INTERNATIONAL STANDARD

ISO 179-2

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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
ISO 179-2:1997(E)

Foreword

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Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

International Standard ISO 179-2 was prepared by Technical Committee ISO/TC 61, *Plastics*, Subcommittee SC 2, *Mechanical properties*.

ISO 179 consists of the following parts, under the general title *Plastics — Determination of Charpy impact properties*:

— *Part 1: Non-instrumented impact test*

— *Part 2: Instrumented impact test*

Annexes A to C of this part of ISO 179 are for information only.

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Plastics — Determination of Charpy impact properties —

Part 2:
Instrumented impact test

1 Scope

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

Dynamic effects such as load-cell/striker resonance, test specimen resonance and initial-contact/inertia peaks are described (see figure 1, curve b, and annex A).

1.2 For the comparison between Charpy and Izod test methods, see ISO 179-1, clause 1.

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, annex C). This part of ISO 179 is used if a force-deflection or force-time diagram is necessary for detailed characterization of the impact behaviour, and for developing automatic apparatus, i.e. avoiding the need, mentioned above, to match energy.

1.3 For the range of materials which may be tested by this method, see ISO 179-1, clause 1.

1.4 For the general comparability of test results, see ISO 179-1, clause 1.

1.5 The method may not be used as a source of data for design calculations on components. However, the possible use of data is not the subject of this part of ISO 179. Any application of data obtained using this part of ISO 179 should be specified by a referring standard or agreed upon by the interested parties.

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 part of ISO 179 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 are comparable only if the conditions of test specimen preparation, as well as the test conditions, are the same. Comprehensive evaluation of the reaction to impact stress requires that determinations be made as a function of deformation rate and temperature for different material variables such as crystallinity and moisture content. The impact behaviour of finished products cannot, therefore, be predicted directly from this test, but test specimens may be taken from finished products for testing by this method.

1.7 Impact strengths determined by this method may replace those determined using ISO 179-1 if comparability has been established by previous tests.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this part of ISO 179. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this part of ISO 179 are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

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

ISO 13802:—2), *Plastics — Verification of pendulum impact-testing machines — Charpy, Izod and tensile impact testing*.

3 Definitions

For the purposes of this part of ISO 179, the definitions given in part 1 apply, together with the following:

3.1 impact velocity, v_0**:** The velocity of the striker relative to the test specimen supports at the moment of impact.

It is expressed in metres per second (m/s).

3.2 inertial peak: The first peak in a force-time or force-deflection diagram. It 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**:** The force exerted by the striking edge on the test specimen in the direction of impact.

It is expressed in newtons (N).

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

It is expressed in millimetres (mm).

3.5 impact energy, W**:** The energy expended in accelerating, deforming and breaking the test specimen during the deflection s.

It is expressed in joules (J).

It is measured by integrating the area under the force-deflection curve from the point of impact to the deflection s.

3.6 maximum impact force, F_M**:** The maximum value of the impact force in a force-time or force-deflection diagram (see figure 1).

It is expressed in newtons (N).

3.7 deflection at maximum impact force, s_M**:** The deflection at which the maximum impact force F_M occurs (see figure 1).

It is expressed in millimetres (mm).

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1) To be published. (Revision of ISO 179:1993)

2) To be published.

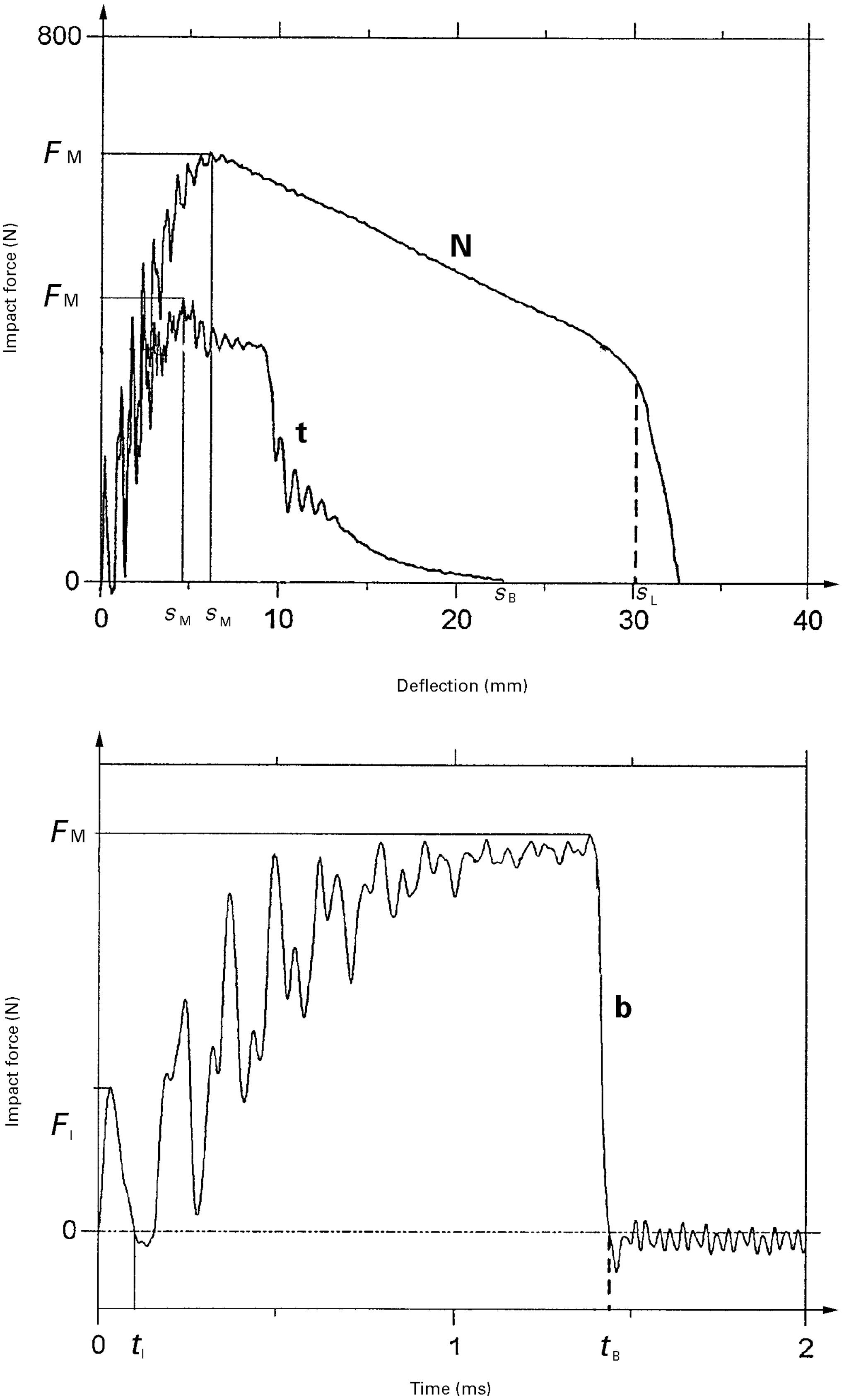
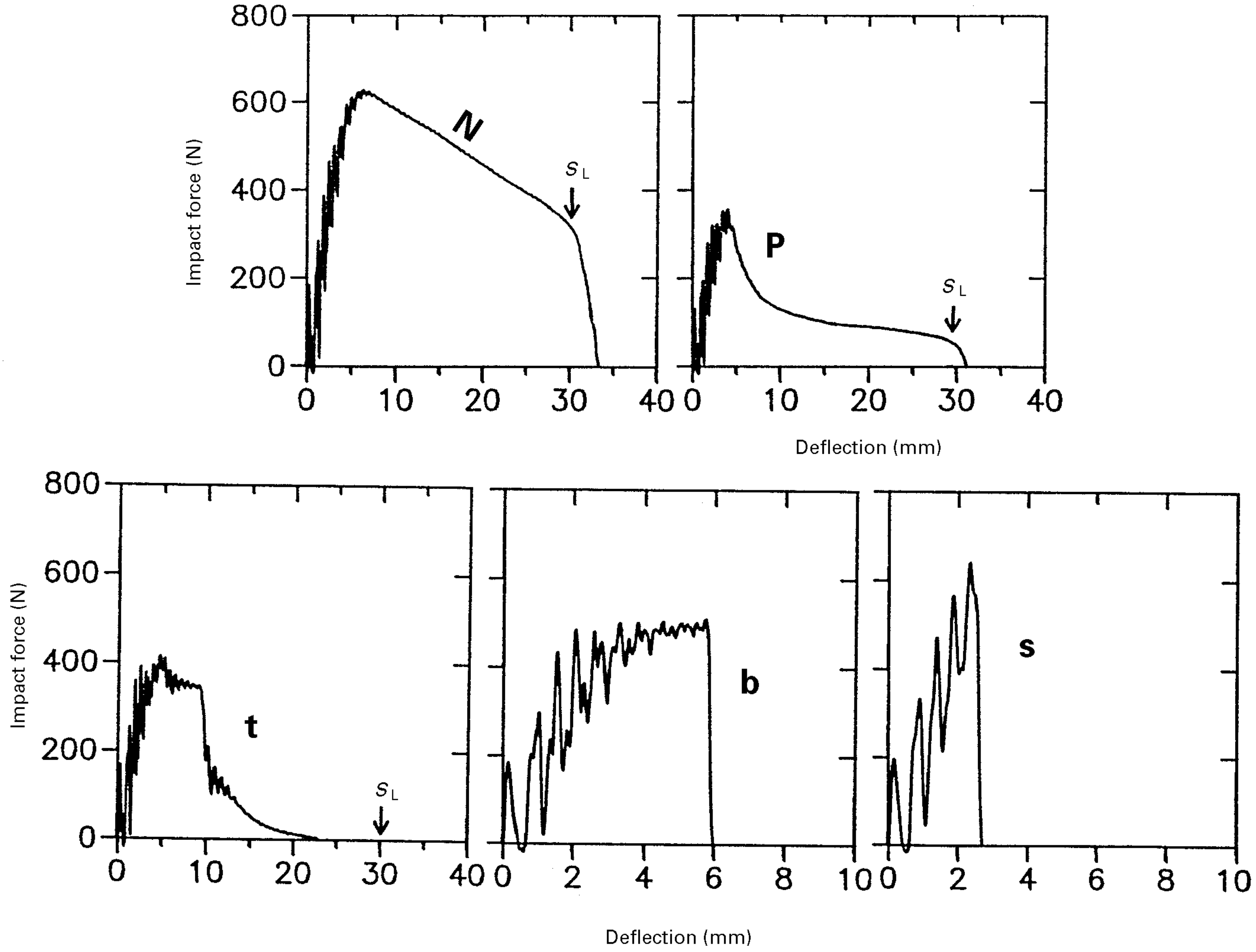


Figure 1 — Typical force-deflection (N and t) and force-time (b) curves
(for the types of failure, see figure 2)



N = no break: yielding followed by plastic deformation up to the deflection limit s_L;

P = partial break: yielding followed by stable cracking, resulting in a force at the deflection limit s_L which is greater than 5 % of the maximum force;

t = tough break: 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;

b = brittle break: yielding followed by unstable cracking;

s = splintering break: unstable cracking followed by yielding;

s_L = deflection limit; beginning of pull-through.

NOTE — Due to the different modes of deformation, force-deformation curves obtained using this part of ISO 179 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).

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

3.8 energy to maximum impact force, W_M: The energy expended up to the deflection at maximum impact force.

It is expressed in joules (J).

3.9 deflection at break, s_B: The deflection at which the impact force is reduced to less than or equal to 5 % of the maximum impact force F_M (see figure 1).

It is expressed in millimetres (mm).

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 32 mm to 34 mm.

NOTE — Using type 1 specimens tested edgewise, apparent deflection limits are sometimes observed, i.e. unexpectedly low values (down to only 20 mm) at which the impact force drops to zero, but the specimens do not break. Carrying out the test slowly shows that, in such cases, 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.

This phenomenon may be avoided by fitting guide elements in front of, but not connected to, the instrumented striking edge, thus preventing the central part of the specimen from twisting to any great extent.

3.10 impact energy at break, W_B: The impact energy up to the deflection at break s_B.

It is expressed in joules (J).

3.11 Charpy (notched) impact strength, a_{cU} (a_{cN}): The impact energy at break relative to the initial central cross-sectional area A (A_N) of the unnotched (notched) specimen (see 8.4 and ISO 179-1, 3.1 and 3.2).

It is expressed in kilojoules per square metre (kJ/m^2).

3.12 type of failure: The type of deformation behaviour of the material under test (see figure 2). It may be either no break (N), partial break (P), tough (t), brittle (b) or splintering (s).

Types t, b and s represent subgroups of the complete break C and hinge break H defined in part 1 of ISO 179. 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, subclause 7.6. For specimens showing more than one failure type, see ISO 179-1, subclause 7.7.

NOTE — 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.

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. The impact geometry is described in ISO 13802, clause 5. During the impact, the impact force is recorded. 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.

5.1.2 Energy carrier

For the low-energy pendulum types specified in ISO 179-1 (see also ISO 13802, subclause 5.2.3), the impact velocity v_0 is 2,90 m/s ± 0,15 m/s and for the high-energy types it is 3,8 m/s ± 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 part of ISO 179 shall be 2,90 m/s ± 0,15 m/s, although it may be desirable to also use the impact velocity v_0 = 3,8 m/s ± 0,2 m/s (see also notes 1 and 2 below).

To avoid obtaining results which cannot be compared due to the viscoelastic behaviour of the material under test, the decrease in the velocity during impact shall not be greater than 10 % (see note 3 below).

The hydraulic-type energy carrier is a high-speed impact-testing machine with suitable attachments. Any inaccuracy in the velocity of the striker relative to the specimen supports during impact shall be checked, e.g. by recording the deflection-time curve and checking the slope.

In the case of gravitationally accelerated energy carriers, the above impact velocities correspond to drop heights of 43 cm ± 5 cm and 74 cm ± 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 of 10 % specified above means that the kinetic energy E, in joules, at impact must satisfy the condition

$$E/W^* \geqslant 5 \qquad \text{. . . (1)}$$

where W^* is the highest value, in joules, of the energy to be measured (see ISO 13802, annex C, and note 2).

The mass m_C, in kilograms, of the energy carrier must therefore satisfy inequalities (2) and (3):

$$m_\mathrm{C} \geqslant 10\,W^*/v_0^2 \qquad \text{. . . (2)}$$

$$m_\mathrm{C} \geqslant 1{,}2\,W^* \text{ when } v_0 = 2{,}9\text{ m/s} \qquad \text{. . . (3)}$$

e.g.

$$m_\mathrm{C} \geqslant 12\text{ kg when } W^* = 10\text{ J}$$

NOTES

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 [2] in annex C. For further information about the interpretation of the inertial peak and the damping of vibrations, see annex A.

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

3 This condition is in accordance with the conditions given in ISO 179-1, subclause 7.3 (see ISO 13802, annex C). 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

See ISO 13802, subclause 5.8.1 and table 3.

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 — 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.

5.1.4 Pendulum

The pendulum shall conform to ISO 13802, subclause 5.2 and table 3.

5.1.5 Test specimen supports

The test specimen supports shall conform to ISO 13802, subclause 5.7.1.

5.1.6 Frame

The frame of the test machine shall be capable of being levelled so that the striker and the specimen supports conform to 5.1.3 and 5.1.5.

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.

NOTES

1 ISO 13802, subclause 5.3.3, requires a pendulum mass to foundation mass ratio of 40 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.

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).

5.1.7 Losses due to friction

For energy carriers which give a frictionless impact, e.g. a falling dart or a pendulum, in cases when the deflection is not measured, the impact velocity shall not deviate by more than 1 % from the calculated value. I.e, the frictional loss W_f shall be less than 2 % of the nominal energy E for the first quarter-swing of the pendulum, i.e. less than 8 % for full swing (see also ISO 13802, subclause 5.6).

NOTE — If the deflection is measured directly, the energy lost by the energy carrier due to friction does not influence the test results, provided the impact velocity is in the defined range.

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 equal to or within 1 % of the maximum value of the force concerned.

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]). Errors in force measurement after calibration shall be less than ± 2 %.

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 below).

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).

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)].

NOTES

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 would generally be 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, curve 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].

2 The force-measurement system will be excited to oscillate at its natural frequency by the impact. The amplitude of this oscillation will depend 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 may 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.

3 Vibration of the specimen (see figure 1, curve b), as well as noise on the trace, generate uncertainties in the maximum impact force, but almost no uncertainty in the energy to maximum impact force or the energy at break.

In order to monitor adequately the inertial peak, the duration of which t_I (see figure 1, curve 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, (see note 4 below).

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

NOTE 4 — The impact is a fast event with an impact velocity of 2,9 m/s and a maximum duration of about 13 ms. This necessitates the storage of the sampled force and, if applicable, deflection data in transient recorders. About 50 % of the available storage space can be used for the actual test data.

Higher sampling frequencies lead to better time resolution, and this may be helpful in assessing impact tests on brittle materials which give small values of the time to break t_B.

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.

In most cases, the instruments used to measure the force and deflection show a difference in their signal-transit times, generating 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 conform to ISO 179-1, subclause 5.2.

6 Test specimens

Test specimens shall conform to ISO 179-1, clause 6.

7 Procedure

7.1 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 the testing of low-temperature-conditioned specimens at room temperature, a time between conditioning and testing of less than 10 s has been successfully used. Differences in humidity between the conditioning and test atmospheres are less critical. For polyamides, specimen-transfer times of up to 30 min did not generate significant differences in impact behaviour.

7.2 Determine the width and thickness of the specimens in accordance with ISO 179-1, subclause 7.1.

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 figure 1 in ISO 179-1).

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.

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 1 below).

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 equation (4) or (5), as applicable (see note 1 below).

For horizontally impacting pendulum-type energy carriers:

$$s(t) = v_0 t - \frac{L_\mathrm{P} \times g}{M_\mathrm{H}} \int_0^t \int_0^{t_1} F(t)\,\mathrm{d}t\,\mathrm{d}t_1 \qquad \text{. . . (4)}$$

For vertically impacting free-falling energy carriers:

$$s(t) = v_0 t - \frac{1}{m_\mathrm{C}} \int_0^t \int_0^{t_1} F(t)\,\mathrm{d}t\,\mathrm{d}t_1 + \frac{1}{2} g t^2 \qquad \text{. . . (5)}$$

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, subclause 5.2.1);

M_H is the horizontal moment of the pendulum, in newton metres (see ISO 13802, subclause 5.2.3);

$F(t)$ 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.

NOTES

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 equations (4) and (5) constitutes a correction of less than 5 % of $v_0 t$.

2 The relative contribution of the last term in equation (5) 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 equation (6) (see the note below).

$$W_j = \int_0^{s_j} F(s)\, ds \qquad \ldots (6)$$

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 the equation

$$W_j = W_{ja}\left(1 - W_{ja}/4E\right) \qquad \ldots (7)$$

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

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

The second term inside the brackets in equation (7) 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.

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 following equation:

$$a_{cU} = \frac{W_B}{bh} \times 10^3 \qquad \text{. . . (8)}$$

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 following equation:

$$a_{cN} = \frac{W_B}{hb_N} \times 10^3 \qquad \text{. . . (9)}$$

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 denotes one of the notch types A, B or C (see ISO 179-1, subclause 6.3).

8.5 Statistical parameters

See ISO 179-1, subclause 8.3.

8.6 Number of significant figures

Report all mean values to two significant figures.

9 Precision

See ISO 179-1, clause 9.

10 Test report

The test report shall include the following information:

a) a reference to this part of ISO 179;

b) the method of designation used:

either in accordance with table 3 of ISO 179-1, e.g.

Instrumented Charpy impact test ISO 179-2/1 e A
Specimen type (see table 2 of ISO 179-1)
Direction of blow (see figure 5 of ISO 179-1)
Type of notch (see figure 4 of ISO 179-1)

or in accordance with table 4 of ISO 179-1, e.g.

Instrumented Charpy impact test ISO 179-2/2 n
Specimen type (see table 2 of ISO 179-1)
Direction of blow (see figure 5 of ISO 179-1)

c) to k) See items c) to k) in clause 10 of ISO 179-1;

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 or coefficient of variation for

the maximum force F_M, in newtons;
the deflection at maximum force s_M, in millimetres;
the energy to maximum force W_M, in joules;
the deflection at break s_B, in millimetres;
the energy at break W_B, in joules;
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 [3]

The inertial peak 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 time 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 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 part of ISO 179, it is recommended that “bouncing” vibrations are not damped.

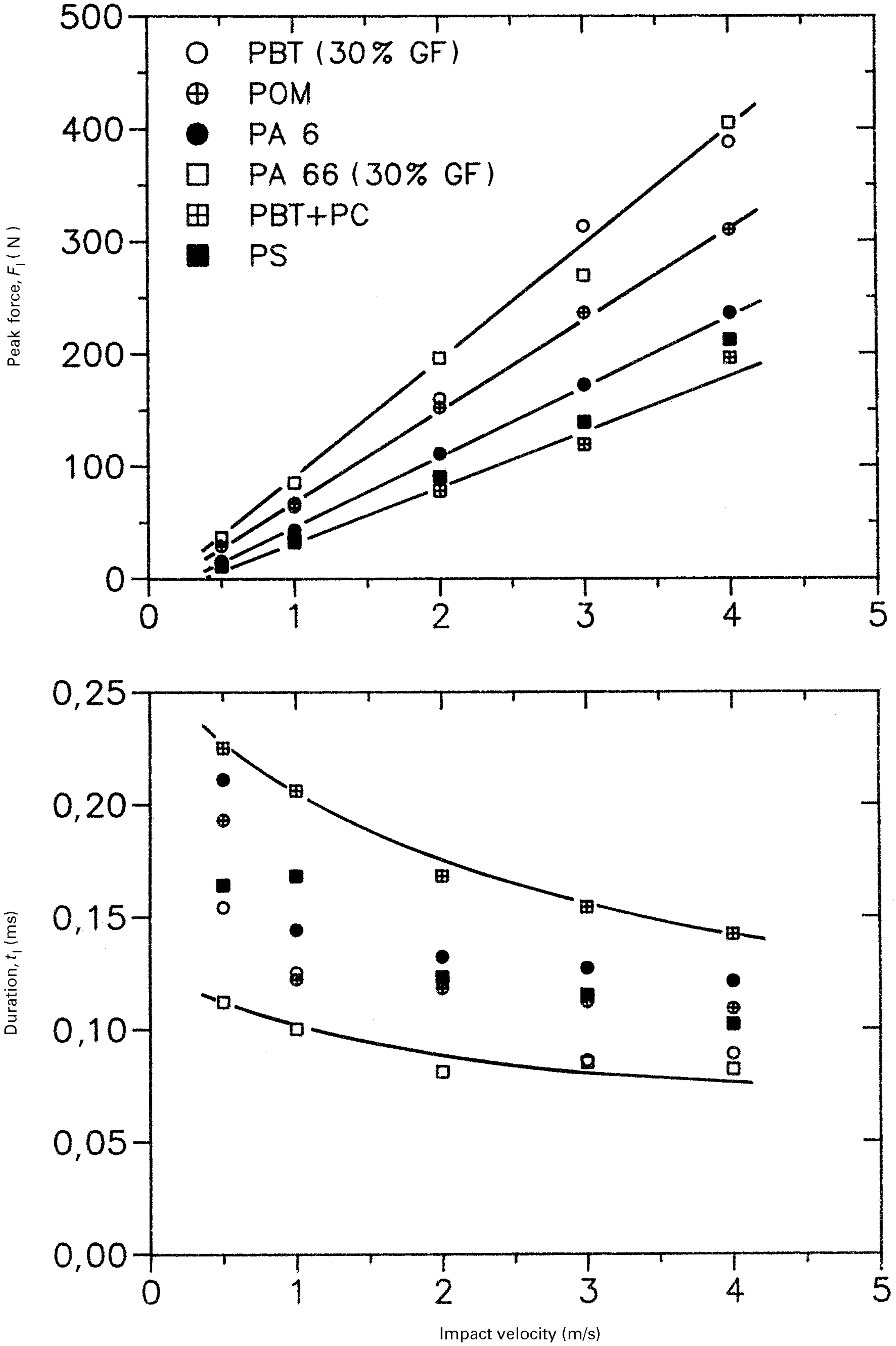
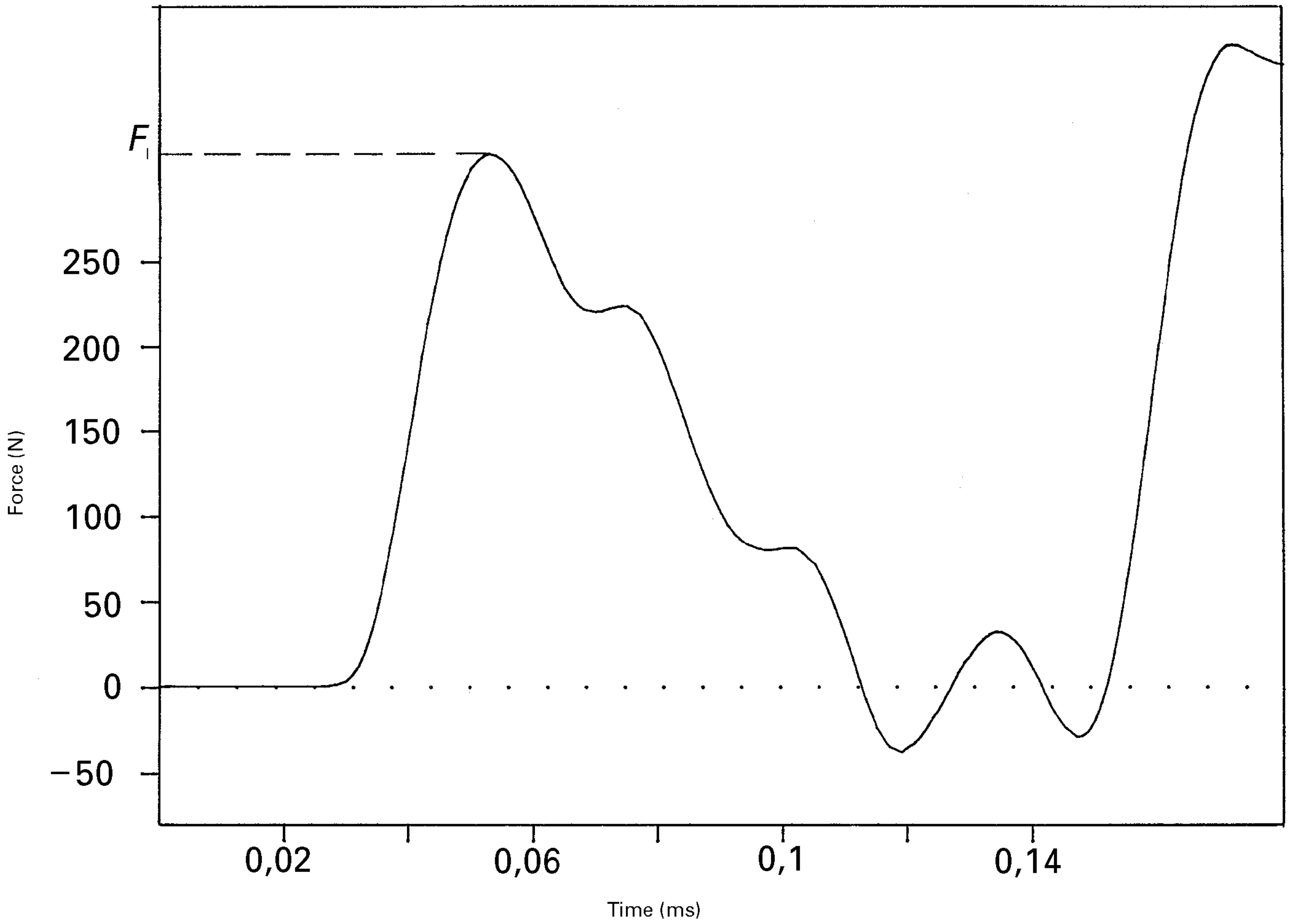


Figure A.1 — Peak force F_l and duration t_l of the inertial peak as a function of impact velocity



Note that the peak negative forces occurring after the inertial peak are less than 20 % of F_I .

Figure A.2 — Example of a force-time curve with an inertial peak

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 the equation

$$I = \int_0^{t_B} F dt$$

$$\approx v_F m_F \quad \text{. . . (B.1)}$$

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

$$W^* \approx I \times v_0$$

$$\approx v_F m_F \times v_0 \quad \text{. . . (B.2)}$$

where

v_0 is the impact velocity, in metres per second.

From equation (B.2), it follows that

$$v_F / v_0 \approx W^* / m_F \, v_0{}^2 \quad \text{. . . (B.3)}$$

If the ratio W^*/E of the maximum work to the kinetic energy of the energy carrier is denoted by k, then

$$W^* = k \times \frac{1}{2} m_C v_0{}^2 \quad \text{. . . (B.4)}$$

where m_C is the mass of the energy carrier.

Equation (B.3) can therefore be written as

$$v_F / v_0 \approx 0{,}5k \times m_C / m_F \quad \text{. . . (B.5)}$$

If $v_F/v_0 \leqslant 0{,}01$ is acceptable, equation (B.5) yields the relation

$$k \leqslant 0{,}02 \, m_F / m_C \quad \text{. . . (B.6)}$$

For a mass ratio m_F/m_C of 10, the frame will be 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)

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3) To be published. (Revision of ISO 6603-2:1989)

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