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Metallic materials — Sheet and strip — Determination of plastic strain ratio

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National foreword

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Metallic materials — Sheet and strip — Determination of plastic strain ratio

Matériaux métalliques — Tôles et bandes — Détermination du coefficient d'anisotropie plastique

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Foreword

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ISO 10113 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 10113:1991), which has been technically revised.

Metallic materials — Sheet and strip — Determination of plastic strain ratio

1 Scope

This International Standard specifies a method for determining the plastic strain ratio of flat products (sheet and strip) made of metallic materials.

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 6892:1998, *Metallic materials — Tensile testing at ambient temperature*

ISO 9513:1999, *Metallic materials — Calibration of extensometers used in uniaxial testing*

3 Terms and definitions

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

3.1
plastic strain ratio
r
ratio of the true width strain to the true thickness strain in a test piece that has been subjected to uniaxial tensile stress

$$r = \frac{\varepsilon_b}{\varepsilon_a} \tag{1}$$

where

ε_a is the true plastic thickness strain;

ε_b is the true plastic width strain.

NOTE 1 The above expression using a single point is only valid in the region where the plastic strain is homogeneous.

NOTE 2 Since it is easier and more precise to measure changes in length than in thickness, the following relationship derived from the law of constancy of volume is used to up to the percentage plastic extension at maximum force, A_g, to calculate the plastic strain ratio, r.

$$r = \frac{\ln\left(\frac{b}{b_0}\right)}{\ln\left(\frac{L_0 b_0}{Lb}\right)} \quad (2)$$

NOTE 3 Because the value r depends on the orientation of the test piece relative to the rolling direction, as well as on the strain level, the symbol r may be supplemented by the angle which characterises this orientation and the strain level. For example $r_{45/20}$ (see Table 1).

NOTE 4 For some materials exhibiting a phase change during plastic deformation, the volume of the measured section cannot always be assumed to be constant. In such cases, the procedure should be defined and agreed between the parties involved.

3.2
weighted average plastic strain ratio
$\bar{r}$
weighted average of the $r_{x/y}$ values for different test-piece orientations as calculated using the formula[1)]

$$\bar{r} = \frac{r_0 + r_{90} + 2r_{45}}{4} \quad (3)$$

NOTE All tests should be performed at the same strain/strain range, if $\bar{r}$ is determined.

3.3
degree of planar anisotropy
Δr
value calculated using the following formula[1)]

$$\Delta r = \frac{(r_0 + r_{90} - 2r_{45})}{2} \quad (4)$$

NOTE All tests should be performed at the same strain/strain range, if Δr is determined.

1) For some materials, other test-piece orientations may be chosen, in which case formulae other than those given in 3.2 and 3.3 should be used.

4 Symbols

The designations of the symbols used in this International Standard are given in Table 1.

Table 1 — Symbols and designations

Symbol	Designation	Unit
a_o	Original thickness of the test piece	mm
b_o	Original gauge width of the test piece	mm
L_o	Original gauge length	mm
L_e	Extensometer gauge length	mm
ΔL	Instantaneous elongation/extension of the measurement base	mm
Δb	Instantaneous width extension	mm
L	Gauge length after straining to a specified plastic elongation/extension	mm
a	Thickness after straining to a specified plastic elongation/extension	mm
b	Gauge width of the test piece after straining to a specified elongation/extension	mm
e	Specified plastic strain at which the plastic strain ratio should be determined (single data point method)	%
$e_{\alpha-\beta}$	Specified plastic strain range at which the plastic strain ratio should be determined (linear regression method, α = lower limit of the plastic strain in percent, β = upper limit of the plastic strain in percent)	%
r	Plastic strain ratio	—
$r_{x/y}$	Plastic strain ratio in x-direction (in degrees) relative to the rolling direction at plastic strain/plastic strain range of y %	—
$\overline{r}$ [a]	Weighted average of $r_{x/y}$ values	—
Δr	Degree of planar anisotropy	—
ε_a	True plastic thickness strain	—
ε_b	True plastic width strain	—
ε_l	True plastic length strain	—
F	Force	N
S_o	Original cross-sectional area of the parallel length	mm^2
S	True cross-sectional area	mm^2
ν	Poisson´s ratio	—
m_E	Slope of the elastic part of the stress/percentage-extension curve multiplied by 100 %	MPa
m_r	Slope of the corresponding straight line of the true plastic width strain vs. true plastic length strain curve	—
A_g	Percentage plastic extension at maximum force	%
α, β, x, y	Variables used as subscripts	

NOTE 1 In the literature, the readers may encounter other symbols: for an international comparison of symbols, see Annex A.

NOTE 2 1 MPa = 1 N/mm^2.

[a] In some countries, r_m is used instead of $\overline{r}$.

5 Principle

A test piece is subjected to a tensile test to a specified plastic strain level and the plastic strain ratio, r, is calculated from measurements of the changes in length and width. The orientation of the test piece relative to the rolling direction, and the plastic strain level for which the values of r are determined, are as specified in the relevant product standard. As a rule, the strain level shall be lower than the plastic extension at maximum force.

6 Test equipment

The tensile testing machine used shall comply with the requirements of ISO 6892.

For the manual method, the device for the measurement of the changes in gauge length shall be capable of measuring to within ± 0,01 mm. The device used for determining the changes in gauge width shall be capable of measuring to within ± 0,005 mm.

For the automatic method (see Clause 8), extensometers defined in ISO 9513:1999, of class 1 or better, shall be used.

NOTE When a long gauge length and large elongation are applied, the maximum relative error of the class 1 extensometer may be greater than ± 0,01 mm.

The method of gripping the test piece shall be as specified in ISO 6892.

7 Test piece

7.1 The test piece shall be taken in accordance with the requirements of the relevant product standard or, if not specified therein, as agreed between the interested parties.

The type of the test piece and its preparation, including machining tolerances, the tolerances on shape and the marking of the original gauge length, shall be as defined in ISO 6892:1998, Annex A, but within the gauge length the edges shall be sufficiently parallel that two width measurements do not differ by more than 0,1 % of the mean of all the width measurements.

7.2 The test piece thickness shall be the full sheet thickness, unless otherwise specified.

7.3 The surface of the test piece shall not be damaged, e.g. by scratches.

8 Procedure

8.1 In general, tests are carried out at ambient 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 If the measurements are made manually, the original width of the test piece shall be measured at a minimum of three points evenly distributed along the gauge length, including one measurement at each end of the gauge length. The mean value of these width measurements shall be used in calculating the plastic strain ratio.

8.3 If the measurements are made automatically, the extension and the change of width, at least at one measurement point, shall be measured using an extensometer, as specified in Clause 6.

8.4 In the plastic range, the strain rate of the parallel length shall not exceed 0,008/s.

8.5 Mount the test piece in the grips of the testing machine and, keeping the test rate within the limit specified in 8.4, apply the required deformation:

a) either to achieve the plastic strain level specified in the relevant product standard (manual determination);

b) or to determine width values at the plastic strain level specified in the relevant product standard (automatic determination).

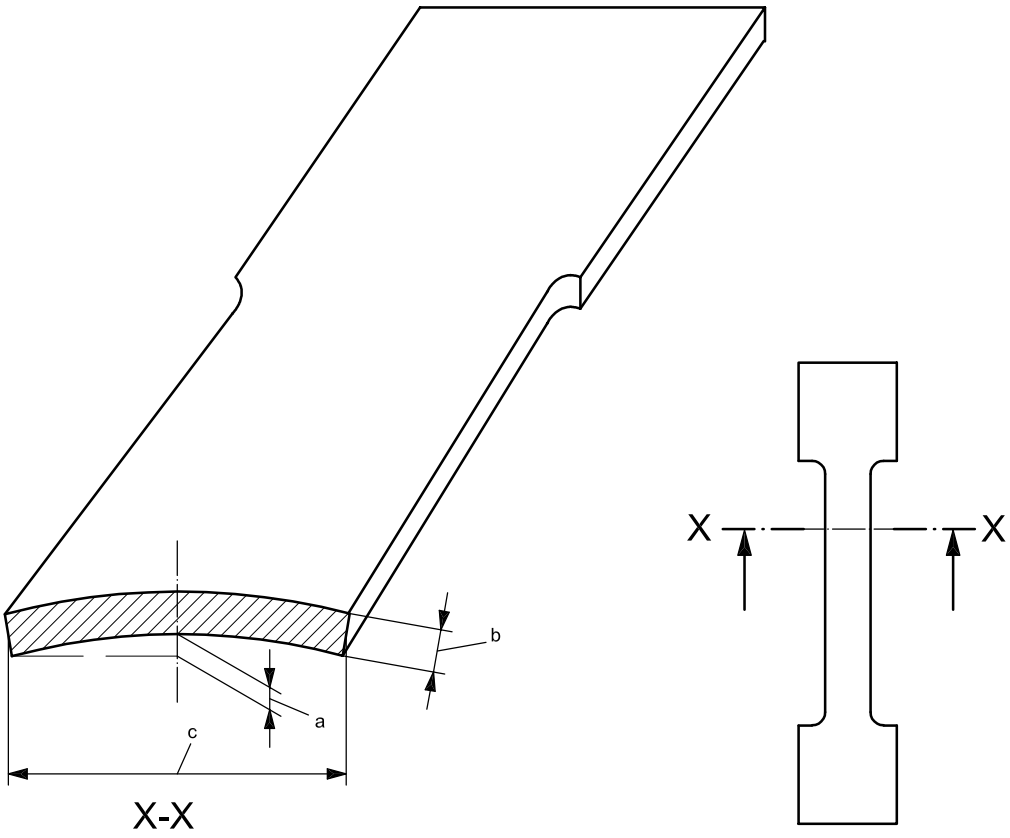
8.6 In the case of manual determination, after unloading, measure the gauge length L and the gauge width b in the same manner and to the same tolerances as for the original gauge length and width.

8.7 In the case of automatic determination, the measurements of length and width at the specified plastic strain level shall be made using an extensometer as specified in Clause 6.

8.8 If the test piece shows transverse bow (see Figure 1) which could influence the test results, the test shall be considered invalid and a new test shall be carried out.

8.9 If the plastic strain is not homogeneous, a manual determination of the r-value is not possible. With continuously measured data for the width change against extension and using statistical methods, as specified in 9.2, it is possible to determine a reproducible r-value.

8.10 In the case of coated material (e.g. galvanised or with organic coatings), the r-values obtained may differ from those of base material without coating.



Key

a transverse bow

b thickness after straining to a specified plastic elongation/extension

c gauge width of the test piece after straining to a specified elongation/extension

Figure 1 — Schematic illustration of transverse bow in a test piece cross-section

9 Expression of results

9.1 For a manual determination, calculate the plastic strain ratio, the weighted average of the plastic strain ratio for different test piece orientations and the degree of planar anisotropy using the Formulae (2), (3) and (4). When formulae other than (3) and (4) are used, they shall be indicated in the test report.

9.2 For materials with homogeneous deforming behaviour, a single data point method can be used. For a better reproducibility, a determined range should be used.

For materials with inhomogeneous deforming behaviour, the following method shall be used to give reproducible results.

The true plastic length strain shall be calculated using Equation (5).

$$\varepsilon_l = \ln\left[\left(L_\mathrm{o} + \Delta L\right)/L_\mathrm{o} - F/\left(S_\mathrm{o} \times m_\mathrm{E}\right)\right] \tag{5}$$

The true plastic width strain shall be calculated using Equation (6).

$$\varepsilon_\mathrm{b} = \ln\left[\left(b_\mathrm{o} - \Delta b + \frac{b_\mathrm{o} \times \nu \times F}{S_\mathrm{o} \times m_\mathrm{E}}\right)\Big/ b_\mathrm{o}\right] \tag{6}$$

where ν is Poisson's ratio (e.g. 0,30 for steel, 0,33 for aluminium).

The plastic strain (at a given moment during the test) shall be calculated using Equation (7).

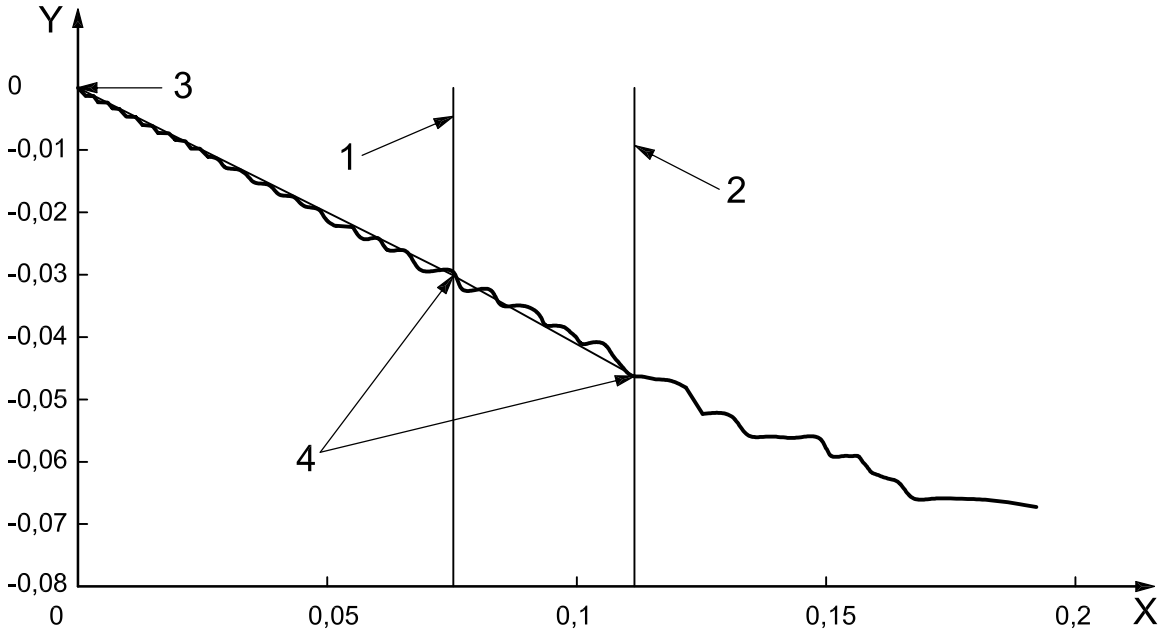
$$e = \left[\Delta L/L_\mathrm{o} - F/\left(S_o \times m_\mathrm{E}\right)\right] \times 100\ \% \tag{7}$$

For an explanation, see Figure 2.

If the automatic method is used, in Equations (5) and (7) L_o should be replaced by L_e .

From a strictly physical standpoint, in Equations (5), (6) and (7) the true cross-sectional area S according to Equation (8) should be used instead of the original cross-sectional area S_o, to calculate the true plastic length strain ε_l, the true plastic width strain ε_b and the plastic strain e. Practice has proved that the results obtained with S_o or S are not significantly different. Hence, the original cross-sectional area S_o should be used in Equations (5), (6) and (7).

$$S = S_\mathrm{o} \times L_\mathrm{o}/(L_\mathrm{o} + \Delta L) \tag{8}$$



Key

X True plastic length strain, ε_l

Y True plastic width strain, ε_b

1 lower limit: e. g. 8 % plastic strain

2 upper limit: e. g. 12 % plastic strain

3 origin

4 linear regression between the lower limit and upper limit through the origin:

$\varepsilon_b = m_r \times \varepsilon_l$

$m_r = -0{,}39833$

$r_{8\text{-}12} = 0{,}662$

Figure 2 — Relationship between true plastic width strain and true plastic length strain

The linear regression of Equation (6) vs. Equation (5) shall be fitted in the selected range through the origin. The slope m_r of this linear regression is equal to $[-r/(1 + r)]$. The r-value shall be calculated by using Equation (9):

$$r = -m_r/(1 + m_r) \tag{9}$$

9.3 The calculated values of the plastic strain ratio shall be reported to the nearest 0,05.

9.4 If there is a difference in the result of automatic and manual determination on the same test piece, the origin of this difference shall be evaluated.

NOTE The differences in results of automatic and manual r-value determination can be caused by non-homogeneous deformation.

10 Test report

The test report shall include the following information:

a) a reference to this International Standard;

b) identification of the material tested;

c) the method used (manual or automatic);

d) the type of test piece used;

e) the orientation of the test piece relative to the rolling direction;

f) the plastic strain/plastic strain range at which the measurements were made, e.g.:

— $r_{45/8\text{-}12}$ (linear regression between 8 % and 12 % plastic strain),

— $r_{45/10}$ (single data point method at 10 % plastic strain);

g) test results;

h) the formulae used to calculate r, $\bar{r}$ and Δr, if different from Formulae (3) and (4).

Annex A
(informative)

International comparison of symbols used in the determination of plastic strain ratio

English	French	German	German symbol	Anglo-American symbol	Unit
Engineering strain	Allongement	Dehnung	ε	E	%
Engineering stress	Contrainte conventionnelle	Spannung or Nennspannung	σ	S	MPa
True strain (logarithmic strain)	Déformation vraie	Wahre Dehnung or Umformgrad	φ	ε	—
True stress	Contrainte vraie	Wahre Spannung	k_f	σ or R	MPa
Plastic strain ratio (r-value)	Coefficient d'anisotropie, r plastique	Senkrechte Anisotropie (r-Wert)	r	R	—

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