INTERNATIONAL STANDARD

ISO 10275

Second edition
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Metallic materials — Sheet and strip — Determination of tensile strain hardening exponent

Matériaux métalliques — Tôles et bandes — Détermination du coefficient d'écrouissage en traction

Reference number
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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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 10275 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 10275:1993), which has been technically revised.

Introduction

In the former version of this International Standard, for the calculation of the true strain, the elastic strain did not need to be subtracted from the total strain if it was lower than 10 % of the total strain.

In this new International Standard, the elastic strain is subtracted from the total strain for calculation of the true strain, which is now referred to as "true plastic strain".

Metallic materials — Sheet and strip — Determination of tensile strain hardening exponent

1 Scope

This International Standard specifies a method for determining the tensile strain hardening exponent n of flat products (sheet and strip) made of metallic materials.

The method is valid only for that part of the stress-strain curve in the plastic range where the curve is continuous and monotonic (see 7.4).

In the case of materials with a serrated stress-strain curve in the work hardening range (materials which show the Portevin-Le Chatelier effect, e.g. AlMg-alloys) the automatic determination (linear regression of the logarithm true stress vs. the logarithm true plastic strain, see 7.7) should be used to give reproducible results.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only 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 7500-1:2004, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tension/compression testing machines — Verification and calibration of the force-measuring system*

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

ISO 10113, *Metallic materials — Sheet and strip — Determination of plastic strain ratio*

3 Symbols and designations

The symbols and corresponding designations used in determining the tensile strain hardening exponent are given in Table 1.

Table 1 — Symbols and designations

Symbol	Designation	Units
L_e	Extensometer gauge length (L_e)	mm
ΔL	Instantaneous extension of the measurement base	mm
L	Instantaneous length of the extensometer gauge length $L = L_e + \Delta L$	mm
e_p	Specified plastic (engineering) strain at which the tensile strain hardening exponent should be determined (single data point method)	%
$e_{p\alpha} - e_{p\beta}$	Specified plastic (engineering) strain range at which the tensile strain hardening exponent should be determined (linear regression method, $e_{p\alpha}$ = lower limit of the plastic strain in percent, $e_{p\beta}$ = upper limit of the plastic strain in percent)	%
S_o	Original cross-sectional area of the parallel length	mm^2
S	True cross-sectional area	mm^2
F	Instantaneous force applied to the test piece	N
R	Stress	MPa
σ	True stress	MPa
ε	True plastic strain	—
m_E	Slope of the elastic part of the stress/percentage extension-curve	MPa
n	Tensile strain hardening exponent	—
C	Strength coefficient	MPa
N	Number of measurements made in determining the tensile strain hardening exponent	—
r	Plastic strain ratio	—
R_m	Tensile strength	MPa
A_e	Percentage yield point extension	%
A_g	Percentage plastic extension at maximum force	%
A, B, x, y	Variables used for the evaluation of n by the manual method	

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.

3.2 The tensile strain hardening exponent n is defined as the exponent of the true plastic strain in the mathematical equation relating the true stress to the true plastic strain (during uniaxial application of a force). This equation can be taken as follows:

$$\sigma = C \times \varepsilon^n \quad (1)$$

3.3 This equation can be transformed into a logarithmic one as follows:

$$\ln \sigma = \ln C + n \ln \varepsilon \quad (2)$$

The strain hardening exponent in the logarithmic system of coordinates is defined as the slope of the corresponding straight line.

4 Principle

A test piece is subjected to uniaxial tensile strain at a prescribed constant rate within the region of uniform plastic strain. The tensile strain hardening exponent n is calculated either by considering a portion of the stress-strain curve in the plastic region, or by considering the whole uniform plastic strain region.

5 Test equipment

5.1 Tensile testing machine, verified and calibrated in accordance with ISO 7500-1:2004 and of class 1 or better. The method of gripping the test piece shall conform to the requirements of ISO 6892.

5.2 Extensometer, of class 2 or better (class 1 in the event of determination of the plastic strain ratio r, see ISO 10113) in accordance with ISO 9513:1999, for measuring changes in the gauge length.

5.3 Dimension-measuring equipment, capable of measuring the width and thickness of the parallel-sided section of the test piece to within the tolerances specified for these dimensions in ISO 6892.

6 Test pieces

6.1 Sampling to obtain test pieces shall be in accordance with the requirements of the relevant product standard or, if not specified therein, by agreement. Machining tolerances, tolerances on shape, and the marking shall be as specified in ISO 6892.

6.2 In the event of the plastic strain ratio r and the tensile strain hardening exponent n being determined simultaneously, the conditions of ISO 10113 shall apply.

6.3 The thickness of the test piece shall be that of the full sheet, unless otherwise specified.

6.4 The surface of the test piece shall not be damaged (by scratches, etc.).

7 Procedure

7.1 In general, the test shall be carried out at ambient temperature, i.e. between 10 °C and 35 °C. Tests carried out under controlled conditions, where required, shall be made at a temperature of (23 ± 5)°C.

7.2 The test piece shall be mounted in the tensile testing machine (see 5.1) so that the force can be applied axially in accordance with ISO 6892.

7.3 In the plastic range, the strain rate of parallel length shall not exceed 0,008 s^{-1}, unless otherwise specified in the relevant standard. This rate shall be kept constant during the time interval over which the tensile strain hardening exponent is determined.

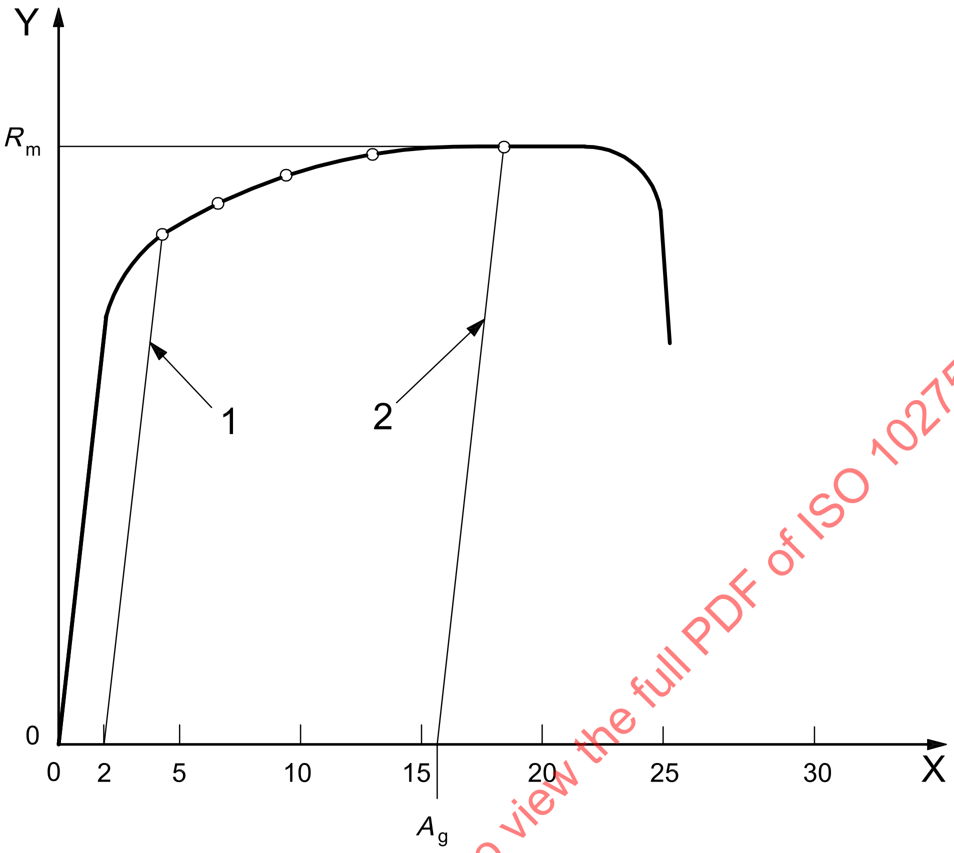
If a proof strength or the yield strength is determined during the same tensile test, the strain rate for this determination shall be as defined in ISO 6892.

7.4 When n is determined over the whole uniform plastic strain range, the upper limit for these data points shall be immediately prior to the strain at which the maximum force occurs.

For materials with homogenous deformation behaviour (i.e. materials without upper and/or lower yield strength), the lower limit of the range over which n is determined shall not be lower than a point after which the final testing rate used for determining R_m has been achieved (see Figure 1).

For the materials exhibiting yield point phenomena (upper and/or lower yield strengths), the lower limit shall not be lower than the start of uniform work hardening and after which the final testing rate used for determining R_m has been achieved (see Figures 2 and 3).

The lower limit and the upper limit shall be reported.



Key

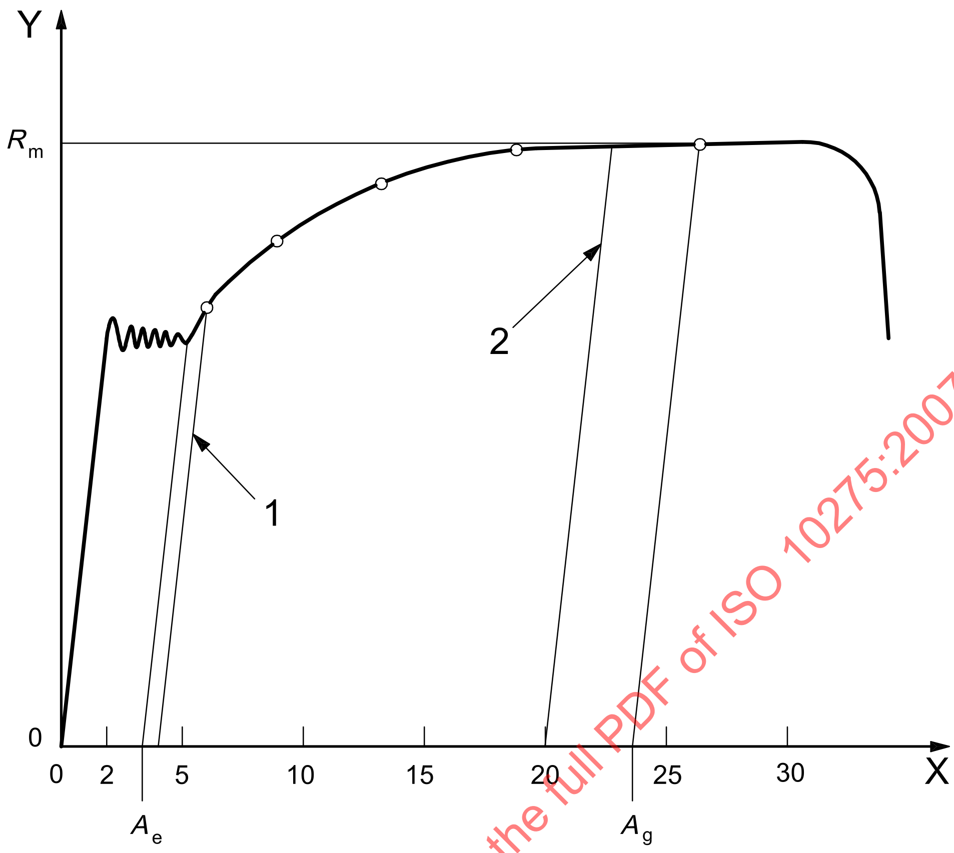
X strain %

Y stress

1 lower limit

2 upper limit

Figure 1 — Range for n_{2-20/A_g} or n_{2-A_g}



Key

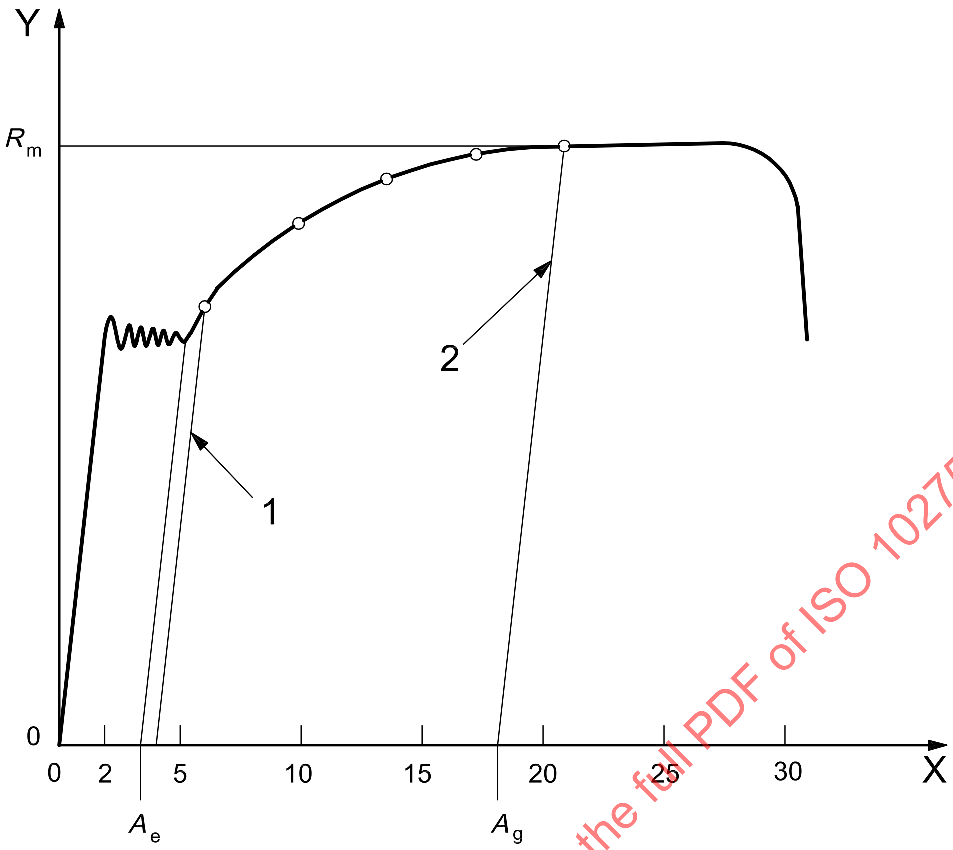
X strain %

Y stress

1 lower limit

2 upper limit

Figure 2 — Range for n_{4-20/A_g} or n_{4-20}



Key

X strain %
Y stress
1 lower limit
2 upper limit

Figure 3 — Range for n_{4-20/A_g} or n_{4-A_g}

7.5 From the values of the force and corresponding strain, calculate the true stress using the equation

$$\sigma = (F/S_o) \times [(L_e + \Delta L)/L_e] \quad (3)$$

Calculate the true plastic strain using the equation

$$\varepsilon = \ln[(L_e + \Delta L)/L_e - F/(S_o \times m_E)] \quad (4)$$

NOTE From the physical view, in Equation (4) the true cross-sectional area S according to Equation (5) should be used instead of the original cross-sectional area S_o to calculate the true plastic strain ε. The code of practice has proved that the results obtained with S_o or S are not significantly different. With respect to this and the lower complexity of the calculation, the original cross-sectional area S_o should be used in Equation (4):

$$S = S_o \times L_e/(L_e + \Delta L) \quad (5)$$

7.6 If the measurements are evaluated manually, calculate the tensile strain hardening exponent at a minimum of five points distributed in a geometric progression (see Figure 1), from Equation (2) given in 3.3 using the method of least squares. For this purpose, Equation (2) may be rewritten in the form

$$y = Ax + B \quad (6)$$

where

$y = \ln \sigma$

$x = \ln \varepsilon$

$A = n$

$B = \ln C$

From this equation, the following relationship can be derived for the tensile strain hardening exponent:

$$n = \frac{N\sum_{i=1}^{N} x_i y_i - \sum_{i=1}^{N} x_i \sum_{i=1}^{N} y_i}{N\sum_{i=1}^{N} x_i^2 - \left(\sum_{i=1}^{N} x_i\right)^2} \tag{7}$$

7.7 In the case of automatic determination, the tensile strain hardening exponent is obtained directly using an automatic tensile testing machine and data processing programme.

The n-value is determined from a linear regression of the logarithm of true stress vs. the logarithm of true plastic strain. The interval for the regression shall be expressed as plastic strains, with a minimum range of 2 %. It is possible to determine n-values over different intervals based on the same test.

EXAMPLES:

n_{4-6}: linear regression $\lg(\sigma) = n \times \lg(\varepsilon) + \lg C$, between 4 % and 6 % plastic strain;

n_{10-15}: linear regression $\lg(\sigma) = n \times \lg(\varepsilon) + \lg C$, between 10 % and 15 % plastic strain;

$n_{10\text{-}20/A_g}$: linear regression $\lg(\sigma) = n \times \lg(\varepsilon) + \lg C$, between 10 % and 20 % plastic strain resp. A_g if $A_g < 20$ % strain;

$n_{2\text{-}20/A_g}$: linear regression $\lg(\sigma) = n \times \lg(\varepsilon) + \lg C$, between 2 % and 20 % plastic strain resp. A_g if $A_g < 20$ % strain.

If fixed limits are defined (e.g. n_{10-15}) and A_g is lower than the upper limit, the n value cannot be determined.

For materials which are known to follow a power law [Equation (1)], the minimum number of points for the determination of the tensile strain hardening exponent shall be at least two.

7.8 The values calculated for the tensile strain hardening exponent shall be rounded to the nearest 0,01.

NOTE It is also useful to calculate and plot instantaneous strain hardening rates versus strain.

8 Test report

The test report shall include the following information:

a) a reference to this International Standard;

b) all details necessary for identification of the tested material;

c) the type of test piece used;

d) the range(s) of uniform strain over which the tensile strain hardening exponent was determined (see examples in 7.7);

e) the number of measurements made in determining the tensile strain hardening exponent only if the manual method was used;

f) the method used (manual or automatic);

g) the test results;

h) any deviation from the conditions specified in this International Standard.

