TECHNICAL REPORT

ISO/TR 15461

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

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

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International Organization for Standardization
Case postale 56 • CH-1211 Genève 20 • Switzerland
Internet central@iso.ch
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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 eletrotechnical standardization.

The main task of technical committees is to prepare International Standards, but in exceptional circumstances a technical committee may propose the publication of a Technical Report of one of the following types:

- type 1, when the required support cannot be obtained for the publication of an International Standard, despite repeated efforts;

- type 2, when the subject is still under technical development or where for any other reason there is the future but not immediate possibility of an agreement on an International Standard;

- type 3, when a technical committee has collected data of a different kind from that which is normally published as an International Standard ("state of the art", for example).

Technical Reports of types 1 and 2 are subject to review within three years of publication, to decide whether they can be transformed into International Standards. Technical Reports of type 3 do not necessarily have to be reviewed until the data they provide are considered to be no longer valid or useful.

ISO/TR 15461, which is a Technical Report of type 2, was prepared by Technical Committee ISO/TC 17, *Steel* Subcommittee SC 10, *Steel for pressure purposes*.

This document is being issued in the Technical Report (type 2) series of publications (according to subclause G.3.2.2 of part 1 of the ISO/IEC Directives, 1995) as a "prospective standard for provisional application" in the field of mechanical testing of steel forgings because there is an urgent need for guidance on how standards in this field should be used to meet an identified need.

This document is not to be regarded as an "International Standard". It is proposed for provisional application so that information and experience of its use in practice may be gathered. Comments on the content of this document should be sent to the ISO Central Secretariat.

A review of this Technical Report (type 2) will be carried out not later than three years after its publication with the options of: extension for another three years; conversion into an International Standard; or withdrawal.

Annexes A and B form an integral part of this Technical report. Annexes C and D are for information only.

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

1 Scope

1.1 This Technical Report is intended to provide possibilities for the simplification and harmonization of the specifications for mechanical testing of open die and closed die forgings in ISO Standards and other technical delivery conditions for forgings of steel.

For this purpose this Technical Report

a) offers various options for
   — the frequency of testing and
   — sampling conditions;

b) introduces a designation system for the options, mentioned under (a);

c) specifies the test methods for
   — room temperature tensile tests
   — elevated temperature tensile tests
   — impact tests and
   — uniformity checks by hardness tests.

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

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

2 Normative references

The following standards contain provisions which, through reference in this text, constitute provisions of this Technical Report. At the time of publication, the editions indicated were valid. All standards are subject to revision, and parties to agreements based on this Technical Report 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 83:1976, *Steel - Charpy impact test (U-notch).*

ISO 148:1983, *Steel - Charpy impact test (V-notch).*

ISO 377:1997, *Steel and steel products - Location and preparation of samples and test pieces for mechanical testing.*

ISO 404:1992, *Steel and steel products - General technical delivery requirements.*

ISO 783:—[1], *Metallic materials - Tensile testing at elevated temperature.*

ISO 2566-1:1984, *Steel - Conversion of elongation values - Part 1: Carbon and low alloy steels.*

ISO 2566-2:1984, *Steel - Conversion of elongation values - Part 2: Austenitic steels.*

ISO 3785:—[2], *Metallic materials - Designation of test piece axes.*

ISO 6506:1981, *Metallic materials - Hardness test - Brinell test.*

ISO 6507-1:—[3], *Metallic materials - Vickers hardness test - Part 1: Test method.*

ISO 6508:1986, *Metallic materials - Hardness test - Rockwell test (scales A-B-C-D-E-F-G-H-K).*

ISO 6892:—[4], *Metallic materials - Tensile testing at ambient temperature.*

3 Definitions

For the purposes of this Technical Report the following definitions apply.

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.
[ISO 404:1992, 3.5]

3.2 test unit:
the 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.
[ISO 404:1992, 3.7]

3.3 sample product:
item (e.g. bar, sheet, coil) selected for inspection and/or testing.
[ISO 377:1997, 3.2]

1) To be published. (Revision of ISO 783:1989)
2) To be published. (Revision of ISO 3785:1976)
3) To be published. (Revision of ISO 6501-1:1982, ISO 6507-2:1983, ISO 6507-3:1987, ISO 409-1:1982, ISO 409-2:1983 and ISO/DIS 409-3)
4) To be published. (Revision of ISO 6892:1984)

3.4 sample:
a sufficient quantity of material taken from the sample product for the purpose of producing one or more test pieces.
[ISO 377:1997, 3.3]

NOTE - In certain cases, the sample may be the sample product.

3.5 test piece:
part of the sample, with specified dimensions, machined or unmachined, brought to a required condition for submission to a given test.
[ISO 377:1997, 3.5]

NOTE - In certain cases the test piece may be the sample.

3.6 Ruling section:
that section for which the mechanical properties are specified.

4 Testing frequency

4.1 For the testing frequency of room temperature tensile tests and of impact tests, the requirements given in 4.1.1 to 4.1.3 apply.

4.1.1 The product standard or order shall specify, by reference to the appropriate symbol(s) in table 1, column 1,

— the composition of the test unit as defined in table 1, columns 2 to 8;

— whether uniformity checks by hardness tests in accordance with annex A are required and, if so, the percentage of products to be subjected to the hardness tests, and

— the number of sample products to be taken from the test unit. (See in this respect the explanations in table 1, footnote 1), 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 may be regarded as equivalent to a test unit characterized by the symbol CHD10 or CMHD15 and the test unit CU100 may be regarded as equivalent with CMHDU10. Consequently, it seems possible and reasonable to specify in the product standards or orders not only one distinct test unit, but to leave, as in the example in table C.1, column 5, various equivalent test units to the choice of the manufacturer or to an agreement at the time of enquiry and order.

4.1.2 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.

4.1.3 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.

4.2 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 C.1, column 9).

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

5 Sampling conditions

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

— by reference to the symbols in table 3 the type of sample product and, where surplus material is required, the way of mounting this;

— by reference to the symbols in table 4, the distance of the test piece axis from the surface of the sample product in the as heat treated condition;

— by reference to the symbols in table 5, 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.

6 Test methods

6.1 Tensile test at room temperature

6.1.1 Tensile tests at room temperature shall be carried out in accordance with ISO 6892 at a temperature of 20 °C ± 5 °C.

6.1.2 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 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.

6.2 Impact tests

6.2.1 Impact tests shall be carried out according to the rules for sequential tests specified in ISO 404 and

— when values for Charpy V-notch impact test pieces are to be verified in accordance with ISO 148;

— when values for Charpy U-notch test pieces are to be verified in accordance with ISO 83.

6.2.2 If, for a steel, 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.

6.3 Verification of the elevated temperature proof strength

6.3.1 The verification shall be carried out in accordance with the test method described in ISO 783.

6.3.2 Unless otherwise agreed at the time of enquiry and order the test temperature shall be

— for unalloyed steels and for weldable fine grain steels with high proof strength ..... 300 °C
— for other steels ..... 450 °C.

6.3.3 For non-austenitic steels the 0,2 % proof strength value and for austenitic steels, depending on the characteristic specified in the product standard, the 0,2 % and/or 1,0 % elevated temperature proof strength value shall be determined.

Table 1 — Options for the test units, the number of sample products to be taken per test unit

1	2	3	4	5	6	7	8	
Test unit symbol	**The test unit shall be composed of products**							
		of the same forming				**having been subjected to**		
	of the same cast	**process**	**cycle**[2]	**of the same shape and dimensions**	**of similar**[3] **shape and dimensions**	**the same type**[4] **of heat treatment**	**the same conditions**[5] **of heat treatment**	
tu[1]	C[1]		F[1]	D[1]			H[1]	
C*n*	×	×	—	—	×	×	—	
CH*n*	×	×	—	—	×	×	×	
CHD*n*	×	×	—	×	—	×	×	
CFHD*n*	×	×	×	×	—	×	×	
CU*x*	×	×	—	—	×	×	—	
CHU*x*	×	×	—	—	×	×	×	
CHDU*x*	×	×	—	×	—	×	×	
CFHDU*x*	×	×	×	×	—	×	×	
CnU*x*	×	×	—	—	×	×	—	
CH*n*U*x*	×	×	—	—	×	×	×	
CHD*n*U*x*	×	×	—	×	—	×	×	
CFHD*n*U*x*	×	×	×	×	—	×	×	
IND	The test unit sample product shall							

1) In the symbols for the test unit in column 1 the individual letters have, as is additionally indicated in the headings of columns 2 to 10, the following meaning:

C products of the same Cast;

F same Forming cycle [2];

H same Heat treatment conditions [3];

D same shape and Dimensions;

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

U*x* For checking the Uniformity of the test unit, *x* % of the products and at least the number of products given in table A.1, 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

2) 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

3) The shape and dimensions of the forgings are regarded as similar when the following conditions are complied with:

a) the forgings have the same shape; round, hexagon or square bars may, however, be covered in one test unit;

b) the difference in the thickness of the ruling section of the forgings of the test unit is less than 30 % of the forging possessing the greatest thickness;

c) where, in the technical delivery conditions, the specifications for the tensile and/or impact properties of the forgings vary for different thicknesses, the

4) Different types of heat treatment are here considered e.g. normalizing, stress relieving, quenching and tempering.

5) The forgings shall be regarded as having been subjected to the same heat treatment conditions when they were subjected to the same temperature-time-cycle in

In the past a usual requirement was that the products covered in a test unit had to be taken from the same heat treatment batch. In the case of continuous or batch no longer justified. Where, however, the purchaser still regards this as appropriate he may specify in his enquiry and order that the test unit be composed of products

and the percentage of products to be subjected to hardness tests for uniformity checks

	9	10	11	12	13	14	15
	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**
		$\leqslant n$ 1)	$> n$ $\leqslant 2n$	$> 2n$ $\leqslant 4n$	$> 4n$ $\leqslant 8n$	$> 8n$ $\leqslant 16n$	
	Ux1)	x 1000 kg					
	—						In general not for quenched and tempered products.
	— — —	1	2	3	4	5	
	an x % uniformity check by hardness tests (see annex A)	Independant 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).
		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.
consist of the individual forging.							Not for small products.

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 should be preferred).

in accordance with annex A. The value of x shall be specified in the product standard or order (e.g. CHU10).

is 10 t one sample product is to be tested; if its weight is $> 4\ n$ but $\leqslant 8\ n$, (that means in this example > 40 t but ⩽ 80 t) four samples are to be tested.

same forming process under the same conditions or, in other words, when they were produced in series.

thicknesses of all forgings of the test unit shall fall within one of the specified ranges.

the same heat treatment apparatus but not necessarily at the same time.

type furnaces with modern equipment for the steering and with registration of the time-temperature-cycle and the composition of the furnace atmosphere this is of the same heat treatment batch.

Table 2 — Conditions (s2) for taking two samples per sample product

Symbols, (s2)		**Conditions for taking two samples per sample product** [2]
in general numbers [1]	**example**	
l*y*	l5	Forgings with a length or greatest dimension greater than *y* (5) meters
w*z*	w4	Forgings with an as heat treated individual weight greater than *z* (4) tonnes.
l*y*+w*z*	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 w*z*	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.

1) 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.

2) The values given in parentheses apply for the example given in column 2.

Table 3 — 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	1)
pc			the test pieces are taken by core drilling	
ppl	Complete product with prolongations	The prolongation shall be positioned as indicated.	figure 1a	2)
ppld			d in figure 1a	
pple			e in figure 1a	
pp2			figure 1b	2), 3)
pp2d			d in figure 1b	
pp2e			e in figure 1b	
pp2f			f in figure 1b	
pp0			in the order	2)
pi1	Complete product with integral surplus material	The integral surplus material shall be positioned as indicated.	in figure 2a	2)
pi2			in figure 2b	2), 3)
pi0			in the order	2)
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	2)
pb2			in figure 4	2), 3)
pb0			in the order	2)
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 2). Dimensions of the sample.	T x 2T x 2T (T = thickness of the ruling section of the forging)	2)
ss0			as agreed when ordering	

1) Only for small (closed die) forgings.

2) 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.

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

Table 4 — Options for the distance of the centre of the test pieces from the surface

Symbols dis	Distance of the centre of test pieces from the surface of the as heat treated product in the direction of the thickness (*t*) | length and width of the ruling section		Notes	See examples in figure
t/4x*t*/2	*t*/4, max. 60 mm	*t*/2, but max. 90 mm		5 a)
t/4x*t*/4	*t*/4, but max. 40 mm	*t*/4, but max. 40 mm	1)	5 b)
a 2)	a, but min. 20 mm	2*a*, but min. 40 mm	4)	
hs	$d_t \geqslant d_1, d_2, d_3$..., but min. 20 mm	2 d_t, but min. 40 mm	3), 4)	6
dr	The location of the test pieces shall be as indicated in a purchaser approved drawing (dr) showing as heat treated dimensions.		4)	

1) Mainly for austenitic steels.

2) 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”.

3) Special case which 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 x d_t, but never less than 40 mm.

4) The mechanical properties applicable for this location are to be agreed at the time of enquiry and order.

Table 5 — Options for the direction of the test piece axes and of the direction of the notch of impact test pieces refering to the direction of grain flow or grain

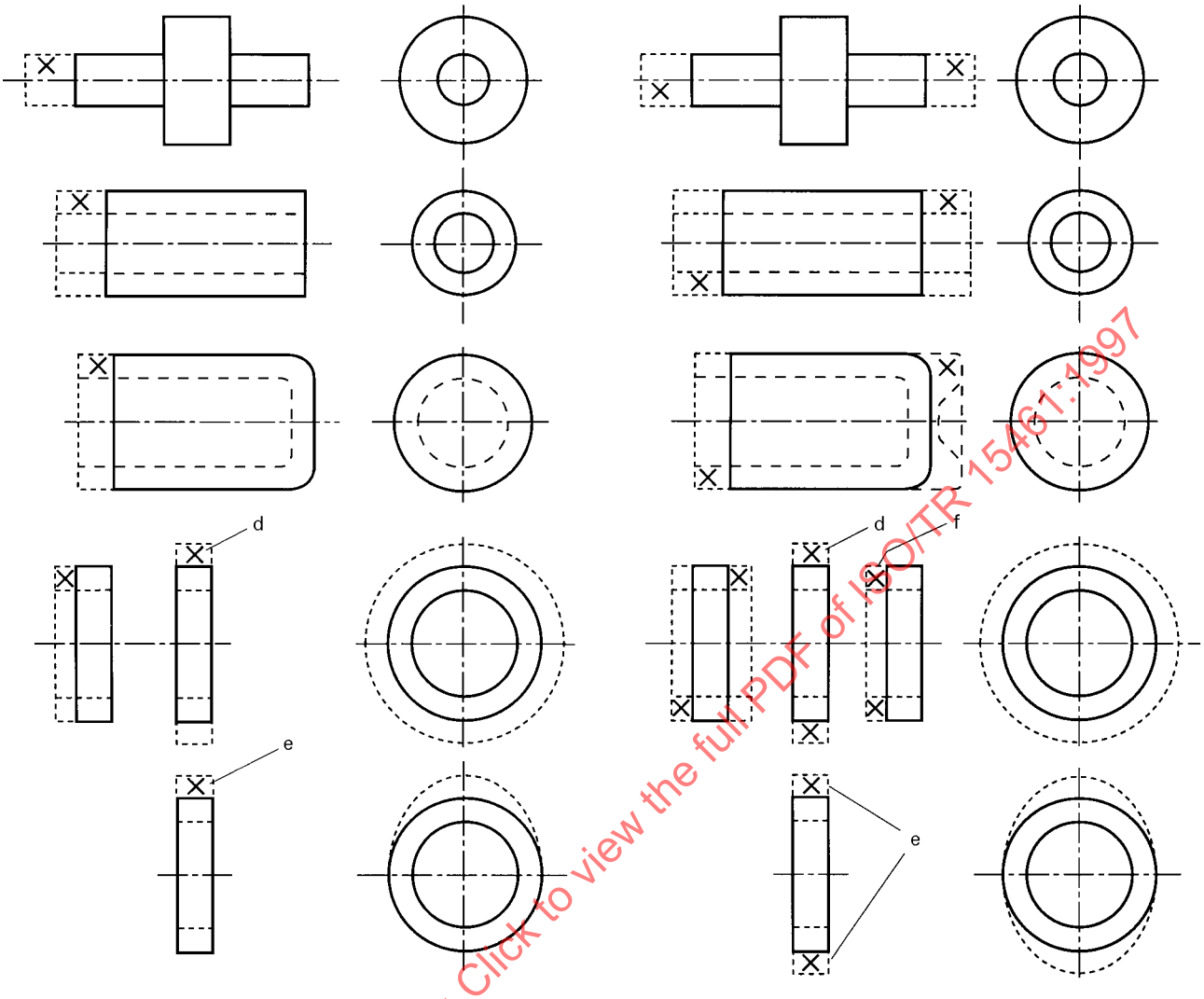
Symbols dir	Applicable for	Meaning of the symbol		
		The direction of the		See figure
		tensile or impact test pieces	notch of the impact test pieces[1]	
		shall be parallel to the direction[2]		
X Y Z	tensile test pieces	X Y Z	- - -	7
X-Y[3] X-X[3] Z-Y X-Z Y-Z Z-X	impact test pieces	X Y Z X Y Z	Y X Y Z Z X	8

1) Also of the direction of propagation of fracture predetermined by the notch.

2) 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 B.3.

3) 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.



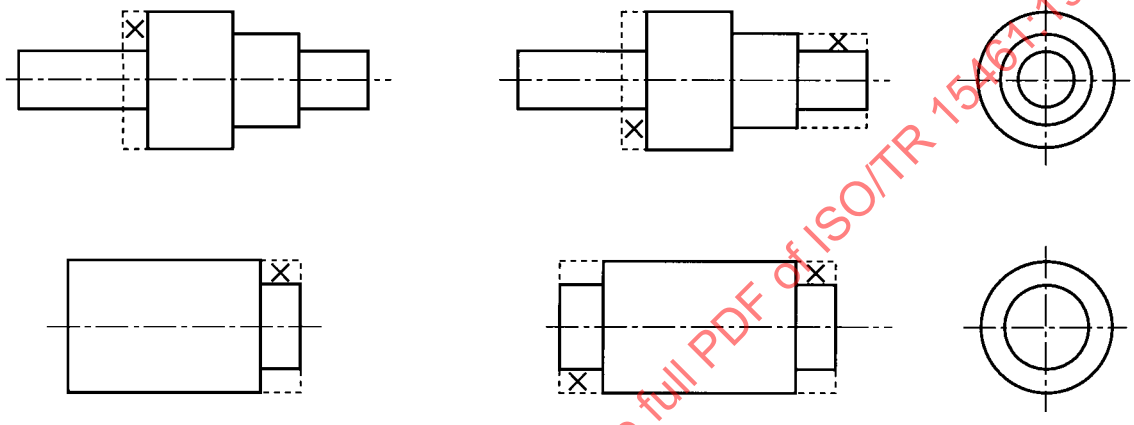
a) One sample per sample product to be taken

b) Two samples per sample product to be taken

NOTE — The examples for rings apply also for discs.

Key
d Diameter mounting
e Earlike mounting
f Frontside mounting
x Test piece position

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



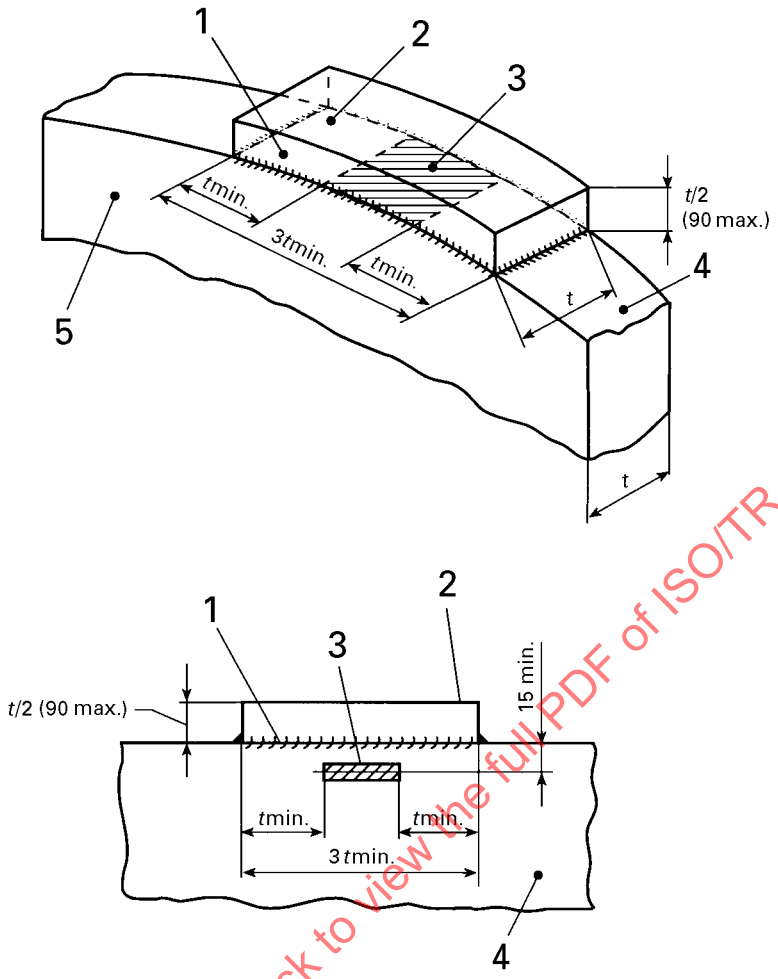
a) One sample per sample product to be taken

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



Key
1 Surface of heat buffer
2 Heat buffer
3 Test piece position
4 Steel forging
5 Heat treated surface

Figure 3 — Example of an on welded heat buffer

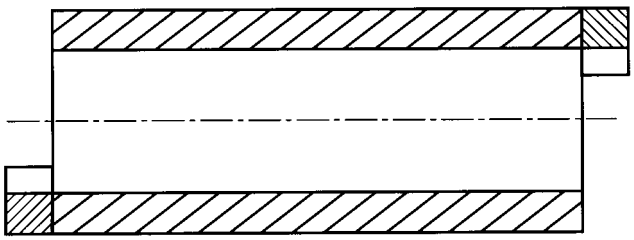
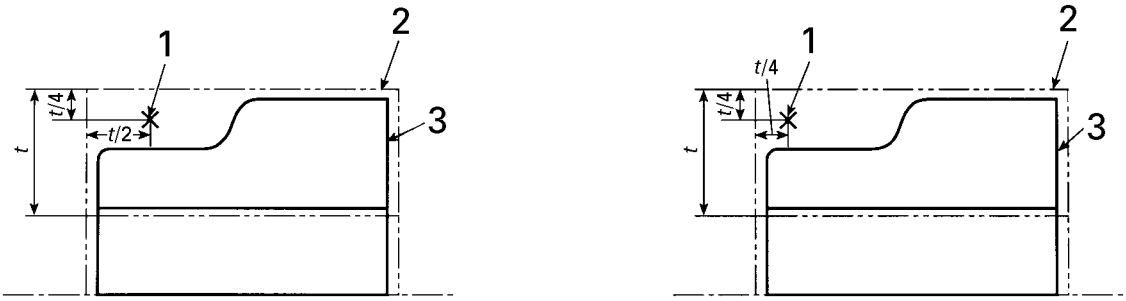


Figure 4 — Example of mounting two on welded heat buffers on a sample product

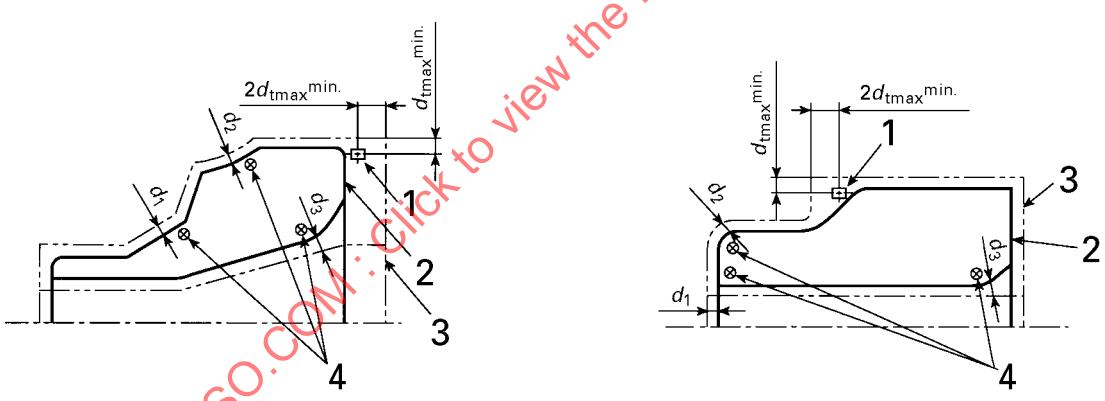


a) dis = *t*/4 x *t*/2

b) dis = *t*/4 x *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

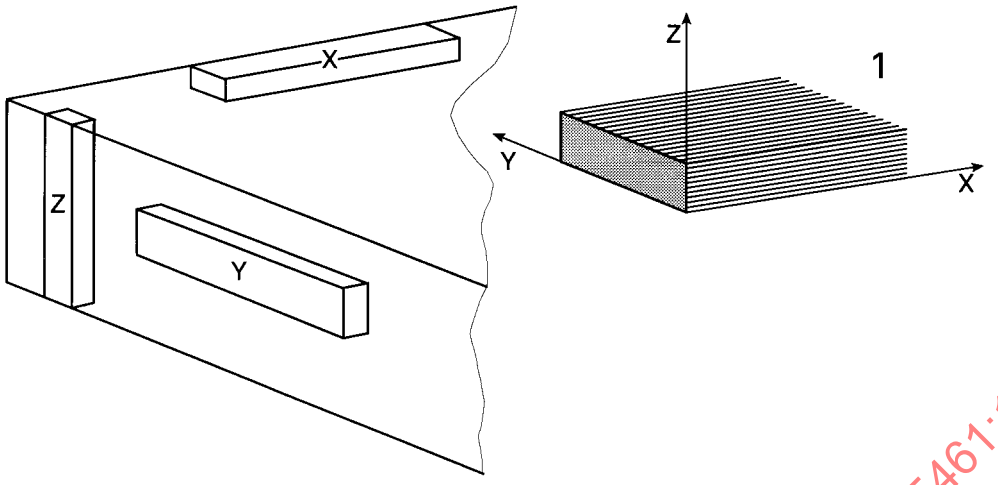


a) Sample product with prolongations

b) Sample product with integral surplus material

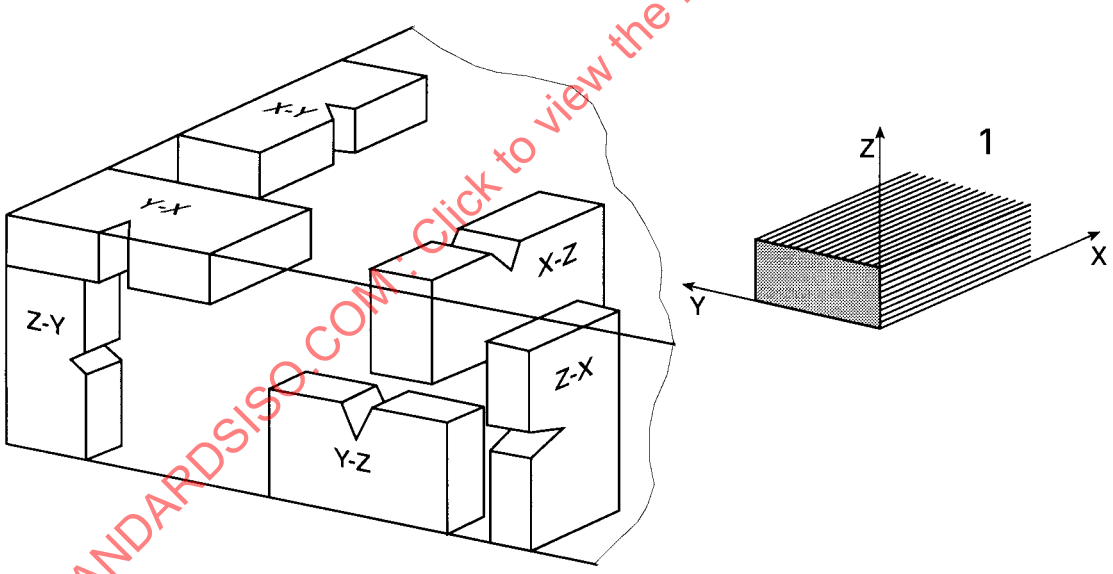
Key
1 Test piece position
2 Shape of final product
3 Shape at the time of heat treatment
4 High stress zone

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. (See footnote 3 of table 4).



Key
1 Axial grain flow

Figure 7 — Meaning of the symbols given in table 5 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 5 for the direction of impact test pieces and their notches in relation to the main directions of strain X, Y and Z.

Annex A
(normative)

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 following number of products shall be selected at random for the hardness tests:

Table A.1 — Number of products to be checked

x 1), 2)	**Number of products to be checked**
5	5 % but at least 5 in number
10	10 % but at least 10 in number
20	20 % but at least 20 in number
30	30 % but at least 30 in number
50	50 % but at least 50 in number
100	100 %

1) For x the values given above should preferably be used.

2) 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

— the Brinell test in accordance with ISO 6506;

— the Vickers test in accordance with ISO 6507-1;

— the Rockwell test in accordance with ISO 6508.

Annex B
(normative)

Designation and determination of the direction of the test piece axis

B.1 Introduction

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 B.1 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 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 the following.

B.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:

— X for the direction of greatest positive strain or the main direction of grainflow

— Z for the direction of greatest negative strain or the main direction of hot working (See figures 7 and 8.)

— Y for the direction perpendicular to X and Z

B.3 Determination of X, Y and Z

B.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.

B.3.2 For simply shaped forgings the strain shall, as indicated in figure B.2, be calculated:

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

— 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 B.2 it shall then be indicated by the symbols given in table B.1 or by indicating the directions X, Y and Z in sketches of the product as shown in figure B.3, with which geometrical main directions the directions X, Y and Z coincide.

B.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 B.1 — 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	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 cylinders
		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 rectangulars 2)
		Y	width	
		Z	thickness	
	WLT	X	width	Ingots or blooms forged by enlarging their width to rectangulars 2)
		X	length	
		Z	thickness	
Hollow (cylinders, rings and flanges)	ATR	X	axial	See figure B.1
		Y	tangential	
		Z	radial	
	TRA	X	tangential	
		X	radial	
		Z	axial	
	RTA	X	radial	
		Y	tangential	
		Z	axial	

1) 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 B.3.

2) 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 then apply. For a part with XYZ = LWT this is shown in figure B.3.

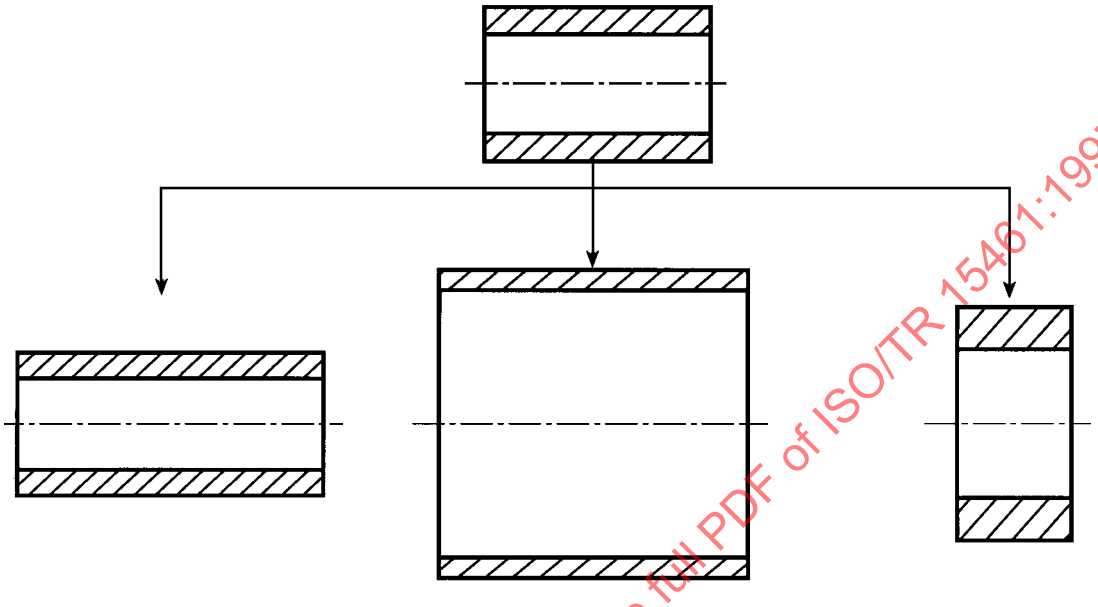


Figure B.1 — Example of the dependance of the X direction on greatest positive strain from the type of forming