending-rate-sensitive, especially at temperatures close to transition temperatures.

5.1.3 Striking edge and test specimen support

The striking edge and the test specimen support shall fulfil the conditions of ISO 13802:2015, Annex A. Regarding verification of these elements, ISO 13802:2015, 6.3 applies.

Any material with sufficient resistance to wear and sufficiently high strength to prevent it from being deformed, as well as being capable of transmitting the forces exerted upon the specimen to the load-measuring device, can be used for the striking edge.

NOTE 1 Experience shows that steel is generally suitable. However, a material of lower density, e.g. titanium, can be used to increase the natural frequency of the load-measuring system.

NOTE 2 Test specimens (Type 1, edgewise impact) can show the tendency to flip over. The effects of such instability phenomena can be decreased by attaching guide elements to the hammer close to, but not connected to, the instrumented striking edge, allowing passage of the test specimen but close enough together to prevent the central part of the specimen from twisting to any great extent.

5.1.4 Frame

For pendulum impact testing machines, the frame of the test machine shall be levelled to conform to ISO 13802:2015, Annex A.

When calculating deflections from the kinetic energy of the energy carrier, the ratio m_F/m_C of the mass of the frame to the mass of the energy carrier shall be at least 10 (see Annex B and Notes 1 and 2 below). For directly measured deflections, this ratio is a recommendation only. Impact-testing machines are generally susceptible to acoustic vibrations. Therefore, the centre of gravity of the frame shall be positioned in the line of impact.

NOTE 1 ISO 13802:2015, Annex D recommends a pendulum mass to foundation mass ratio of 40:1 in order to minimize the energy transfer into the foundation. However, here the force exerted by the striker upon the specimen and its deflection are determined, and any energy transfer into the foundation does not influence the test result.

NOTE 2 The value of 10 for the ratio m_F/m_C prevents the frame from being accelerated at the end of the test to more than 1 % of the impact speed (see Annex B).

5.1.5 Losses due to friction

If a pendulum impact type machine is used, it shall either fulfil the requirements of ISO 13802:2015, 6.7, or it shall be equipped with instrumentation to determine the exact impact velocity, v_I.

If a falling dart type or a hydraulic machine is being used, it shall be equipped with instrumentation to determine the exact impact velocity, v_I.

5.1.6 Impact velocity measurement

For falling mass instrument types not fulfilling the requirements of ISO 13802:2015, 6.7, the impact velocity shall be measured at a vertical midpoint distance of not more than 25 mm from the point of impact.

The distance over which the impact speed is measured shall not be longer than 15 mm to avoid significant effects due to acceleration.

The measurement of this impact velocity shall be accurate to ±1 %.

The measured velocity shall be corrected by the increase of velocity between the point of measurement and the point of impact. See Formula (2):

$$v_0 = \sqrt{v^* + 2 \cdot g \cdot \Delta H} \qquad (2)$$

where

v_0 is the impact velocity in m/s;

v^* is the velocity of the striking edge at the speed measurement point, in m/s;

ΔH is the vertical travel distance of the mass between the mid-point of speed measurement and the point of impact in m.

For dart drop type instruments, working by a vertical movement of the mass, the instantaneous speed, t_i, can be determined without need for measurement of ΔH by Formula (3):

$$v_i = v^* + g \cdot t_i - \frac{1}{m}\int_0^{t_i} F(t)\,dt \qquad (3)$$

where

v_i is the velocity at any moment in time t_i, in m/s;

$F(t)$ is the force, in newtons, measured at a time, t, after the determination of v^*;

t_i is the time elapsed since the moment of measurement of v^*, in s;

m is the mass of the energy carrier, in kg.

Determine the impact velocity, v_0, using either Formula (2) or Formula (4):

$$v_0 = v^* + g \cdot \Delta t \quad (4)$$

where Δt is the time elapsed between the measurement of v^* and the moment of impact.

5.2 Instruments for measuring force and deflection

5.2.1 Force measurement

To measure the force exerted on the specimen, the striker may be equipped with strain gauges or a piezoelectric transducer, which may be placed close to the striking edge. Any other suitable method of force measurement is acceptable. The measurement system shall be able to measure forces with an accuracy of ±1 % of the maximum impact force, F_M, which has occurred during the test. The force-measurement system shall be calibrated as set up ready for use. Calibration may be performed statically (e.g. by imposing known loads on the striker) or dynamically (see e.g. Reference [4]). The range for which the force measurement system works within an accuracy of ±1 % of the reading shall be indicated.

The natural frequency, f_n, of the force-measurement system in the test configuration shall be greater than three times the resonance frequency, f_s, of the specimen after impact (see NOTE 1).

NOTE 1 For plastics test specimens, the resonance frequency, f_s, is of the order of 2 kHz to 10 kHz. A natural frequency, f_n, of 30 kHz for the force-measurement system is generally acceptable for plastics. The greater the difference between f_n and f_s, the easier the detection of crack initiation and growth.

Furthermore, this requirement makes it possible to differentiate between oscillations in the test specimen [see Figure 1, b) part of trace to the left of t_B] and those in the force-measurement system (to the right of t_B). For basic information relating to the nature of the vibrations occurring in Charpy tests, see e.g. Reference [2].

It is recommended that the force-measurement system be designed so that negative forces after the inertial peak are minimized. This ensures that the system is fast enough to measure correctly the forces involved in specimen deflection (see NOTES 2 and 3). A force-measurement system with which the size of the negative force following the inertial peak does not exceed 20 % of the peak value of the inertial peak is acceptable (see Figure A.2).

NOTE 2 The force-measurement system will be excited to oscillate at its natural frequency by the impact. The amplitude of this oscillation depends on the mass and the stiffness of the system, which in turn are determined by its design. During the period of time when contact is lost between the striking edge and the specimen, i.e. after the inertial peak, negative forces can be observed if the amplitude of the excited oscillation is large, and the effective mass “pulls” at the force-measurement device. These negative forces are not related to specimen deflection, however.

NOTE 3 Vibration of the specimen [see Figure 1, b)], as well as noise on the force-time-trace, generate uncertainties in the maximum impact force F_M but almost no uncertainty in the energy to maximum impact force or the energy at break.

The upper bandwidth limit of the amplifier train (direct-current or carrier-frequency amplifier) shall be selected so that it does not cut across the frequency response of the test device.

If post-impact filtering is used, the type of filter and its basic characteristics shall be given in the test report [see Clause 10, item m)].

In order to monitor the inertial peak adequately, the duration of which t_I (see Figure 1, b) is typically 0,1 ms, and the following vibrations which, depending on the modulus of the specimen, are in the range 2 kHz to 10 kHz, the sampling frequency of the force-measurement system (transient recorder) shall be at least 100 kHz.

The sampling frequency used (≥100 kHz) and the time to break t_B (≤13 ms) determine the amount of storage capacity that needs to be provided.

5.2.2 Deflection measurement

The deflection of the specimen as a function of time may be either calculated by double integration of the force-time curve (see 8.2) or measured directly.

If deflections are measured directly, the same sampling frequencies shall be used as for the impact force. The resolution of the time measurement and that of the distance measurement shall be matched.

Instruments used to measure the force and deflection, which show a difference in their signal-transit times, generate an offset in the force-deflection curve. This offset increases in proportion to the impact velocity. The time traces shall be synchronized by a time shift corresponding to the transit-time difference.

5.3 Micrometers and gauges

Micrometers and gauges shall allow to determine the relevant dimensions of the test specimens with an uncertainty not larger than 0,02 mm. For the determination of the dimension b_N of notched test specimens measuring tips appropriate for the contour of the notch shall be used. For general information on determination of specimen dimensions, see ISO 16012.

6 Test specimens

Test specimens shall conform to ISO 179-1:2010, Clause 6.

7 Procedure

7.1 Condition the test specimens according to ISO 291 for at least 16 h at (23 ± 2) °C/(50 ± 10) % R.H. unless specified differently in the relevant material standard, or as agreed. Conduct the test in the same atmosphere as used for conditioning or ensure that the time between conditioning and testing is short enough to prevent the specimens from undergoing any changes in their material state and hence mechanical behaviour.

For tests at temperatures below or above 23 °C, the test specimens shall be transferred from the cooling/heating unit to the supports. The transfer time (equal to time interval between taking the specimen from the cooling unit until the test is started) shall not be greater than 10 s.

NOTE Moisture sensitive materials like Polyamide are frequently tested in the dry state. Moisture uptake from the laboratory atmosphere softens the surface layer of dry test specimens and over time leads to an increase of the impact strength. It has been shown that dwell times of dry test specimens in the standard laboratory climate [ISO 291, class 2, (23 ± 2) °C/(50 ± 10) % R.H.] of 30 min do not significantly change the impact strength. For dry PA6 a storage time of 3h under these conditions leads to an increase in impact strength of less than 5 %.

7.2 Determine the width and thickness of the specimens in accordance with ISO 179-1:2010, 7.2.

7.3 Check that the test machine has the specified impact velocity (see 5.1.2) and that, for inertial-type carriers, the mass of the carrier is the minimum required value (see 5.1.2). Record the impact velocity to an accuracy of ±1 %.

7.4 Bring the energy carrier into its starting position. Position a specimen on the supports in such a manner that the striking edge will hit the centre of the specimen. Align notched specimens so that the centre of the notch is located directly in the plane of impact (see left-hand side of ISO 179-1:2010, Figure 1).

7.5 Release the energy carrier. Record the force exerted during the impact, and, if applicable, the deflection of the specimen, as a function of time.

7.6 After the test, assign failure types according to 3.12.

8 Calculation and expression of results

8.1 General

Take the force-time curve, and, where applicable, the deflection-time curve, obtained during the test as the test result. Other results shall be calculated employing these data. For the calculation of impact energies, force as a function of deflection is required (see NOTE).

It is necessary to differentiate between the deflection at break, s_B, and the deflection limit, s_L, at the beginning of pull-through (see Figure 1, Curve N) which is determined by the length l and width b of the test specimen and the distance L between the specimen supports. For Type 1 specimens in the edgewise position, s_L is in the range 31 mm to 34 mm.

NOTE Using Type 1 specimens tested edgewise, unexpectedly low deflection limits are sometimes observed, i.e. values (down to only 20 mm) at which the impact force drops to zero, but the specimens do not break. This can happen when the specimen changes from the edgewise to the more stable flatwise position by a combined bending-twisting deformation. This can easily be confirmed by checking the specimen after the test: it is bent with respect to an axis not parallel, but inclined to, the specimen width. This behaviour is caused by the high ratio between the edgewise and the flatwise flexural rigidity of the specimen and is triggered by a small asymmetry feature, e.g. the draft angle.

8.2 Calculation of deflection

If, in the case of energy carriers which give a frictionless impact, the deflection of the specimen is not measured directly by a displacement-measuring system, it shall be calculated from the force-time trace using Formulae (5) or (6), as applicable (see NOTE 1), realized in a suitable routine for digital processing.

NOTE 1 If the ratio W_B/E (energy to break to energy of pendulum or falling weight at impact) is less than 0,2, the double integral in Formulae (5) and (6) constitutes a correction of less than 5 % of $v_I t$.

For horizontally impacting pendulum-type energy carriers, see Formula (5):

$$s(t)=v_0 t-\frac{L_P g}{M_H}\int\int_0^t F(t)dt^2 \tag{5}$$

For vertically impacting free-falling energy carriers, see Formula (6):

$$s(t)=v_0 t-\frac{1}{m_C}\int\int_0^t F(t)dt^2+\frac{1}{2}gt^2 \tag{6}$$

where

v_0 is the impact velocity, in metres per second;

t is the time after impact, in seconds, at which the deflection is calculated;

L_P is the (physical) pendulum length, in metres (see ISO 13802:2015, 6.2.9);

M_H is the horizontal moment of the pendulum, in newton metres (see ISO 13802:2015, 6.2.8);

$F(t)$ is the force, in newtons, measured at time t after impact;

$s(t)$ is the deflection, in metres, of the specimen at time t after impact;

m_C is the mass, in kilograms, of the energy carrier;

g is the local acceleration due to gravity, in metres per second squared.

NOTE 2 The relative contribution of the last term in Formula (6) increases with decreasing impact velocity for a given striker mass.

8.3 Calculation of energy

Once the forces and deflections are known for the same times, t, after impact, calculate the energy W, in joules, expended up to specific deflections by determining the area under the force-deflection curve, i.e. by integrating in accordance with Formula (7) (see NOTE).

$$W_j=\int_0^{s_j} F(s)\,\mathrm{d}s \tag{7}$$

where

j denotes one of the following points on the force-deflection curve:

break (B),

maximum (M);

s is the deflection, in metres;

F is the force, in newtons.

NOTE In the case of horizontally impacting frictionless energy carriers, the energy can be calculated without measuring the deflection $s(t)$ by using Formula (8)

$$W_j = W_{ja}\left(1 - W_{ja}/4E\right) \quad (8)$$

where W_{ja} is the approximate value of the energy, given by t_j

$$W_{ja} = v_0 \int_0^{t_j} F(t)\,\mathrm{d}t$$

The second term inside the brackets in Formula (8) is less than 5 % if the ratio W/E of the measured energy to the energy of the energy carrier at impact is less than 0,2.

If a pendulum type instrument equipped by means for angular measurement is being used, it is possible to countercheck the correct function of the measurement by comparing of the total energy up to break or up to sL being measured by the instrumentation with the energy determined by the raise of the pendulum hammer, as described in ISO 179-1.

It is recommended that the pendulum-type instrument and its instruments for measuring force and deflection be re-checked, if the energies determined by both methods for materials showing complete break and tough materials behaviour differ more than ±5 % from each other.

8.4 Calculation of impact strength

8.4.1 Unnotched test specimens

Calculate the Charpy impact strength of unnotched test specimens, a_{cU}, in kilojoules per square metre, using the Formula (9):

$$a_{cU} = \frac{W_B}{bh} \times 10^3 \quad (9)$$

where

h is the thickness, in millimetres, of the test specimen;

b is the width, in millimetres, of the specimen;

W_B is the energy at break, in joules.

8.4.2 Notched test specimens

Calculate the Charpy impact strength of notched test specimens, a_{cN}, in kilojoules per square metre, using the Formula (10):

$$a_{cN} = \frac{W_B}{hb_N} \times 10^3 \quad (10)$$

where

W_B is the energy at break, in joules;

h is the thickness, in millimetres, of the test specimen;

b_N is the width, in millimetres, remaining at the base of the notch in the specimen;

N is either one of the notch type designations A, B or C (see ISO 179-1:2010, 6.3).

8.5 Statistical parameters

See ISO 179-1:2010, 8.3.

Calculate as test result, for each type of failure within one sample set, the mean and the standard deviation of the individual test results using the procedure given in ISO 2602, and report the number of test specimens in each failure type.

NOTE The standard deviation is identical to the two sided

— 95 % confidence interval of the mean if the number of test specimens is $n = 6$

— 99 % confidence interval of the mean if the number of test specimens is $n = 10$.

8.6 Number of significant figures

Report all mean values to two significant figures.

9 Precision

See Annex C.

10 Test report

The test report shall include the following information:

a) a reference to this document, i.e. ISO 179-2:2020;

b) the method of designation used:

either in accordance with ISO 179-1:2010, Table 2, e.g.

Instrumented Charpy impact test ISO 179-2/1 e A

Specimen type (see table 2 of ISO 179-1) — 1

Direction of blow (see figure 5 of ISO 179-1) — e

Type of notch (see figure 4 of ISO 179-1) — A

or in accordance with ISO 179-1:2010, Table 3, e.g.

Instrumented Charpy impact test ISO 179-2/2 n

Specimen type (see table 2 of ISO 179-1) — 2

Direction of blow (see figure 5 of ISO 179-1) — n

c) to k) see items c) to k) in ISO 179-1:2010, Clause 10;

l) the natural frequency of the force-measurement device;

m) the type of post-impact filter used, if any, and its basic characteristics;

n) the impact velocity;

o) the individual test results, their arithmetic mean and the standard deviation and/or coefficient of variation for

1) the maximum force, F_M, in newtons,

2) the deflection at maximum force, s_M, in millimetres,

3) the energy to maximum force, W_M, in joules,

4) the deflection at break, s_B, in millimetres,

5) the energy at break, W_B, in joules,

6) the type of failure;

p) the measured force-deflection and/or force-time curve;

q) the date of the test.

Annex A
(informative)

Inertial peak

The inertial peak[3] of a force-time or force-deflection curve is caused by the inertia of that part of the specimen (referred to as the contact mass) which is accelerated after the initial contact with the striker. The peak force, F_I, and the duration, t_I, of the inertial peak depend on the contact mass and the contact stiffness. The contact stiffness is higher than the flexural stiffness of the specimen. For a range of plastics, the contact stiffness has been found to be about 7 times the flexural stiffness.

The peak force, F_I, increases approximately linearly with increasing impact velocity, while the duration t_I decreases (see Figure A.1). At impact velocities above 2 m/s, the duration, t_I, is approximately constant, but characteristic of the material being tested (see Figure A.1, lower set of curves).

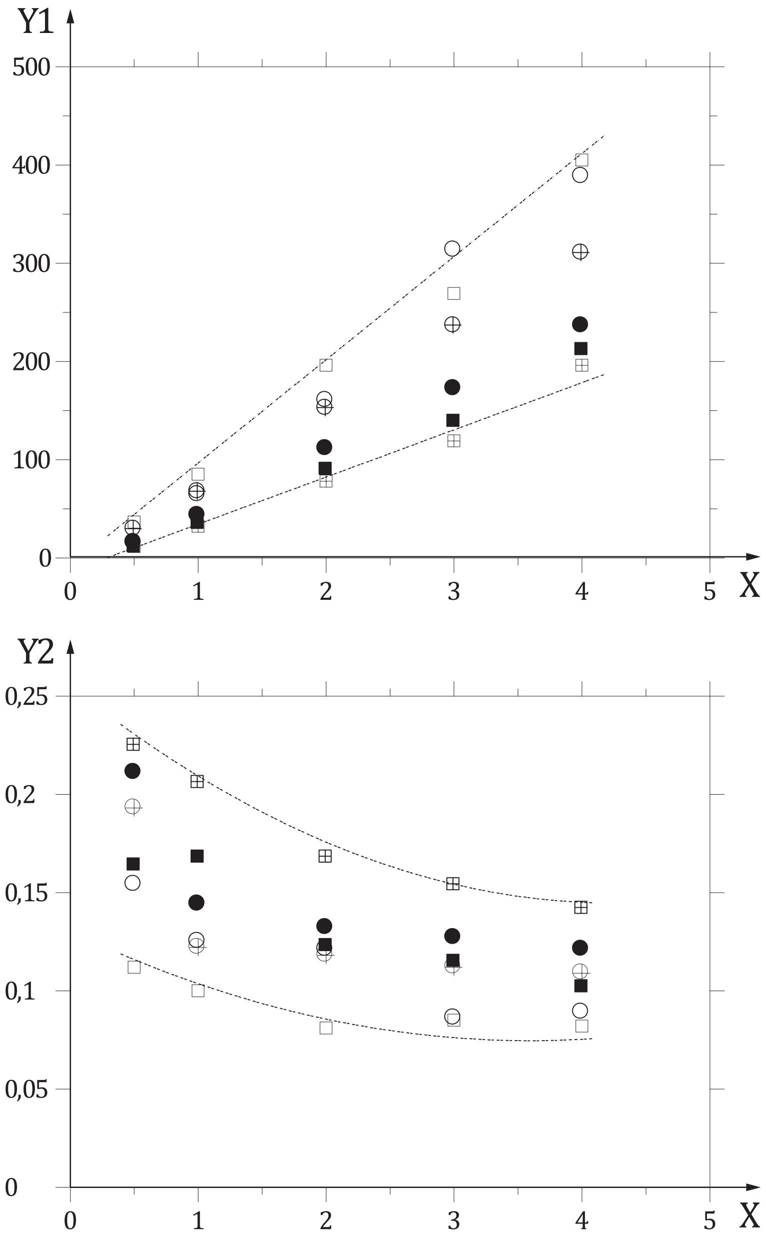
Due to the elastic component of the impact event, “bouncing” generally occurs. This means that the specimen is accelerated to speeds higher than the impact velocity so that, after duration, t_I, contact is lost between specimen and striker. Figure A.2 shows an example of an inertial peak with negligible negative forces after the loss of contact. Depending on the damping properties of the test material, each impact test may consists of a series of multiple impacts.

If it is of interest to determine the force-deflection curve without the oscillations caused by these inertial effects, soft damping materials, e.g. lead wire or soldering wire, can be placed between the striking edge and the specimen. Due to the plastic deformation of these damping materials, the force, F_I, and the amplitude of the vibrations will be considerably reduced. For effective damping of the inertial peak, the minimum thickness of the damping material should correspond to the deflection up to the duration, t_I, in an undamped test. For an impact velocity of 2,9 m/s, this is about 0,4 mm. Note that, when damping materials are used, the energy measured is changed for the following two reasons:

— energy is required to deform the damping material;

— brittle materials in particular may show different behaviour with and in the absence of vibrations.

For the purposes of this document, it is recommended that “bouncing” vibrations are not damped.



Key

X impact velocity in metres per second, m/s

Y1 peak force, FI, of inertial peak in newtons, N

Y2 duration, tI, of the inertial peak in milliseconds, ms

○ PBT, 30 % GF

⊕ POM

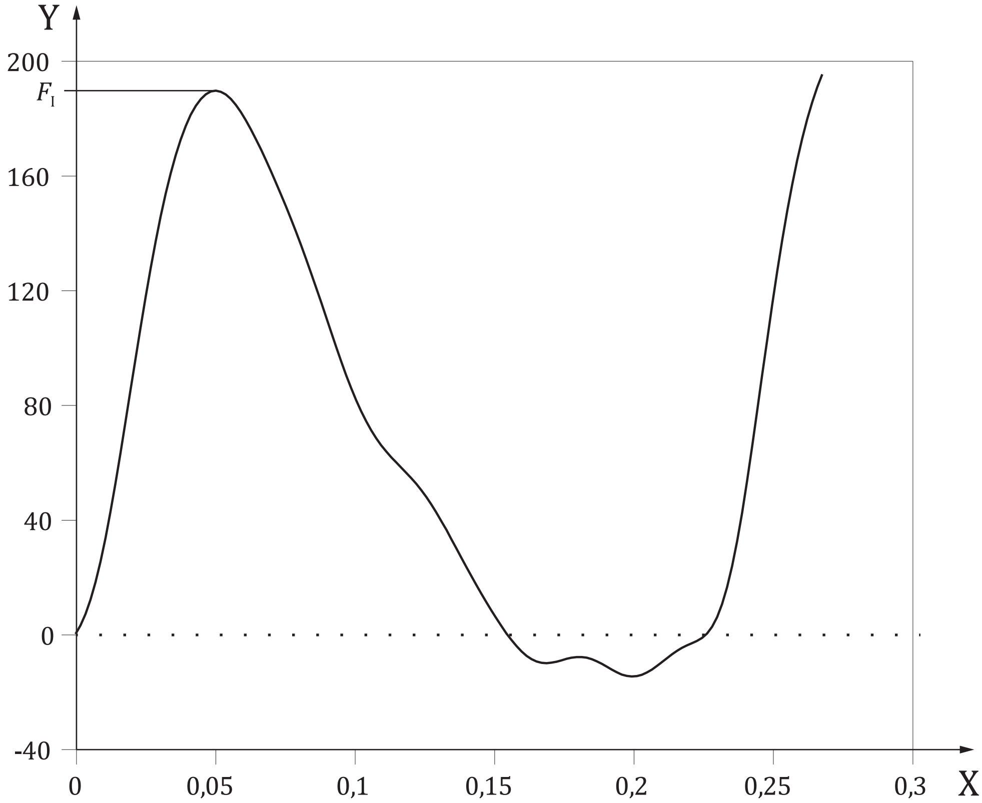
● PA 6

□ PA 66, 30 % GF

⊞ PBT+PC

■ PS

Figure A.1 — Peak force, F_I, and duration, t_I, of the inertial peak as a function of impact velocity



Key

X time after impact in milliseconds, ms

Y force in newtons, N

F_I peak force of inertial peak

NOTE The negative forces occurring after the inertial peak are less than 20 % of F_I.

Figure A.2 — Example of the inertial peak in a force-time curve

Annex B
(informative)

Mass of frame

The momentum, I, in kilogram metres per second (kg·m/s), transferred to the frame of the test machine at the end of the impact is given by Formula (B.1)

$$I = \int_0^{t_B} F \mathrm{d}t \approx v_F m_F \tag{B.1}$$

where

F is the force measured, in newtons;

t_B is the time to break, in seconds;

v_F is the maximum velocity, expressed in metres per second, of the frame, assuming that it moves freely during the short time, t_B, of the impact;

m_F is the mass, in kilograms, of the frame.

The maximum energy expended can be approximated (see the note to 8.3) by Formula (B.2)

$$W^* = I\, v_I \approx v_F\, m_F\, v_I \tag{B.2}$$

where v_I is the impact velocity, in metres per second.

From Formula (B.2), it follows that

$$v_F / v_I \approx W^* / (m_F\, v_I^2) \tag{B.3}$$

If the ratio W^*/E of the maximum work to the kinetic energy of the energy carrier is denoted by k, then [see Formula (B.4)]:

$$W^* = k\, m_C\, v_I^2 / 2 \tag{B.4}$$

where m_C is the mass of the energy carrier.

Formula (B.3) can therefore be written as Formula (B.5)

$$v_F/v_I \approx k\, m_C/(2m_F) \tag{B.5}$$

If $v_F/v_I \leq 0,01$ is acceptable, Formula (B.5) yields the relation shown as Formula (B.6):

$$k \leq 0,02\, m_F / m_C \tag{B.6}$$

For a mass ratio m_F/m_C of 10, the frame is accelerated to less than 1 % of the impact velocity if the energy expended is less than 20 % of the energy of the energy carrier.

Annex C
(informative)

Precision data

C.1 Tables C.1 and C.2 are based on an interlaboratory test involving four laboratories and one material. All of the test samples were produced and distributed by one source. Each “test result” was the average of 10 individual determinations. Each laboratory obtained and reported 10 test results for each material.

C.2 Tables C.3 and C.4 are based on an interlaboratory test involving three laboratories and one material. All of the test samples were produced and distributed by one source. Each “test result” was the average of 10 individual determinations. Each laboratory obtained and reported 10 test results for each material.

C.3 Due to the limited number of laboratories and materials, the explanations of r and R given in C.4 are only intended to present a meaningful way of considering the approximate precision of this test method. The data in Tables C.1 to C.4 should not be rigorously applied to acceptance or rejection of material, as those data are specific to the round robin and might not be representative of other lots, conditions, materials or laboratories.

C.4 Concept of “r” and “R” in Tables C.1 to C.4: If s_r and s_R have been calculated from a large enough body of data, and for test results that were averages from testing 10 specimens for each test result, then the following applies:

a) Repeatability — Two test results obtained within one laboratory should be judged not equivalent if they differ by more than the r value for that material, r being the interval representing the critical difference between two test results for the same material, obtained by the same operator using the same equipment in the same laboratory.

b) Reproducibility — Two test results obtained by different laboratories should be judged not equivalent if they differ by more than the R value for that material, R being the interval representing the critical difference between two test results for the same material, obtained by different operators using different equipment in different laboratories.

The judgements in a) and b) will have an approximately 95 % (0,95) probability of being correct.

Table C.1 — Precision for Charpy (notched) impact strength

Values in kilojoules per square metre

Material	**Average**	s_r	s_R	r	R
PS-HI	13,03	0,099	1,56	0,28	4,36
s_r within-laboratory standard deviation; s_R between-laboratory standard deviation; r 95 % repeatability limit (= 2,8s_r); R 95 % reproducibility limit (= 2,8s_R).					

Table C.2 — Precision for impact energy at break

Values in joules

Material	Average	s_r	s_R	r	R
PS-HI	0,40	0,004	0,04	0,01	0,11

s_r within-laboratory standard deviation;
s_R between-laboratory standard deviation;
r 95 % repeatability limit (= $2{,}8s_r$);
R 95 % reproducibility limit (= $2{,}8s_R$).

Table C.3 — Precision for maximum impact force

Values in newtons

Material	Average	s_r	s_R	r	R
PS-HI	193,7	3,62	9,72	10,14	27,23

s_r within-laboratory standard deviation;
s_R between-laboratory standard deviation;
r 95 % repeatability limit (= $2{,}8s_r$);
R 95 % reproducibility limit (= $2{,}8s_R$).

Table C.4 — Precision for deflection at maximum impact force

Values in millimetres

Material	Average	s_r	s_R	r	R
PS-HI	1,89	0,049	0,06	0,14	0,17

s_r within-laboratory standard deviation;
s_R between-laboratory standard deviation;
r 95 % repeatability limit (= $2{,}8s_r$);
R 95 % reproducibility limit (= $2{,}8s_R$).

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