



BSI Standards Publication

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

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## National foreword

This British Standard is the UK implementation of ISO 15461:2018.

The UK participation in its preparation was entrusted to Technical Committee ISE/107, Steels for Pressure Purposes.

A list of organizations represented on this committee can be obtained on request to its secretary.

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**Compliance with a British Standard cannot confer immunity from legal obligations.**

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# Contents

|   | Page      |
|---|-----------|
| <b>Foreword</b> .....   | <b>iv</b> |
| <b>1 Scope</b> .....  | <b>1</b>  |
| <b>2 Normative references</b> .....   | <b>1</b>  |
| <b>3 Terms and definitions</b> .....  | <b>1</b>  |
| <b>4 General</b> .....  | <b>2</b>  |
| <b>5 Testing frequency</b> .....  | <b>3</b>  |
| <b>6 Uniformity checks on test units by hardness tests</b> .....  | <b>6</b>  |
| <b>7 Sampling conditions</b> .....  | <b>7</b>  |
| <b>8 Designation and determination of the direction of the test piece axis</b> .....  | <b>16</b> |
| 8.1 General.....  | 16        |
| 8.2 Designation for the main direction of strain during forming.....  | 16        |
| 8.3 Determination of X, Y and Z.....  | 17        |
| <b>9 Test methods</b> .....   | <b>20</b> |
| 9.1 Tensile test at room temperature .....  | 20        |
| 9.2 Impact tests.....   | 20        |
| 9.3 Verification of the elevated temperature proof strength.....  | 21        |
| <b>Annex A (informative) Presentation of the specifications for the testing frequency and the sampling conditions in tabulated form</b> ..... | <b>22</b> |
| <b>Bibliography</b> .....   | <b>24</b> |

## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

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](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

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](http://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                     |  |  |   |   | $\leq n^a$  | $> n$     | $> 2n$     | $> 4n$ | $> 8n$   |       |
|                                     | of the same cast                            | process              | cycle <sup>b</sup>   | of the same shape and dimensions | of similar <sup>c</sup> shape and dimensions | the same type <sup>d</sup> of heat treatment | the same conditions <sup>e</sup> of heat treatment |   | $\leq 2n$   | $\leq 4n$   | $\leq 8n$ | $\leq 16n$ |        |  |       |
| <i>t<sub>u</sub><sup>a</sup></i>    | <i>C<sub>a</sub></i>                        | <i>F<sub>a</sub></i> | <i>D<sub>a</sub></i> | <i>H<sub>a</sub></i>             |  |  |  | <i>U<sub>X<sup>a</sup></sub></i>  | x tonnes  |   |           |            |        |  |       |
| <i>C<sub>n</sub></i>                | x   | x                    | —                    | —                                | x  | x  | —  | —   | 1   | 2   | 3         | 4          | 5      | In general not for quenched and tempered products  |       |
| <i>CH<sub>n</sub></i>               | x   | x                    | —                    | —                                | x  | x  | x  | —   | —   | —   | —         | —          | —      |  |       |
| <i>CHD<sub>n</sub></i>              | x   | x                    | —                    | x                                | —  | x  | x  | —   | 1   | 2   | 3         | 4          | 5      |  |       |
| <i>CFHD<sub>n</sub></i>             | x   | x                    | x                    | x                                | —  | x  | x  | —   | —   | —   | —         | —          | —      |  |       |
| <i>CU<sub>x</sub></i>               | x   | x                    | —                    | —                                | x  | x  | —  | an % uniformity check by hardness tests (see <a href="#">Clause 6</a> ) | Independent from the weight of the test unit, two sample products, namely the hardest and softest, shall be tested. |   |           |            |        |  |       |
| <i>CHU<sub>x</sub></i>              | x   | x                    | —                    | —                                | x  | x  | x  |   |   |   |           |            |        |  |       |
| <i>CHDU<sub>x</sub></i>             | x   | x                    | —                    | x                                | —  | x  | x  |   |   |   |           |            |        |  |       |
| <i>CFHDU<sub>x</sub></i>            | x   | x                    | x                    | x                                | —  | x  | x  |   |   |   |           |            |        |  |       |
| <i>C<sub>n</sub>U<sub>x</sub></i>   | 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 |       |
| <i>CH<sub>n</sub>U<sub>x</sub></i>  | x   | x                    | —                    | —                                | x  | x  | x  |   |   |   |           |            |        |  |       |
| <i>CHD<sub>n</sub>U<sub>x</sub></i> | x   | x                    | —                    | x                                | —  | x  | x  |   |   |   |           |            |        |  |       |
| <i>CFD<sub>n</sub>H</i>             | x   | x                    | x                    | x                                | —  | x  | x  |   |   |   |           |            |        |  |       |

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                          |         |                          |                                  |  |  |  |  |   |      |      |       |      |    |
|                        | of the same forming  |         | having been subjected to |                                  |  |  |  |  |   |      |      |       |      |    |
|                        | of the same cast   | process | cycle <sup>b</sup>       | of the same shape and dimensions | of similar <sup>c</sup> shape and dimensions | the same type <sup>d</sup> of heat treatment | the same conditions <sup>e</sup> of heat treatment | 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 |      |      |       |      |    |
| tu <sup>a</sup>        | Ca   |         | Fa                       | Da                               |  |  | Ha   | Ux <sup>a</sup>                            | ≤ n <sup>a</sup>  | > n  | > 2n | > 4n  | > 8n |    |
|                        |  |         |                          |                                  |  |  |  |  | ≤ 2n  | ≤ 4n | ≤ 8n | ≤ 16n |      |    |
| IND                    | The test unit sample product shall consist of the individual forging |         |                          |                                  |  |  |  |  |   |      |      |       |      |    |
| Not for small products |  |         |                          |                                  |  |  |  |  |   |      |      |       |      |    |

**Table 2 — Conditions for taking two samples per sample product**

| Symbols   |          | Conditions for taking two samples per sample product <?>   |
|---|----------|--|
|   | example  |  |
| ly  | 15       | 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.  |
| ly+wz   | 15+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. |
| ly or wz  | 15 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.    |
| <p>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.</p> <p>b The values given in parentheses apply for the example given in column 2.</p> |          |  |

## 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 <sub>a,b</sub>  | Number of products to be checked |
|---|----------------------------------|
| 5   | 100 %                            |
| 10  |                                  |
| 20  |                                  |
| 30  |                                  |
| 50  |                                  |
| 100   |                                  |
| <p>a For x the values given above should be used.</p> <p>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.</p> |                                  |

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                            |
|-----------|-------------------------------------|--|----------------------------------|
|           |                                     | The sample product consists of   | the product is destroyed         |
| pl        |                                     | a complete product without   | by taking of the test pieces     |
|           | Complete products                   | prolongation or integral surplus material  | the test pieces are taken        |
| pc        |                                     |  | by core drilling                 |
| ppl       |                                     |  | <a href="#">Figure 1 a)</a>      |
| ppld      |                                     |  | d in <a href="#">Figure 1 a)</a> |
| pple      |                                     |  | e in <a href="#">Figure 1 a)</a> |
| pp2       | Complete product with prolongations | The prolongation shall be positioned as indicated  | <a href="#">Figure 1 b)</a>      |
| pp2d      |                                     |  | d in <a href="#">Figure 1 b)</a> |
| pp2e      |                                     |  | e in <a href="#">Figure 1 b)</a> |
| pp2f      |                                     |  | f in <a href="#">Figure 1 b)</a> |
| pp0       |                                     |  | in the order                     |
| pi1       | Complete product with               |  | in <a href="#">Figure 2 a)</a>   |
| pi2       | integral surplus material           | The integral surplus material shall be positioned as indicated   | in <a href="#">Figure 2 b)</a>   |
| pi0       |                                     |  | in the order                     |
| pb1       | Complete product with               | The buffer shall consist of unalloyed or low alloy steel and   | in <a href="#">Figure 3</a>      |
| pb2       | welded heat buffer                  | shall be positioned as indicated by  | in <a href="#">Figure 4</a>      |
| pb0       |                                     | a completely sealing weld  | in the order                     |

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.

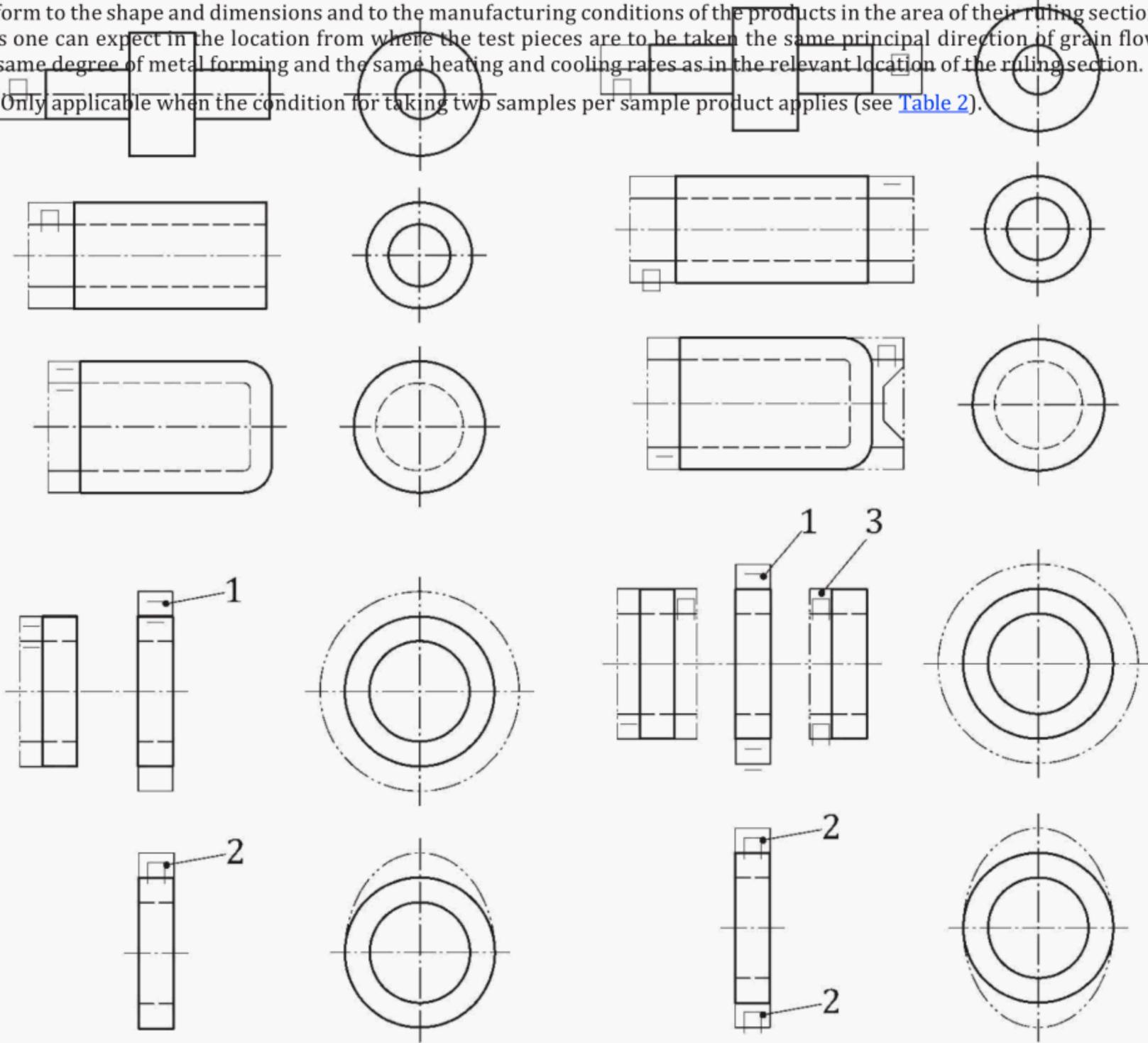
- c Only applicable when the condition for taking two samples per sample product applies (see [Table 2](#)).

| 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   |
|-----------|---------------------------|---|---|
|           |                           |   | the product is destroyed  |
| pl        |                           | The sample product consists of a complete product without   | by taking of the test pieces  |
| pc        | Complete products         | prolongation or integral surplus material   | the test pieces are taken by core drilling  |
| 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 <?>).<br>Dimensions of the sample. | $T \times 2T \times 2T$ (T = thickness of the ruling section of the forging)<br>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

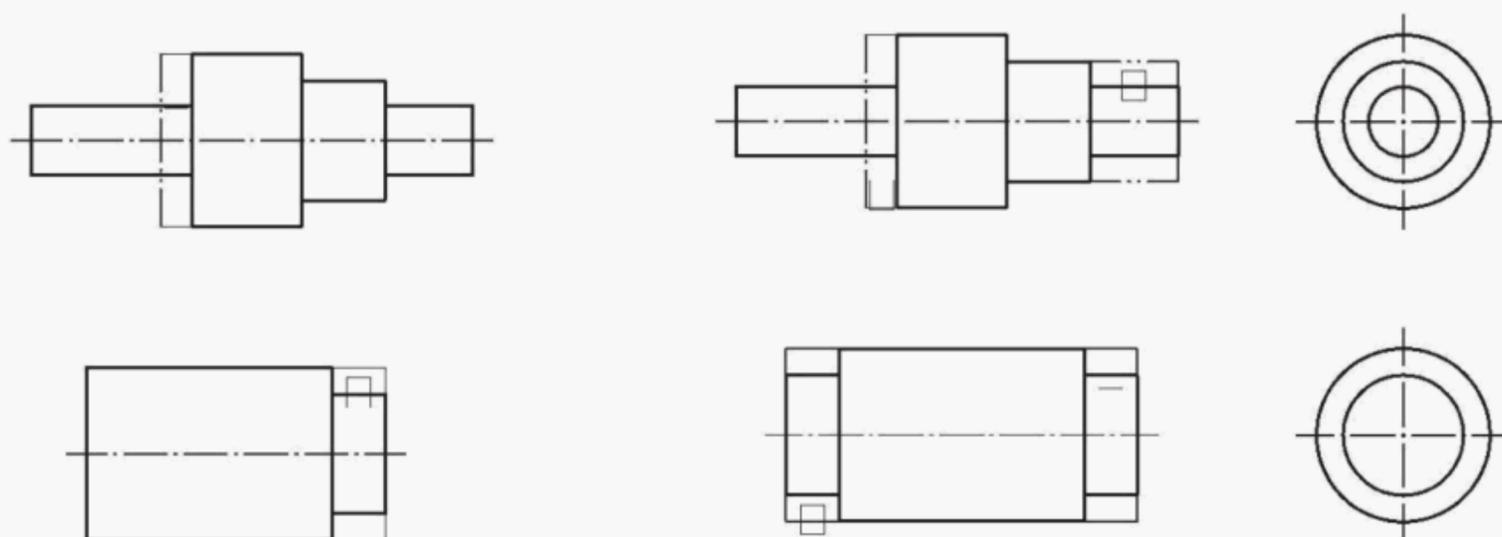
b) Two samples per sample product to be taken

**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

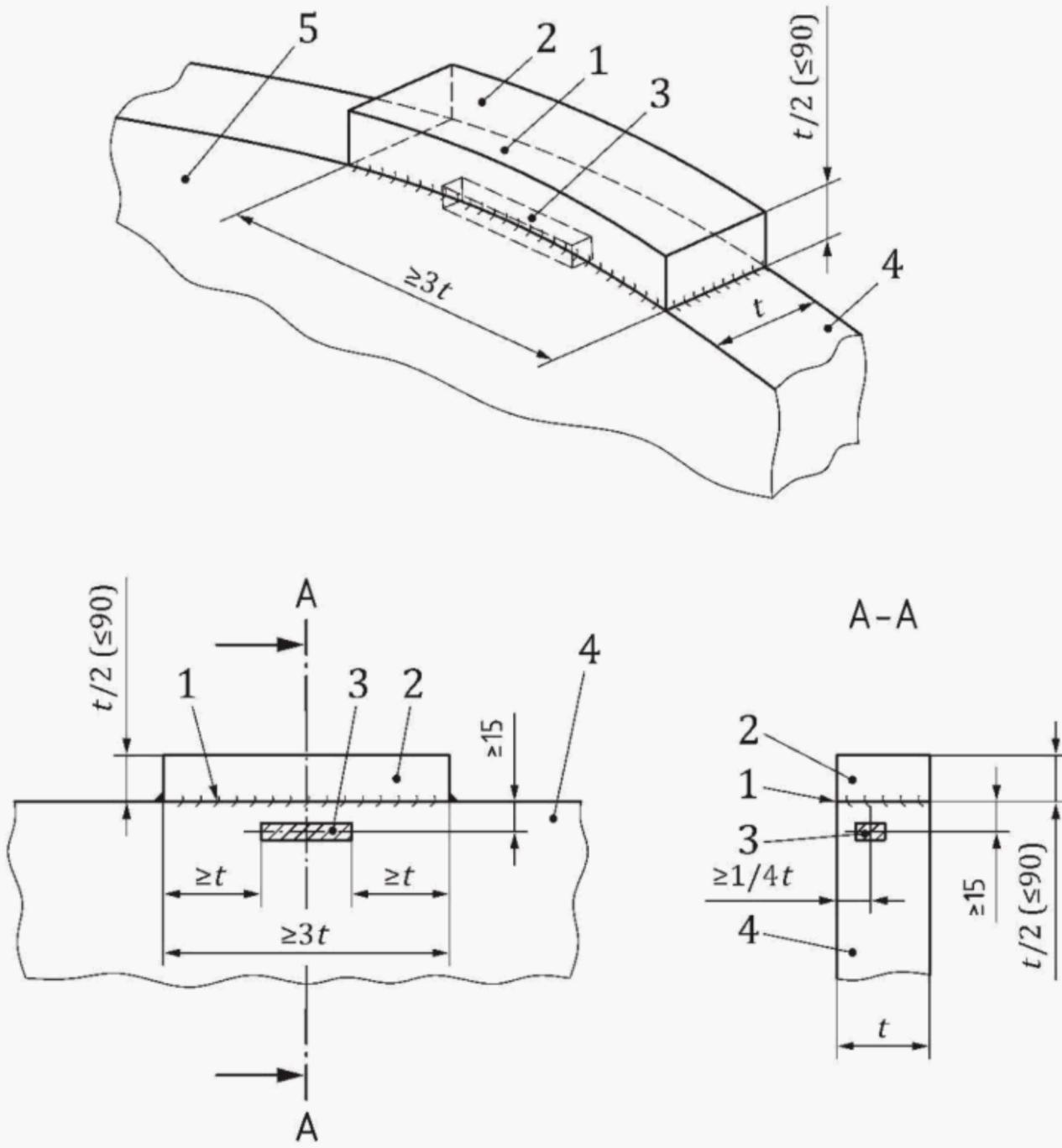
b) Two samples per sample product to be taken

**Key**

- x test piece position

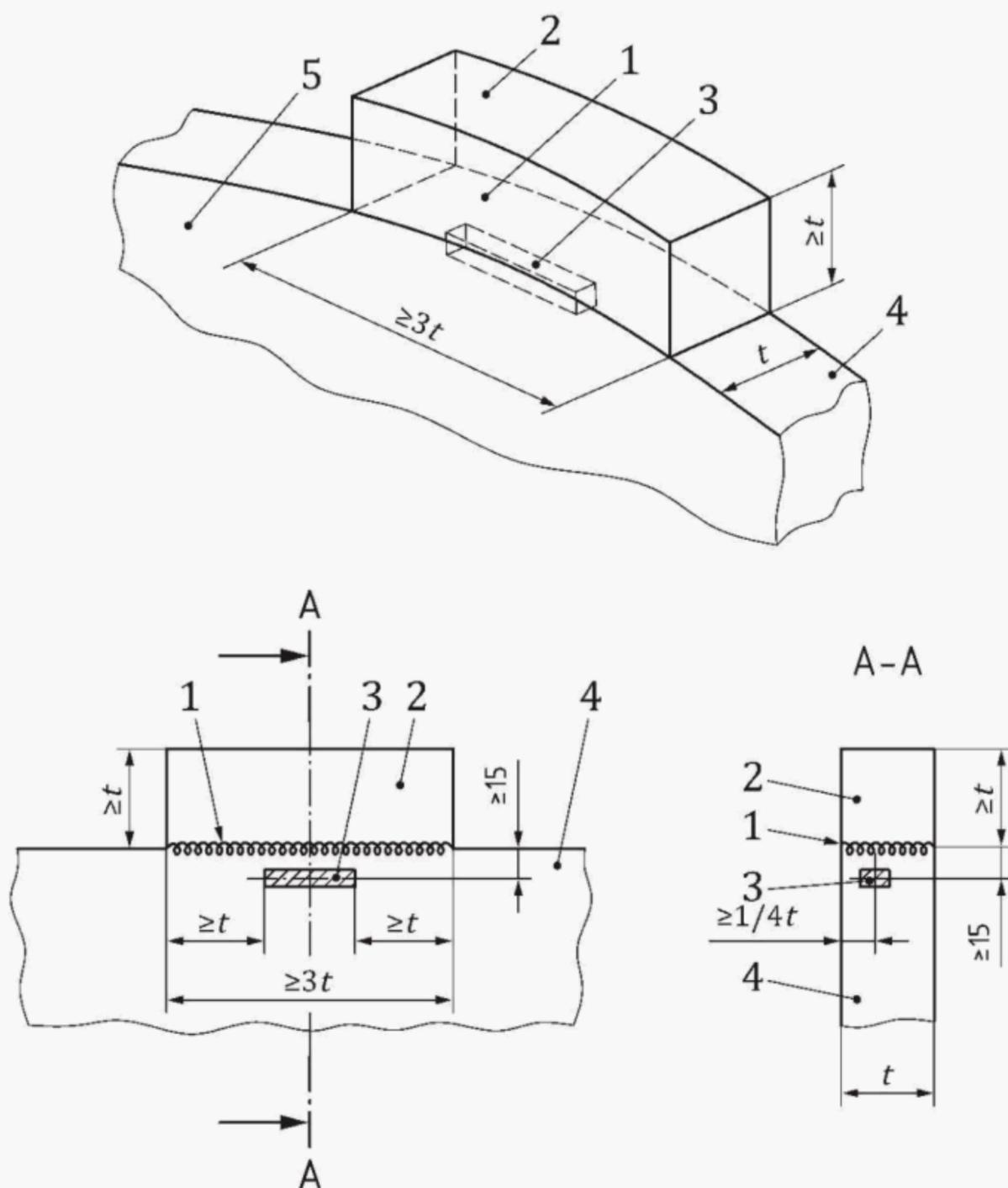
**Figure 2 — Examples of the mounting of integral surplus material and of the location of test pieces**

Dimensions in millimetres



a)

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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**

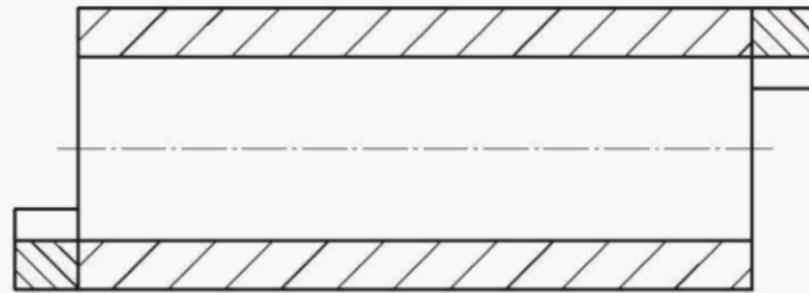


Figure 4 — Example of mounting two on welded heat buffers on a sample product

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

| Symbols<br>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 ( <i>t</i> )  | length and width         |       |                             |
|                  | of the ruling section   |                          |       |                             |
| $t/4 \times t/2$ | $t/4$ , max. 60 mm  | $t/2$ , max. 90 mm       |       | <a href="#">Figure 5 a)</a> |
| $t/4 \times t/4$ | $t/4$ , but max. 40 mm  | $t/4$ , max. 40 mm       | <?>   | <a href="#">Figure 5 b)</a> |
| $a<?>$           | $a$ , but min. 20 mm  | $2a$ , but min. 40 mm    | <?>   |                             |
| hs               | $d_t \geq d_1, d_2, d_3 \dots$ , but  |                          |       |                             |
|                  | min. 20 mm  | $2 d_t$ , but min. 40 mm | c, d  | <a href="#">Figure 6</a>    |
| dr               | The location of the test pieces shall be as indicated in a purchaser approved drawing (dr) showing as heat treated dimensions |                          | <?>   |                             |
| $t/4 \times t$   | $t/4$   | $t$                      | <?>   | <a href="#">Figure 5 c)</a> |

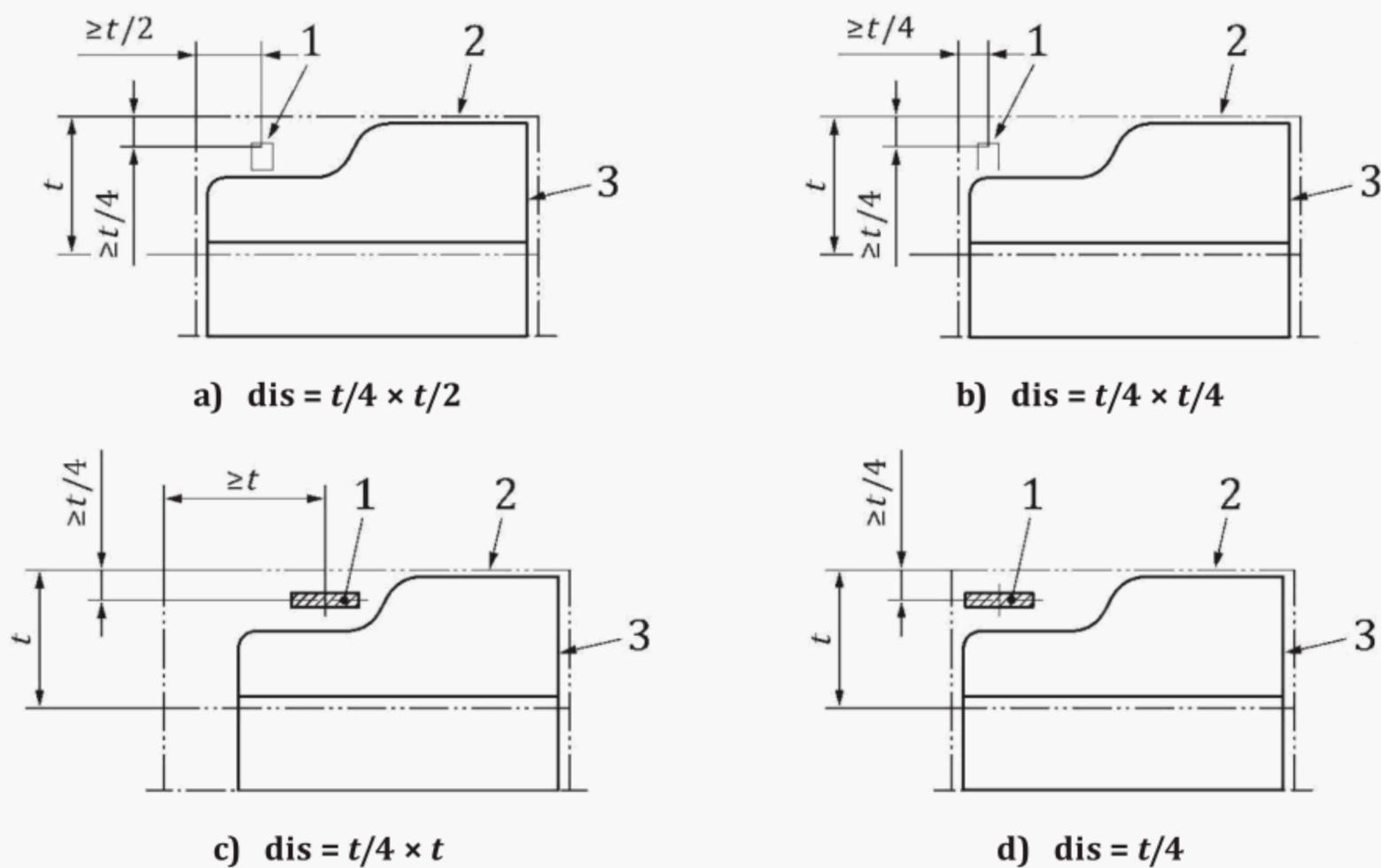
a Mainly for austenitic and austenitic-ferritic steels.

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 ( $d_1, d_2, d_3 \dots$ ) 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  $2 \times d_t$  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.

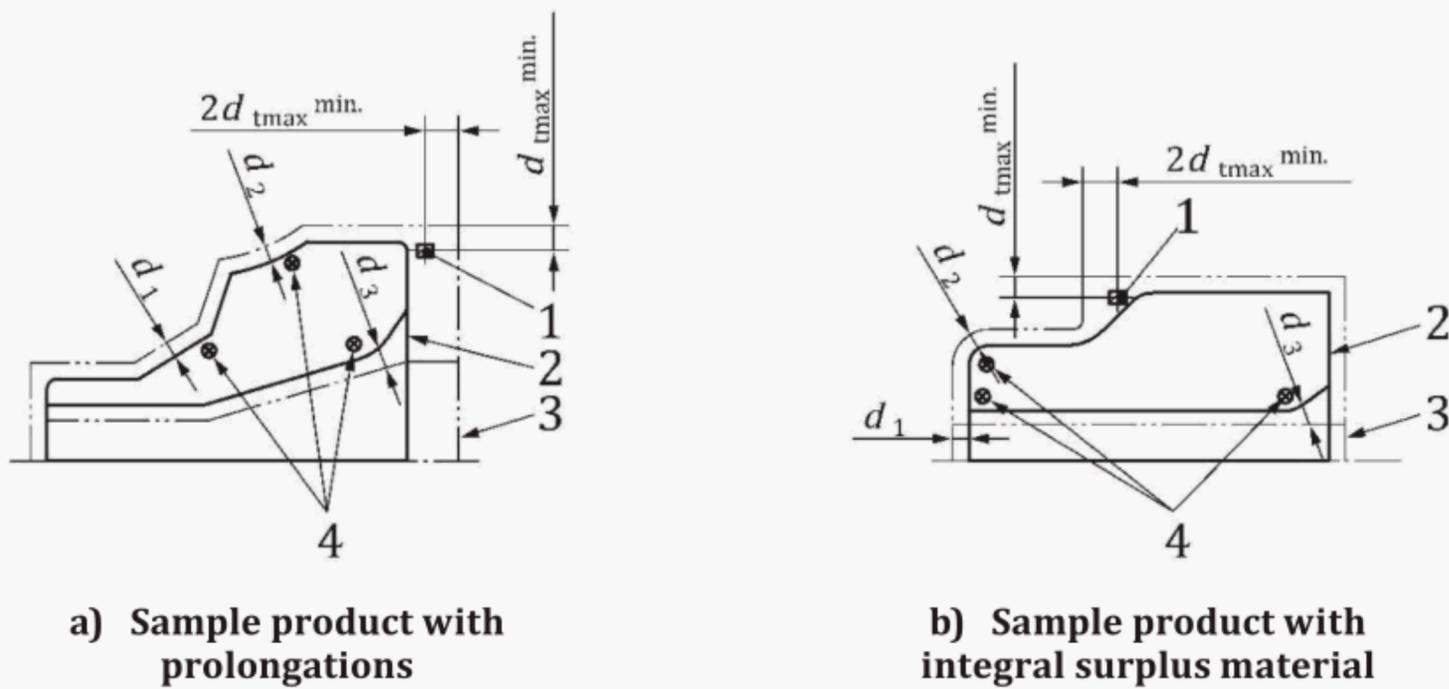
e Mainly for pressure equipment.



**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**



**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**

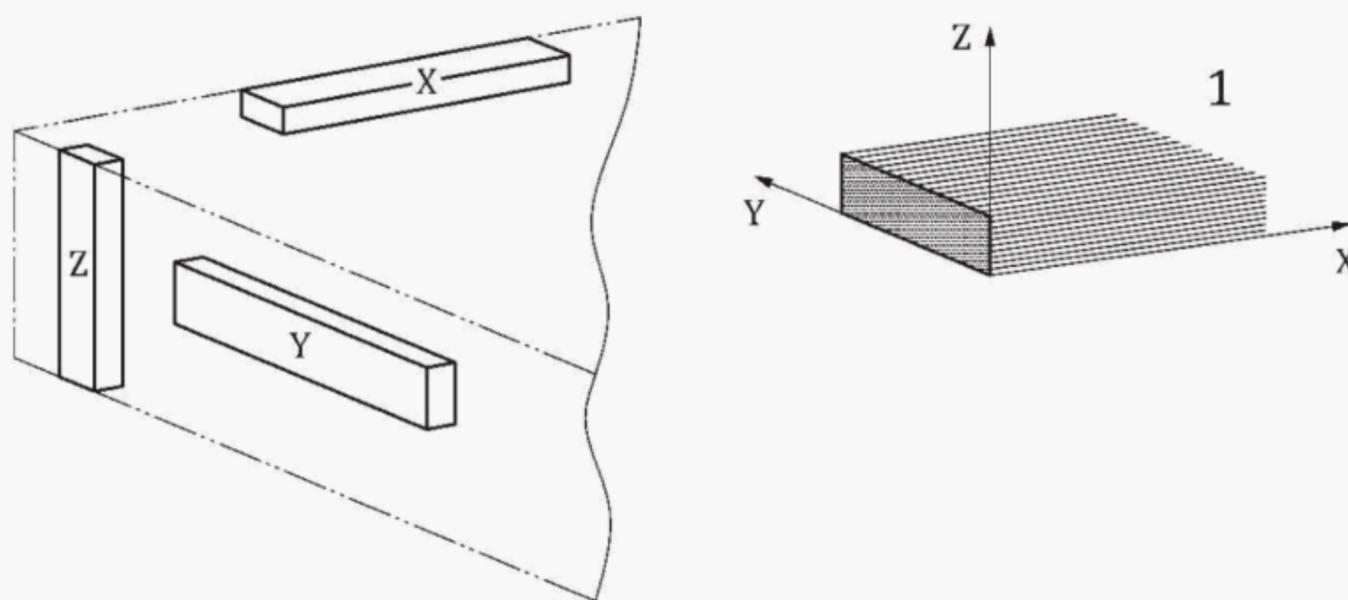
**Table 6 — Options for the direction of the test piece axes and of the direction of the notch of impact test pieces referring to the direction of grain flow or grain**

| Symbols       | Applicable for      | Meaning of the symbol                  |                                     | See                      |
|---------------|---------------------|--|-------------------------------------|--------------------------|
|               |                     | tensile or impact test pieces          | notch of the impact test pieces <?> |                          |
| Direction <?> |                     | shall be parallel to the direction <?> |                                     |                          |
| X             | tensile test pieces | X                                      | —                                   | <a href="#">Figure 7</a> |
| Y             |                     | Y                                      | —                                   |                          |
| Z             |                     | Z                                      | —                                   |                          |

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](#).

| Symbols  | Applicable for     | Meaning of the symbol                  |                                     | See      |
|--|--------------------|--|-------------------------------------|----------|
|  |                    | The direction of the                   |                                     |          |
|  |                    | tensile or impact test pieces          | notch of the impact test pieces <?> |          |
| <b>Direction &lt;?&gt;</b><br>X-Y<?><br>X-X<?><br>Z-Y<br>X-Z<br>Y-Z<br>Z-X | impact test pieces | shall be parallel to the direction <?> |                                     | Figure 8 |
|  |                    | X                                      | Y                                   |          |
|  |                    | Y                                      | X                                   |          |
|  |                    | Z                                      | Y                                   |          |
|  |                    | X                                      | Z                                   |          |
|  |                    | Y                                      | Z                                   |          |
|  |                    | Z                                      | X                                   |          |

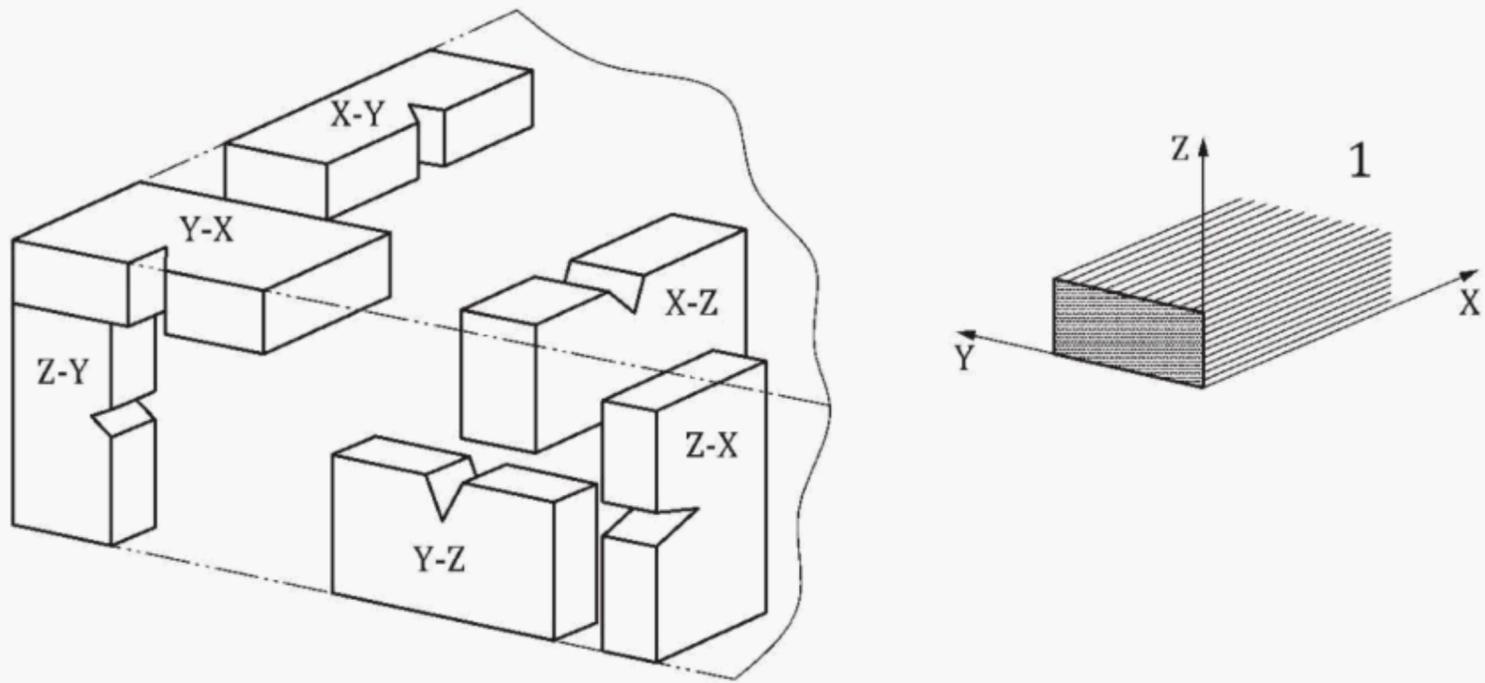
a Also of the direction of propagation of fracture predetermined by the notch.  
 b X = direction of the greatest positive strain (main direction of grain flow).  
 Z = direction of the greatest negative strain (main direction of forming).  
 Y = direction perpendicular to X and Z.  
 For the determination 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 <?> | Geometric axes of the product | Examples  |
|---|------------|----------|-------------------------------|---|
| Round<br>(bars, shafts and discs)       | ATR        | X        | axial                         | Stretch forged bars or discs cut from these                         |
|   |            | Y        | tangential                    |   |
|   |            | Z        | radial                        | Stretch forged shafts and cylinder                                  |
|   | RTA        | X        | radial                        | Discs produced by upset forging                                     |
|   |            | X        | tangential                    |   |
|   |            | Z        | axial                         |   |
| Rectangular<br>(bars and flat products) | LWT        | X        | length                        | Stretch forged rectangular <?>                                      |
|   |            | Y        | width                         |   |
|   |            | Z        | thickness                     |   |
|   | WLT        | Z        | thickness                     | Ingots or blooms forged by enlarging their width to rectangular <?> |
|   |            | X        | width                         |   |
|   |            | 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](#).



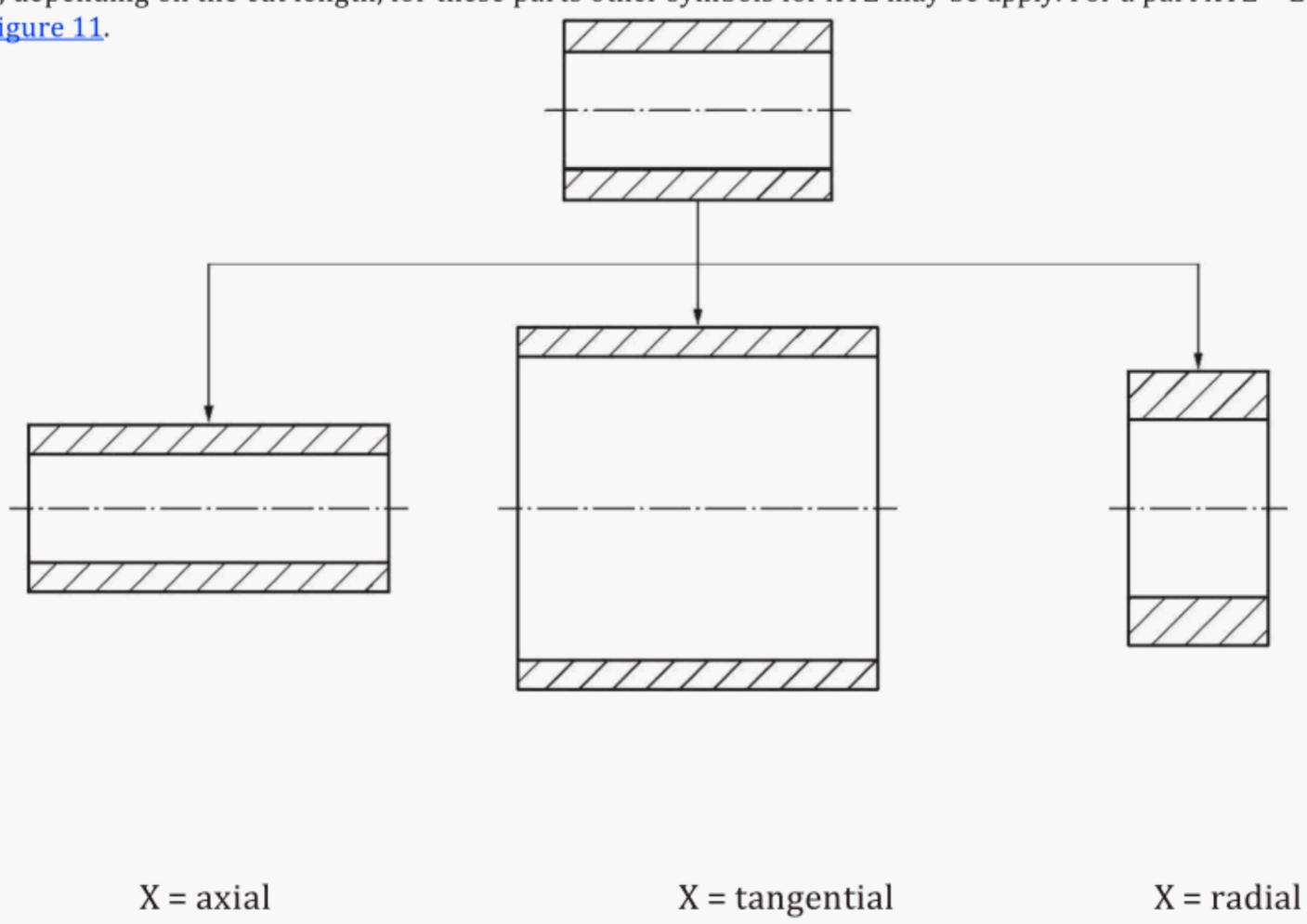
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| Shape of the product                     | Symbol XYZ | Axis <?> | Geometric axes of the product | Examples                     |
|--|------------|----------|-------------------------------|------------------------------|
| Hollow<br>(cylinders, rings and flanges) | ATR        | X        | axial                         | See <a href="#">Figure 9</a> |
|  |            | Y        | tangential                    |                              |
|  |            | Z        | radial                        |                              |
|  | TRA        | X        | tangential                    |                              |
|  |            | X        | radial                        |                              |
|  |            | Z        | axial                         |                              |
|  |            | X        | radial                        |                              |
|  |            |          |                               |                              |
|  |            |          |                               |                              |
|  |            |          |                               |                              |
|  | RTA        | 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.

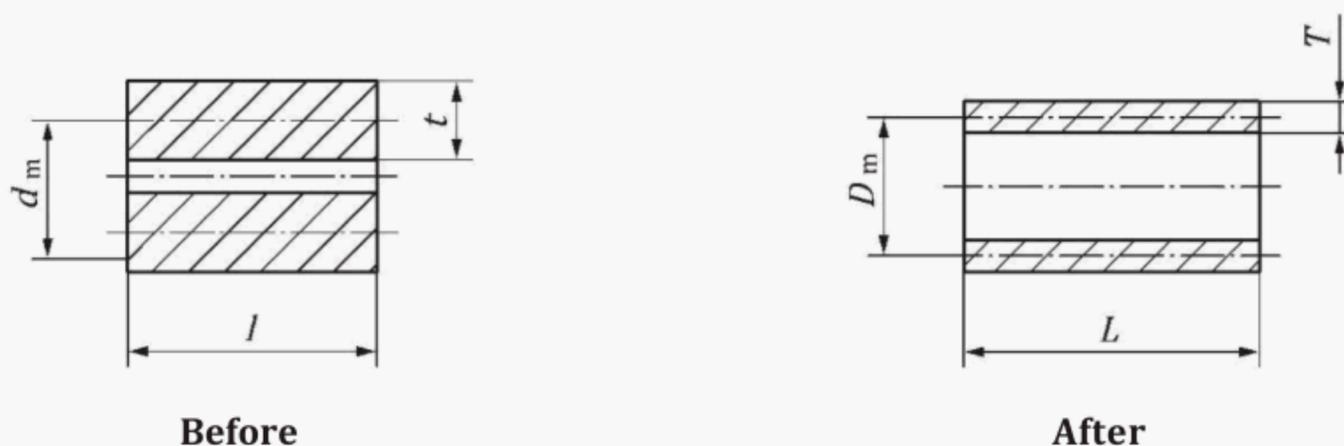
For the determination of the directions see [8.3](#).

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**





Logarithmic strain:

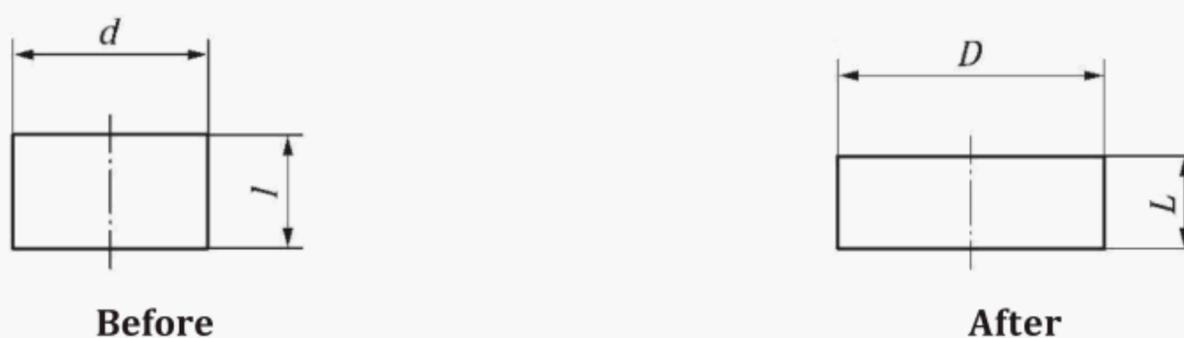
$$\bar{\epsilon}_t = \ln (D_m/d_m) \text{ in tangential direction,}$$

$$\bar{\epsilon}_a = \ln (L/l) \text{ in axial direction,}$$

$$\bar{\epsilon}_r = \ln (T/t) \text{ in radial direction, and}$$

$$\epsilon_t + \epsilon_r = 0, \text{ since the volume of the forging is constant.}$$

**a) For enlarging and mandrel forging**



Logarithmic strain:

$$\epsilon_t = \ln (D/d) \text{ in tangential direction,}$$

$$\epsilon_a = \ln (L/l) \text{ in axial direction,}$$

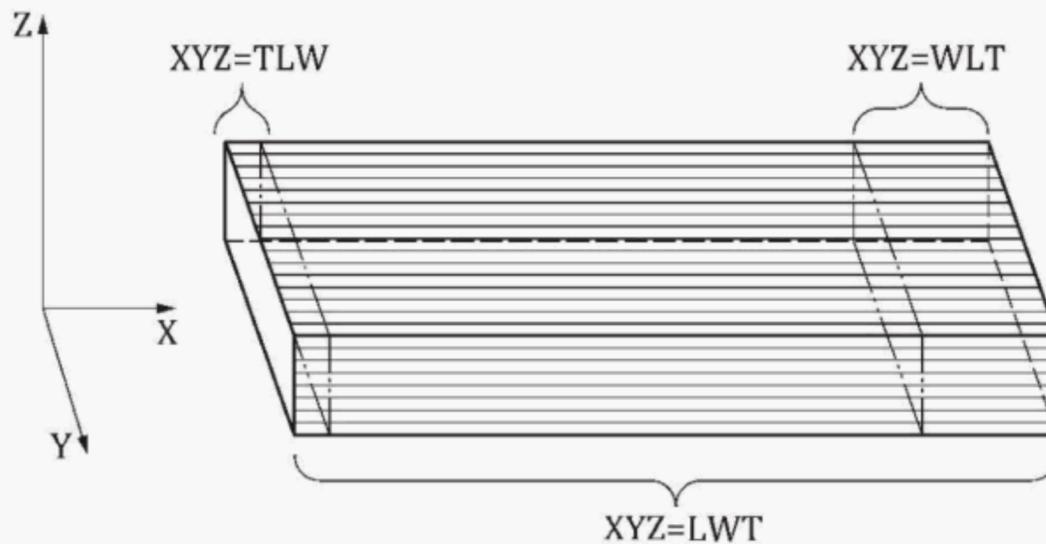
$$\epsilon_r = \ln (D/d) \text{ in radial direction, and}$$

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

**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.

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### 9.3 Verification of the elevated temperature proof strength

9.3.1 The verification shall be carried out in accordance with the test method described in [ISO 6892-2](#).

9.3.2 The test temperature shall be in accordance with the product standards.

9.3.3 For non-austenitic steels the 0,2 % proof strength value and for austenitic and austenitic-ferritic 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.

## Annex A (informative)

### Presentation of the specifications for the testing frequency and the sampling conditions in tabulated form

This annex suggests a model for the presentation of the testing frequency and the sampling conditions in tabulated form, as shown in [Tables A.1](#) and [A.2](#), respectively. The tables correspond to those given in ISO 9327-1.

**Table A.1 — Testing frequency**

| 1  | 2                    | 3   | 4                     | 5   |                                    | 6   | 7         | 8      | 9  |
|--|----------------------|---|-----------------------|---|------------------------------------|---|-----------|--------|--|
| Product characteristics  |                      |   |                       | Testing frequency for room temperature tensile tests and for impact tests         |                                    | Conditions for taking two samples per sample product <sup>a</sup> | Number of |        | Testing frequency for elevated temperature tensile tests |
| Type of steel  | Treatment condition  | As heat-treated individual mass <i>m</i> of |                       |   |                                    |   | tensile   | impact |  |
|  |                      | forgings other than bars                    | rolled or forged bars | Test units and number of sample products to be taken per test unit <sup>a,b</sup> | test pieces to be taken per sample |   |           |        |  |
|  |                      | kg  |                       |   |                                    |   |           |        |  |
| Austenitic steels or normalized unalloyed steels with $R_m \text{ min } c \leq 500 \text{ N/mm}^2$ | Finally heat treated | $m \leq 60$                                 | —                     | CH5, CHD10 or CFHD15  | or<br>CU100, CHDU20 or CFHDU10     | —   |           |        |  |
|  |                      | $60 < m \leq 2\,000$                        | —                     | CH10, CHD15 or CFHD20   |                                    |   |           |        |  |
|  |                      | —   | $\leq 3\,000$         | CH15, CHD20 or CFHD25   |                                    |   |           |        |  |
|  |                      | $m > 2\,000$                                | $> 3\,000$            | IND   | L5 or W4                           |   |           |        |  |

<sup>a</sup> The symbols used in columns 5 and 6 belong to the system of symbols for sampling conditions explained in [Table 1](#).

<sup>b</sup> Where for the same conditions several units are indicated, the choice between these test units is, unless otherwise agreed at the time of enquiry and order, left to the discretion of the manufacturer.

<sup>c</sup>  $R_m$ , min corresponds to the minimum value of the tensile strength. Where several minimum tensile strength values are specified depending on thickness of the steel, the highest minimum value shall be decisive.

<sup>d</sup> Where the test units according to column 5 are not to be subjected to uniformity checks by hardness test (i.e. test units without "U" in the symbol) from each third sample product taken, in addition to the test pieces to be taken according to columns 7 and 8, one tensile test piece shall be taken for testing the elevated temperature proof strength. Where, according to column 5, the test units are to be subjected to uniformity checks by hardness tests (i.e. test units with a "U" in the symbol), from the sample product with the lowest hardness (in addition to the test pieces to be taken according to columns 7 and 8) one tensile test piece shall be taken for testing the elevated temperature proof strength.

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| 1                       | 2                    | 3   | 4                     | 5   |              | 6   | 7                                  | 8      | 9  |
|-------------------------|----------------------|---|-----------------------|---|--------------|---|------------------------------------|--------|--|
| Product characteristics |                      |   |                       | Testing frequency for room temperature tensile tests and for impact tests         |              | Conditions for taking two samples per sample product <sup>a</sup> | Number of                          |        | Testing frequency for elevated temperature tensile tests |
| Type of steel           | Treatment condition  | As heat-treated individual mass <i>m</i> of |                       |   |              |   | tensile                            | impact |  |
|                         |                      | forgings other than bars                    | rolled or forged bars | Test units and number of sample products to be taken per test unit <sup>a,b</sup> |              |   | test pieces to be taken per sample |        |  |
|                         |                      | kg  |                       |   |              |   |                                    |        |  |
| Other steels            | Finally heat treated | $m \leq 40$                                 | —                     | CH2,5 or CFHD5  | or CHDU30 or | —   |                                    |        |  |
|                         |                      | $40 < m \leq 1\,000$                        | —                     | CHD5 or CFHD10  |              |   |                                    |        |  |
|                         |                      |   |                       | CFHDU20   |              |   |                                    |        |  |
|                         |                      |   |                       |   |              |   |                                    |        |  |
|                         |                      |   | $\leq 2\,000$         | CHD10 or CFHD15   |              |   |                                    |        |  |
|                         |                      | $m > 1\,000$                                | $> 2\,000$            | IND   |              | L5 or W4  |                                    |        |  |

- a The symbols used in columns 5 and 6 belong to the system of symbols for sampling conditions explained in [Table 1](#).
- b Where for the same conditions several units are indicated, the choice between these test units is, unless otherwise agreed at the time of enquiry and order, left to the discretion of the manufacturer.
- c  $R_m$ , min corresponds to the minimum value of the tensile strength. Where several minimum tensile strength values are specified depending on thickness of the steel, the highest minimum value shall be decisive.
- d Where the test units according to column 5 are not to be subjected to uniformity checks by hardness test (i.e. test units without "U" in the symbol) from each third sample product taken, in addition to the test pieces to be taken according to columns 7 and 8, one tensile test piece shall be taken for testing the elevated temperature proof strength. Where, according to column 5, the test units are to be subjected to uniformity checks by hardness tests (i.e. test units with a "U" in the symbol), from the sample product with the lowest hardness (in addition to the test pieces to be taken according to columns 7 and 8) one tensile test piece shall be taken for testing the elevated temperature proof strength.

| Table A.2 — Sampling conditions   |   |  |                     |                    |
|---|---|--|---------------------|--------------------|
| 1   | 2   | 3  | 4                   |                    |
| Type of sample product  | Distance (dis.) of the test pieces from the surface | for  | tensile test pieces | impact test pieces |
| The type of sample product with, where necessary, indications on the way of mounting surplus materials and on the location of the test pieces shall be agreed at the time of enquiry and order, where possible, by reference to the relevant symbols in <a href="#">Table 3</a> | $t/4 \times t/2$                                    | bars and shafts in thicknesses $\leq 160$ mm | X                   | X-Y                |
|   |   | otherwise                                    | Y                   | Y-X                |



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- [9] ASTM E448, *Standard Practice for Scleroscope Hardness Testing of Metallic Materials*
- [10] JIS Z 2246, *Shore hardness test — Test method*



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