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Plastics — Determination of Charpy impact strength

Plastiques — Détermination de la résistance au choc Charpy

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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.

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 was prepared by Technical Committee ISO/TC 61, *Plastics*, Sub-Committee SC 2, *Mechanical properties*.

This second edition cancels and replaces the first edition (ISO 179:1982), which has been revised in the following ways.

— The recommended specimen types for testing moulding materials are reduced to one only, which can be taken from the multipurpose test specimen complying with ISO 3167 by simple machining.

— The notch types are reduced to three only: V-type, 45°, with different notch base radii.

— The preferred direction of blow is changed from "flatwise" (parallel to the dimension thickness) to "edgewise" (parallel to the dimension width) in order to align the test method with that of the Izod test according to ISO 180.

— Special test methods are included for laminated sheets in order to respect the thicknesses of semifinished products and interlaminar shear failure.

— The designation of sizes are harmonized with those of a great number of other International Standards for testing plastics, in accordance with ISO 31.

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— The method designations are harmonized with the modifications described above (direction of blow and types of notch).

Annex A of this International Standard is for information only.

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Plastics — Determination of Charpy impact strength

1 Scope

1.1 This International Standard specifies a method for determining the Charpy impact strength of plastics under defined conditions. A number of different types of specimen and test configurations are defined. Different test parameters are specified according to the type of material, the type of test specimen and the type of notch.

1.2 The method is used to investigate the behaviour of specified types of specimen under the impact conditions defined and for estimating the brittleness or toughness of specimens within the limitations inherent in the test conditions.

The method has a greater range of applicability than that given in ISO 180 (Izod)[1] and is more suitable for the testing of materials showing interlaminar shear fracture or of materials exhibiting surface effects due to environmental factors.

1.3 The method is suitable for use with the following range of materials:

— rigid thermoplastics moulding and extrusion materials, including filled and reinforced compounds in addition to unfilled types; rigid thermoplastics sheets;

— rigid thermosetting moulding materials, including filled and reinforced compounds; rigid thermosetting sheets, including laminates;

— fibre-reinforced thermoset and thermoplastics composites incorporating unidirectional or non-unidirectional reinforcements such as mat, woven fabrics, woven rovings, chopped strands, combination and hybrid reinforcements, rovings and milled fibres; sheets made from pre-impregnated materials (prepregs);

— thermotropic liquid-crystal polymers.

The method is not normally suitable for use with rigid cellular materials and sandwich structures containing cellular material. Also, notched specimens are not normally used for long-fibre-reinforced composites or for thermotropic liquid-crystal polymers.

1.4 The method is adapted to the use of specimens which may be either moulded to the chosen dimensions, machined from the central portion of a standard multipurpose test specimen (see ISO 3167) or machined from finished and semifinished products such as mouldings, laminates and extruded or cast sheet.

1.5 The method specifies preferred dimensions for the test specimen. Tests which are carried out on specimens of different dimensions and notches, or on specimens which are prepared under different conditions, may produce results which are not comparable. Other factors, such as the energy capacity of the pendulum, its impact velocity and the conditioning of the specimens can also influence the results. Consequently, when comparative data are required, these factors must be carefully controlled and recorded.

1.6 The method should not be used as a source of data for design calculations of components. Information on the typical behaviour of a material can be obtained, however, by testing at different temperatures, by varying the notch radius and/or the thickness and by testing specimens prepared under different conditions.

2 Normative references

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

1) ISO 180:1993, *Plastics — Determination of Izod impact strength.*

Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 291:1977, *Plastics — Standard atmospheres for conditioning and testing.*

ISO 293:1986, *Plastics — Compression moulding test specimens of thermoplastic materials.*

ISO 294:—[2], *Plastics — Injection moulding of test specimens of thermoplastic materials.*

ISO 295:1991, *Plastics — Compression moulding of test specimens of thermosetting materials.*

ISO 1268:1974, *Plastics — Preparation of glass fibre reinforced, resin bonded, low-pressure laminated plates or panels for test purposes.*

ISO 2557-1:1989, *Plastics — Amorphous thermoplastics — Preparation of test specimens with a specified maximum reversion — Part 1: Bars.*

ISO 2557-2:1986, *Plastics — Amorphous thermoplastics — Preparation of test specimens with a specified reversion — Part 2: Plates.*

ISO 2602:1980, *Statistical interpretation of test results — Estimation of the mean — Confidence interval.*

ISO 2818:—[3], *Plastics — Preparation of test specimens by machining.*

ISO 3167:1993, *Plastics — Multipurpose test specimens.*

3 Definitions

For the purposes of this International Standard, the following definitions apply.

3.1 Charpy impact strength of unnotched specimens, a_{cU}**:** Impact energy absorbed in breaking an unnotched specimen, referred to the original cross-sectional area of the specimen.

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

3.2 Charpy impact strength of notched specimens, a_{cN}**:** Impact energy absorbed in breaking a notched specimen, referred to the original cross-sectional area of the specimen at the notch, where N = A, B or C depending on the notch type (see 6.3.1.1.2).

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

3.3 edgewise impact (e)**:** Direction of blow parallel to the dimension b, with impact on the narrow longitudinal surface $h \times l$ of the specimen (see figure 1, left, and figures 2 and 5).

3.4 flatwise impact (f)**:** Direction of blow parallel to the dimension h, with impact on the broad longitudinal surface $b \times l$ of the specimen (see figure 1, right, and figures 3 and 5).

3.5 normal impact (n)**:** Direction of blow normal to the plane of reinforcement (see figure 5).

It is used for laminar-type reinforced plastics.

3.6 parallel impact (p)**:** Direction of blow parallel to the plane of reinforcement (see figure 5).

4 Principle

The test specimen, supported as a horizontal beam, is broken by a single swing of a pendulum, with the line of impact midway between the supports.

In the case of edgewise impact with notched specimens, the line of impact is directly opposite the single notch (see figure 1, left, and figure 2).

5 Apparatus

5.1 Testing machine

5.1.1 The testing machine shall be of the pendulum type and shall be of rigid construction. It shall be capable of measuring the impact energy, W, absorbed in breaking a test specimen. The value of this energy is defined as the difference between the initial energy, E, of the pendulum and the energy remaining in the pendulum after breaking the test specimen. The energy shall be accurately corrected for losses due to friction and air resistance (see table 1 and 7.4).

5.1.2 The machine shall have the characteristics shown in table 1.

In order to apply the test to the full range of materials specified in 1.3, it is necessary to use more than one machine or to use a set of interchangeable pendulums (see 7.3). It is not advisable to compare results obtained with different pendulums. The frictional losses shall be periodically checked.

2) To be published. (Revision of ISO 294:1975)

3) To be published. (Revision of ISO 2818:1980)

Table 1 — Characteristics of pendulum impact testing machines

Energy E (nominal) J	Velocity of impact v_0 m/s	Maximum permissible frictional loss without specimen J	Permissible error[1] after correction with specimen J
0,5 1,0 2,0 4,0 5,0	2,9 (± 10 %)	0,02	0,01 0,01 0,01 0,02 0,02
7,5 15,0 25,0 50,0	3,8 (± 10 %)	0,04 0,05 0,10 0,20	0,05 0,05 0,10 0,10

1) The permissible error shall not be exceeded within the 10 % to 80 % range of the pendulum capacity.

5.1.3 The machine shall be securely fixed to a foundation having a mass at least 40 times that of the heaviest pendulum in use. The foundation shall be capable of being adjusted so that the striker and supports are as specified in 5.1.4 and 5.1.6.

5.1.4 The striking edge of the pendulum shall be hardened steel tapered to an included angle of 30° ± 1° and shall be rounded to a radius R_1 = 2 mm ± 0,5 mm. It shall pass midway, to within ± 0,2 mm, between the test specimen supports, and shall be aligned so that it contacts the full width or thickness of rectangular test specimens. The line of contact shall be perpendicular, within ± 2°, to the longitudinal axis of the test specimen.

5.1.5 The distance between the axis of rotation and the point of impact at the centre of the specimen shall be within ± 1 % of the pendulum length L_p.

NOTE 1 The pendulum length L_p, in metres, may be determined experimentally from the period of small amplitude oscillations of the pendulum by means of the following equation:

$$L_p = \frac{g_n}{4\pi^2} \times T^2 \qquad \ldots (1)$$

where

g_n is the standard acceleration of free fall, in metres per second squared (9,81 m/s^2);

T is the period, in seconds, of a single complete swing (to and fro) determined from at least 50 consecutive and uninterrupted swings (known to an accuracy of 1 part in 2 000). The angle of swing shall be less than 5° to each side of the centre.

5.1.6 The test specimen supports shall be two rigidly mounted smooth blocks, arranged so that the longitudinal axis of a perfectly rectangular test specimen is horizontal to within 1 part in 200, and the striking face of such a test specimen is parallel to the striking edge of the pendulum to within 1 part in 200 at the moment of impact. The specimen supports shall not inhibit the movement of the specimen.

The shape of the supports shall be as shown in figure 1. The span, L, is the distance between the contact lines of the specimen on the supports and shall be as specified in table 2. Means shall be provided to centre test specimens, in relation to the striker, to within ± 0,5 mm. Separate support blocks may be required for each type of test specimen.

5.2 Micrometers and gauges

Micrometers and gauges suitable for measuring the essential dimensions of test specimens to an accuracy of 0,02 mm are required. For measuring the dimension b_N of notched specimens, the micrometer shall be fitted with an anvil of width 2 mm to 3 mm and of suitable profile to fit the shape of the notch.

6 Test specimens

6.1 Preparation

6.1.1 Moulding or extrusion compounds

Specimens shall be prepared in accordance with the relevant material specification. When none exists, or unless otherwise specified, specimens shall be either directly compression moulded or injection moulded from the material in accordance with ISO 293, ISO 294, ISO 295, ISO 2557-1 or ISO 2557-2 as appropriate, or machined in accordance with ISO 2818 from sheet that has been compression or injection moulded from the compound.

NOTE 2 Type 1 specimens may be cut from multipurpose test specimens complying with ISO 3167 type A.

Table 2 — Specimen types, dimensions and span (see figure 1)

Dimensions in millimetres

Specimen type[1]	Length[2] l	Width[2] b	Thickness[2] h	Span L
1	80 ± 2	10,0 ± 0,2	4,0 [3] ± 0,2	62 $^{+0,5}_{0}$
2 [4] **3** [4]	25 h (11 or 13) h	10 or 15 [5]	3 [3]	20 h (6 or 8) h

1) Attention is drawn to the changes in the specimen type numbers from those used in ISO 179:1982.

2) The specimen dimensions (thickness h, width b and length l) are defined according to: $h \leqslant b < l$.

3) Preferred thickness. If the specimen is cut from a sheet or a piece, h shall be equal to the thickness of the sheet or piece, up to 10,2 mm (see 6.3.1.2).

4) Specimen types 2 and 3 shall be used only for materials described in 6.3.2.

5) 10 mm for materials reinforced with a fine structure, 15 mm with a large stitch structure (see 6.3.2.2).

6.1.2 Sheets

Specimens shall be machined from sheets in accordance with ISO 2818.

6.1.3 Long-fibre-reinforced polymers

A panel shall be prepared in accordance with ISO 1268 or another specified or agreed upon preparation procedure. Specimens shall be machined in accordance with ISO 2818.

6.1.4 Checking

The specimens shall be free of twist and shall have mutually perpendicular parallel surfaces. The surfaces and edges shall be free from scratches, pits, sink marks and flash.

The specimens shall be checked for conformity with these requirements by visual observation against straightedges, squares and flat plates, and by measuring with micrometer calipers.

Specimens showing measurable or observable departure from one or more of these requirements shall be rejected or machined to proper size and shape before testing.

6.1.5 Notching

6.1.5.1 Machined notches shall be prepared in accordance with ISO 2818. The profile of the cutting tooth shall be such as to produce in the specimen a notch of the contour and depth shown in figure 4, at right angles to its principal axes.

6.1.5.2 Specimens with moulded-in notches may be used if specified for the material being tested. Specimens with moulded-in notches do not give results comparable to those obtained from specimens with machined notches.

6.2 Anisotropy

Certain types of sheet or panel materials may show different impact properties according to the direction in the plane of the sheet or panel. In such cases, it is customary to cut groups of test specimens with their major axes respectively parallel and perpendicular to the direction of some feature of the sheet or panel which is either visible or inferred from knowledge of the method of its manufacture.

6.3 Shape and dimensions

6.3.1 Materials not exhibiting interlaminar shear fracture

6.3.1.1 Moulding and extrusion compounds

6.3.1.1.1 Type 1 test specimens with three different types of notch shall be used as specified in tables 2 and 3, and shown in figures 2 and 4. The notch shall be located at the centre of the specimen.

NOTE 3 Type 1 specimens (see table 2) may be taken from the central part of the multi-purpose test specimen type A complying with ISO 3167.

Table 3 — Method designations, specimen types, notch types and notch dimensions — Materials not exhibiting interlaminar shear fracture

Dimensions in millimetres

Method designation[1) 2)]	Specimen type[1)]	Blow direction	Notch type[1)]	Notch base radius r_N	Remaining width, b_N, at notch base
ISO 179/1eU [3)]	1	edgewise	unnotched		
			single notch		
ISO 179/1eA [3)]			A	0,25 ± 0,05	8,0 ± 0,2
ISO 179/1eB			B	1,00 ± 0,05	8,0 ± 0,2
ISO 179/1eC			C	0,10 ± 0,02	8,0 ± 0,2
ISO 179/1fU [4)]	1	flatwise	unnotched		

1) Attention is drawn to the changes in the specimen type number, notch type letter designations and method designation number from those used in ISO 179:1982,

2) If specimens are taken from sheet or products, the thickness of the sheet or product shall be added to the designation, and unreinforced specimens shall not be tested with their machined surface under tension.

3) Preferred method.

4) Especially for study of surface effects (see 1.2 and 6.3.1.1.3).

6.3.1.1.2 The preferred type of notch is type A (see table 3 and figure 4). For most materials, unnotched specimens or specimens with a single notch of type A tested according to 3.3 (edgewise impact) are suitable. If specimens with notch type A do not break during the test, specimens with notch type C shall be used. If information on the notch sensitivity of the material is desired, specimens with notch type A, B and C shall be tested.

NOTE 4 Notch type C replaces the former U notch, which in some cases gives test results that are not comparable.

6.3.1.1.3 Unnotched or double-notched specimens tested according to 3.4 (flatwise impact) can be used to study surface effects (see 1.2 and annex A).

6.3.1.2 Sheet materials

The recommended thickness h is 4 mm. If the specimen is cut from a sheet or a piece taken from a structure, the thickness of the specimen, up to 10,2 mm, shall be the same as the thickness of the sheet or the structure.

Specimens taken from pieces thicker than 10,2 mm shall be machined to 10 mm ± 0,2 mm from one surface, providing that the sheet is homogeneous in its thickness and contains only one type of reinforcement regularly distributed. If unnotched or double-notched specimens are tested according to 3.4 (flatwise impact), the original surface shall be tested under tension, in order to avoid surface effects.

6.3.2 Materials exhibiting interlaminar shear fracture (e.g. long-fibre-reinforced materials)

6.3.2.1 Unnotched specimens of type 2 or 3 are used. There are no specified specimen sizes. The only important parameter is the ratio of the span, L, to the specimen dimension in the direction of blow (see table 2).

Usually specimens are tested in the normal direction (see figure 5).

6.3.2.2 "Flatwise normal" testing (see figure 5): the width of the specimen shall be 10 mm for materials reinforced with a fine structure (thin fabrics and parallel yarns) and 15 mm for materials reinforced with a large stitch structure (roving fabrics) or an irregularly manufactured structure.

6.3.2.3 "Edgewise parallel" testing (see figure 5): when testing specimens in the parallel direction, the specimen dimension perpendicular to the blow direction shall be the thickness of the sheet from which the specimen was cut.

6.3.2.4 The length, l, of the specimen shall be chosen according to the span to thickness ratio L/h of 20 (for type 2 specimens) and 6 (for type 3 specimens) as indicated in table 2.

If the apparatus does not allow a ratio $L/h = 6$, a ratio $L/h = 8$ may be used, especially for thin sheets.

6.3.2.5 With type 2 specimens, tensile-type failure occurs; with type 3 specimens, interlaminar shear failure of the sheet can occur. The different types of failure that can occur are summarized in table 4.

NOTE 5 In some cases (thin-fabric reinforcement) shear failure does not occur. In the case of type 3 specimens, the fracture initiates as a single- or multiple-shear failure and continues as a tensile failure.

6.4 Number of test specimens

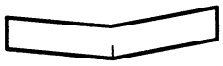
6.4.1 Unless otherwise specified in the standard for the material being tested, a set consisting of a minimum of ten specimens shall be tested. When the coefficient of variation (see ISO 2602) has a value of less than 5 %, a minimum number of five test specimens is sufficient.

6.4.2 If laminates are tested in the normal and parallel directions, ten specimens shall be used for each direction.

6.5 Conditioning

Unless otherwise specified in the standard for the material under test, the specimens shall be conditioned for at least 16 h at 23 °C and 50 % relative humidity according to ISO 291, unless other conditions are agreed upon by the interested parties.

Table 4 — Method designations, specimen types, notch types and notch dimensions — Materials exhibiting interlaminar shear fracture

Method designation	Specimen type	L/h	Type of failure		Schematic
ISO 179/2	2	20	tension	t	
n or p [1]			compression	c	
			buckling	b	
ISO 179/3	3	6 or 8	shear	s	
n or p [1]			multiple shear	ms	
			shear followed by a tensile failure	st	

1) n is the normal direction and p is the parallel direction with respect to the sheet plane (see figure 5).

7 Procedure

7.1 Conduct the test in the same atmosphere as that used for conditioning, unless otherwise agreed upon by the interested parties, e.g. for testing at high or low temperatures.

7.2 Measure the thickness, h, and the width, b, of each test specimen, in the centre, to the nearest 0,02 mm. In the case of notched specimens, carefully measure the remaining width b_N to the nearest 0,02 mm.

NOTE 6 In the case of injection-moulded specimens, it is not necessary to measure the dimensions of each specimen. It is sufficient to measure one specimen from a set to make sure that the dimensions correspond to those in table 2.

With multiple cavity moulds, ensure that the dimensions of the specimens are the same for each cavity.

In the case of specimens type 2 or 3, adjust the span L according to table 2.

7.3 Check that the pendulum machine has the specified velocity of impact (see table 1) and that it is in the correct range of absorbed energy, W, which shall be between 10 % and 80 % of the pendulum energy, E. If more than one of the pendulums described in table 1 meet these requirements, the pendulum having the highest energy shall be used.

7.4 Carry out a blank test (i.e. without a specimen in place) and record the frictional energy loss. Ensure that this energy loss does not exceed the appropriate value given in table 1.

If frictional losses are equal to or less than the values indicated in table 1, they may be used in the calculations of corrected energy absorbed. If frictional losses exceed the values indicated in table 1, care should be taken to evaluate the cause of any excess frictional losses and corrections made as necessary to the equipment.

7.5 Lift and support the pendulum. Place the specimen on the supports of the machine in such a manner that the striking edge will hit the centre of the specimen. Carefully align notched specimens so that the centre of the notch is located directly in the plane of impact (see figure 1, left).

7.6 Release the pendulum. Record the impact energy absorbed by the specimen and apply any necessary corrections for frictional losses etc. (see table 1 and 7.4).

7.7 For moulding and extrusion compounds, four types of failure according to the following letter codes may occur:

C complete break; a break in which the specimen separates into two or more pieces

H hinge break; an incomplete break such that both parts of the specimen are held together only by a thin peripheral layer in the form of a hinge having no residual stiffness

P partial break; an incomplete break that does not meet the definition for a hinge break

NB non-break; in the case where there is no break, and the specimen is only bent and pushed through the support blocks, possibly combined with stress whitening

The measured values of complete and hinged breaks can be used for a common mean value without remark. If in the case of partial breaks a value is required, it shall be designated with the letter P. In the case of non-break, NB, no values shall be reported.

For materials with interlaminar shear fracture, the types of failure and their codes are shown in table 4.

7.8 If, within one sample, the test specimens show both P and C (or H) failures, the mean value for each failure type shall be reported.

8 Calculation and expression of results

8.1 Unnotched specimens

Calculate the Charpy impact strength of unnotched specimens, a_{cU}, expressed in kilojoules per square metre, using the formula

$$a_{cU} = \frac{W}{h \cdot b} \times 10^3 \qquad \ldots (2)$$

where

W is the corrected energy, in joules, absorbed by breaking the test specimen;

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

b is the width, in millimetres, of the test specimen.

8.2 Notched specimens

Calculate the Charpy impact strength of notched specimens, a_{cN}, expressed in kilojoules per square metre, with notches N = A, B or C, using the formula

$$a_{cN} = \frac{W}{h \cdot b_N} \times 10^3 \qquad \ldots (3)$$

where

W is the corrected energy, in joules, absorbed by breaking the test specimen;