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

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

Reference number
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Foreword

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ISO 24213 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Subcommittee SC 2, *Ductility testing*.

Introduction

This International Standard 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.

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

1 Scope

This International Standard 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.

2 Normative references

The following referenced documents relate to 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 31-0, *Quantities and units — Part 0: General principles*

3 Terms and definitions

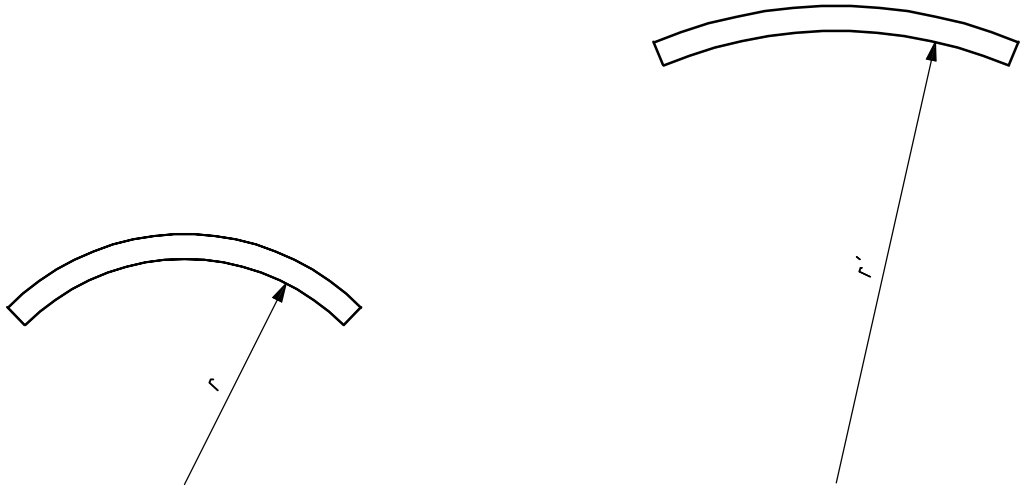
For the purposes of this document, the following terms and definitions apply.

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

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

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

$$\eta = \frac{\left|\kappa' - \kappa\right|}{\kappa} = \frac{r' - r}{r'} \tag{2}$$



a) Under force

b) After removal of the force

Figure 1 — Radius of curvature of 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

NOTE The method for calculating the blank holding pressure is shown in Annex A.

3.5
nominal tensile stress
tensile force per unit cross-sectional area of the test piece

NOTE The method for calculating the nominal tensile stress is shown in Annex B.

4 Symbols and designations

The symbols used in this International Standard 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 Equations 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

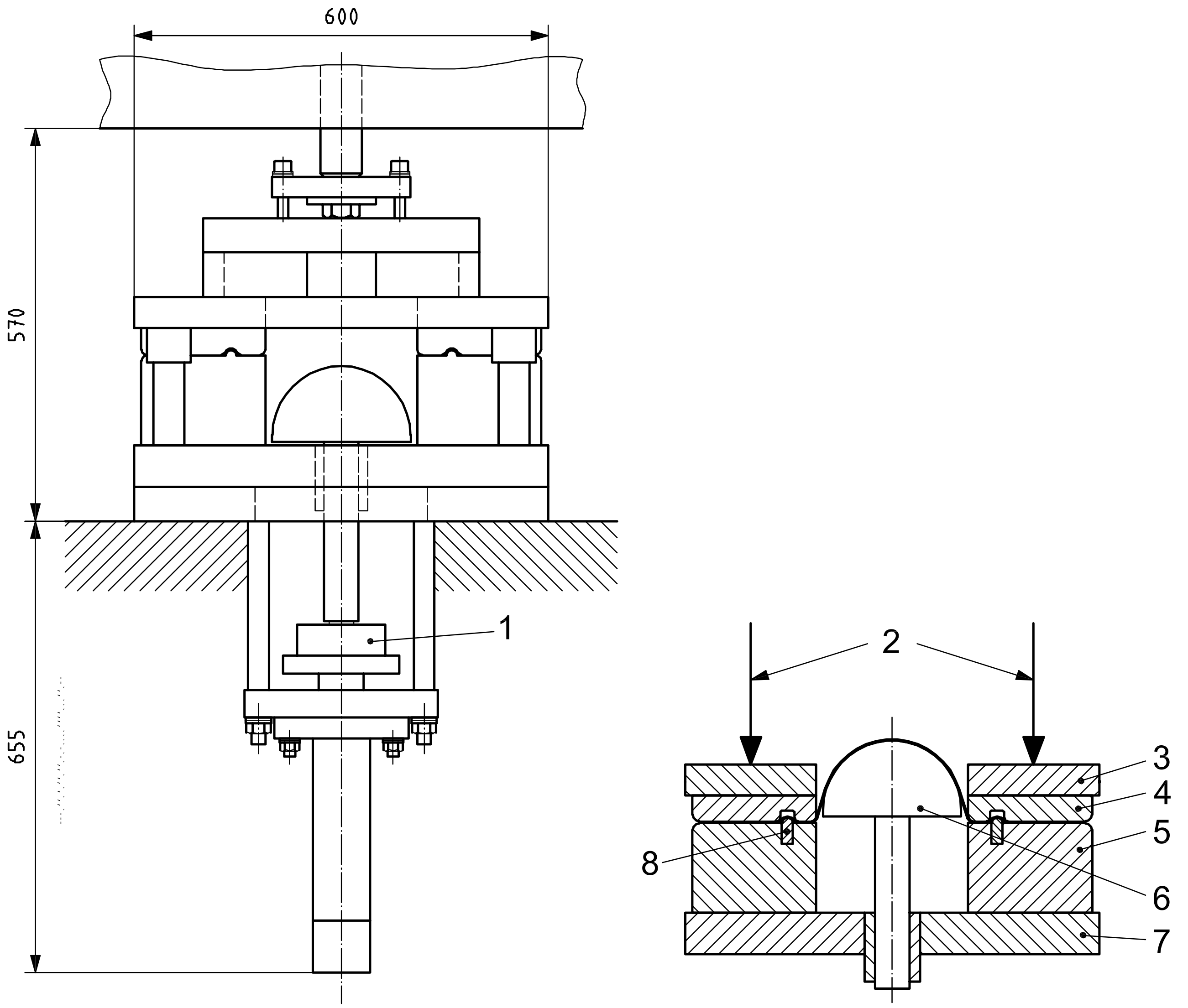
The test apparatus is described below.

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.

Dimensions in millimetres



a) Test apparatus **b) Tool setup**

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

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 parallel and perpendicular to the rolling direction.

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 °C to 35 °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 ± 5) °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 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 a dial gauge as described in Annex C. 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 equation 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 31-0.

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;

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.

Annex A
(normative)

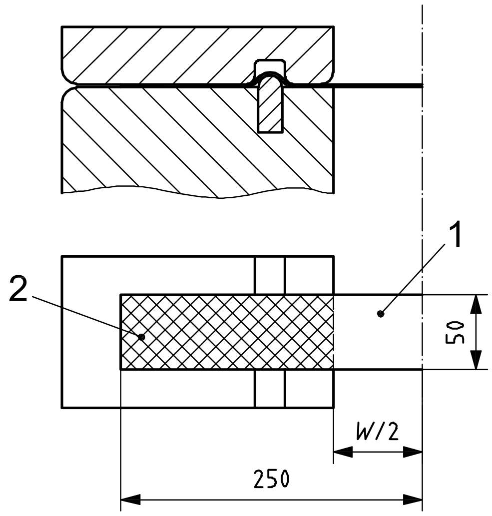
Method for calculating blank holding pressure

The blank holding pressure shall be calculated using Equations (A.1) and (A.2) (see Figure A.1):

$$p = \frac{F_\mathrm{h}}{S} \quad \text{(A.1)}$$

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

Dimensions in millimetres



Key

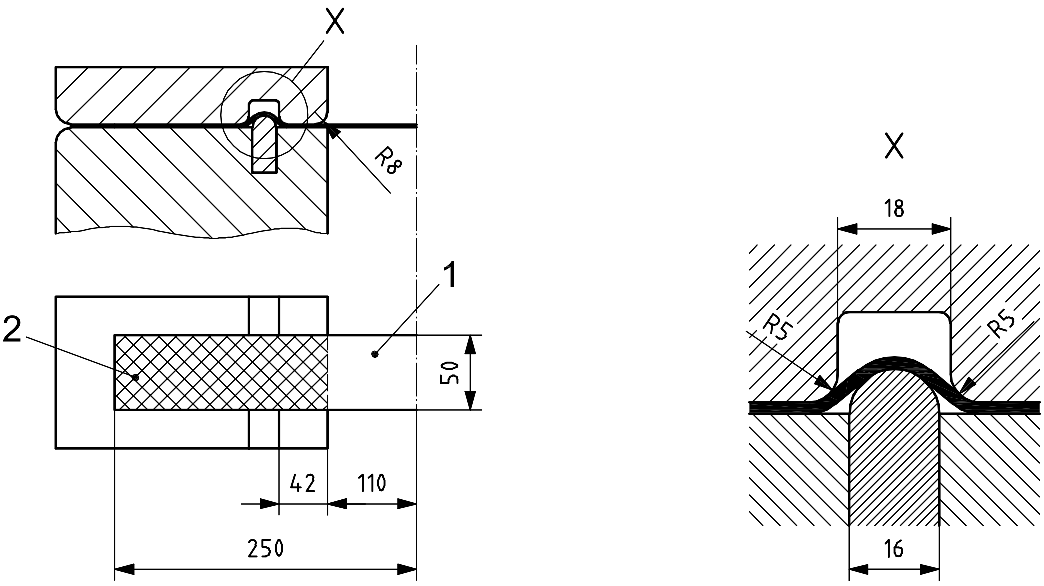
1 test piece

2 total surface area of test piece in contact with dies

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

An example of the dimensions of the tool [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

Annex B
(normative)

Method for calculating nominal tensile stress

The nominal tensile stress applied to the test piece shall be calculated using Equations (B.1) and (B.2) (see Figure B.1).

$$T = \frac{F_p}{2ba\sin\theta} \tag{B.1}$$

where

$$\theta = \sin^{-1}\frac{R_p + r_d + a}{\sqrt{\left(\frac{W}{2} + r_d\right)^2 + (R_p + r_d + a - h)^2}} - \tan^{-1}\frac{2(R_p + r_d + a - h)}{W + 2r_d} \tag{B.2}$$

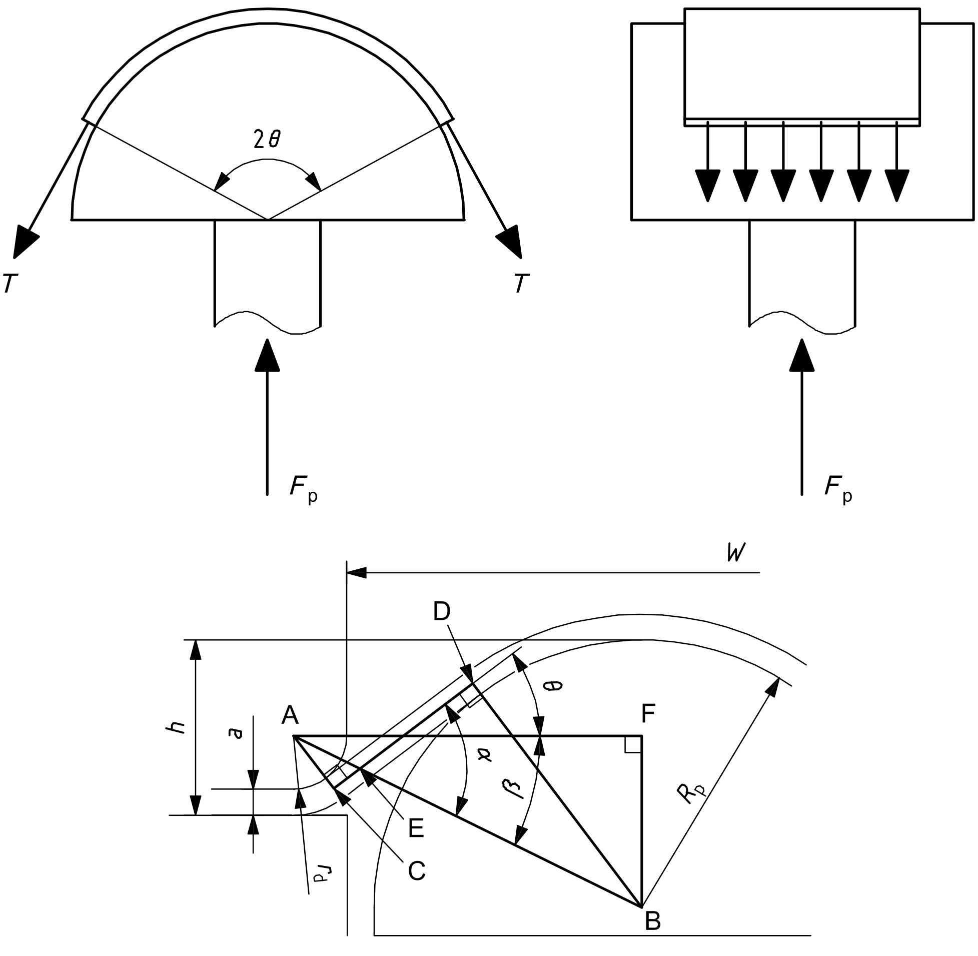


Figure B.1 — Relationship between punch force and nominal tensile stress

Annex C
(normative)

Device for determining radius of curvature using a dial gauge

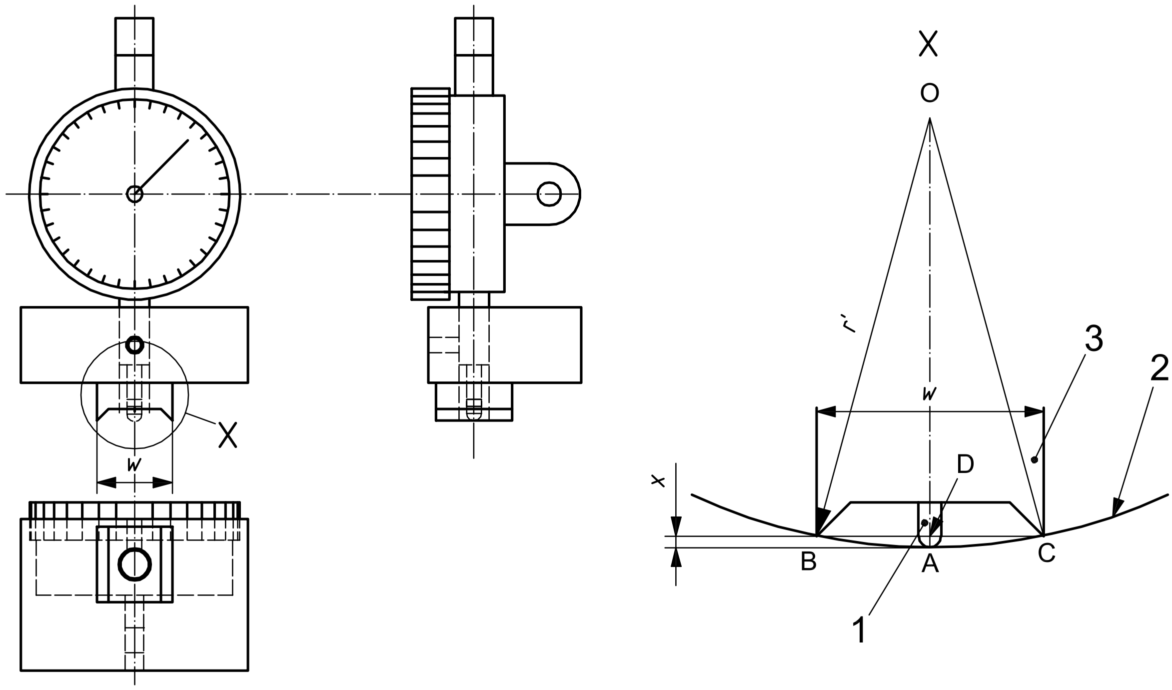
Figure C.1 shows an example of a device for determining the radius of curvature of a test piece using a dial gauge. The point of contact with the stylus of the dial gauge is A, the points of contact with the base tips are B and C, the centre of the radius of curvature is O, and the point of intersection between AO and BC is D. The width of the base is w, and the value measured by the dial gauge (length of AD) is x. As $BO^2 = BD^2 + DO^2$ for triangle BOD, r' can be calculated using Equation (C.1).

$$(r')^2 = \left(\frac{w}{2}\right)^2 + (r' - x)^2 \quad \text{(C.1)}$$

Equation (C.1) is reduced to

$$r' = \frac{x}{2} + \frac{w^2}{8x} \quad \text{(C.2)}$$

EXAMPLE If $w = 20{,}00$ mm and $x = 0{,}100$ mm, then $r' = 0{,}05$ mm $+ 500{,}00$ mm $= 500{,}05$ mm.



Key

1 stylus of dial gauge

2 inner surface of test piece

3 base

Figure C.1 — Device for determining the radius of curvature of a test piece using a dial gauge

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