INTERNATIONAL STANDARD

ISO 15461

First edition
2018-01

Steel forgings — Testing frequency, sampling conditions and test methods for mechanical tests

Pièces forgées en acier — Fréquence des essais, conditions d'echantillonnage et méthodes d'essai pour essais mécaniques

Reference number
ISO 15461:2018(E)

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Published in Switzerland

Contents

Page

Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation on the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 17, *Steel*, Subcommittee SC 10 *Steel for pressure purposes*.

This first edition of ISO 15461 is based on Technical Report ISO/TR 15461:1997, which has been withdrawn. The main changes are as follows:

— Figures 3 a) and b) have been revised;

— Table 3 has been revised;

— Table 5 has been extended to steels for pressure purposes;

— the text of the document has been generally revised.

Steel forgings — Testing frequency, sampling conditions and test methods for mechanical tests

1 Scope

This document gives guidelines for the simplification and harmonization of the specifications for mechanical testing of open die and closed die forgings in International Standards and other technical delivery conditions for forgings of steel.

This document

a) offers various options for
   1) the frequency of testing, and
   2) sampling conditions,
b) introduces a designation system for the options, mentioned under (a), and
c) specifies the test methods for
   1) room temperature tensile tests,
   2) elevated temperature tensile tests,
   3) impact tests, and
   4) uniformity checks by hardness tests.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements 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 148-1, *Metallic materials — Charpy pendulum impact test — Part 1: Test method*

ISO 377:2017, *Steel and steel products — Location and preparation of samples and test pieces for mechanical testing*

ISO 404, *Steel and steel products — General technical delivery requirements*

ISO 3785, *Metallic materials — Designation of test specimen axes in relation to product texture*

ISO 6892-1, *Metallic materials — Tensile testing — Part 1: Method of test at room temperature*

ISO 6892-2, *Metallic materials – Tensile testing at elevated temperature — Part 2: Method of test at elevated temperature*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— IEC Electropedia: available at https://www.electropedia.org/

— ISO Online browsing platform: available at https://www.iso.org/obp

3.1
specific inspection and testing
inspection and testing carried out before delivery, according to the technical requirements of the order, on the products to be supplied or on test units of which the product supplied is part, in order to verify whether these products comply with the requirements of the order

[SOURCE: ISO 404:2013, 3.4, modified — "and testing" has been added and the wording has been altered.]

3.2
test unit
number of pieces or the tonnage of products to be accepted or rejected together, on the basis of the tests to be carried out on sample products in accordance with the requirements of the product standard or order

[SOURCE: ISO 404:2013, 3.6, modified — the wording has been altered slightly and the notes to entry have been deleted.]

3.3
sample product
item (e.g. bar, sheet, coil) selected for inspection or testing

[SOURCE: ISO 377:2017, 3.2]

3.4
sample
sufficient quantity of material taken from the sample product for the purpose of producing one or more test pieces

Note 1 to entry: In certain cases, the sample can be the sample product.

[SOURCE: ISO 377:2017, 3.3, modified — a note to entry has been deleted.]

3.5
test piece
part of a sample, with specified dimensions, machined or unmachined, brought to a required condition for submission to a given test

[SOURCE: ISO 377:2017, 3.5, modified — the wording has been altered slightly and a note to entry has been deleted.]

Note 1 to entry: In certain cases the test piece can be the sample.

3.6
ruling section
section for which the mechanical properties are specified

4 General

Unless otherwise specified in this document, the general conditions given in ISO 377 for the marking and preparation of samples and test pieces apply.

Where the conditions specified in this document differ from the conditions specified in the product standard or order, then the conditions of the product standard or order apply.

5 Testing frequency

5.1 For the testing frequency of room temperature tensile tests and of impact tests, the requirements given in 5.1.1 to 5.1.3 apply.

5.1.1 The product standard or order shall specify, by reference to the appropriate symbol(s) in Table 1, column 1, the following:

a) the composition of the test unit as defined in Table 1, columns 2 to 8;

b) whether uniformity checks by hardness tests in accordance with Table 1, column 9 are required and, if so, the percentage of products to be subjected to the hardness tests;

c) the number of sample products to be taken from the test unit. (See the explanations in Table 1, footnote [a], for replacing the letter "*n*" of the symbol by the mass of the test unit up to which the taking of one sample product is sufficient.)

NOTE Less stringent requirements for the composition of the test unit can be compensated by more stringent requirements for the number of sample products to be tested. Therefore, for example, a test unit characterized by the symbol CH5 can be regarded as equivalent to a test unit characterized by the symbol CHD10 or CFHD15 and the test unit CU100 can be regarded as equivalent with CFHDU10. Consequently, it seems possible and reasonable to specify in the product standards or orders not only one distinct test unit, but to leave various equivalent test units to the choice of the manufacturer or to an agreement at the time of enquiry and order, as shown in the example in Table A.1, column 5.

5.1.2 In general one sample is to be taken per sample product. The product standard or order may, however, by reference to the symbols in Table 2, specify that in the case of products with a length and/or mass greater than a certain limiting value two samples per sample product shall be taken.

5.1.3 If room temperature tensile tests are to be carried out, one tensile test piece shall be taken per sample. If impact tests are to be carried out, three impact test pieces shall be taken per sample.

5.2 If elevated temperature tensile tests are to be carried out, the product standard or order shall specify the number of test pieces to be taken for this test in relation to the number of test pieces to be taken for the room temperature tensile test (see example in Table A.1, column 9).

5.3 For simplifying comparisons the data for the frequency of testing should preferably be specified in the form of a table. (See the example in Table A.1.)

Table 1 — Options for the test units, the number of sample products to be taken per test unit and the percentage of products to be subjected to hardness tests for uniformity checks

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Test unit symbol	**The test unit shall be composed of products**							**The test unit shall have been subjected to**	**Number of sample products to be taken from test units with an as heat-treated weight of**					**Notes**
	of the same forming				**having been subjected to**				**≤ *n*[a]**	**> *n* ≤ 2*n***	**> 2*n* ≤ 4*n***	**> 4*n* ≤ 8*n***	**> 8*n* ≤ 16*n***	
	of the same cast	**process**	**cycle[b]**	**of the same shape and dimensions**	**of similar[c] shape and dimensions**	**the same type[d] of heat treatment**	**the same conditions[e] of heat treatment**		**x tonnes**					
tu[a]	C[a]		F[a]	D[a]			H[a]	U*x*[a]						
C*n*	x	x	—	—	x	x	—	—	1	2	3	4	5	In general not for quenched and tempered products
CH*n*	x	x	—	—	x	x	x	—	1	2	3	4	5	—
CHD*n*	x	x	—	x	—	x	x	—						
CFHD*n*	x	x	x	x	—	x	x	—						
CU*x*	x	x	—	—	x	x	—	an % uniformity check by hardness tests (see Clause 6)	Independent from the weight of the test unit, two sample products, namely the hardest and softest, shall be tested.					Only applicable where the test pieces for the mechanical tests can be taken from the products themselves (no prolongations)
CHU*x*	x	x	—	—	x	x	x							
CHDU*x*	x	x	—	x	—	x	x							
CFHDU*x*	x	x	x	x	—	x	x							
C*n*U*x*	x	x	—	—	x	x	—		1	2	3	4	5	Normally only applied where, for the tensile and impact tests, prolongations or integral surplus-material is provided. The product standard shall, in this case, include specifications for the maximum hardness range
CH*n*U*x*	x	x	—	—	x	x	x							
CHD*n*U*x*	x	x	—	x	—	x	x							
CFD*n*H	x	x	x	x	—	x	x							
IND	The test unit sample product shall consist of the individual forging													Not for small products

Table 1 *(continued)*

1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Test unit symbol	**The test unit shall be composed of products**							**The test unit shall have been subjected to**	**Number of sample products to be taken from test units with an as heat-treated weight of**					**Notes**
	of the same forming				**having been subjected to**				**≤ *n*[a]**	**> *n* ≤ 2*n***	**> 2*n* ≤ 4*n***	**> 4*n* ≤ 8*n***	**> 8*n* ≤ 16*n***	
	of the same cast	**process**	**cycle[b]**	**of the same shape and dimensions**	**of similar[c] shape and dimensions**	**the same type[d] of heat treatment**	**the same conditions[e] of heat treatment**		**x tonnes**					
tu[a]	C[a]		F[a]	D[a]			H[a]	U*x*[a]						

[a] The symbols for the test unit in column 1 and in the headings of columns 2 to 10 have the following meaning:

tu test unit;

C products of the same cast;

F same forming cycle;

D same shape and dimensions;

H same heat treatment conditions.

n in the product standard or order, the letter n of the symbol for the test unit given in column 1 is to be replaced by the mass of the test unit in tonnes up to which, in accordance with the indications in column 10, the testing of one sample product is sufficient. (For n the values 5, 10, 20 and 40 is preferred.)

Ux for checking the uniformity of the test unit, x % of the products and at least the number of products given in Table 3 are to be subjected to a hardness test.

EXAMPLE

The symbol CHD10 would, in accordance with the indications in columns 2 to 15, mean the following:

The test unit covers products of the same cast and the same dimensions and has been subjected to the same heat treatment condition. If the weight of the test unit is 10 t one sample product is to be tested; if its weight is > 4 n but ≤ 8 n, (that means in this example > 40 t but ≤ 80 t) four samples are to be tested.

[b] Forgings are regarded as being taken from the same forming cycle when they were, without any essential interruption, manufactured one after the other by the same forming process under the same conditions or, in other words, when they were produced in series.

Table 2 — Conditions for taking two samples per sample product

Symbols		Conditions for taking two samples per sample product[b]
in general numbers[a]	example	
l*y*	l5	Forgings with a length or greatest dimension greater than y (5) metres.
wz	w4	Forgings with an as heat treated individual weight greater than z (4) tonnes.
l*y*+wz	l5+w4	Forgings with a length or greatest dimension greater than y (5) meters and an as heat treated individual weight greater than z (4) tonnes.
l*y* or wz	l5 or w4	Forgings with a length or greatest dimension greater than y (5) meters or an as heat treated individual mass greater than z (4) tonnes.

[a] Replace as shown in the column "example" the letter *y* in the symbol by the appropriate value for the length in meters and the letter *z* by the appropriate value for the as heat treated individual mass of the forgings in tonnes.

[b] The values given in parentheses apply for the example given in column 2.

6 Uniformity checks on test units by hardness tests

All test units bearing as last letter in their symbol a "U" followed, as indicated in Table 1, by a value x = 5 to 100 shall be subjected as follows to uniformity checks by hardness tests.

Depending on the value of x, given in the symbol for the test unit, the number of products stated in Table 3 shall be selected at random for the hardness tests.

Table 3 — Number of products to be checked

x[a,b]	Number of products to be checked
5 10 20 30 50 100	100 %

[a] For x the values given above should be used.

[b] For test units of the type CU high values of *x* are normally specified, whereas for the more homogeneous test units of the type CHU, CHDU and CFHDU, lower values are normally applied.

On all products to be hardness tested, the same location shall be tested. This location shall lie at the surface of the product and where possible in an area where the thickness of the product corresponds to the thickness of the ruling section.

Decarburized zones and, as far as it may impair the measurement, scale shall be eliminated before the hardness tests are carried out.

All hardness tests on the products of one test unit shall be carried out using to the same method. If the hardness test method is not specified in the product standard or order, the manufacturer may choose the method. Acceptable methods are as follows:

a) Brinell test in accordance with ISO 6506-1;

b) Vickers test in accordance with ISO 6507-1;

c) Rockwell test in accordance with ISO 6508-1;

d) Shore test in accordance with ASTM E448 or JIS Z 2246;

e) "Leeb" test in accordance with ISO 16859-1 or ASTM A956.

7 Sampling conditions

The product standard or order shall, preferably in the form of a table (see example in Table A.2), specify the following:

a) by reference to the symbols in Table 4, the type of sample product and, where surplus material is required, the way of mounting this;

b) by reference to the symbols in Table 5, the distance of the test piece axis from the surface of the sample product in the as heat treated condition;

c) by reference to the symbols in Table 6, the direction of the longitudinal test piece axis and, in the case of impact test pieces, the direction of the notch of the test piece and the fracture plane determined by this to the direction of grain flow or strain.

Table 4 — Options for the types of sample products (ts) and the positioning of prolongations, integral surplus material and heat buffers and the location of the test pieces

Symbol ts	Type of sample product	Description of the type of sample product, the positioning of surplus material and the location of test pieces		Notes
pl	Complete products	The sample product consists of a complete product without prolongation or integral surplus material	the product is destroyed by taking of the test pieces	a
pc			the test pieces are taken by core drilling	
ppl	Complete product with prolongations	The prolongation shall be positioned as indicated	Figure 1 a)	b
ppld			d in Figure 1 a)	
pple			e in Figure 1 a)	
pp2			Figure 1 b)	b, c
pp2d			d in Figure 1 b)	
pp2e			e in Figure 1 b)	
pp2f			f in Figure 1 b)	
pp0			in the order	
pi1	Complete product with integral surplus material	The integral surplus material shall be positioned as indicated	in Figure 2 a)	b
pi2			in Figure 2 b)	b, c
pi0			in the order	b

a Only for small (closed die) forgings.

b The shape, dimensions and manufacturing conditions (including the heat treatment of the prolongations, of integral surplus material and of separately forged samples shall, as far as is possible and practical and unless otherwise specified, conform to the shape and dimensions and to the manufacturing conditions of the products in the area of their ruling section. Thus one can expect in the location from where the test pieces are to be taken the same principal direction of grain flow, the same degree of metal forming and the same heating and cooling rates as in the relevant location of the ruling section.

c Only applicable when the condition for taking two samples per sample product applies (see Table 2).

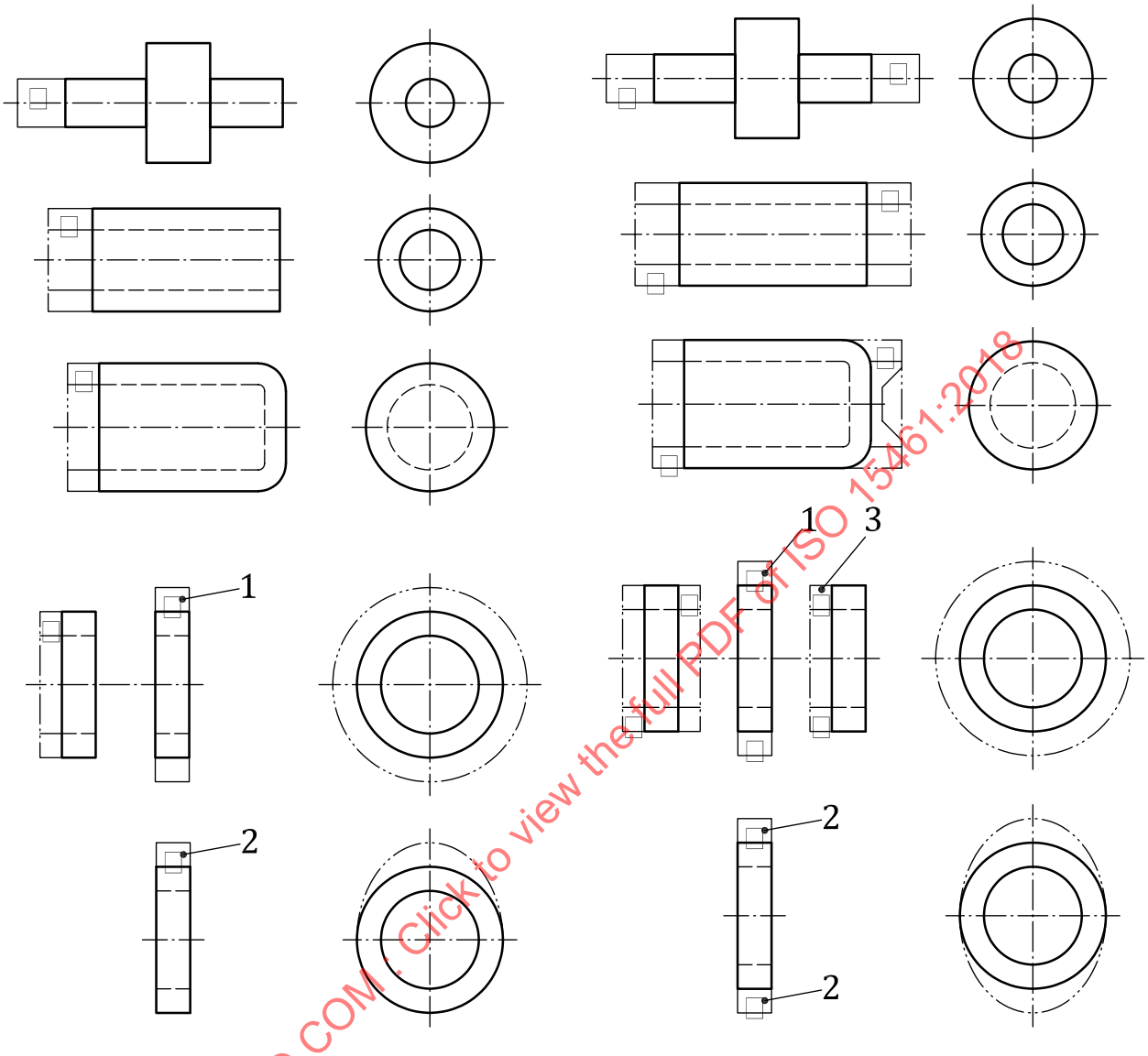
Table 4 *(continued)*

Symbol ts	Type of sample product	Description of the type of sample product, the positioning of surplus material and the location of test pieces		Notes
pl	Complete products	The sample product consists of a complete product without prolongation or integral surplus material	the product is destroyed by taking of the test pieces	a
pc			the test pieces are taken by core drilling	
pb1	Complete product with welded heat buffer	The buffer shall consist of unalloyed or low alloy steel and shall be positioned as indicated by a completely sealing weld	in Figure 3	b
pb2			in Figure 4	b, c
pb0			in the order	b
ss1	Separately forged samples	The samples shall be taken from the same cast as the forgings and shall be heat treated together with these (see also footnote b). Dimensions of the sample.	T × 2T × 2T (T = thickness of the ruling section of the forging)	b
ss0			as agreed when ordering	

a Only for small (closed die) forgings.

b The shape, dimensions and manufacturing conditions (including the heat treatment of the prolongations, of integral surplus material and of separately forged samples shall, as far as is possible and practical and unless otherwise specified, conform to the shape and dimensions and to the manufacturing conditions of the products in the area of their ruling section. Thus one can expect in the location from where the test pieces are to be taken the same principal direction of grain flow, the same degree of metal forming and the same heating and cooling rates as in the relevant location of the ruling section.

c Only applicable when the condition for taking two samples per sample product applies (see Table 2).



a) One sample per sample product to be taken

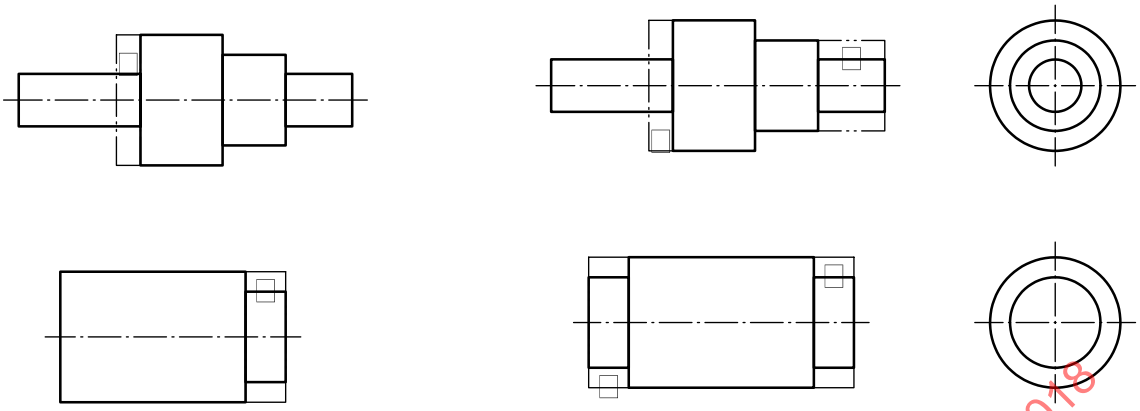
b) Two samples per sample product to be taken

Key

1 diameter mounting
2 earlike mounting
3 front side mounting
x test piece position

NOTE The examples for rings apply also for discs.

Figure 1 — Example of the mounting of prolongation and of the location of test pieces



a) One sample per sample product to be taken

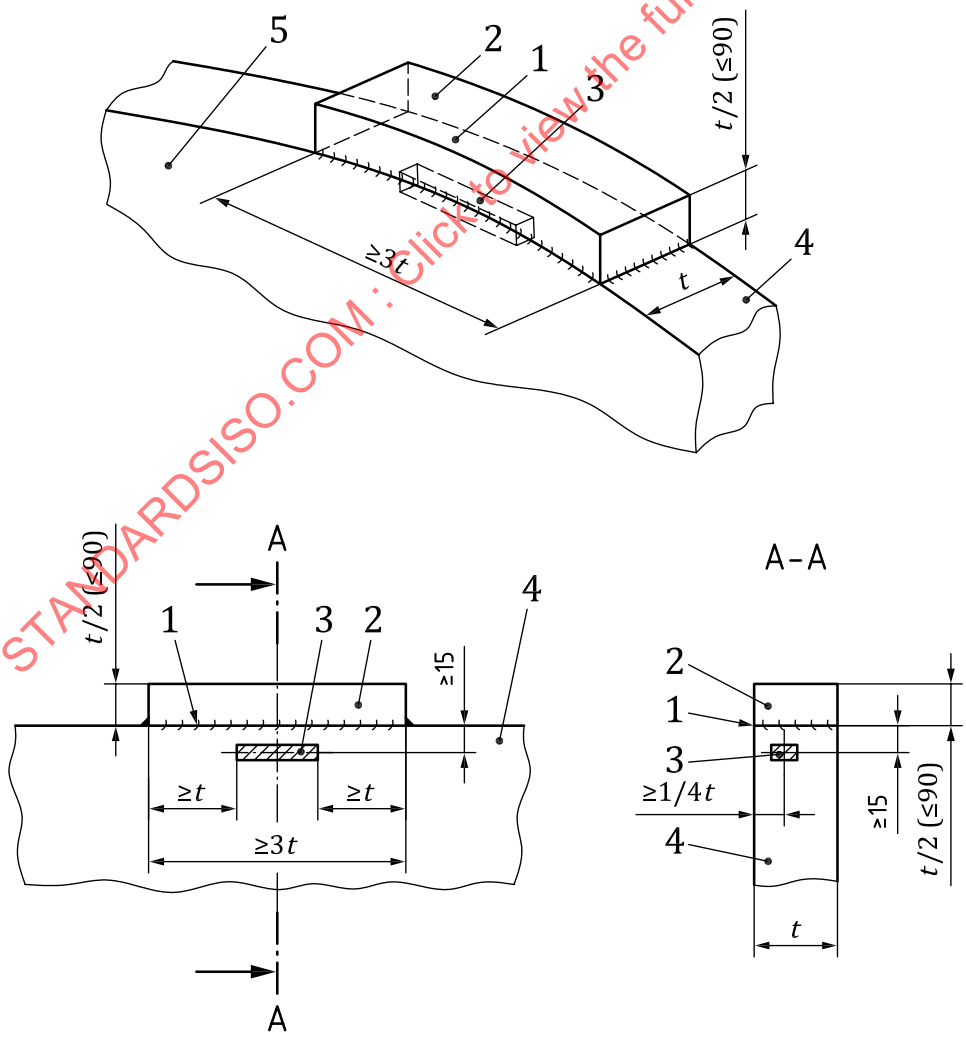
b) Two samples per sample product to be taken

Key

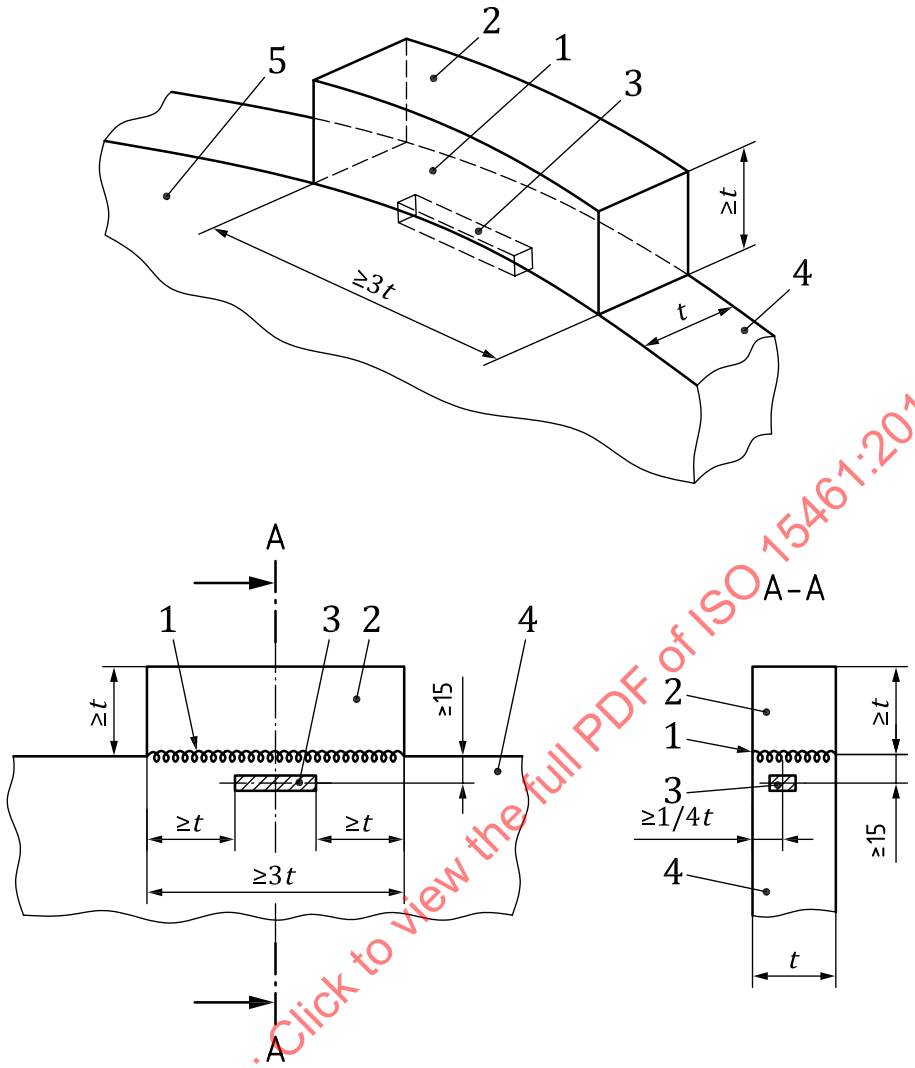
x test piece position

Figure 2 — Examples of the mounting of integral surplus material and of the location of test pieces

Dimensions in millimetres



a)



b)

Key

1 surface of heat buffer
2 heat buffer
3 test piece position
4 steel forging
5 heat treated surface

Figure 3 — Examples of an on welded heat buffer

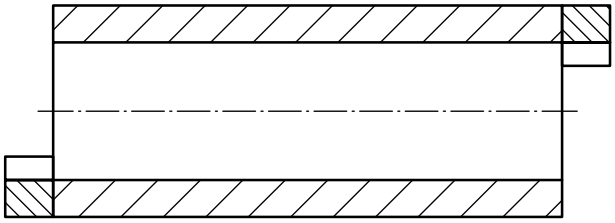


Figure 4 — Example of mounting two on welded heat buffers on a sample product

Table 5 — Options for the distance of the centre of the test pieces from the surface

Symbols dis	Distance of the centre of test piece from the surface of the as heat treated product in the direction of the		Notes	See examples
	thickness (t)	length and width		
	of the ruling section			
$t/4 \times t/2$	$t/4$, max. 60 mm	$t/2$, max. 90 mm		Figure 5 a)
$t/4 \times t/4$	$t/4$, but max. 40 mm	$t/4$, max. 40 mm	a	Figure 5 b)
a[b]	a, but min. 20 mm	$2a$, but min. 40 mm	d	
hs	$d_t \geq d_1, d_2, d_3$ ..., but min. 20 mm	2 d_t, but min. 40 mm	c, d	Figure 6
dr	The location of the test pieces shall be as indicated in a purchaser approved drawing (dr) showing as heat treated dimensions		d	
$t/4 \times t$	$t/4$	t	e	Figure 5 c)

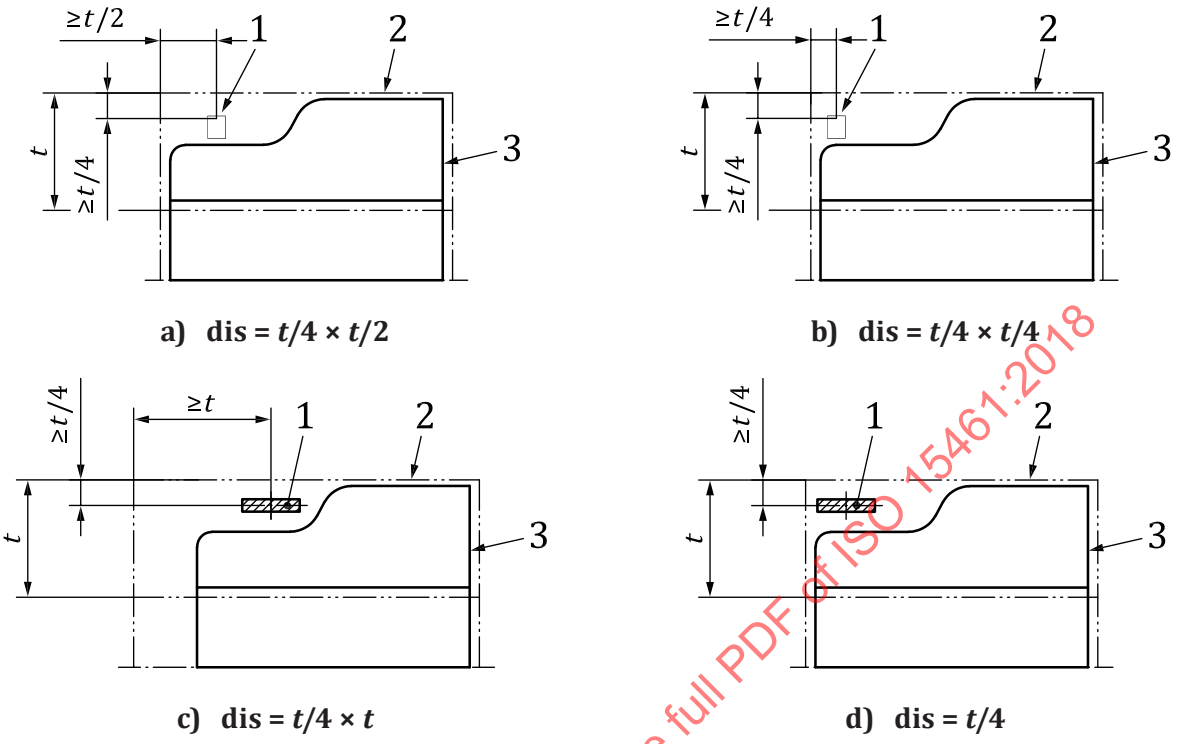
[a] Mainly for austenitic and austenitic-ferritic steels.

[b] The letter a in the symbol "dis = a" shall be replaced by the value agreed for the distance of the test pieces from the surface in the direction of the thickness of the ruling section; if, for example, this distance shall in one case be 40 mm and in another be one sixth of the thickness (t), the symbol would read in the first case "dis = 40" and in the second case "dis = $t/6$".

[c] A special case applies, as shown in Figure 6, for complicatedly shaped forgings which suffer stressed surface zones during service and which before heat treatment were formed to their final shape and dimensions. In this case, the purchaser shall mark the highly stressed surface zones. The distance d_t from the centre of the test piece to the heat treated surface in the direction of the thickness shall be not less than the largest distance (d_1, d_2, d_3 ...) between the highly stressed surface zones and the as heat treated surface nearest to these and shall in all cases be greater than 20 mm. In the direction of the length or width the distance of the centre of the test piece from the as heat treated surface shall be at least 2 × d_t but never less than 40 mm.

[d] The mechanical properties applicable for this location are to be agreed at the time of enquiry and order.

[e] Mainly for pressure equipment.



a) dis = $t/4 \times t/2$

b) dis = $t/4 \times t/4$

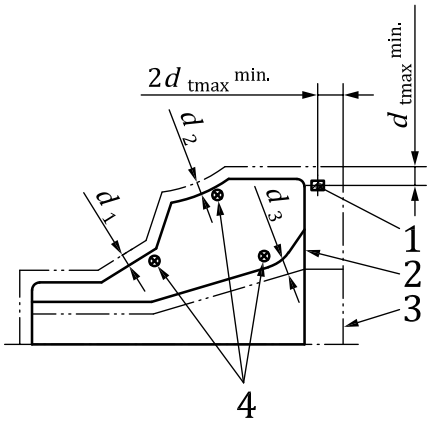
c) dis = $t/4 \times t$

d) dis = $t/4$

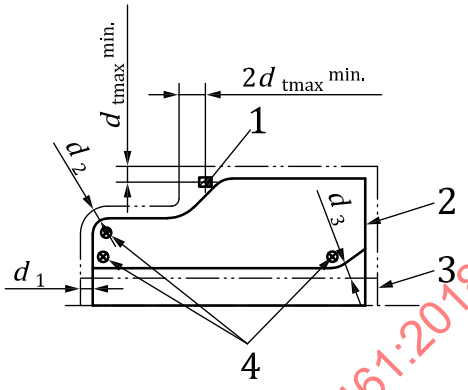
Key

1 test piece position
2 shape at the time of heat treatment
3 shape of final product

Figure 5 — Example of the position of the test pieces in a sample product with integral surplus material in accordance with Table 4 concerning the distance of the test pieces from the surface of the as heat-treated forging



a) Sample product with prolongations



b) Sample product with integral surplus material

Key

1 test piece position
2 shape of final product
3 shape at the time of heat treatment
4 high stress zone

NOTE See footnote [c] of Table 4.

Figure 6 — Example of the position of test pieces in the case where, for the distance of the test pieces from the surface of the heat treated forging in accordance with Table 4, dis = hs is specified

Table 6 — Options for the direction of the test piece axes and of the direction of the notch of impact test pieces referring to the direction of grain flow or grain

Symbols	Applicable for	Meaning of the symbol		
		The direction of the		See
		tensile or impact test pieces	notch of the impact test pieces[a]	
Direction[d]		shall be parallel to the direction[b]		
X	tensile test pieces	X	—	Figure 7
Y		Y	—	
Z		Z	—	
X-Y[c]	impact test pieces	X	Y	Figure 8
X-X[c]		Y	X	
Z-Y		Z	Y	
X-Z		X	Z	
Y-Z		Y	Z	
Z-X		Z	X	

[a] Also of the direction of propagation of fracture predetermined by the notch.

[b] X = direction of the greatest positive strain (main direction of grain flow).

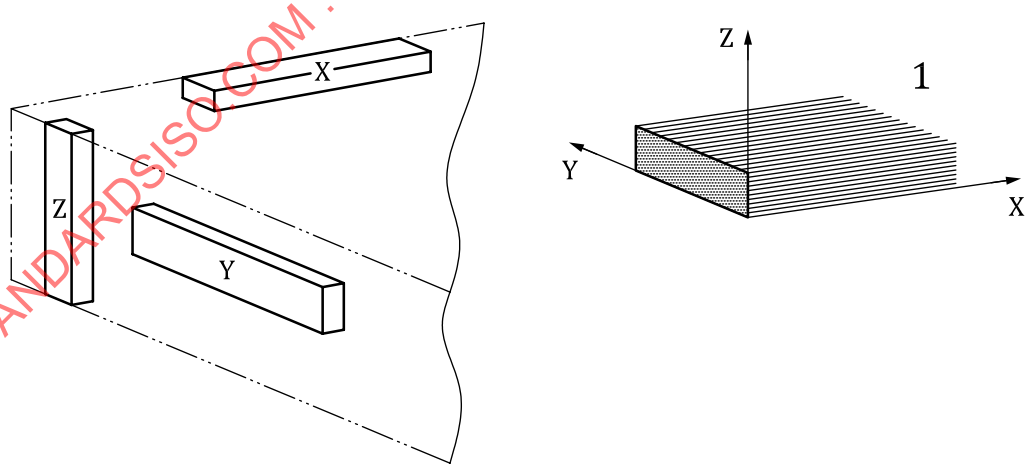
Z = direction of the greatest negative strain (main direction of forming).

Y = direction perpendicular to X and Z.

For the determination of these directions see 8.3.

[c] Where no further specification for the direction of the notch for longitudinal or transverse impact test pieces is made it shall be accepted that the direction of the test piece and its notch correspond to that characterized by the symbol X-Y or Y-X respectively.

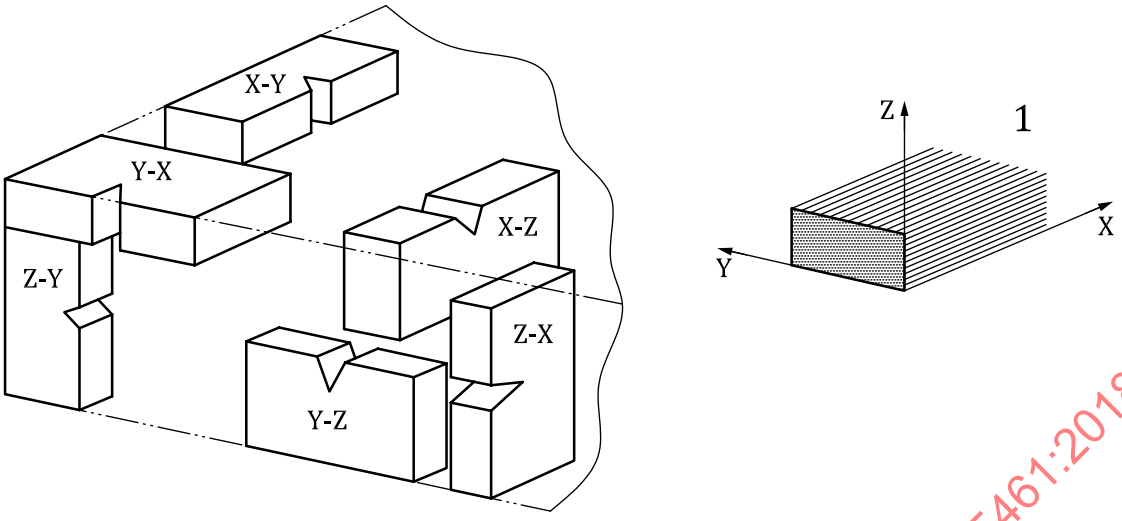
[d] See Figures 7 and 8.



Key

1 axial grain flow

Figure 7 — Meaning of the symbols given in Table 6 for the direction of tensile test pieces in relation to the three main directions of strain X, Y and Z



Key

1 axial grain flow

Figure 8 — Meaning of the symbols given in Table 6 for the direction of impact test pieces and their notches in relation to the main directions of strain X, Y and Z

8 Designation and determination of the direction of the test piece axis

8.1 General

The impact properties and the values for the elongation and the reduction of area of test pieces taken with their longitudinal axis parallel to the direction of the greatest material strain caused by forming is in general considerably higher than for test pieces taken in the direction of the greatest reduction of cross section of the material, in the direction of greatest negative strain. In delivery conditions for rolled materials this phenomenon is taken into consideration by specifying the direction of the test piece axis in relation to the geometrical main directions (length, thickness and width) of the product, as these coincide with the direction X of greatest strain, the direction Z of greatest negative strain and the direction Y perpendicular to X and Z.

In the case of forgings, however, the direction of strain cannot be related unequivocally to the geometrical main directions of the product. Figure 7 shows, for example, that for hollow forgings, depending on the process of manufacturing, the direction of greatest strain in the forming process can be axial, tangential or radial.

Therefore, standards for forgings normally specify the impact properties and the values of elongation and reduction of area with direct reference to the main directions of strain and oblige the manufacturer to indicate, in his or her offer, the directions for the area from which the test pieces are to be taken.

The designations to be applied in such cases and the methods for determining the main directions of strain and their relation to the geometrical main directions are given in 8.2 and 8.3.

8.2 Designation for the main direction of strain during forming

To designate the direction of the strain or grain flow, in accordance with ISO 3785, the following symbols shall be applied:

a) X for the direction of greatest positive strain or the main direction of grain flow;

b) Z for the direction of greatest negative strain or the main direction of hot working (see Figures 7 and 8);

c) Y for the direction perpendicular to X and Z.

8.3 Determination of X, Y and Z

8.3.1 The directions X, Y and Z shall be determined for the areas of the forging from which the test pieces are to be taken and shall consequently be representative of the ruling section of the forging.

8.3.2 For simply shaped forgings the strain shall be calculated, as indicated in Figure 10:

a) in the case of round products; for the direction of the rotation axis and for the tangential and the radial direction of the forging;

b) in the case of rectangular products, for the direction of the length, width and thickness of the forging.

On the basis of the results of these calculations and the definitions given in 8.2 it shall then be indicated by the symbols given in Table 7 or by indicating the directions X, Y and Z in sketches of the product as shown in Figure 11, with which geometrical main directions the directions X, Y and Z coincide.

8.3.3 For more complicated shapes and small products (e.g. closed die forgings) it may be more appropriate or necessary to determine the relation of the direction X, Y and Z to the geometrical characteristics of the forgings by suitable metallographic examinations in the frame work of type tests.

Table 7 — Relation between the three main directions of strain (X, Y and Z) and the geometric axes of the product

Shape of the product	Symbol XYZ	Axis[a]	Geometric axes of the product	Examples
Round (bars, shafts and discs)	ATR	X	axial	Stretch forged bars or discs cut from these Stretch forged shafts and cylinder
		Y	tangential	
		Z	radial	
	RTA	X	radial	Discs produced by upset forging
		X	tangential	
		Z	axial	
Rectangular (bars and flat products)	LWT	X	length	Stretch forged rectangular[b]
		Y	width	
		Z	thickness	
	WLT	X	width	Ingots or blooms forged by enlarging their width to rectangular[b]
		X	length	
		Z	thickness	

[a] X = direction of the greatest positive strain (main direction of grain flow).

Z = direction of the greatest negative strain (main direction of forming).

Y = direction perpendicular to X and Z.

For the determination of the directions see 8.3.

[b] When cutting parts, e.g. discs, from rectangular bars or flat products which correspond to the symbol XYZ = LWT or XYZ = WLT, depending on the cut length, for these parts other symbols for XYZ may be apply. For a part XYZ = LWT this is shown in Figure 11.

Table 7 *(continued)*

Shape of the product	Symbol XYZ	Axis[a]	Geometric axes of the product	Examples
Hollow (cylinders, rings and flanges)	ATR	X	axial	See Figure 9
		Y	tangential	
		Z	radial	
	TRA	X	tangential	
		X	radial	
		Z	axial	
	RTA	X	radial	
		Y	tangential	
		Z	axial	

[a] X = direction of the greatest positive strain (main direction of grain flow).

Z = direction of the greatest negative strain (main direction of forming).

Y = direction perpendicular to X and Z.

For the determination of the directions see 8.3.

[b] When cutting parts, e.g. discs, from rectangular bars or flat products which correspond to the symbol XYZ = LWT or XYZ = WLT, depending on the cut length, for these parts other symbols for XYZ may be apply. For a part XYZ = LWT this is shown in Figure 11.

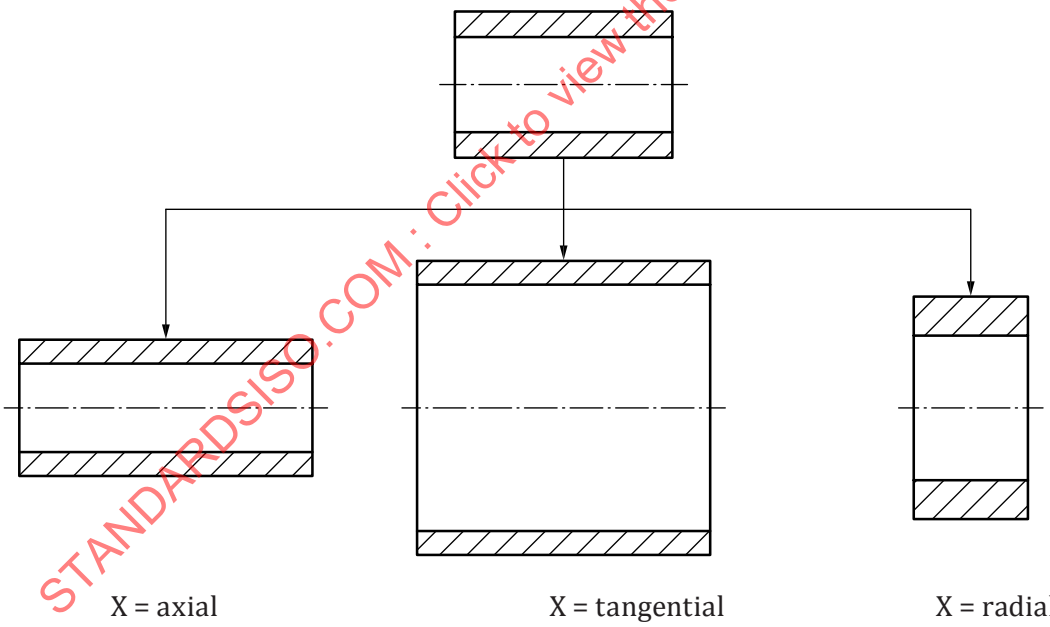


Figure 9 — Example of the dependence of the X direction on greatest positive strain from the type of forming

Before **After**

Logarithmic strain:

$\bar{\varepsilon}_t$ = In (D_m/d_m) in tangential direction,

$\bar{\varepsilon}_a$ = In (L/l) in axial direction,

$\bar{\varepsilon}_r$ = In (T/t) in radial direction, and

$\bar{\varepsilon}_t + \bar{\varepsilon}_r = 0$, since the volume of the forging is constant.

a) For enlarging and mandrel forging

Before **After**

Logarithmic strain:

$\bar{\varepsilon}_t$ = In (D/d) in tangential direction,

$\bar{\varepsilon}_a$ = In (L/l) in axial direction,

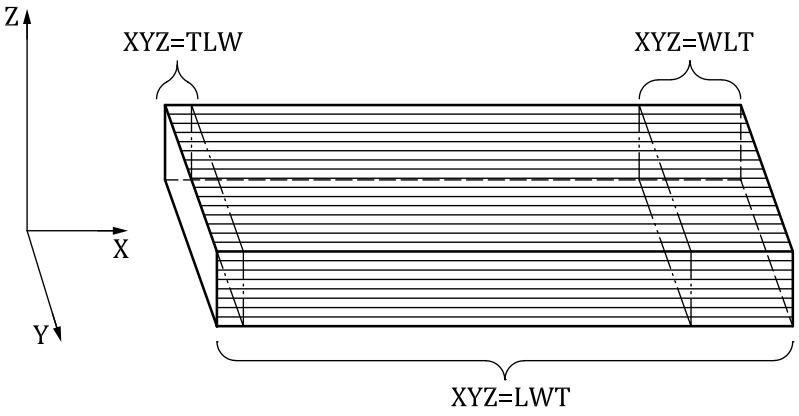
$\bar{\varepsilon}_r$ = In (D/d) in radial direction, and

$\bar{\varepsilon}_t + \bar{\varepsilon}_r = \frac{1}{2}\bar{\varepsilon}_a$.

b) For solid forging and upsetting

NOTE See Table 6 and 8.2.

Figure 10 — Examples for calculating the strain in order to determine the direction of the strain and the flow lines



Key

L length: longest edge

W width: second longest edge

T thickness: shortest edge

NOTE See also Table 7, footnote [b].

Figure 11 — Example of the change in the symbols XYZ for the relation between the three main direction of strain and the geometrical axes of rectangular products when from such products parts such as discs, are cut off

9 Test methods

9.1 Tensile test at room temperature

9.1.1 Tensile tests at room temperature shall be carried out in accordance with ISO 6892-1.

9.1.2 For the verification of the yield strength R_e of non-austenitic steels, where a yield phenomenon occurs, the upper yield strength R_{eH}, or alternatively the 0,2 % proportional elongation proof strength $R_{p0,2}$ shall be determined.

In the case of austenitic and austenitic-ferritic steels depending on the characteristic specified in the product standard, the 0,2 % and/or 1,0 % proportional elongation proof strength ($R_{p0,2}$ or $R_{p1,0)}$ shall be determined.

The percentage elongation shall be reported with reference to a $5{,}65\sqrt{S_0}$ gauge length; (S_0 represents the area of the initial cross section of the test piece within the gauge length). If other gauge lengths are used, the corresponding elongation on $5{,}65\sqrt{S_0}$ should be obtained, in accordance with ISO 2566-1 or ISO 2566-2. In cases of dispute, a gauge length of $5{,}65\sqrt{S_0}$ shall be used.

9.2 Impact tests

9.2.1 If values for Charpy V-notch impact properties are to be verified, tests shall be performed in accordance with ISO 148-1 and the rules for sequential tests specified in ISO 404. If a specific strike radius is required, it shall be stated in the product standard.

9.2.2 If, for a steel grade, the impact properties are specified for several testing temperatures, unless otherwise agreed in the order, the test shall be carried out at the lowest temperature for which a value is specified.