INTERNATIONAL STANDARD

ISO 10275

First edition
1993-02-15

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

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

Reference number
ISO 10275:1993(E)

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.

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.

International Standard ISO 10275 was prepared by Technical Committee ISO/TC 164, *Mechanical testing of metals*, Sub-Committee SC 2, *Ductility testing*.

Annex A of this International Standard is for information only.

International Organization for Standardization
Case Postale 56 • CH-1211 Genève 20 • Switzerland
Printed in Switzerland

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.

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this International Standard. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the standards indicated below. Members of IEC and ISO maintain registers of currently valid International Standards.

ISO 6892:1984, *Metallic materials — Tensile testing.*

ISO 7500-1:1986, *Metallic materials — Verification of static uniaxial testing machines — Part 1: Tensile testing machines.*

ISO 9513:1989, *Metallic materials — Verification of extensometers used in uniaxial testing.*

ISO 10113:1991, *Metallic materials — Sheet and strip — Determination of plastic strain ratio.*

3 Symbols and their meanings

3.1 The meanings of the symbols used in determining the strain hardening exponent are given in table 1.

3.2 The strain hardening exponent n is defined as the exponent of the true strain in the mathematical equation relating the true stress to the true strain (during uniaxial application of a force). This equation can be expressed approximately by the relationship

$$\sigma = K \cdot \varepsilon^n \qquad \dots (1)$$

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

$$\ln \sigma = \ln K + n \ln \varepsilon \qquad \dots (2)$$

The strain hardening exponent in the logarithmic system of coordinates is defined as the gradient of the straight line

$$n = \tan \alpha$$

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 strain region, or by considering the whole of the uniform plastic strain region.

Table 1

Symbol	Meaning	Units
L_e	Extensometer gauge length	mm
ΔL	Instantaneous elongation of measurement base	mm
L	Instantaneous length of measurement base $L = L_e + \Delta L$	mm
S_o	Original cross-sectional area of parallel-sided section of test piece	mm²
S	Cross-sectional area of parallel-sided section of test piece under action of force F $S = S_o\left(\frac{L_e}{L}\right)$	mm²
ε	True strain in test piece under action of force F $\varepsilon = \ln\left(\frac{L}{L_e}\right)$	
σ	True stress in test piece under action of force F $\sigma = F\left(\frac{L}{L_e S_o}\right)$	N/mm²
F	Instantaneous force applied to test piece	N
n	Strain hardening exponent	
K	Strength coefficient	N/mm²
α	Gradient of line ln σ versus ln ε	
N	Number of measurements made in determining tensile strain hardening exponent	

5 Test equipment

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

5.2 Extensometer, of class 1 or better in accordance with ISO 9513, 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 6892:1984, annex B.

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 of the original gauge length shall be as specified in ISO 6892.

6.2 In the event of the plastic strain ratio r and the 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 conditons shall be made at a temperature of 23 °C ± 5 °C.

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

7.3 The speed of separation of the cross-heads of the machine, expressed as a percentage of the length of the parallel-sided section of the test piece per minute, shall in no case exceed 50. This speed shall be kept constant during the time interval over which the tensile strain hardening exponent is determined.

For special materials, the speed shall be as specified in the relevant product standard.

If the proof stress (for non-proportional elongation) or the yield stress is determined in the course of the same tensile test, the strain rate for this determination shall be as defined in ISO 6892.

7.4 The force and the corresponding strain shall be recorded so as to give a suitable number of points in the portion of the curve over which the tensile strain hardening exponent is to be calculated (see figure 1 and 7.7 and 7.8). When n is determined over the whole uniform plastic strain range, the greatest of these strain measurement points shall be immediately prior to the strain at which the maximum force occurs, and the lower limit of these strain measurement points shall be the yield strain, for material not exhibiting yield phenomena, or the end of yield-point extension for material exhibiting yield phenomena (see figure 2). When the elastic strain is less than 10 % of the total strain, it need not be subtracted.

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

$$\sigma = F\left(\frac{L}{L_e S_o}\right)$$

Calculate the true strain using the equation

$$\varepsilon = \ln\left(\frac{L}{L_e}\right)$$

Calculate the logarithms of the values thus obtained.

7.6 If the measurements are evaluated manually, calculate the 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

$$y = Ax + B$$

where

$y = \ln \sigma$

$x = \ln \varepsilon$

$A = n$

$B = \ln K$

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

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

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

The minimum number of points for determination of the strain hardening exponent shall be five. If the number of points for the determination of the strain hardening exponent is less than 20, they shall be distributed in accordance with a geometric progression.

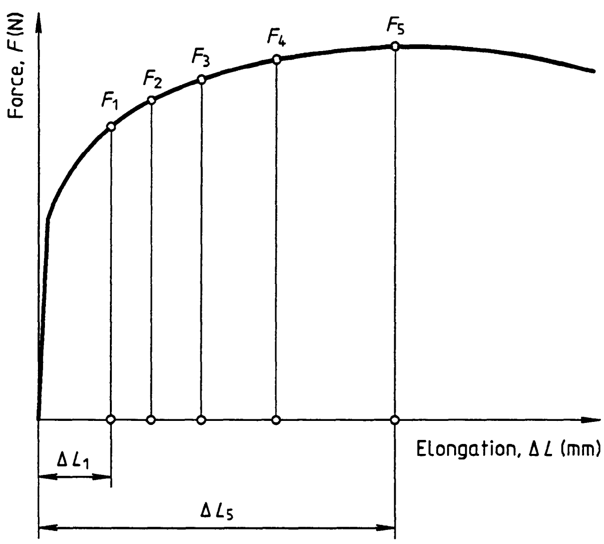

Figure 1

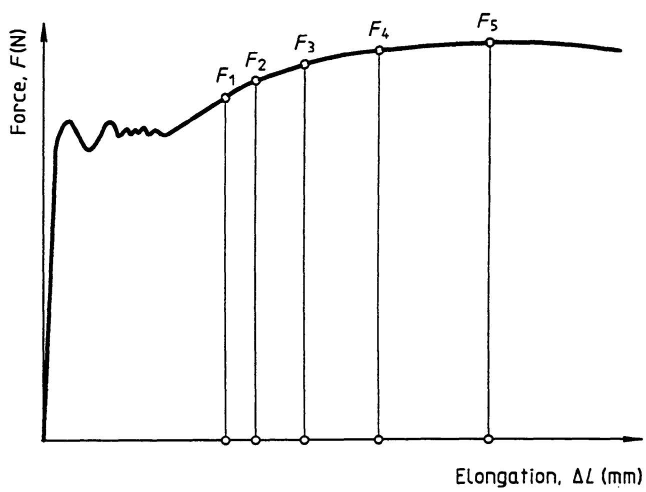

Figure 2

7.8 The values calculated for the strain hardening exponent shall be rounded to the nearest 0,005.

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 of uniform strain over which the strain hardening exponent was determined;

e) the number of measurements made in determining the strain hardening exponent;

f) the method used (manual or automatic);

g) the test results;

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

Annex A
(informative)

Strength coefficient and standard deviation

A.1 The strength coefficient K is numerically equal to the extrapolated value of the true stress at a true strain of 1,00.

A.2 The standard deviation $s_{(n)}$ can be calculated using the equation

$$s_{(n)} = \left\{ \frac{\sum_{i=1}^{N} (\ln \sigma - \ln K - n \ln \varepsilon)^2}{N \sum_{i=1}^{N} (\ln \varepsilon)^2 - \left(\sum_{i=1}^{N} \ln \varepsilon \right)^2} \times \frac{N}{N-2} \right\}^{1/2}$$

UDC 669-41:620.172.2

Descriptors: metals, metallurgical products, sheets, sheet metal, strips, tests, tension tests, determination, strain hardening exponent.

Price based on 5 pages