INTERNATIONAL STANDARD

ISO 16630

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Metallic materials — Sheet and strip — Hole expanding test

Matériaux métalliques — Tôles et bandes — Essai d'expansion de trou

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. 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.

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.

ISO 16630 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 2, *Ductility testing*.

This first edition of ISO 16630 cancels and replaces ISO/TS 16630:2003, which has been technically revised.

Introduction

Modern methods of manufacture of automobile components such as wheels, suspension parts and structural components using sheet metal, mainly steel and possibly other metals, involve, primarily, shearing, bending and stretch drawing operations.

Included with these processes are the bending up (plunging) of flanges (rims) around punched holes, and this can result in rupture of the material.

Various test methods are available to establish the suitability of the sheet metal for the forming processes involved. The hole expanding test is one of the best methods for evaluating the suitability of the sheet metal for forming such “flanges” because it closely resembles the process used under production conditions to form such flanges (plunged rims) starting with punched holes.

Because of the details given in this International Standard, the relevance of the test will be immediately apparent. By adhering to the procedures laid down in this International Standard, scatter in the test results will be minimized.

Metallic materials — Sheet and strip — Hole expanding test

1 Scope

This International Standard describes a method of determining the hole expansion ratio in metallic sheets and strips with a thickness range of 1,2 mm to 6,0 mm inclusive and a width of at least 90 mm.

NOTE This test is normally applicable to sheet metal and is used to assess the suitability of the product for forming flanges.

2 Normative references

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

ISO 497:1973, *Guide to the choice of series of preferred numbers and of series containing more rounded values of preferred numbers*

3 Terms and definitions

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

3.1
limiting hole expansion ratio
amount of hole expansion obtained in a circular punched hole of a test piece when a conical expanding tool is forced into the hole until any one crack in the hole edge extends through the test piece thickness

NOTE The limiting hole expansion ratio is expressed as the ratio of hole diameter expansion to the original hole diameter.

3.2
clearance
⟨between die and punch⟩ gap between the die and the punch, present when punching a hole in a test piece

NOTE Clearance is expressed as the ratio of the gap to the test piece thickness.

4 Symbols and abbreviated terms

Symbols and corresponding designations used in this International Standard are given in Table 1.

Table 1 — Symbols and designations

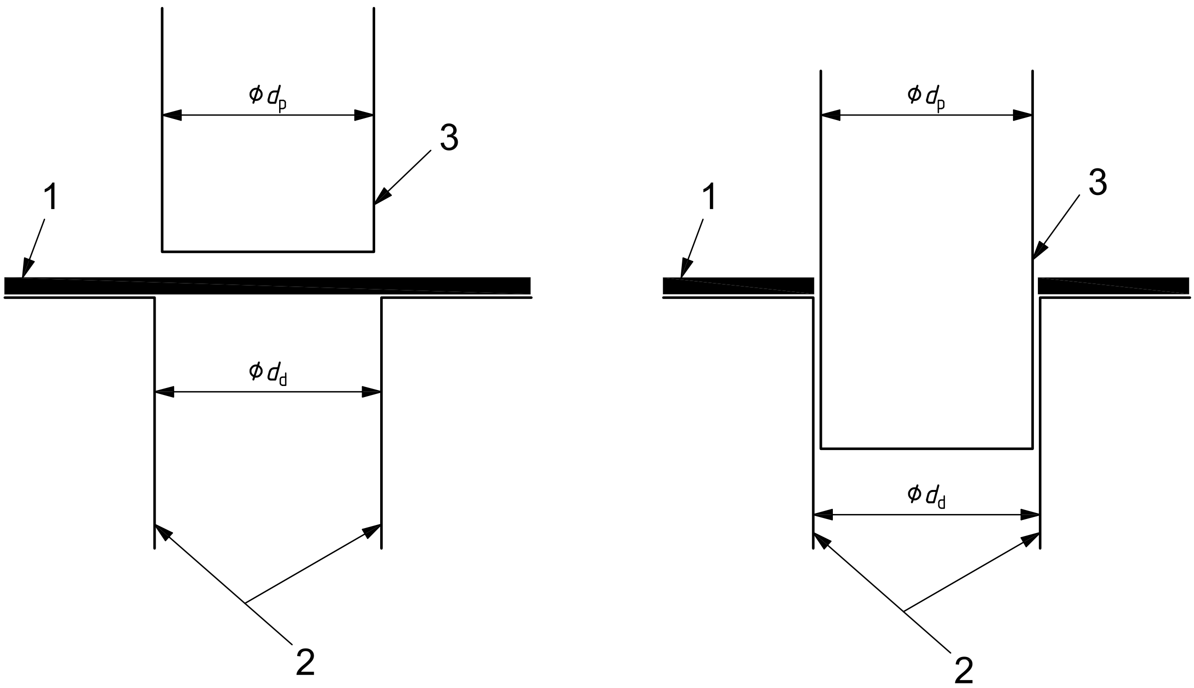
Symbol	Designation	Unit
c	Clearance	%
d_d	Inside diameter of the die used for punching a hole in the test piece	mm
d_p	Diameter of the punch used for punching a hole in the test piece	mm
D_d	Inside diameter of the die of the expanding tool	mm
D_h	Average hole diameter after rupture	mm
D_o	Original hole diameter	mm
D_p	Diameter of the punch of the expanding tool	mm
F	Clamping force	N
R	Corner radius of the die of the expanding tool	mm
t	Thickness of the test piece	mm
λ	Limiting hole expansion ratio	%
$\bar{\lambda}$	Average limiting hole expansion ratio	%

5 Principle

The hole expanding test consists of two steps:

a) punching a hole as indicated in Figure 1;

b) forcing a conical expanding tool into a pre-punched hole until any one crack extends through the test piece thickness of the metallic sheet.



Key

1 test piece

2 die used for punching a hole

3 punch used for punching a hole

Figure 1 — Illustration of punching

6 Apparatus

6.1 General

The apparatus consists of a testing machine and testing tools.

6.2 Testing machine

The testing machine shall have the capability to hold a test piece in place during the test and be able to stop the expanding tool as soon as a crack occurs in the hole edge.

The testing machine shall also be capable of controlling the rate of displacement of the expanding tool.

A testing machine intended exclusively for hole expanding tests, or a deep drawing test machine, or any other press testing machine may be used.

6.3 Testing tools

6.3.1 The dimensions and the shape of the die and of the punch used in the hole expanding test are given in 6.3.2 to 6.3.5 (also see Figure 3).

6.3.2 The punch shall be a conical expanding tool with a tip angle of 60° ± 1°. The diameter, D_p, of the cylindrical portion of the tool shall be sufficiently large that it can expand the hole to such an extent that cracks are generated in the hole edge of the test piece.

6.3.3 The test tool clamping die inside diameter, D_d, shall be selected on the basis of the expected limiting hole expansion ratio.

The inside diameter, D_d, should not be smaller than 40 mm.

6.3.4 The corner radius, R, of the test tool clamping die shall be between 2 mm and 20 mm.

The recommended radius is 5 mm.

6.3.5 The conical expanding tool shall have a minimum hardness of 55 HRC.

7 Test piece

7.1 Three test pieces shall be taken from the same sample (see, however, 8.2).

7.2 The test piece shall be flat and of such dimensions that the centre of any hole is not less than 45 mm from any edge of the test piece nor less than 90 mm from the centre of the adjacent hole (see Figure 2).

Dimensions in millimetres

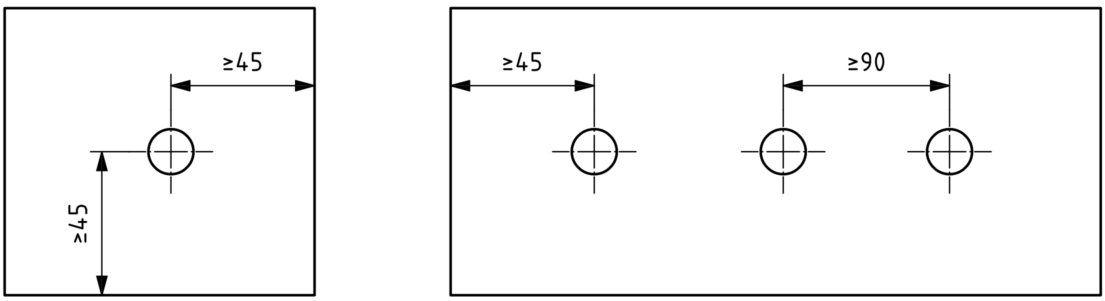


Figure 2 — Dimensions of the test pieces

7.3 In the central part of the test piece, a hole is punched using a 10 mm diameter punch (see Figure 1).

7.4 In punching a hole, select a die that satisfies the clearance given in Table 2. The selection of the die inside diameter shall be in increments of 0,1 mm.

Table 2 — Tolerance on clearance between die and punch

Thickness (t) mm	**Clearance** (c) %
$2{,}0 > t$	12 ± 2
$2{,}0 \leqslant t$	12 ± 1

NOTE Table 3 gives an example of a set of diameters for dies used for punching holes which comply with both of the above-mentioned requirements.

Table 3 — Examples of inside diameters of dies used for punching holes

Dimensions in millimetres

Thickness (t)	**Inside diameter of the die** (d_d)
$1{,}2 \leqslant t < 1{,}5$	10,30
$1{,}5 \leqslant t < 1{,}9$	10,40
$1{,}9 \leqslant t < 2{,}3$	10,50
$2{,}3 \leqslant t < 2{,}7$	10,60
$2{,}7 \leqslant t < 3{,}1$	10,70
$3{,}1 \leqslant t < 3{,}6$	10,80
$3{,}6 \leqslant t < 4{,}0$	10,90
$4{,}0 \leqslant t < 4{,}4$	11,00
$4{,}4 \leqslant t < 4{,}8$	11,10
$4{,}8 \leqslant t < 5{,}2$	11,20
$5{,}2 \leqslant t < 5{,}7$	11,30
$5{,}7 \leqslant t \leqslant 6{,}0$	11,40

7.5 The tolerances of specified dimensions of the punching tools used for the preparation of test pieces shall correspond to the values given in Table 4. The punching tool should be inspected on a regular basis in respect to wear.

Table 4 — Tolerances of specified dimensions of the punching tools

Dimension	**Tolerance** mm
Diameter of the punch used for punching a hole, d_p (10 mm)	$+0{,}02$ $-0{,}03$
Inside diameter of the die used for punching a hole, d_d (see Table 3)	$+0{,}03$ $-0{,}02$

Clearance is defined by the following equation:

$$c = \frac{d_d - d_p}{2t} \times 100 \quad (1)$$

where

c is the clearance, expressed as a percentage;

d_d is the inside diameter of the die used for punching a hole in the test piece, in millimetres;

d_p is the diameter of the punch used for punching a hole in the test piece ($d_p = 10$ mm);

t is the thickness of the test piece, in millimetres.

8 Test procedure

8.1 In general, tests are carried out at a temperature between 10 °C and 35 °C. Tests carried out under controlled conditions, where required, shall be made at a temperature of (23 ± 5) °C.

8.2 Normally, three tests shall be carried out. An increase in the number of tests may, however, be agreed upon between the parties.

8.3 Place the test piece on the die so that the centre of the punched hole in the test piece coincides with the axis of the conical expanding tool and that the plane of the test piece is perpendicular to the drive direction of the conical punch (see Figure 3). Place the test piece so that the exit surface of the punched hole faces the die; this means that the direction of punching and that of hole expanding are the same.

8.4 Apply a sufficiently high clamping force to the test piece to prevent any material draw-in from the clamping area during the test.

EXAMPLE A clamping force of 50 kN or greater is appropriate for a 150 mm × 150 mm test piece.

If draw-in occurs, the test results shall be rejected and another test shall be made.

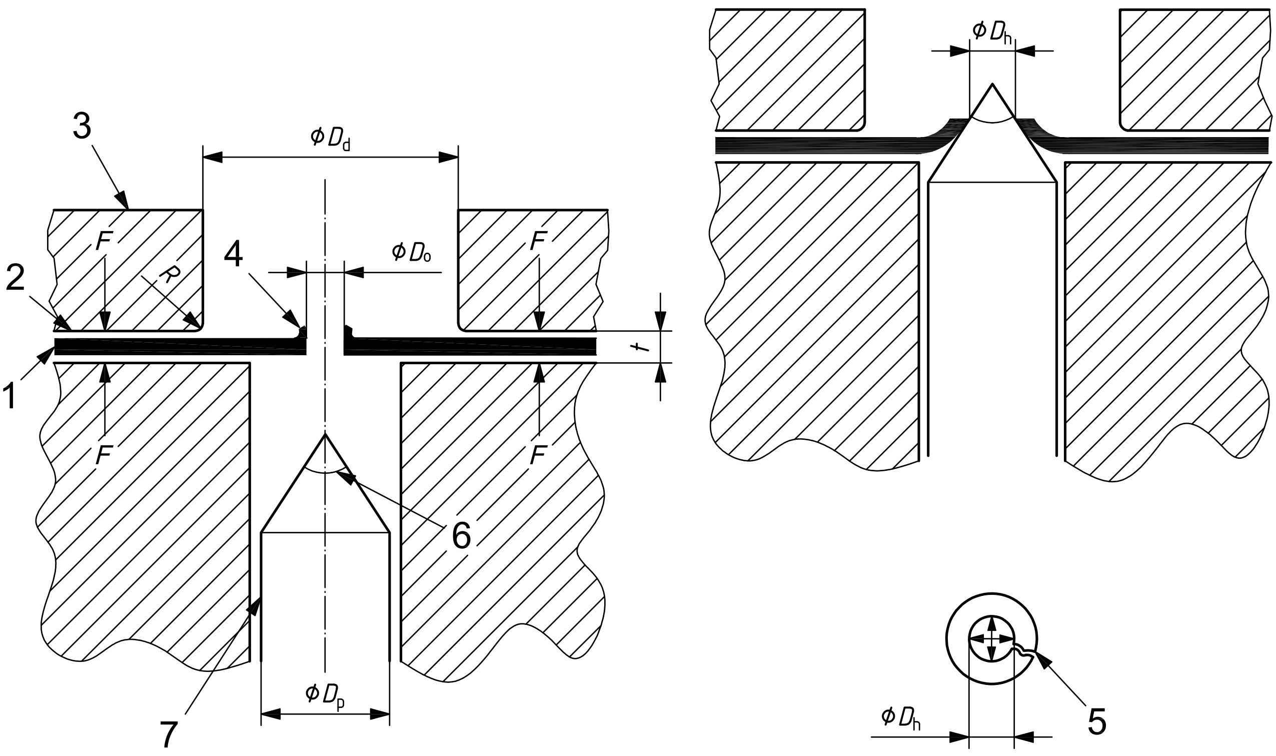
8.5 Press the conical expanding tool into the punched hole of the test piece (see Figure 3) at a rate which enables the operator to stop the test when the first relevant crack appears. The driving speed of the conical punch should not be more than 1 mm/s.

8.6 During the test, keep the hole edge under observation and at the first sign of a crack, reduce the rate of advance of the conical expanding tool to minimize further hole expansion.

8.7 Stop the movement of the punch the instant a crack appears through the full thickness of the test piece. Measure the inside diameter of the ruptured hole in the test piece with slide callipers, or another suitable instrument (e.g. calibrated profile projector), to the nearest 0,05 mm. Make the measurement in two directions, perpendicular to each other, avoiding the crack.

8.8 Some grades of steel can allow the cylindrical portion of the expanding tool to push through the expanded hole without exhibiting edge cracking. In that case, the specimen shall be discarded and a retest performed using the conical expanding tool of a suitably large diameter.

If no appropriate tools are available, the punched hole diameter may be decreased by agreement between the parties.



a) Before the test

b) After the test

Key

1 test piece
2 die shoulder
3 die
4 burr
5 crack
6 punch tip angle
7 punch

Figure 3 — Illustration of hole expanding test

9 Calculation of test data

9.1 The limiting hole expansion ratio, λ, shall be calculated in accordance with 9.2, 9.3 and 9.4.

9.2 Using the measurements taken in accordance with 8.7, determine the average diameter of the ruptured hole.

9.3 Using the average diameter reported to the first decimal place, calculate the limiting hole expansion ratio for each of the three (or more, see 8.2) test pieces as the ratio of the increase in the hole diameter to the original hole size, as defined by the following equation:

$$\lambda = \frac{D_h - D_o}{D_o} \times 100 \quad (2)$$

where

λ is the limiting hole expansion ratio, expressed as a percentage;

D_o is the original hole diameter ($D_o = 10$ mm);

D_h is the average hole diameter after rupture, in millimetres.

9.4 Calculate the average of the limiting hole expansion ratio, $\bar{\lambda}$, from the three (or more, see 8.2) test values from 9.3.

Rounding off of numerical values shall be in accordance with ISO 497.

10 Test report

The test report shall include the following:

a) a reference to this International Standard;

b) the identification of the test piece;

c) the thickness of the test piece;

d) the average limiting hole expansion ratio, and the number of tests when greater than 3;

e) the range of the limiting hole expansion ratio (this may be reported on request);

f) any variation from this International Standard (as agreed upon between the parties).

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