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Metallic materials — Sheet and strip — Hole expanding test

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

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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 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 164, *Mechanical testing of metals*, Subcommittee SC 2, *Ductility testing*.

This second edition cancels and replaces the first edition (ISO 16630:2009), which has been technically revised.

The main changes compared to the previous edition are:

— “through-thickness crack” (3.3) and “microcrack” (3.4) have been added;

— the statement regarding an inspection of the punching tool in 7.5 has been revised and a note has been added;

— the requirement during the punching process has been added as 7.6;

— the test procedures in 8.6 and 8.7 have been revised;

— it has been revised that the average limiting hole expansion ration, $\overline{\lambda}$, shall be rounded to an integer value. Also, the method of rounding-off has been revised from ISO 497 to ISO 80000-1:2009 (Clause 2 and 9.4).

Introduction

In automotive parts manufacturing, sheet metal is primarily processed by 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 document, the relevance of the test will be immediately apparent. By adhering to the procedures laid down in this document, scatter in the test results is minimized.

Metallic materials — Sheet and strip — Hole expanding test

1 Scope

This document 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 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 80000-1:2009, *Quantities and units — Part 1: General*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at http://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

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 1 to entry: The limiting hole expansion ratio is expressed as the ratio of hole diameter expansion to the original hole diameter.

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

Note 1 to entry: Clearance is expressed as the ratio of the gap to the test piece thickness.

3.3
through-thickness crack
crack that has extended through the sample thickness

3.4
microcrack
crack that has not extended through the sample thickness

4 Symbols and designations

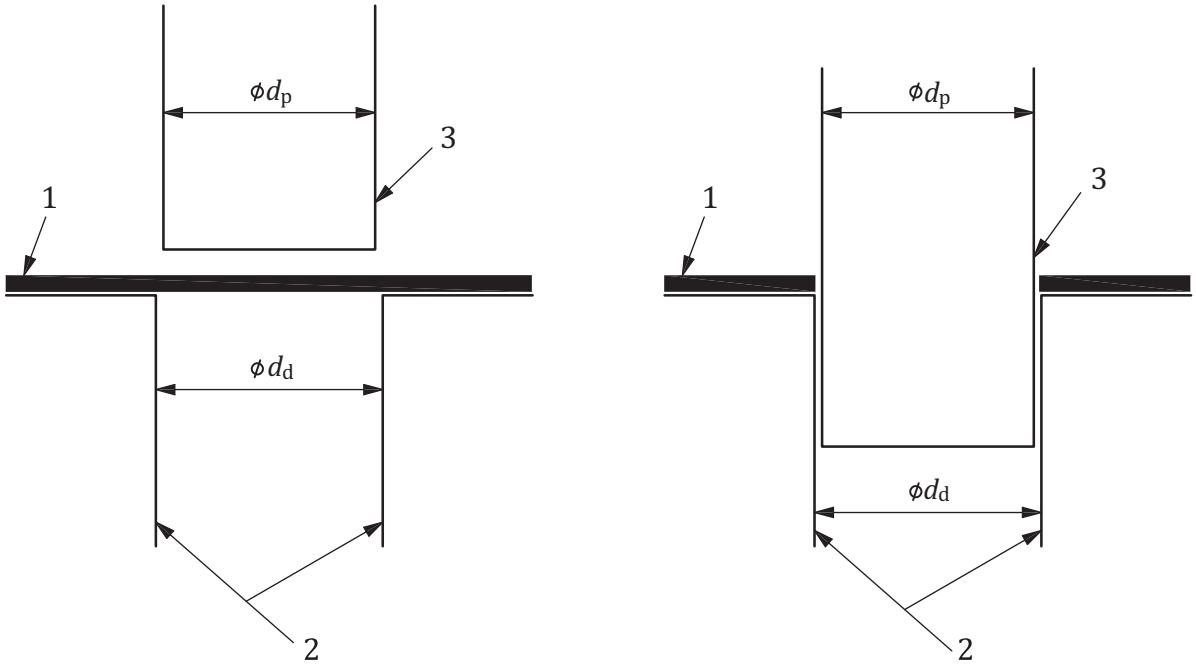
Symbol	Designation	Unit
c	clearance	%
d_d	inside diameter of the die used for punching a hole in the test piece	mm
d_p	diameter of the punch used for punching a hole in the test piece	mm
D_d	inside diameter of the die of the expanding tool	mm
D_h	average hole diameter after rupture	mm
D_o	original hole 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	%
$\overline{\lambda}$	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 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.

6.2 Testing tools

6.2.1 The dimensions and the shape of the die and of the punch used in the hole expanding test are given in 6.2.2 to 6.2.5 (also see Figure 3).

6.2.2 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.

6.2.3 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.

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

The recommended radius is 5 mm.

6.2.5 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 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

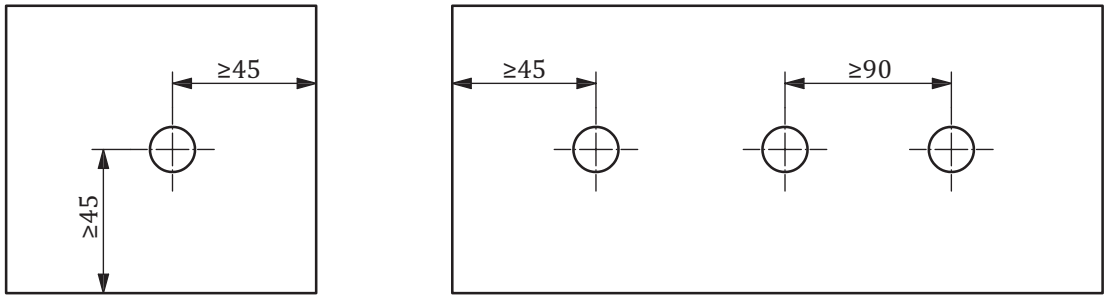


Figure 2 — Dimensions of the test pieces

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 1. The selection of the die inside diameter shall be in increments of 0,1 mm.

Table 1 — Tolerance on clearance between die and punch

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

NOTE Table 2 gives an example of a set of diameters for dies used for punching holes which comply with both of the above-mentioned requirements.

Table 2 — Examples of inside diameters of dies used for punching holes

Dimensions in millimetres

Thickness (t)	**Inside diameter of the die** (d_d)
$1{,}2 \leq t < 1{,}5$	10,30
$1{,}5 \leq t < 1{,}9$	10,40
$1{,}9 \leq t < 2{,}3$	10,50
$2{,}3 \leq t < 2{,}7$	10,60
$2{,}7 \leq t < 3{,}1$	10,70
$3{,}1 \leq t < 3{,}6$	10,80
$3{,}6 \leq t < 4{,}0$	10,90
$4{,}0 \leq t < 4{,}4$	11,00
$4{,}4 \leq t < 4{,}8$	11,10
$4{,}8 \leq t < 5{,}2$	11,20
$5{,}2 \leq t < 5{,}7$	11,30
$5{,}7 \leq t \leq 6{,}0$	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 3. The punching tool should be visually inspected for wear at regular intervals and reground, re-sharpened or changed, if necessary.

NOTE 1 The tooling wear can affect the hole expansion ratio.

Table 3 — 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 2)	+0,03 −0,02

Clearance is defined by Formula (1):

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

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.

NOTE 2 For some products, the punching speed can have an influence on the hole expansion ratio.

7.6 During the punching process, the punch should be concentric to the die and the punch axis shall remain perpendicular to the test piece throughout the punching step.

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.

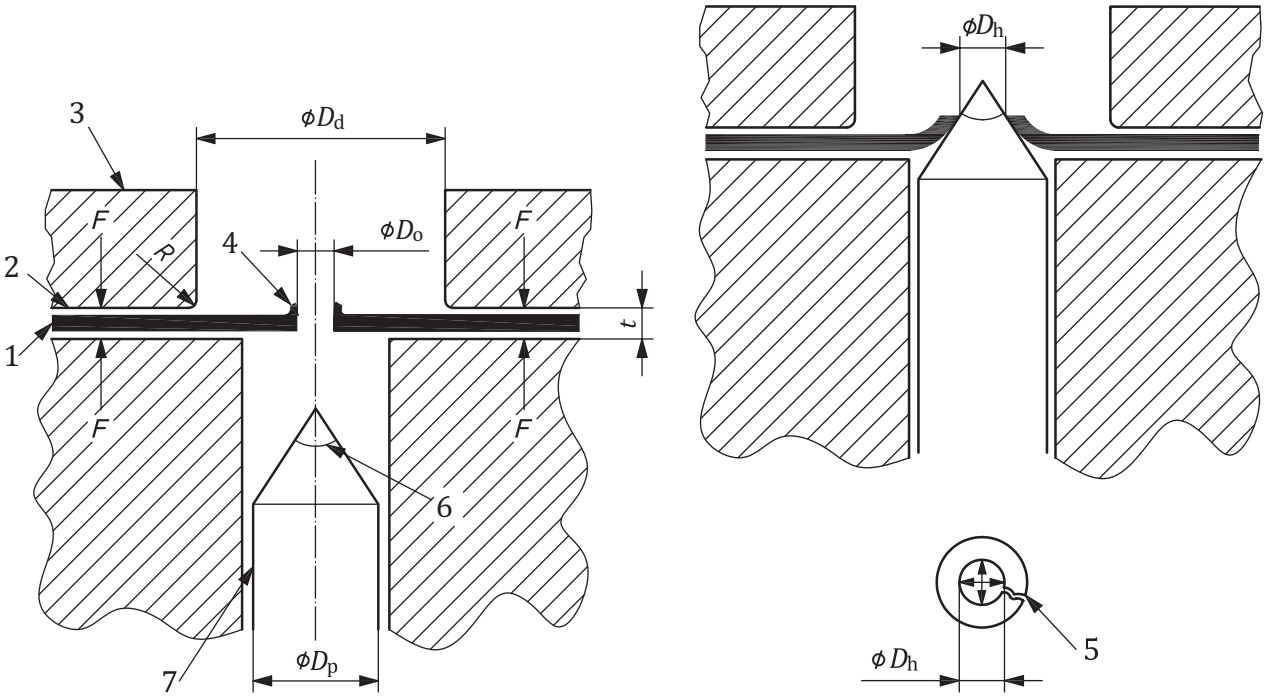
8.5 Press the conical expanding tool into the punched hole of the test piece (see Figure 3) at a rate which enables the operator to stop the test when the first crack appears. The driving speed of the conical punch should not be more than 1 mm/s.

8.6 During the test, keep the hole edge under observation. At the first sign of a microcrack, the rate of advance of the conical expanding tool can be reduced to minimize further hole expansion.

8.7 Stop the movement of the punch the instant of through-thickness crack appears at first in the test piece. This crack should have a maximum opening width of 0,1 mm in the inner diameter. 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 Key

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

Figure 3 — 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 Formula (2):

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

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.

$\bar{\lambda}$ shall be rounded to an integer value in accordance with ISO 80000-1.

10 Test report

The test report shall include the following:

a) a reference to this document, i.e. ISO 16630;

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 three;

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

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

ICS 77.040.10

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