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धात्विक सामग्री — चादर एवं पत्ती —  
होल एक्सपेंडिंग परीक्षण

**Metallic Materials — Sheet and  
Strip — Hole Expanding Test**

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## NATIONAL FOREWORD

This standard which is identical with ISO 16630 : 2017 'Metallic materials — Sheet and strip — Hole expanding test ' issued by the International Organization for Standardization (ISO), was adopted by the Bureau of Indian Standards on recommendation of the Mechanical Testing of Metals Sectional Committee and approval of the Metallurgical Engineering Division Council.

The text of ISO standard has been approved as suitable for publication as an Indian Standard without deviations. Certain terminologies and conventions are, however, not identical to those used in Indian Standard. Attention is particularly drawn to the following:

- a) Wherever the words 'International Standard' appear referring to this standard, they should be as read as 'Indian Standard'
- b) Comma (,) has been used as a decimal marker, while in Indian Standards, the current practice is to use a point (.) as the decimal marker.

In this adopted standard, reference appears to the following International Standard for which Indian Standard also exists. The corresponding Indian Standard, which is to be substituted in its place, is listed below along with its degree of equivalence for the edition indicated:

<i>International Standard</i>	<i>Corresponding Indian Standard</i>	<i>Degree of Equivalence</i>
ISO 80000-1 : 2009 Quantities and units — Part 1: General	IS/ISO 80000-1 : 2009 Quantities and units: Part 1 General	Identical

In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS 2 : 1960 'Rules for rounding off numerical values ( *revised* )'.

## *Indian Standard*

# 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

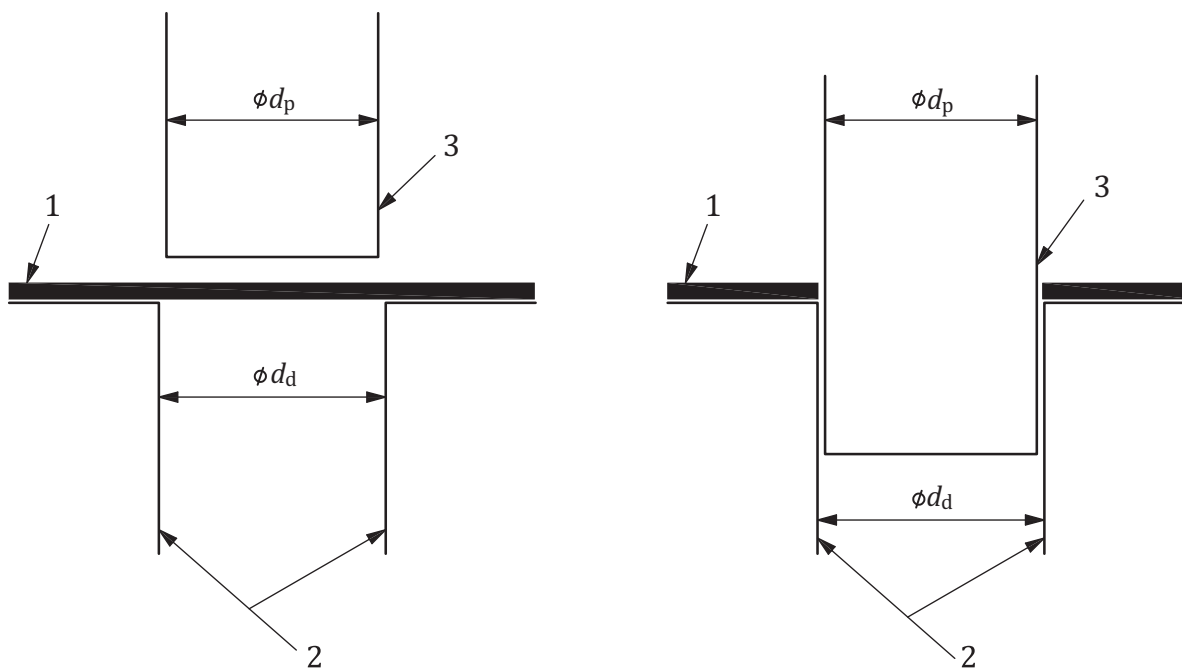
## 4 Symbols and designations

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
$\lambda$	limiting hole expansion ratio	%
$\bar{\lambda}$	average limiting hole expansion ratio	%

## 5 Principle

The hole expanding test consists of two steps:

- punching a hole as indicated in [Figure 1](#);
- 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

- test piece
- die used for punching a hole
- 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  $60^\circ \pm 1^\circ$ . 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.

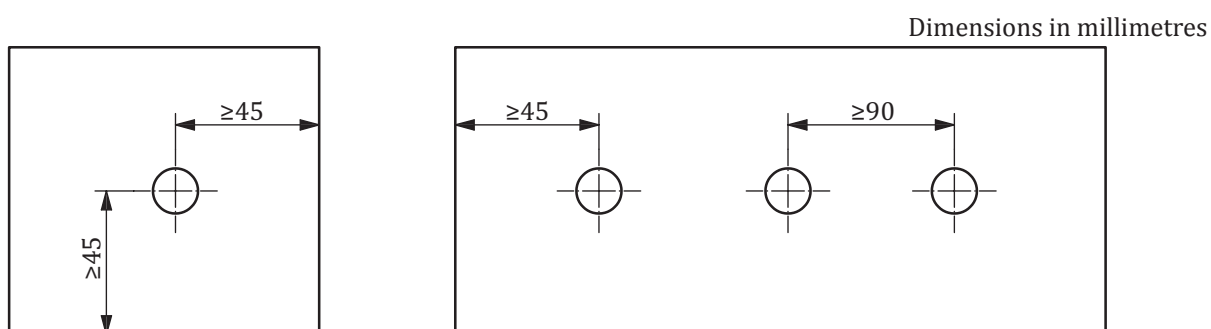
The recommended radius is 5 mm.

**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](#)).



**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 ( $c$ ) %
$2,0 > t$	$12 \pm 2$
$2,0 \leq t$	$12 \pm 1$

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 <a href="#">Table 2</a> )	+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  $(23 \pm 5)$  °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.

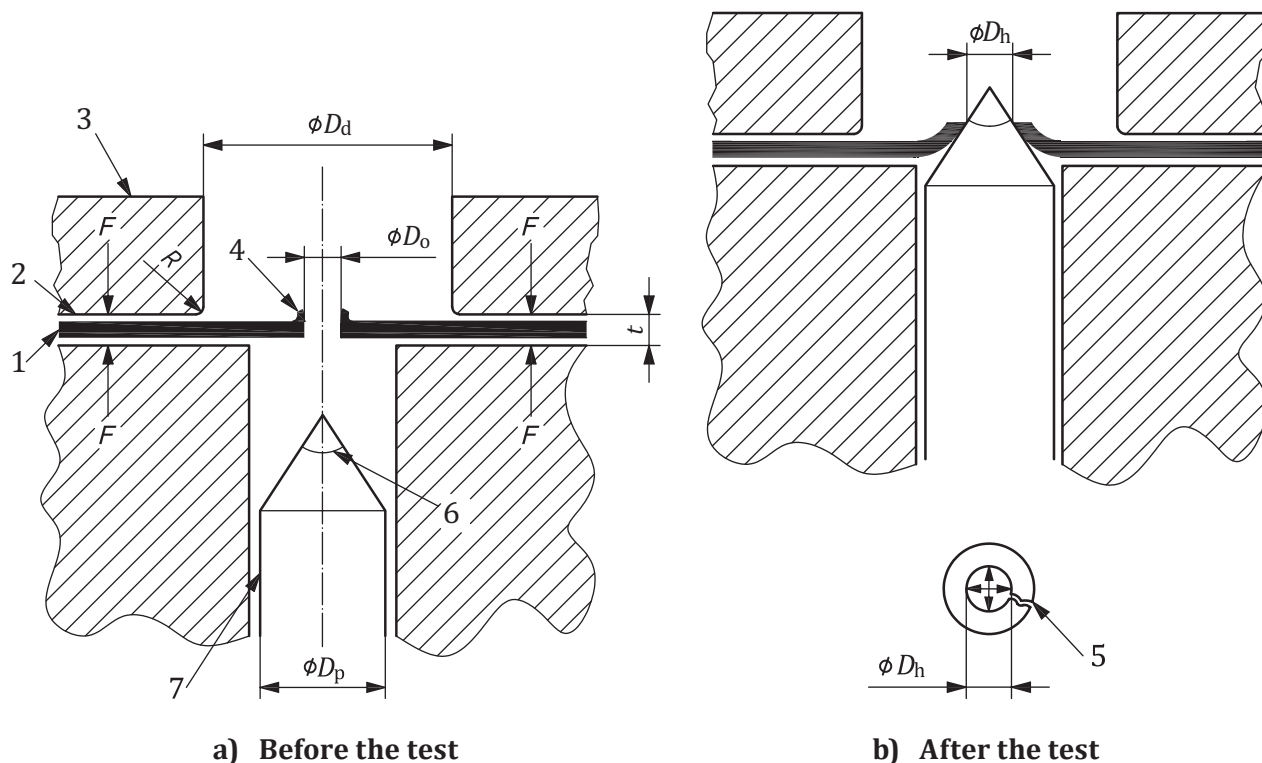
**8.5** Press the conical expanding tool into the punched hole of the test piece (see [Figure 3](#)) at a rate which enables the operator to stop the test when the first crack appears. The driving speed of the conical punch should not be more than 1 mm/s.

**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.



**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,  $\lambda$ , 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

$\lambda$  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).





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### Amendments Issued Since Publication

Amend No.	Date of Issue	Text Affected

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