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Metallic materials — Charpy V-notch pendulum impact test — Instrumented test method

Matériaux métalliques — Essai de flexion par choc sur éprouvette Charpy à entaille en V — Méthode d'essai instrumenté

Reference number
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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).

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 4, *Toughness testing*.

This second edition cancels and replaces the first edition (ISO 14556:2000), which has been technically revised.

Metallic materials — Charpy V-notch pendulum impact test — Instrumented test method

1 Scope

This International Standard specifies a method of instrumented Charpy V-notch pendulum impact testing on metallic materials and the requirements concerning the measurement and recording equipment.

With respect to the Charpy pendulum impact test described in ISO 148-1, this test provides further information on the fracture behaviour of the product under impact testing conditions.

General information about instrumented impact testing can be found in Reference [1] to Reference [5].

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method.*

ISO 148-2, *Metallic materials — Charpy pendulum impact test — Part 2: Verification of testing machines.*

3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

3.1 Characteristic values of force

3.1.1
general yield force
F_{gy}
force at the transition point from the linearly increasing part to the curved increasing part of the force-displacement curve

Note 1 to entry: It represents a first approximation of the force at which yielding has occurred across the entire test piece ligament (see 9.3).

3.1.2
maximum force
F_m
maximum force in the course of the force-displacement curve

3.1.3
unstable crack initiation force
F_{iu}
force at the beginning of the steep drop in the force-displacement curve (unstable crack initiation)

3.1.4
crack arrest force
F_a
force at the end (arrest) of unstable crack propagation

3.2 Characteristic values of displacement

3.2.1
general yield displacement
s_{gy}
displacement corresponding to the general yield force, F_{gy}

3.2.2
displacement at maximum force
s_m
displacement corresponding to the maximum force, F_m

3.2.3
crack initiation displacement
s_{iu}
displacement corresponding to the force at unstable crack initiation, F_{iu}

3.2.4
crack arrest displacement
s_a
displacement corresponding to the force at the end (arrest) of unstable crack propagation, F_a

3.2.5
total displacement
s_t
displacement at the end of the force-displacement curve

3.3 Characteristic values of impact energy

3.3.1
energy at maximum force
W_m
partial impact energy from $s = 0$ to $s = s_m$

3.3.2
unstable crack initiation energy
W_{iu}
partial impact energy from $s = 0$ to $s = s_{iu}$

3.3.3
crack arrest energy
W_a
partial impact energy from $s = 0$ to $s = s_a$

3.3.4
total impact energy
W_t
energy absorbed by the test piece during the test

Note 1 to entry: Calculated from the area under the force-displacement curve from $s = 0$ to $s = s_t$.

4 Symbols and abbreviated terms

For the purposes of this document, the symbols and abbreviations given in Table 1 are applicable (see also Figure 2 and Figure 3).

Table 1 — Symbols and designations

Symbol	Designation	Unit
f_g	Output frequency limit	Hz
F	Force	N
F_a	Crack arrest force	N
F_{gy}	General yield force	N
F_{iu}	Unstable crack initiation force	N
F_m	Maximum force	N
g_n	Acceleration due to gravity	m/s^2
h	Height of fall of the centre of strike of the pendulum (see ISO 148-2)	m
KV	Absorbed energy as defined in ISO 148-1	J
m	Effective mass of the pendulum corresponding to its effective weight (see ISO 148-2)	kg
s	Displacement	m
s_a	Crack arrest displacement	m
s_{gy}	General yield displacement	m
s_{iu}	Displacement at unstable crack initiation	m
s_m	Displacement at maximum force	m
s_t	Total displacement	m
t	Time	s
t_o	Time at the beginning of deformation of the test piece	s
t_r	Signal rise time	s
v_o	Initial striker impact velocity	m/s
v_t	Striker impact velocity at time t	m/s
W_a	Crack arrest energy	J
W_{iu}	Energy at unstable crack initiation	J
W_m	Energy at maximum force	J
W_t	Total impact energy	J

5 Principle

5.1 This test consists of measuring the impact force, in relation to the test piece bending displacement, during an impact test carried out in accordance with ISO 148-1. The area under the force-displacement curve is a measure of the energy absorbed by the test piece.

5.2 Force-displacement curves for different steel products and different temperatures can be quite different, even though the areas under the curves and the absorbed energies are identical. If the force-displacement curves are divided into characteristic parts, various phases of the test can be deduced which provide considerable information about the behaviour of the test piece at impact loading rates.

NOTE The force-displacement curve cannot be used in strength calculations of structures. It is not possible to directly determine the lowest permissible operating temperature for a material in a construction.

6 Apparatus

6.1 Testing machine

A pendulum impact testing machine, in accordance with ISO 148-2, and instrumented to determine the force-time or force-displacement curve shall be used.

Comparisons between the total impact energy, W_t, from the instrumentation and the absorbed energy indicated by the machine dial or encoder, *KV*, shall be made.

NOTE 1 The instrumentation and the machine dial or encoder measure similar but different quantities. Differences are to be expected (see Reference[6]).

If deviations between *KV* and W_t exceed ±5 J, the following should be investigated:

a) friction of the machine;

b) calibration of the measuring system;

c) software used.

6.2 Instrumentation and calibration

6.2.1 Traceable measurement

The equipment used for all calibration measurements shall be traceable to national or international standards of measurement.

6.2.2 Force measurement

Force measurement is usually achieved by using two active electric resistance strain gauges attached to the standard striker to form a force transducer. Suitable designs are shown in Annex A.

A full bridge circuit is made by two equally stressed (active) strain gauges bonded to opposite sides of the striker and by two compensating (passive) strain gauges, or by substitute resistors. Compensating strain gauges shall not be attached to any part of the testing machine which experiences impact or vibration effects.

NOTE 1 Alternately, any other instrumentation to form a force transducer, which meets the required performance levels, may be used.

The force measuring system (instrumented striker, amplifier, recording system) shall have a response of at least 100 kHz, which corresponds to a rise time, *t*, of no more than 3,5 µs.

A simple dynamic assessment of the force measuring chain can be performed by measuring the value of the first inertia peak. By experience, the dynamics of the measuring chain can be considered satisfactory if a steel V-notch test piece shows an initial peak greater than 8 kN when using an impact velocity between 5 m/s and 5,5 m/s. This is valid if the centres of the active strain gauges are 11 mm to 15 mm away from the striker contact point.

The instrumentation of the striker shall be adequate to give the required nominal force range. The instrumented striker shall be designed to minimize its sensitivity to non-symmetric loading.

NOTE 2 Experience shows that with the V-notch test piece, nominal impact forces up to 40 kN can occur for most steel types.

6.2.3 Calibration

Calibration of the recorder and measuring system may be performed statically in accordance with the accuracy requirements given below and in 6.2.4.

It is recommended that the force calibration be performed with the striker built into the hammer assembly.

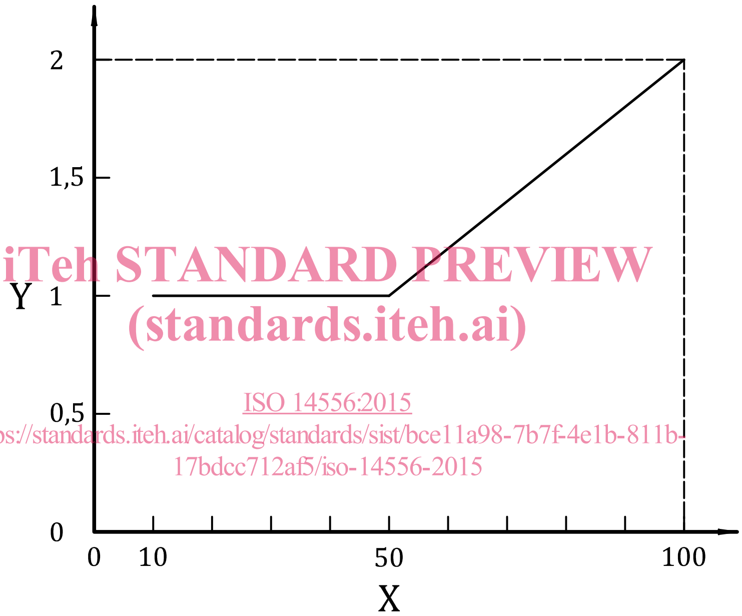
Force is applied to the striker through a special load frame equipped with a calibrated load cell and using a special support block in the position of the test piece.

This support block shall have a high stiffness. The contact conditions shall be approximately equal to those of the test and give reproducible results.

NOTE 1 An example of the support block for the calibration of a 2 mm striker is given in Annex B.

The static linearity and hysteresis error of the built-in, instrumented striker, including all parts of the measurement system up to the recording apparatus (printer, plotter, etc.), shall be within ±2 % of the recorded force, between 50 % and 100 % of the nominal force range, and within ±1 % of the full scale force value between 10 % and 50 % of the nominal force range (see Figure 1).

For the instrumented striker alone, it is recommended that the accuracy be ±1 % of the recorded value between 10 % and 100 % of the nominal range.



Key

X recorded value as percentage of nominal range

Y absolute error as percentage of nominal range

Figure 1 — Maximum permissible error of recorded values within the nominal force range

6.2.4 Displacement measurement

Displacement is normally determined from force-time measurements. See Clause 9.

Displacement can also be determined by non-contacting measurement of the displacement of the striker, relative to the anvil, using optical, inductive, or capacitive methods. The signal transfer characteristics of the displacement measurement system shall correspond to that of the force measuring system in order to make the two recording systems synchronous.

The displacement measuring system shall be designed for nominal values up to 30 mm; linearity errors in the measuring system shall yield measured values to within ±2 % in the range 1 mm to 30 mm. A dynamic calibration of the displacement system can be achieved by releasing the pendulum without a test piece in place, when the velocity is determined by:

$$v_0 = \sqrt{2 g_n h} \tag{1}$$

The velocity signal registered when the pendulum passes through the lowest position shall correspond to velocity v_0.

It is recommended that displacements between 0 mm and 1 mm be determined from time measurements and the striker impact velocity, using double numerical integration as described in 9.1.

6.2.5 Recording apparatus

Recording of the dynamic signals is preferably achieved by digital storage recorders, with output of the test results to an X-Y printer or plotter. In order to meet the accuracies required in 6.2.3 and 6.2.4 with digital measurement and recording systems, at least an 8 bit analogue-digital converter, with a sampling rate of 250 kHz (4 µs), is required; however, 12 bit and 1 MHz are recommended. A minimum storage capacity of 2 000 data points is required for each signal over an 8 ms time period, if the recording is to be adequate; however, 8 000 data points are recommended. For signals less than 8 ms, the required storage capacity may be reduced in proportion.

When values are determined from force-displacement graphs, sufficient precision is achieved by producing graphs at least 100 mm high by 100 mm wide.

6.2.6 Calibration interval

It is recommended that calibration of the instrumentation be performed at intervals not exceeding 12 months, or whenever the pendulum impact machine or instrumentation has undergone dismantling, moving, repair, or adjustment. In the case of striker replacement, it is recommended that a calibration be performed, unless it can be demonstrated that it is not necessary.

7 Test piece

The test piece is a Charpy V-notch test piece, in accordance with ISO 148-1.

8 Test procedure

Perform the Charpy V-notch pendulum impact test in accordance with ISO 148-1. In addition, determine and evaluate the force-displacement curve with respect to various characteristic deformation and fracture stages.

9 Expression of results

9.1 General

If the displacement is not directly measured, calculate the force-displacement curve as follows. The force-time relationship measured on the striker is proportional to the acceleration characteristic. Given an assumed rigid pendulum of effective mass m, the initial impact velocity v_0, and the time t following the beginning of the deformation at t_0, the test piece bending displacement is calculated by double numerical integration using:

$$v(t) = v_0 - \frac{1}{m} \int_{t_0}^{t} F(t) dt \tag{2}$$

$$s(t) = \int_{t_0}^{t} v(t)dt \tag{3}$$

9.2 Evaluation of the force-displacement curve

Characteristic force-displacement curves of various types are shown in Figure 2, in order to simplify evaluation and reporting. These can be classified in the following categories:

— Type A and B (lower shelf);

— Type C, D, and E (transition);

— Type F (upper shelf).

With force-displacement curves of Type A, only unstable crack propagation occurs. For Types B, C, D, and E, various amounts of stable and unstable crack propagation can occur. With Type F curves, only stable crack propagation occurs.

Determine the type of force-displacement curve by comparison with the schematic representations given in Figure 2 (column 2). With force-displacement curves of Type A, only F_{iu} can be evaluated. With curves of Type B, only F_{iu} and F_a can be evaluated.

In the following sections, the evaluation of the force-displacement curve is explained. It should be noted that vibrations are superimposed on the force-displacement signal, which arise from force interaction between the instrumented striker and the test piece. Generally, a fitted curve through the oscillations, as shown in Figure 3, yields reliable characteristic values.

9.3 Determination of the characteristic values of force

Determine the general yield force, F_{gy}, as the force at the intersection between the linear elastic part of the force-displacement curve, discarding the initial inertia peak, and the fitted curve through the oscillations of the force-displacement curve following the onset of yield of the entire ligament (Figure 2, force-displacement curves of Type C to Type F).

Determine the maximum force, F_m, as the maximum value of the fitted curve through the oscillations.

Determine the unstable crack initiation force, F_{iu}, as the force at the intersection between the fitted curve through the oscillations, after the occurrence of general yield, and the steeply dropping part of the force-displacement curve. If the steep drop coincides with the maximum recorded force, then $F_{iu} = F_m$ (force-displacement curves of Types C or D).

Determine the crack arrest force, F_a, as the force at the intersection between the steep drop of the force-displacement curve and the fitted curve through the oscillations of the subsequent part of the force-displacement curve (force-displacement curves of Type D or Type E).

9.4 Determination of the characteristic values of displacement

The characteristic values of displacement given in 3.2 are the abscissa values of the characteristic values of force determined according to 9.3, (see Figure 2).

NOTE 1 The general yield displacement, s_{gy}, can only be approximately determined using common measuring apparatus. Consequently, s_{gy} is not generally used.

NOTE 2 Due to the steep drop in the force-displacement curve between F_{iu} and F_a, it is generally the case that $s_{iu} \approx s_a$.

The total displacement, s_t, is only determined if the test piece becomes completely fractured during the test and the force-displacement curve up to the fracture of the test piece is available. In such a case, the fitted curve through the oscillations of the force-displacement curve approaches asymptotically