Cold rolled uncoated mild steel narrow strip for cold forming

Technical delivery conditions
English version of DIN EN 10139

DIN EN 10139

ICS 77.140.50

Supersedes DIN 1624, June 1987 edition.

Descriptors: Steel, strip.

Kaltband ohne Überzug aus weichen Stählen zum Kaltumformen – Technische Lieferbedingungen

European Standard EN 10139 : 1997 has the status of a DIN Standard.

A comma is used as the decimal marker.

National foreword

This standard has been prepared by ECISS/TC 13.

The responsible German body involved in its preparation was the *Normenausschuß Eisen und Stahl* (Steel and Iron Standards Committee), Technical Committee *Flacherzeugnisse aus Stahl zum Kaltumformen.*

It should be noted that the classification of steel grades and the steel properties for treatment condition LC (skin passed) have been adopted from DIN EN 10130.

The DIN Standards and the *Stahl-Eisen-Prüfblatt* (Iron and steel testing specification) (SEP) corresponding to the CEN document and EURONORMs referred to in clause 2 of the EN are as follows:

EURONORM 5	DIN 50133
EURONORM 49	SEP 1940
CR 10260	DIN V 17006-100

Amendments

In comparison with DIN 1624, June 1987 edition, the following amendments have been made:

a) The scope of the standard has been restricted to cover strip in rolled widths below 600 mm.
b) No requirements regarding the behaviour in the cupping test have been specified.
c) Requirements for the plastic strain ratio and the strain hardening exponent have been specified.

Previous editions

DIN 1624: 1954-08, 1977-07, 1987-06.

National Annex NA

Standards referred to

(and not included in **Normative references**)

DIN V 17006-100	Designation systems for steel – Additional symbols for steel names
DIN 50133	Vickers hardness testing of metallic materials – HV 0,2 to HV 100
DIN EN 10130	Cold rolled flat steel products for cold forming – Technical delivery conditions
Stahl-Eisen-Prüfblatt 1940	Measurement of surface parameters R_a and RPc on cold rolled steel flats with an irregular surface texture*)

*) Obtainable from *Verlag Stahleisen GmbH,* Postfach 10 51 64, D-40042 Düsseldorf.

EN comprises 26 pages.

EUROPEAN STANDARD
NORME EUROPÉENNE
EUROPÄISCHE NORM

EN 10139

November 1997

ICS 77.140.50

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English version

Cold rolled uncoated mild steel narrow strip for cold forming

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Feuillards non revêtus laminés à froid en aciers doux pour formage à froid – Conditions techniques de livraison

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This European Standard was approved by CEN on 1996-11-24.

CEN members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CEN member.

The European Standards exist in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CEN

European Committee for Standardization
Comité Européen de Normalisation
Europäisches Komitee für Normung

Central Secretariat: rue de Stassart 36, B-1050 Brussels

Ref. No. EN 10139 : 1997 E

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Foreword

This European Standard has been prepared by Technical Committee ECISS/TC 13 "Flat products for cold working - Qualities, dimensions, tolerances and specific tests", the secretariat of which is held by IBN/BIN.

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by May 1998, and conflicting national standards shall be withdrawn at the latest by May 1998.

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and the United Kingdom.

1 Scope

1.1 This European Standard applies to cold rolled narrow strip in coils and cut lengths in thicknesses up to 10 mm and of widths less than 600 mm, made from mild, unalloyed and alloyed steels in accordance with table 1.

These products are suitable for cold forming. They are also suitable for surface coating. On the other hand, they are not suitable for hardening treatment followed by tempering.

1.2 This European Standard does not cover cold rolled flat products for which a separate standard already exists, particularly the following products:

- cold rolled non oriented magnetic steel sheet and strip (EN 10106);
- grain-oriented magnetic steel sheet and strip (EN 10107);
- semi-processed steel strip for the construction of magnetic circuits (EN 10126 and EN 10165);
- cold rolled narrow strip for the manufacture of springs (EURONORM 132);
- high yield strength steels for cold forming (EN 10268);
- cold rolled uncoated low carbon steel flat products for cold forming (EN 10130);
- cold reduced blackplate (EN 10205);
- sheet and strip for enamelling (EN 10209).

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate place in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 10002-1	Metallic materials - Tensile test - Part 1: Method of test (at ambient temperature)

EN 10002-2	Metallic materials - Tensile test Part 2: Verification of the force measuring system of the tensile testing machines
EN 10002-4[1)]	Metallic materials - Tensile test Part 4: Verification of extensometer used in uniaxial testing
EN 10020	Definition and classification of grades of steel
EN 10021	Steels and iron and steel products - General technical delivery conditions
EN 10027-1	Designation systems for steel Part 1: Steel names, principal symbols
EN 10027-2	Designation systems for steel Part 2: Numerical system
EN 10079	Definition of steel products
EN 10140	Cold rolled narrow strip - Tolerances on dimensions and shape
EN 10204	Metallic products - Types of inspection documents
EURONORM 5 (1979)[2)]	Vickers hardness test for steel
EURONORM 18 (1979)[2)]	Sampling and preparation of test pieces for steel and iron and steel products
EURONORM 49 (1972)[2)]	Measurement of the roughness of thin products made of cold rolled and uncoated steels
CR 10260	Designation systems for steel - Additional symbols for steel names

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[1)] Currently at draft stage.

[2)] Until they are transformed into European Standards, either the EURONORMS or the corresponding national standards listed in annex C of this European Standard may be used.

3 Definitions

3.1 For the purposes of this European Standard, the definitions of cold rolled flat products given in clause 1 are identical to those given in EN 10079.

NOTE: In the case of narrow widths, strip complying with this standard may also be wound in layers and supplied in the form of a bobbin wound coil.

3.2 After uncoiling and shearing, strip may be supplied in cut lengths.

4 Classification of grades and delivery condition

4.1 This European Standard specifies the grades listed in table 1. In the case of steel grade DC01, the deoxidation method shall be left to the manufacturer's discretion.

Steel grades DC03, DC04, DC05 and DC06 shall be supplied fully killed.

4.2 Products manufactured from these steels may be ordered and supplied in different delivery conditions (see table 1) and with different surface appearances (see 6.4 and table 2).

4.3 For the purposes of the specifications of this European Standard, the selection of steel grade, delivery condition and surface finish are the responsibility of the purchaser.

5 Designation

The symbol designation of the steel grades in this European Standard is in conformity with EN 10027-1 and Information Circular ECISS IC 10 - the numerical designation is allocated in conformity with EN 10027-2.

The standard designation consists of the words narrow strip or cut lengths, followed in order by:

a) reference to this European Standard, EN 10139;

b) the symbol DC, followed by the grade designation (01, 03, 04, 05 and 06);

c) the symbol for delivery condition (see table 1);

d) the symbol for surface appearance (MA, MB or MC, see table 2);

e) the symbol for surface finish where appropriate (RM or RR, see 6.4.3 and table 2).

Examples of standard designations:

Designation of cold rolled steel narrow strip, grade DC04, in a lightly skin-passed condition (LC), with a 'scratch and pit-free' surface appearance (MB) and a 'matt' surface finish (RM):

Narrow strip EN 10139-DC04 + LC MB RM

Designation of cold rolled steel narrow strip, grade DC03, in the annealed condition (A), with 'bright' (MA) surface appearance and a 'smooth' surface finish:

Narrow strip EN 10139-DC03 + AMA

6 Properties

6.1 Production processes and chemical composition

6.1.1 The steel making process of the steel shall be left to the manufacturer's discretion.

The production process of the product - where not stipulated in the order - shall also remain at the manufacturer's discretion.

6.1.2 The chemical composition based on ladle analysis shall be as given in table 1.

6.2 Choice of properties

The products covered by this European Standard shall comply with the specifications given in table 1 of this standard. If agreed separately, they may be supplied with a special suitability for making a particular part; in this case, a maximum percentage of processing scrap may be fixed by common agreement and acceptance tests on the basis of the mechanical properties shall not apply.

6.3 Mechanical and technological properties

6.3.1 The mechanical and technological properties of the products are given in table 1. These properties are guaranteed for the periods specified in table 1 with effect from the date that the products are made available for delivery. The purchaser shall be informed of this date when the products are to be made available, with a warning appropriate to the guarantee of mechanical properties. Storage of grade DC01 products for more than 3 months may cause a change in the mechanical properties likely to give rise to a reduction in the suitability for forming and drawing.

6.3.2 The usual test for checking the mechanical properties given in table 1 is the tensile test. However, if agreed at the time of ordering, hardness values may be specified instead of tensile test properties, but not both.

6.3.3 The tensile test values shall apply to longitudinal test pieces. The requirements of 3.3.2 of EURONORM 18-79, shall not apply.

6.4 Surface characteristics

6.4.1 *General*

Surface characteristics concern surface appearance and surface finish. These shall be specified by the purchaser at the time of ordering.

Unless otherwise specified at the time of ordering, the products shall be supplied with a surface appearance MA and a smooth surface finish (RL; with $R_a \leq 0{,}6$ μm).

6.4.2 *Surface appearance*

6.4.2.1 Cold rolled flat products covered by this European Standard may be supplied with surface appearances MA, MB or MC as described in table 2.

The required surface appearance shall be stated in the designation (see clause 5).

6.4.2.2 The characteristics indicated in table 2 apply to the surface actually inspected, which is generally the outside surface of coils and the top surface of lengths. The appearance of the uninspected surface shall correspond at least to surface appearance MA.

These characteristics shall not apply to the first inner and outer laps of coil or to lengths cut from them.

6.4.3 *Surface finish*

6.4.3.1 The surface finish may be rough, matt, smooth or mirror finish, as given in table 2.

Products with surface appearances MA and MB are generally supplied with a smooth surface finish (RL). If rough (RR) or matt (RM) finishes are required, the corresponding symbol shall be given in the designation (see clause 5).

The surface appearance MC shall only be supplied with a 'mirror' finish (RN).

6.4.3.2 The different surfaces finishes are characterized by the following reference values of mean roughness R_a:

rough: $R_a \geq 1{,}5\ \mu m$;

matt: $0{,}6\ \mu m < R_a \leq 1{,}8\ \mu m$;

smooth: $R_a \leq 0{,}6\ \mu m$;

mirror finish: $R_a \leq 0{,}2\ \mu m$.

6.5 Stretcher strains

The tendency towards the formation of fractures or stretcher strains during forming may be eliminated for a time by light skin-passing (LC).

The period of freedom from stretcher strains can be assumed to be three months for grade DC01 and six months for the other grades, from the agreed date when the product is available for delivery.

6.6 Suitability for the application of surface coatings

6.6.1 The products covered by this European Standard are suitable for surface coatings taking into account the following requirements:

a) all the products shall be suitable for organic coating;

b) all the products shall be suitable for the application of a metallic coating, e.g. zinc, tin or lead by means of hot dipping or thermal spraying;

c) all the products with surface appearances MB or MC shall be suitable for electrolytic coating.

6.6.2 The application of surface coatings requires that the surface be suitably prepared beforehand by the processor. The type of coating shall be agreed at the time of ordering if the types of coatings described in 6.6.1 b) and c) are to be used.

6.6.3 If a metallic coating is to be applied in accordance with 6.6.1 b), it shall be noted that for delivery conditions C290 to C690, recovery or recrystallization caused by higher temperatures could have an effect on the mechanical properties of the product.

6.7 Weldability

All steel grades and delivery conditions shall be suitable for welding using appropriate methods. For delivery conditions C290 to C690, it should be noted that the temperature rises during the welding operation could affect the mechanical properties and the microstructure.

6.8 Dimensions, mass, permissible tolerances

6.8.1 For the dimensions and the tolerances on dimensions and shape, see EN 10140.

6.8.2 A density of 7,85 kg/dm^3 shall be assumed for calculating the masses for all types of steel covered by this European Standard.

7 Testing

7.1 Agreement of acceptance testing

7.1.1 If a test is specified by a purchaser, he shall specify at the time of tendering and ordering:

- the type of test (specific or non-specific) (see EN 10021);

- the type of test document (see EN 10204).

7.1.2 The specific test shall be carried out in conformity with the requirements of 7.2 to 7.5.

7.2 Acceptance units and number of tests

7.2.1 The acceptance unit is 5 t or fraction of 5 t of products of the same steel grade, the same delivery condition and with the same surface characteristics and nominal thickness. Coils weighing more than 5 t shall be regarded as one acceptance unit.

All products belonging to one acceptance unit shall be from the same cast.

7.2.2 For each acceptance unit a tensile test shall be carried out and where appropriate a determination of n and r (see table 1 and annexes A and B). Alternatively if specified at the time of ordering a hardness test shall be carried out.

7.3 Sampling and preparation of test pieces

7.3.1 A sample of adequate size for all the tests to be carried out shall be taken from the products comprising the acceptance unit from any position on the strip or cut length. In cases of dispute, this sample shall be taken from a position at least 3 m from one of the ends of the coil.

7.3.2 The tensile test pieces shall be taken from samples complying with 7.3.1, parallel to the direction in which the product was rolled. The test pieces should not be further worked on either surface.

7.3.3 When cutting the test pieces from the samples, as little deformation as possible shall be caused. If shears or cutting torches are used, an adequate surplus shall be allowed, which will then be further worked (see EURONORM 18).

7.4 Test methods to be followed

7.4.1 All mechanical and technological tests shall be carried out at ambient temperature.

7.4.2 The tensile test shall be carried out in accordance with EN 10002-1.

7.4.3 If agreed separately at the time of ordering, the Vickers hardness test shall be carried out in accordance with EURONORM 5.

7.4.4 If agreed separately at the time of ordering, surface roughness shall be determined in accordance with EURONORM 49.

7.4.5 The determination of plastic strain ratio r and tensile hardening component n shall be carried out in accordance with annexes A and B of this standard.

7.5 Re-tests

7.5.1 If the results obtained from a correctly selected sample do not meet the specified requirements, two further samples from the same acceptance unit shall be tested for each unsatisfactory test in accordance with EN 10021 and both these shall meet the specified requirements.

7.5.2 The manufacturer shall be entitled to submit unsatisfactory acceptance units for re-testing after suitable rectification treatment has been carried out.

8 Marking

Marking of the products in line with the specifications of EN 10021 may be agreed at the time of ordering

9 Oiling

9.1 For all delivery conditions, apart from A, the products are usually covered with traces of rolling oil during the finishing process. However, this does not provide adequate protection against corrosion.

9.2 The products are normally supplied oiled. In this case, both sides are protected by a coat of non-drying neutral oil, free from foreign bodies and spread uniformly so that under the normal packing, transport, loading and storage conditions there will be no corrosion after three months.

If the transport and storage conditions make special corrosion protection necessary, the user shall inform the manufacturer of this at the time of ordering.

The oil film shall be removable by an alkaline solution or other normal solvents.

The selection of protection oils shall be the subject of a separate agreement.

9.3 If the product is to be supplied with the surface degreased at a separate operation, this shall also be agreed at the time of ordering.

9.4 If the product is to be supplied in the as-rolled condition, or without oil, there is an increased risk of scratching and rust formation during transportation and storage.

10 Packing

The type of packing conditions shall be agreed separately at the time of ordering.

11 Information to be supplied by the purchaser

To comply adequately with the requirements of this standard, tenders and orders shall include the following information:

a) The complete designation of the product (see clause 5).

b) If necessary, the delivery condition required, noting the suitability of the product for making a particular part (see 6.2).

c) The suitability for the application of surface coatings (see 6.6).

d) Whether the product is to be supplied with an oiled or an unoiled surface (see 9.2 and 9.3).

e) Nominal dimensions (see 6.8).

f) Quantity to be supplied.

g) The type of acceptance tests required (see 7.1.1).

h) If necessary, the type of test document wanted (see 7.1.1).

i) Marking requirements (see clause 8).

j) Packing requirements, including limits on mass and dimensions of coils and individual bundles (see clause 10).

12 Disputes

The provisions of EN 10021 shall apply to disputes and their settlements.

Table 1: Characteristics

Designation		Classification as specified in EN 10020	Type of deoxidation	Mechanical properties guaranteed for	Delivery condition	Symbol	R_e N/mm²[2) 5)]	R_m N/mm²	Elongation after fracture (% min)			r90	n90	Hardness[11)] HV		Chemical composition (cast analysis) % by mass (max)				
According to EN 10027-1 and ECISS IC 10	According to EN 10027-2								A80	A50	Lo 5,65√So	min[8)9)]	min[8)]	min	max	C	P	S	Mn	Ti
DC01	1.0330	Unalloyed quality steel	At the discretion of the manufacturer	3 months	Annealed	A	-	270-390	28	30	32	-		-	105					
					Skin passed	LC	max. 280[1)4)]	270-410[4)]	28[2)4)]	30[2)4)]	32[2)4)]		-	-	115[4)]					
					Work hardened	C290	200-380	290-430	18	20	24			95	125					
						C340	min. 250	340-490	-	-	-			105	155					
						C390	min. 310	390-540	-	-	-			117	172	0,12	0,045	0,045	0,60	
						C440	min. 360	440-590	-	-	-			135	185					
						C490	min. 420	490-640	-	-	-			155	200					
						C590	min. 520	590-740	-	-	-			185	225					
						C690	min. 630	min. 690[10)]	-	-	-			215	-	[10)]			[10)]	
DC03	1.0347	Unalloyed quality steel	Fully killed	6 months	Annealed	A	-	270-370	34	36	37			-	100					
					Skin passed	LC	max. 240[1)4)]	270-370[4)]	34[2)4)]	36[2)4)]	37[2)4)]	1,3[12)]	-	-	110[4)]					
					Work hardened	C290	210-355	290-390	22	24	26			95	117					
						C340	min. 240	340-440	-	-	-			105	130					
						C390	min. 330	390-490	-	-	-			117	155	0,10	0,035	0,035	0,45	
						C440	min. 380	440-540	-	-	-			135	172					
						C490	min 440	490-590	-	-	-			155	185					
						C590	min. 540	min.590	-	-	-			185	-					

(continued)

Table 1: Characteristics (concluded)

Designation		Classification as specified in EN 10020	Type of deoxidation	Mechanical properties guaranteed for	Delivery condition	Symbol	R_e N/mm² [5]	R_m N/mm²	Elongation after fracture (% min)			r90	n90	Hardness[11] HV		Chemical composition (cast analysis) % by mass (max)				
According to EN 10027-1 and ECISS IC 10	According to EN 10027-2								A80	A50	Lo 5,65√So	min[8][9]	min[8]	min	max	C	P	S	Mn	Ti
DC04	1.0338	Unalloyed quality steel	Fully killed	6 months	Annealed	A	-	270-350	38	40	40			-	95	0,08	0,030	0,30	0,40	
					Skin passed	LC	max.210[1][3][4]	270-350[4]	38[2][4]	40[2][4]	40	1,6[12]	0,180	-	105[4]					
					Work hardened	C290	220-325	290-390	24	26	28			95	117					
						C340	min. 240	340-440	-	-	-			105	130					
						C390	min. 350	390-490	-	-	-			117	155					
						C440	min. 400	440-540	-	-	-			135	172					
						C490	min.460	490-590	-	-	-			155	185					
						C590	min.560	590-690	-	-	-			185	215					
DC05	1.0312	Unalloyed quality steel	Fully killed	6 months	Skin passed	LC	max. 180[1][4]	270-330[4]	40[2][8]	42[4]	42[4]	1,9[12]	0,200	-	100[4]	0,06	0,0250	0,025	0,35	
												- r	- n							
DC06	1.0873	Alloy quality steel	Fully killed	6 months	Skin passed	LC	max.180[1][4][6]	270-350[4]	38[2][4]	40[2][4]	40[2][4]	1,8	0,220	-	-	0,02	0,020	0,020	0,25	0,3[7]

Notes to table 1.

NOTE 1: If the yield point is not pronounced, the yield point values apply to the 0,2 % proof stress, otherwise to the lower yield point (R_{eL}).

For thicknesses $\leq 0,7$ mm, but $> 0,5$ mm, 20 N/mm^2 higher maximum values are permitted for the yield point. In the same way, the HV values increased by 5 units. For thicknesses $\leq 0,5$ mm, 40 N/mm^2 higher maximum values are permitted for the yield point. In the same way, the HV values increase by 10 units.

NOTE 2: For thicknesses $0,5$ mm $< e \leq 0,7$ mm, minimum values 2 units lower are permitted for the elongation after fracture. For thicknesses between $0,2$ mm $< e \leq 0,5$ mm, minimum values 4 units lower are permitted for the elongation after fracture. For $e \leq 0,2$ mm, minimum values 6 units lower are permitted for the elongation after fracture.

NOTE 3: For thicknesses $> 1,5$ mm, a maximum value of 235 N/mm^2 is permitted.

NOTE 4: The values given in the table apply only to surface appearance MA. For surface appearances MB and MC, the yield point and tensile strength values increase by 20 N/mm^2 and the elongation after fracture values fall by two units. In the same way, the HV values increase by 5 units.

NOTE 5: For calculation purposes, a minimum yield point value (R_e) of 140 N/mm^2 may be assumed for steel grades DC01, DC03, DC04 and DC05 in treatment conditions A and LC.

NOTE 6: For calculation purposes, a minimum yield point value (R_e) of 120 N/mm^2 may be assumed for steel grade DC06.

NOTE 7: Titanium may be replaced by niobium. Carbon and nitrogen shall be fully fixed.

NOTE 8: For thicknesses 5 mm $< e < 3$ mm, the r and n values may be determined by agreement at the time of ordering. These values apply only to strip widths > 250 mm.

NOTE 9: For thicknesses > 2 mm, the value of r or $\bar{r}$ is reduced by 0,2.

NOTE 10: For grade DC01 in the delivery condition C690, the C and Mn contents may be exceeded.

NOTE 11: See 6.3.2.

NOTE 12: The longitudinal values of r (r_0) for grades DC03, DC04 and DC05 are respectively 1,1, 1,3 and 1,6.

Table 2: Surface appearances and finishes

Surface appearance (see also 6.4.1)			
Symbol	Characteristics	Field of application	Surface finish (see 6.4.3)
MA	Bright, metallically clean surface, pitting, small defects and scratches are permitted.	All thicknesses and treatment conditions	RR, RM, RL[2)]
MB	Bright, metallically clean surface; pitting grooves and scratches are permitted as long as the uniform smooth appearance is not substantially impaired when viewed with the naked eye.	Thicknesses $\leq 2{,}0$ mm[1)] all treatment conditions except A	RM, RL[2)]
MC	Bright, metallically clean surface; pitting grooves and scratches are permitted as long as the uniform appearance of the mirror surface is not impaired.	Thicknesses $\leq 1{,}0$ mm[1)] all treatment conditions except A	RN[2)]

[1)] The supply of products of greater thicknesses with this surface appearance shall be agreed separately.

[2)] The code letters need not be given in the designation.

Annexes

Annex A (normative Method of determination of the plastic strain ratio *r*

NOTE: This annex is based upon the procedures being developed by ISO/TC 164/SC2.

A.1 Definitions, symbols and designations

A.1.1 Plastic strain ratio *r* is defined as the ratio of true width and thickness strains in a test piece that has been submitted to uniaxial tensile stress.

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

where

ε_a is the true thickness strain

ε_b is the true width strain.

The plastic strain shall be homogeneous.

A.1.2 Since measurements of length are more easily made than of thickness changes the following relationship derived from the law of constancy of volume before and after plastic strain is normally used for calculation of *r*:

$$r = \frac{1n \frac{b_o}{b}}{1n \frac{L_b}{L_o b_o}}$$

The symbol *r* shall be completed by index figure x giving the orientation of the test piece relative to the rolling direction and by index figure *y* giving the strain level, for example, $r_{45/20}$ (see table A.1).

A.1.3 The weighted average $r_{x/y}$ value is calculated using the formula:

$$\bar{r} = \frac{r_o + r_{90} + 2r_{45}}{4}$$

A.1.4 Symbols and designations used in measurement and calculations for determining the plastic strain ratio r are given in table A.1.

A.2 Principle

The method involves carrying out a tensile test to a specified strain level of 20 % and of determining the plastic strain ratio by calculation from measurements of the changes in length and width for a given test piece.

As the determination shall be carried out in the range of homogeneous deformation, then if the uniform elongation of the tested material is lower than 20 %, strain values of 15 % to 20 % can be applied. The strain level shall be given as index y. The orientation of the test piece relative to the rolling direction shall be given as index x (see A.1.2.).

Table A.1:

Symbol	Designation	Unit
b_o	Original gauge width of the test piece	mm
b	Gauge width of the test piece after straining to a specified elongation	mm
L_o	Original gauge length	mm
L	Gauge length after straining to a specified elongation	mm
r	Plastic strain ratio	
$r_{x/y}$	Plastic strain ratio in direction x (in degrees) relative to the rolling direction for the strain level y %	
$\bar{r}$ [1)]	Weighted average of $r_{x/y}$ values	
ε_a	True thickness strain	
ε_b	True width strain	

[1)] In some countries r_m is used instead of $\bar{r}$

A.3 Testing equipment

A.3.1 The testing machine and method of gripping shall comply with the requirements of EN 10002: Parts 1 and 2.

A.3.2 When the gauge length and width are determined by an extensometer, the class of the extensometer shall be 1 or better according to EN 10002-4.

A.4 Test piece

A.4.1 The sample and preparation of the test piece shall be in accordance with EN 10002: Part 1. The test piece type shall be No. 2 (80 mm/20 mm).

A.4.2 The gauge length shall be between 50 mm and 80 mm but preferably 80 mm. The gauge length shall be measured within ± 0,01 mm and the test piece width shall be measured within ± 0,005 mm, using devices using adequate accuracy.

A.5 Procedure

A.5.1 In general, the test is carried out at ambient temperature between 10 °C and 35 °C. Tests carried out under controlled conditions shall be made at a temperature of 23 °C ± 5 °C.

A.5.2 If the measurement is made manually, the original width of the test piece shall be measured in at least three evenly distributed places within the gauge length (one measurement at each end of the gauge length). The mean value of the width shall be taken for calculations of plastic strain ratio r.

A.5.3 If the measurements are made automatically, the original gauge length and at least one width measurement shall be set according to the requirements of class 1 extensometers or better as specified by EN 10002-4.

A.5.4 The speed of the machine, as defined by the speed of separation of cross-heads of the machine, expressed as a percentage of the parallel length per minute, shall in no case exceed 50.

A.5.5 Mount the test piece in the grips of the testing machine and apply the load in accordance with A.5.4:

a) to achieve the prescribed strain (manual determination);

b) to determine the width values at the prescribed strain level (automatic determination).

A.5.6 For manual determination after removing the load measure the gauge length L and gauge width b in the same manner and to the same tolerance as for original values.

A.5.7 For automatic determination the measurements of length and width at prescribed strain level are made according to A.4.2

A.5.8 For manual determination calculate the plastic strain ratio in accordance to A.1.2.

A.5.9 For automatic determination the plastic strain ratio is obtained directly using an automatic tensile testing machine and data processing program. The elastic strains (in both width and length directions) shall be considered.

A.5.10 Calculate the weighted average $\bar{r}$ (see A.1.3)

A.6 Interpretation of results

A.6.1 Determined values of plastic strain ratio r shall be rounded to 0,05/

A.6.2 If the test piece shows any transverse bow, which could influence the test results, the test shall be considered invalid and a new test shall be carried out.

A.6.3 If the plastic strain was inhomogeneous, the test results shall be considered invalid and a new test shall be carried out.

A.6.4 In case of dispute the testing shall be carried out with three test pieces of specified orientation relative to the rolling direction. The average value of the 3 tests shall be considered.

A.7 Test report

The orientation of the applied strain relative to the rolling direction shall be added as an index figure x. The applied strain value, if not 20 %, shall be give as an index figure y.

Annex B (normative) Method of determination of strain hardening exponent *n*

NOTE: This annex is based upon the procedures being developed by IS0/TC164/SC2.

B.1 Definition, symbols and designations

B.1.1 Symbols and designations used in determining the strain hardening exponent are given in table B.1.

B.1.2 The strain hardening exponent *n* is defined as an exponent in the mathematical equation of the relation between true stress and true strain (during uniaxial application of the force):

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

or in the logarithmic form:

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

B.1.3 The symbol *n* shall be completed by an index figure *x* giving the orientation of the test piece relative to the rolling direction and by an index figure *y* giving the upper limit of the strain range if the latter is not the standard value of 20 %.

i.e. $n_{45/18}$

B.1.4 The weighted average of n_x values is calculated using the formula.

$$\bar{n} = \frac{n_o + n_{90} + 2n_{45}}{4}$$

B.2 Principle

The test involves uniaxial tensile straining of the test piece at the prescribed rate in the interval including the region of the uniform plastic strain.

The strain hardening exponent is determined within the strain range of 10 % to 20 %. As the determination shall be carried out in the range of homogeneous deformation, then if the uniform elongation of the tested material is lower than 20 %, values for the upper limit of the strain range of 15 % to 20 % can be applied. In this case the upper strain limit shall be given as index *y* (see B.1.3).

B.3 Testing equipment

B.3.1 The testing machine and method of gripping shall comply with the requirements of EN 10002: Parts 1 and 2.

B.3.2 The accuracy of the extensometer used shall be class 1 or better according to EN 10002-4.

Table B.1:

Symbol	Designation	Unit
L_o	Original extensometer gauge length of the test piece	mm
L	Instantaneous gauge length of the test piece after instantaneous action of the force F	mm
S_o	Original cross section of the gauge part of the test piece	mm^2
S	Instantaneous cross section of the gauge part of the test piece after instantaneous action of the force F $S = S_o \frac{L_o}{L}$	mm^2
ε	Instantaneous true strain after instantaneous action of the force F $\varepsilon = \ln \frac{L}{L_o}$	
σ	Instantaneous true stress after instaneous action of the force F $\sigma = \frac{F}{L_o} \cdot \frac{L}{S_o}$	$N.mm^2$
F	Instantaneous force applied to the test piece	N
n	Strain hardening exponent	
K	Strength coefficient	$N.mm^2$
$n_{x/y}$	Strain hardening exponent ratio in direction x (in degrees) relative to the rolling direction for the strain level y %	
n[1)]	Weighted average of n_x values	
N	Number of measurements for determination of strain hardening exponent	
[1)] In some countries n_m is used instead of n.		

B.4 Test piece

B.4.1 The sampling and preparation of the test piece shall be in accordance with EN 10002: Part 1, the test piece type is no 2 (80 mm/20 mm).

B.4.2 The gauge length shall be between 50 mm and 80 mm but preferably 80 mm. The gauge length shall be measured within ± 0,01 mm using a device having adequate accuracy.

B.5 Procedure

B.5.1 In general, the test is carried out at ambient temperature between 10 °C and 35 °C. Tests carried out under controlled conditions shall be made at a temperature of 23 °C ± 5 °C.

B.5.2 The test piece shall be mounted in the testing machine so that the force can be applied axially in accordance with EN 10002: Part 1.

B.5.3 The speed of the machine, as defined by the speed of separation of the cross-heads of the machine, expressed as a percentage of the parallel length per minute, shall in no case exceed 50. This speed shall be kept constant in the time interval over which the tensile hardening exponent is calculated.

B.5.4 The force and corresponding strain shall be recorded at a minimum of 5 points, distributed at equal distances within the strain range of 10 % to 20 % (10 % to 15 % ... 18 % refer to B.2) for which the strain hardening exponent is calculated.

B.5.5 From the values of the force and the corresponding strain, the true stress shall be calculated using the formula:

$$\sigma = \frac{F}{S_o} \cdot \frac{L}{L_o}$$

and the true strain shall be calculated using the formula:

$$\varepsilon = \ln \frac{L}{L_o}$$

and the logarithms of these values shall be obtained.

B.5.6 The n value is calculated using the formula given below, the standard formula for calculating the inclination of a straight line using the statistical method of least squares:

$$n = \frac{N\sum x_i y_i - \sum x_i \sum y_i}{N\sum x_i^2 - (\sum x_i)^2}$$

where

$$y = Ax + B$$

with

$$y = \ln \sigma$$

$$x = \ln \varepsilon$$

$$A = n$$

$$B = \ln K$$

B.5.7 Calculated values of the strain hardening exponent, n, shall be rounded to 0,005.

B.5.8 In the case of dispute the testing shall be carried out with three test pieces of the specified orientation relative to the rolling direction. The average value of the 3 tests shall be considered.

B.6 Test report

The orientation of the applied strain relative to the rolling direction shall be added as an index figure x, the upper limit of the applied strain range, if not 20 %, shall be given as an index figure y.

Annex C (informative) List of national standards complying with the euronorms given in the references (see clause 2)

Until they are transformed into European Standards, either the EURONORMS or the corresponding national standards given in table C.1 may be used.

Table C.1: Euronorm and corresponding national standards

Euronorm	Germany	France	United Kingdom	Italy	Belgium	Sweden	Spain
	DIN	NF	BS	UNI	NBN	SS	UNE
5	50133	A03-154	427	1955	A11-107	-	7423
18	-	A 03-111	1449/1	UNI-EU 18	A 03-001	11 0120 11 0105	36-300
49	-	-	-	-	-	-ISO 4288	