
**Metallic materials — Sheet and strip
— Method for springback evaluation
in stretch bending**

*Matériaux métalliques — Tôles et bandes — Méthode d'évaluation du
retour élastique lors d'un cintrage sous traction*

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ISO copyright office
Ch. de Blandonnet 8 • CP 401
CH-1214 Vernier, Geneva, Switzerland
Tel. +41 22 749 01 11
Fax +41 22 749 09 47
copyright@iso.org
www.iso.org

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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.

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).

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. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see www.iso.org/patents).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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 24213:2008), which has been technically revised.

The main changes compared to the previous edition are:

- the Normative references has been updated;
- [Clause 7](#) c) and [Clause 9](#) a) have been revised to specify the test piece more clearly;
- In [Figure 2](#) b), a label to the test piece has been added;
- [Clause 8](#) d) has been revised because the use of dial gauge is one of the methods for determining the radius of curvature;
- the Bibliography has been updated.

Introduction

This document has been established to evaluate the amount of springback occurring in metallic sheets deformed by stretch bending. It may be used for specifying a material, directly controlling a forming operation, designing dies, or calibrating finite element programs.

In metallic sheet forming processes, the geometry of the formed parts may deviate from the design geometry after the parts are removed from the dies due to elastic recovery. This phenomenon is referred to as springback.

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Metallic materials — Sheet and strip — Method for springback evaluation in stretch bending

1 Scope

This document specifies a method for evaluating the amount of springback of sheets of metallic materials known to exhibit large amounts of springback subjected to plane-strain stretch bending, which is a typical deformation mode generated in press-formed panels. By using this method, the amount of springback under stretch bending is evaluated accurately and quantitatively [1][2].

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, *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:

- IEC Electropedia: available at <http://www.electropedia.org/>
- ISO Online browsing platform: available at <http://www.iso.org/obp>

3.1

curvature

κ

reciprocal of the radius of curvature, r , determined at the centre of a stretch-bent specimen on the inner surface in the longitudinal direction

$$\kappa = \frac{1}{r}$$

3.2

amount of springback

η

relative change in curvature of a test piece under force and after removal of the force shown in [Figure 1](#)

$$\eta = \frac{|\kappa' - \kappa|}{\kappa} = \frac{r' - r}{r'}$$

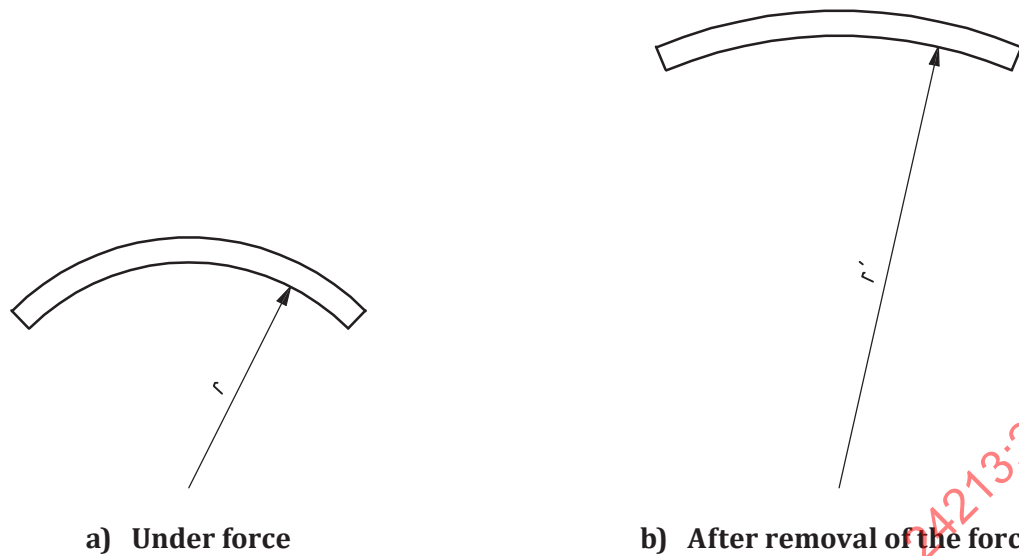


Figure 1 — Radius of curvature of a test piece under force and after removal of the force

3.3

stretch bending

method of bending a test piece under tension

3.4

blank holding pressure

force applied on the test piece in the direction of its thickness, divided by the surface area of the test piece contacting the die

3.5

nominal tensile stress

tensile force per unit cross-sectional area of the test piece

4 Symbols and designations

The symbols used in this document and the corresponding designations are given in [Table 1](#).

Table 1 — Symbols and corresponding designations

Symbol	Designation	Unit
a	Thickness of test piece	mm
b	Width of test piece	mm
F_h	Blank holding force	N
h	Amount of punch penetration	mm
F_p	Punch force	N
p	Blank holding pressure	MPa
R_p	Punch radius	mm
r	Radius of curvature of the inner surface of the test piece under force	mm
r'	Radius of curvature of the inner surface of the test piece after removal of the force	mm
r_d	Die profile radius	mm
S	Total surface area of test piece in contact with dies	mm ²
T	Nominal tensile stress applied to test piece	MPa
W	Distance between dies	mm
w	Width of the base of a dial gauge for measuring the curvature of the test piece after removal of the force (see Annex C).	mm
x	Measured value by a dial gauge for measuring the curvature of the test piece after removal of the force (length of AD in Figure C.1)	mm
κ	Curvature of the inner surface of the test piece under force ($= r^{-1}$)	mm ⁻¹
κ'	Curvature of the inner surface of the test piece after removal of the force [$= (r')^{-1}$]	mm ⁻¹
η	Amount of springback	
2θ	Spread angle of test piece around punch	rad

5 Principle

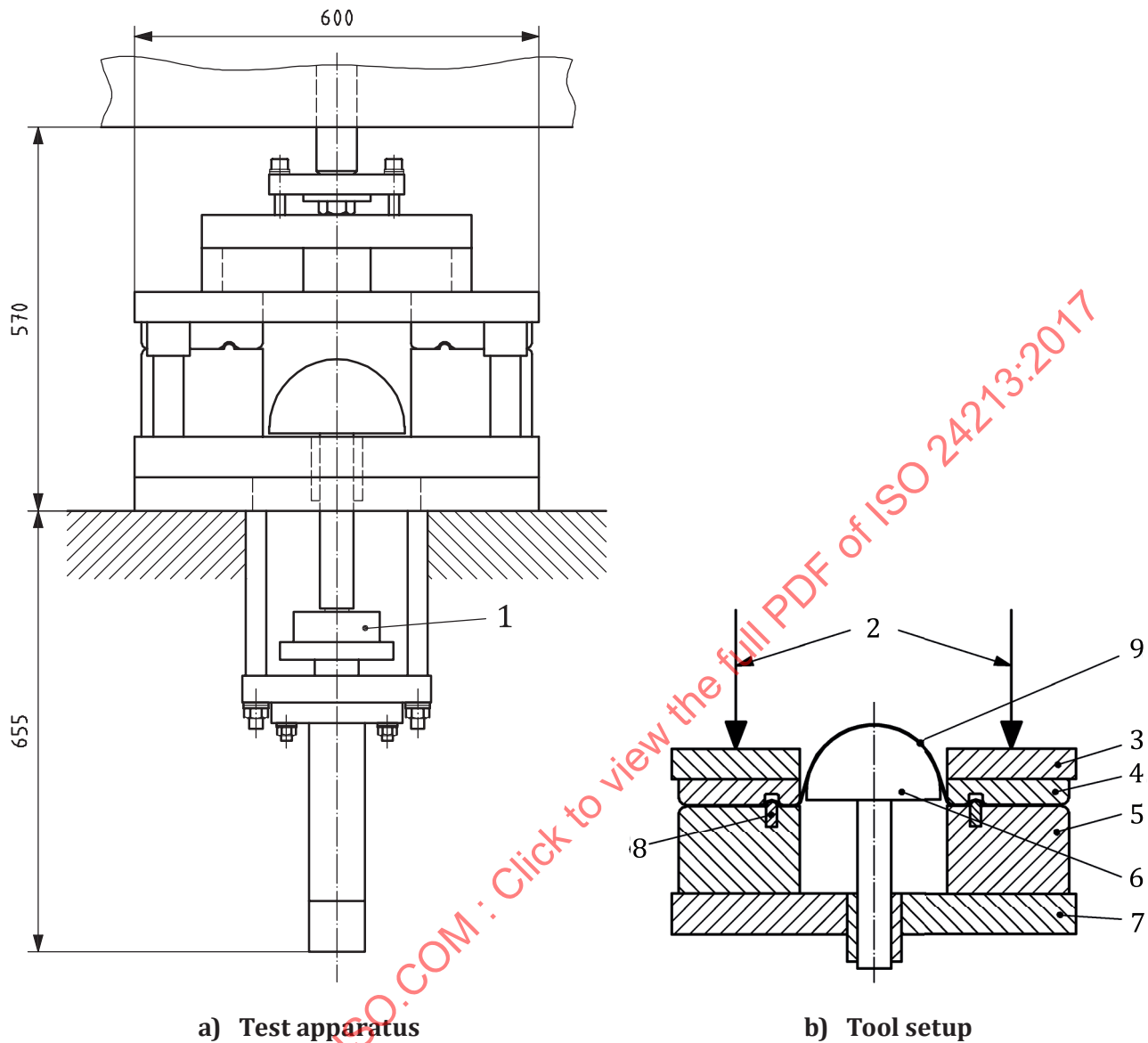
This test is a method for evaluating the springback of a metal sheet using a stretch-bending method. The amount of springback is determined as the change in curvatures of a test piece under force and after removal of the force (see formulae in [3.1](#) and [3.2](#)). The nominal tensile stress applied to the test piece is determined using the measured value of punch penetration and punch force (see [Annex B](#)).

6 Test apparatus

The test apparatus is described below.

6.1 Stretch-bending testing device for springback evaluation. An example of the stretch-bending device used in the test is shown in [Figure 2](#). The radius of the semi-cylindrical punch shall be (100 ± 1) mm. However, the radius of the punch tip and its tolerance may be determined by agreement between the parties involved.

6.2 Device for determining the radius of curvature of a test piece. The principle for determining the radius of curvature with a dial gauge is shown in [Annex C](#), in which a dial gauge with an accuracy of 0,001 mm shall be employed. The use of optical micrometers or other non-contacting length probes is also recommended.



Key

- 1 load cell
- 2 blank holding force
- 3 die top plate
- 4 die
- 5 blank holder
- 6 punch (R100)
- 7 die bottom plate
- 8 draw beads
- 9 test piece

Figure 2 — Example of stretch-bending test apparatus for springback evaluation

7 Test piece

The test piece used for the test shall be as follows.

- a) The test piece shall be rectangular in shape, (500 ± 10) mm in length and (50 ± 1) mm in width.
- b) Its thickness shall be the original thickness of the sheet.
- c) The test piece shall be cut either parallel or perpendicular to the rolling direction as agreed between the parties.
- d) The edges of the test piece shall be as cut. Unnecessary alteration or heating of the test piece shall be avoided, unless otherwise specified or caused by cutting.
- e) The surface of the test piece shall be free from harmful defects, such as scratches, that may affect the test results.

8 Procedure

Testing shall be conducted as follows.

- a) **Testing temperature.** The ambient temperature shall be within the range of $10\text{ }^{\circ}\text{C}$ to $35\text{ }^{\circ}\text{C}$, and the temperature shall be recorded, if necessary. When the temperature control is especially necessary, it shall be kept in the range of $(23 \pm 5)\text{ }^{\circ}\text{C}$.
- b) **Stretch bending.** A test piece shall be fixed in position on the blank holder (see [Figure 2](#)); the blank holding pressure shall then be applied. The blank holding pressure shall be calculated in accordance with [Annex A](#). The maximum blank holding pressure should be 2 % to 3 % of the tensile strength of the test material. The punch is pushed up until the amount of punch penetration, h , reaches a predetermined value. The amount of punch penetration, which should be determined so that the spread angle, 2θ , of the test piece around the punch tip becomes greater than 120° (see [Figure B.1](#)), and lubricant shall be agreed between the parties involved. The amount of friction between the test piece and the punch surface should be as small as possible. Preferably, the coefficient of friction should be less than 0,05, so that the nominal tensile stress applied to the test piece should be distributed uniformly over the punch head. A thin sheet of polymer film and machine oil is recommended for the lubricant on the punch surface. The polymer film shall be replaced with a new one before each test. The amount of punch penetration shall be measured with a displacement gauge, and the punch force, F_p , with a load cell. The minimum levels of resolution on the displacement gauge for punch penetration and on the load cell for the punch force should be less than 0,5 mm and 100 N, respectively.
- c) **Calculation of tension.** The calculation shall be as shown in [Annex B](#).
- d) **Determination of radius of curvature and calculation of springback.** The radius of curvature, r' , of the inner surface of the test piece, after removal of the force, shall be determined at the centre of the stretch-bent specimen in its longitudinal direction, using an appropriate measurement device (see [6.2](#)). The radius of curvature, r , of the inner surface of the test piece under force shall be the radius of the punch tip. The amount of springback, η , is calculated using the formula in [3.2](#). The width of the base of a dial gauge, w , for determining the curvature of the test piece, after removal of the force, is recommended to be 20 mm (see [Annex C](#)). This is based on the observation, in preliminary experiments, that the curvature of the specimen after springback was almost uniform in the central 20 mm section of the specimen.
- e) **Rounding.** Measured data shall be rounded according to ISO 80000-1.

9 Test report

If a test report is required, the reported items shall be determined by agreement between the parties and shall be selected from the following:

- a) test conditions: punch radius, amount of punch penetration, lubricant, type and thickness of polymer film, punch force, blank holding pressure, and orientation of the test piece to the material rolling direction;
- b) test results: nominal tensile stress, amount of springback, η ;
- c) type and thickness of material;
- d) an estimate of the uncertainty (or precision and bias) for all the measurements reported

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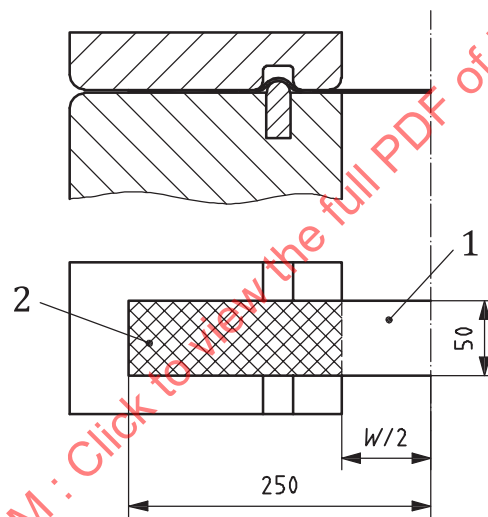
Annex A (normative)

Method for calculating blank holding pressure

The blank holding pressure shall be calculated using [Formula \(A.1\)](#) and [Formula \(A.2\)](#) (see [Figure A.1](#)):

$$p = \frac{F_h}{S} \quad (\text{A.1})$$

$$S = 50 \times \left(250 - \frac{W}{2} \right) \times 2 = 50 \times (500 - W) \quad (\text{A.2})$$



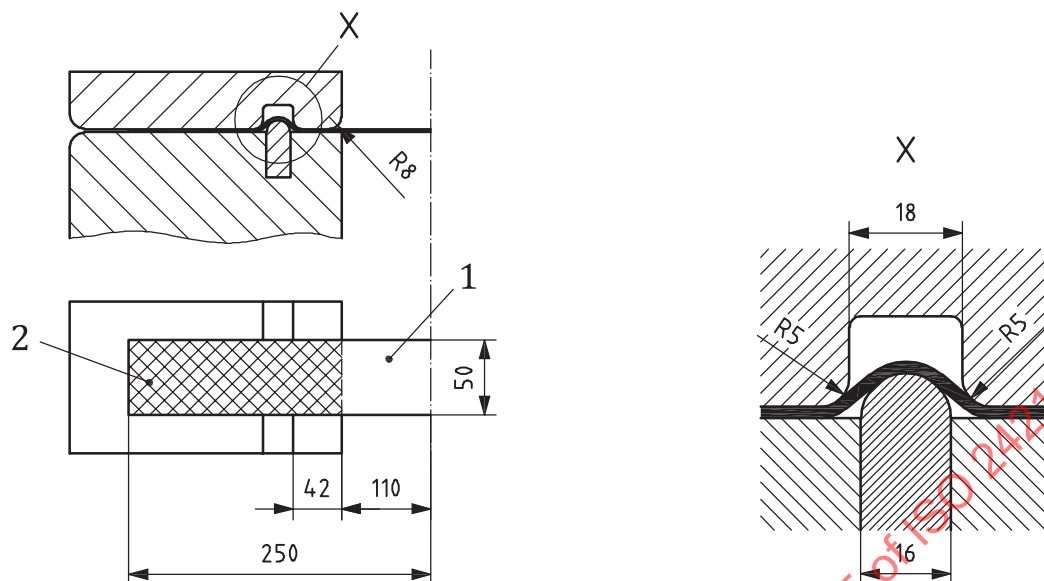
Key

- 1 test piece
- 2 total surface area of test piece in contact with dies

Figure A.1 — Contact area of a test piece with dies

An example of the dimensions of the tool [see [Figure 2 b\)](#)] is shown in [Figure A.2](#).

Dimensions in millimetres



Key

- 1 test piece
- 2 total surface area of test piece in contact with dies

Figure A.2 — Example of dimensions of tool