
**Destructive tests on welds in metallic
materials — Bend tests**

*Essais destructifs des soudures sur matériaux métalliques — Essais de
pliage*



Reference number
ISO 5173:2009(E)

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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 electrotechnical standardization.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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.

ISO 5173 was prepared by Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 5, *Testing and inspection of welds*.

This third edition cancels and replaces the second edition (ISO 5173:2000) which has been technically revised.

Requests for official interpretations of any aspect of this International Standard should be directed to the Secretariat of ISO/TC 44/SC 5 via your national standards body, of which a complete listing can be found at www.iso.org.

Destructive tests on welds in metallic materials — Bend tests

1 Scope

This International Standard specifies a method for making transverse root, face and side bend tests on test specimens taken from butt welds, butt welds with cladding (subdivided into welds in clad plates and clad welds) and cladding without butt welds, in order to assess ductility and/or absence of imperfections on or near the surface of the test specimen. It also gives the dimensions of the test specimen.

In addition, this International Standard specifies a method for making longitudinal root and face bend tests to be used instead of transverse bend tests for heterogeneous assemblies when base materials and/or filler metal have a significant difference in their physical and mechanical properties in relation to bending.

This International Standard applies to metallic materials in all forms of product with welded joints made by any fusion arc welding process.

2 Terms and definitions

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

2.1

transverse face bend test specimen for a butt weld

TFBB

specimen for which the surface in tension is the side that contains the greater width of the weld or the side from which the welding arc was first applied, applicable to transverse butt weld specimens

See Figure 1.

2.2

transverse root bend test specimen for a butt weld

TRBB

specimen for which the surface in tension is the side opposite to that of the face butt weld bend test specimen, applicable to transverse butt weld specimens

See Figure 2.

2.3

transverse side bend test specimen for a butt weld

SBB

specimen for which the surface in tension is a cross-section of the weld

See Figure 3.

2.4

longitudinal face test specimen for a butt weld

root bend test specimen for a butt weld

LFBB

LRBB

specimen whose direction is parallel to butt weld direction, applicable to face and root bend specimens

See Figure 4.

2.5
face bend test specimen for cladding without a butt weld
FBC

specimen for which the cladding is in tension, applicable to both transverse and longitudinal specimens

See Figure 5.

2.6
side bend test specimen for cladding without a butt weld
SBC

specimen for which the cross-section of the cladding overlay is in tension, applicable to both transverse and longitudinal specimens

See Figure 6.

2.7
face bend test specimen for cladding with a butt weld
side bend test specimen for cladding with a butt weld
FBCB
SBCB

specimen for which the cladding is in tension or for which the cross-section of the cladding overlay is in tension and which contains a butt weld

See Figures 7 and 8.

3 Principle

Submitting a test specimen, taken transversely or longitudinally from a welded joint, to plastic deformation by bending it, without reversing the bending direction, in such a way that one of the surfaces or cross-sections of the welded joint is in tension.

Unless otherwise specified, the test shall be carried out at an ambient temperature of $(23 \pm 5) ^\circ\text{C}$.

The test shall be made in accordance with one of the methods described in Clause 6.

4 Symbols and abbreviated terms

4.1 Symbols

See Table 1 and Figures 1 to 15.

4.2 Abbreviated terms

TFBB	Transverse face bend test specimen for a butt weld
TRBB	Transverse root bend test specimen for a butt weld
SBB	Transverse side bend test specimen for a butt weld
LFBB	Longitudinal face bend test specimen for a butt weld
LRBB	Longitudinal root bend test specimen for a butt weld
FBC	Face bend test specimen for cladding without a butt weld
SBC	Side bend test specimen for cladding without a butt weld
FBCB	Face bend test specimen for cladding with a butt weld
SBCB	Side bend test specimen for cladding with a butt weld

Table 1 — Symbols and designations

Symbol	Designation	Unit
A	minimum percentage elongation after fracture required by the material specification	%
b	width of the test specimen	mm
b_1	width of outside fusion line	mm
d	diameter of the former or the inner roller	mm
D	outside diameter of the pipe ^a	mm
l	distance between the rollers	mm
L_f	initial distance between contact of the roller and the centre line of the weld	mm
L_o	original gauge length	mm
L_s	maximum width of the weld after machining	mm
L_t	total length of the test specimen	mm
r	radius of the test specimen edges	mm
R	radius of the rollers	mm
t	thickness of the test piece	mm
t_c	thickness of the cladding	mm
t_s	thickness of the test specimen	mm
t_w	thickness of base material under cladding	mm
α	bending angle	°

^a The term "pipe", alone or in combination, is used to mean "pipe", "tube" or "hollow section (without rectangular cross section)".

4.3 Figures corresponding to the abbreviations

Figures 1 to 8 represent bend test specimens for butt welds and cladding.

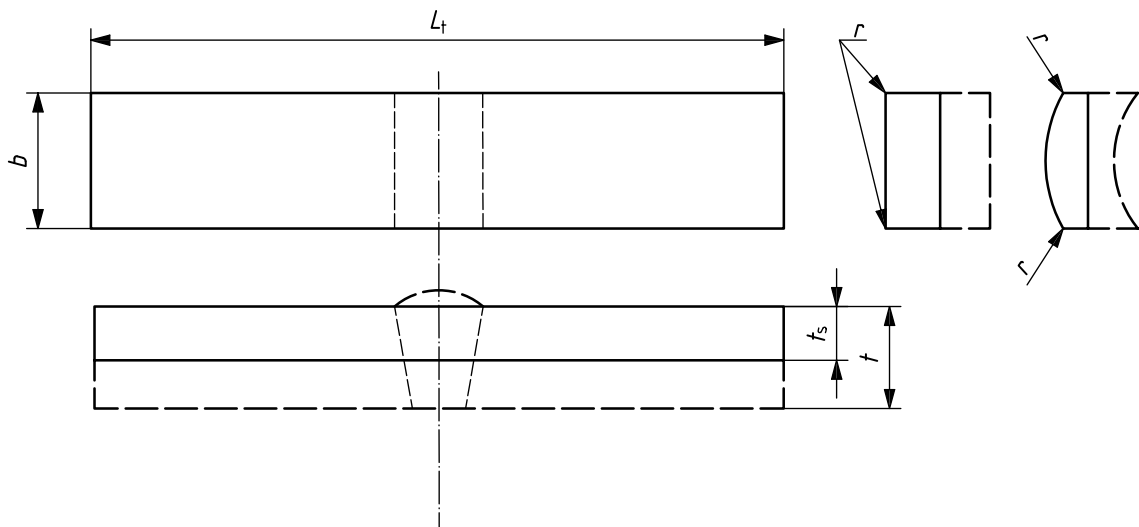


Figure 1 — Transverse face bend test specimen for a butt weld (TFBB)

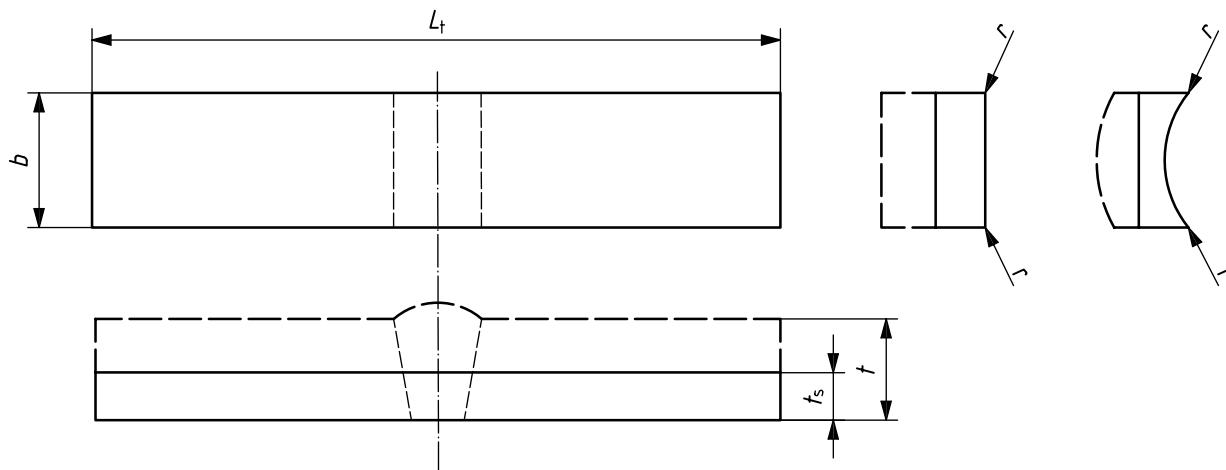


Figure 2 — Transverse root bend test specimen for a butt weld (TRBB)

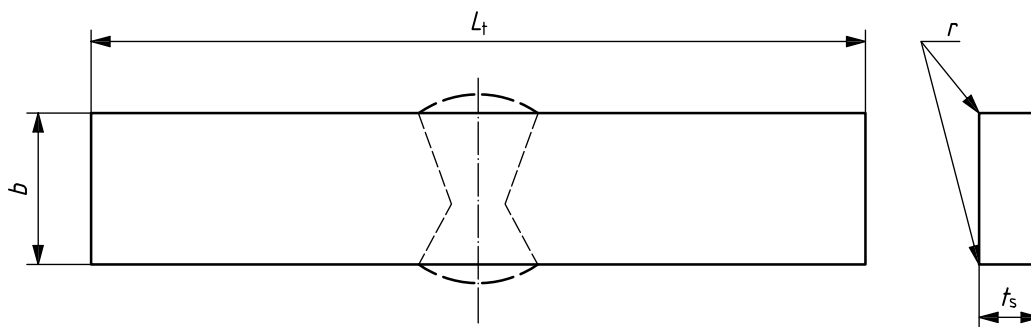


Figure 3 — Transverse side bend test specimen for a butt weld (SBB)

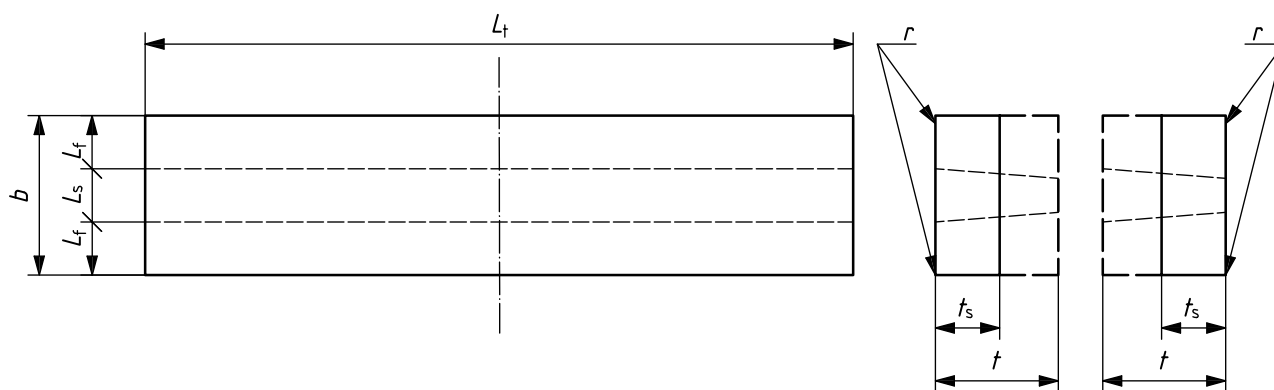


Figure 4 — Longitudinal bend test specimen for a butt weld (LFBB and LRBB)

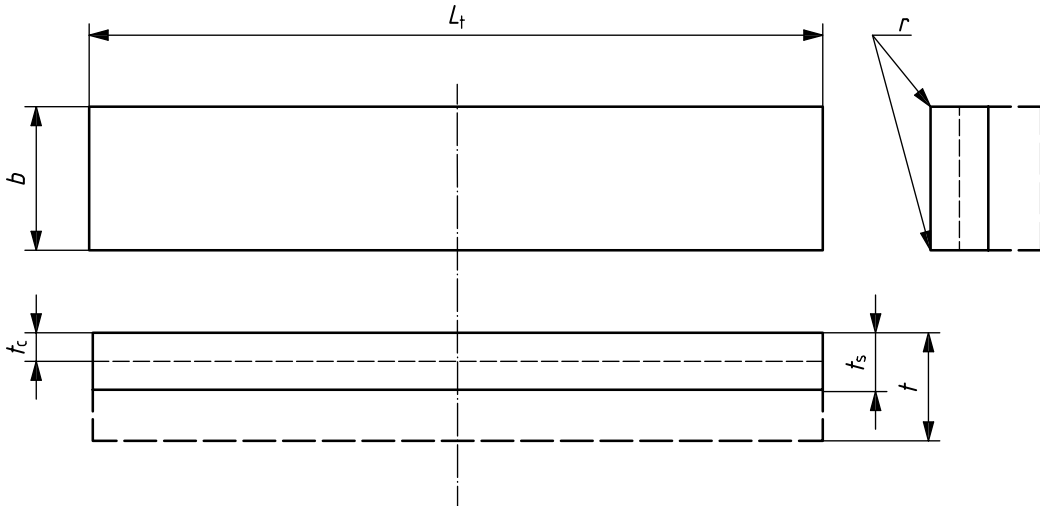


Figure 5 — Face bend test specimen for cladding without a butt weld (FBC)

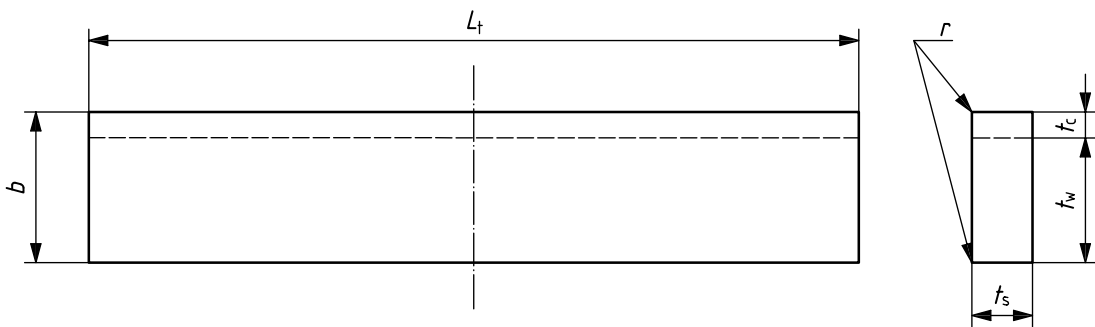


Figure 6 — Side bend test specimen for cladding without a butt weld (SBC)

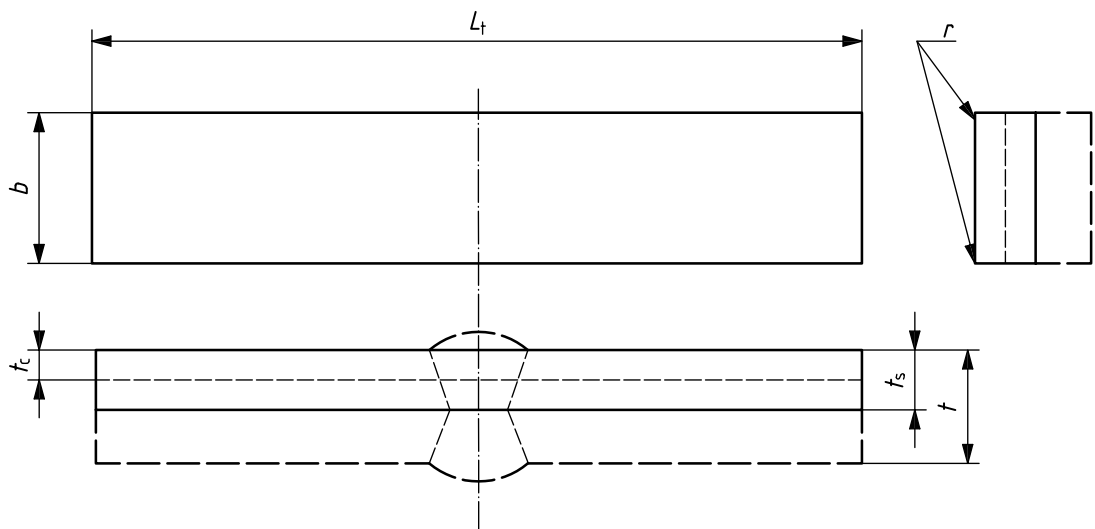


Figure 7 — Face bend test specimen for cladding with a butt weld (FBCB)

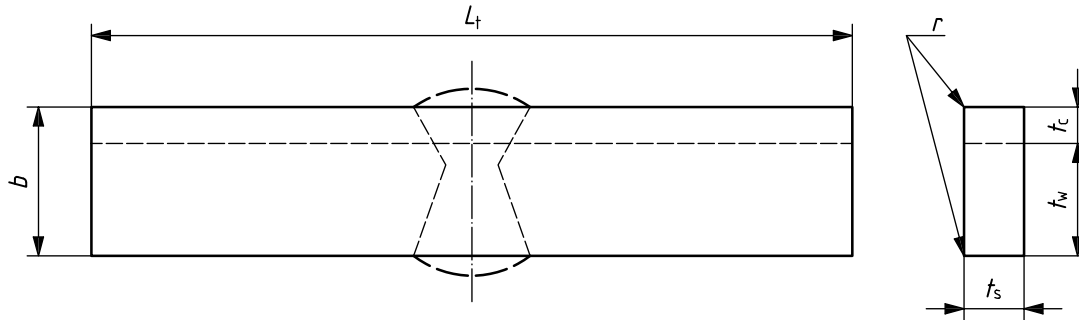


Figure 8 — Side bend test specimen for cladding with a butt weld (SBCB)

5 Preparation of test specimens

5.1 General

Specimens shall be prepared in such a manner that the preparation does not affect either the base material or the weld metal.

5.2 Location

For transverse bend testing of butt welds, the test specimen shall be taken transversely from the welded joint of the manufactured product or from the welded test piece in such a way that after machining the weld axis will remain in the centre of the test specimen or at a suitable position for testing.

For longitudinal bend testing of butt welds, the test specimen shall be taken longitudinally from the welded joint of the manufactured product or from the welded test piece.

The location and orientation of bend test specimens of cladding material shall be specified by the application standard or by agreement between the contracting parties.

5.3 Marking

Each test piece shall be marked to identify its exact location in the manufactured product or in the joint from which it has been removed.

If required by the relevant application standard, the direction of working (e.g. rolling or extrusion) shall be marked.

Each test specimen shall be marked to identify its exact location in the test piece from which it has been removed.

5.4 Heat treatment and/or ageing

No heat treatment shall be applied to the welded joint or to the test specimen unless it is specified or permitted by the relevant application standard dealing with the welded joint to be tested. Details of any heat treatment shall be recorded in the test report. If natural ageing of aluminium alloys takes place, the time between welding and testing shall be recorded.

5.5 Extraction

5.5.1 General

The mechanical or thermal processes used to extract the test specimen shall not change the properties of the test specimen in any way. It is permissible to mechanically remove any material that is affected by thermal cutting provided the finished dimensions of the specimens required by this International Standard are met.

5.5.2 Steel

Shearing shall not be used for thicknesses > 8 mm. If thermal cutting or other cutting methods which could affect the cut surfaces are used to extract the test specimen from the welded plate, or from the test piece, the cuts shall be made at a distance ≥ 3 mm from the test specimen but in any case sufficient (depending on the process used) not to introduce metallurgical effects which could affect the test results.

5.5.3 Other metallic materials

Sheared or thermal cut surfaces are not permitted on bend specimens; only machining (e.g. sawing, grinding or milling) shall be used.

5.6 Specimen size

5.6.1 Transverse root and face bend tests of a butt weld (TFBB and TRBB)

See Figures 1, 2 and 9.

For transverse root and face bend tests, the test specimen thickness, t_s , shall be equal to the thickness of the base material adjacent to the welded joint up to a maximum thickness of 30 mm. If the test piece thickness, t , is greater than 10 mm, the test specimen thickness, t_s , may be machined or otherwise mechanically finished from one side to a thickness equal to $(10 \pm 0,5)$ mm as indicated in Figures 1 and 2. The face or root of the weld shall be in tension when the specimen is bent.

When a relevant application standard requires testing of a full thickness > 10 mm, several test specimens may be taken in order to cover the full thickness of the joint as indicated in Figure 9.

In such cases, the location of the test specimen in the welded joint thickness shall be identified.

5.6.2 Transverse side bend tests of a butt weld (SBB)

See Figures 3 and 10.

For side bend tests, the test specimen width, b , shall be equal to the thickness of the base material of the welded joint. The specimen shall have a thickness, t_s , of at least $(10 \pm 0,5)$ mm, unless otherwise specified in the relevant application standard.

When the joint thickness exceeds 40 mm, it is permissible to split the specimen in the plane of the test piece thickness as shown in Figure 10. In these cases the location of the test specimen in the welded joint thickness shall be identified.

5.6.3 Longitudinal bend tests of a butt weld (LFBB and LRBB)

See Figure 4.

For longitudinal bend tests, the test specimen thickness, t_s , shall be equal to the thickness of the base material near the welded joint, but should not exceed 10 mm. If the test piece thickness, t , is greater than 10 mm, the test specimen thickness, t_s , may be machined or otherwise mechanically finished from one side to a thickness equal to $(10 \pm 0,5)$ mm as indicated in Figure 4. The face or root of the weld shall be in tension when the specimen is bent.

5.6.4 Face bend tests of cladding material without a butt weld (FBC)

See Figure 5.

For face bend tests, the test specimen thickness, t_s , shall be equal to the thickness of the base material plus the thickness of the cladding, but should not exceed 10 mm. If the test piece thickness, t , is greater than 10 mm, the test specimen thickness, t_s , may be machined or otherwise mechanically finished from the base metal to a thickness equal to $(10 \pm 0,5)$ mm as indicated in Figure 5, if cladding thickness permits.

When the thickness of the base material plus cladding is greater than t_s , it is permissible to remove base material in order to produce a test specimen thickness, t_s , in accordance with the application standard or as agreed between the contracting parties.

5.6.5 Side bend tests of cladding material without a butt weld (SBC)

See Figure 6.

For side bend tests, the test specimen width, b , shall be equal to the thickness of the base material plus the thickness of the cladding, up to a maximum of 40 mm. The specimen shall have a thickness, t_s , of at least $(10 \pm 0,5)$ mm, unless otherwise specified in the relevant application standard.

When the thickness of the base material plus cladding exceeds 40 mm, it is permissible to remove base material to produce a test specimen width, b , in accordance with the relevant application standard or as agreed between the contracting parties.

5.6.6 Transverse face bend tests of cladding material with a butt weld (FBCB)

See Figure 7.

For transverse face bend tests of cladding with a butt weld, the test specimen thickness, t_s , shall be equal to the thickness of the base material plus the thickness of the cladding, but should not exceed 10 mm. If the test piece thickness, t , is greater than 10 mm, the test specimen thickness, t_s , may be equal to $(10 \pm 0,5)$ mm, if cladding thickness permits.

In such a case, the location of the weld shall remain in the middle of the test specimen or at a suitable position for testing.

When the test concerns the complete joint incorporating both the butt joint and the cladding and when the thickness of the joint is greater than t_s , several specimens may be taken as described in 5.6.1 and Figure 9.

When the purpose of the test is to examine the cladding only and when the thickness of the base material plus cladding is greater than t_s , no further tests on the base material are required.

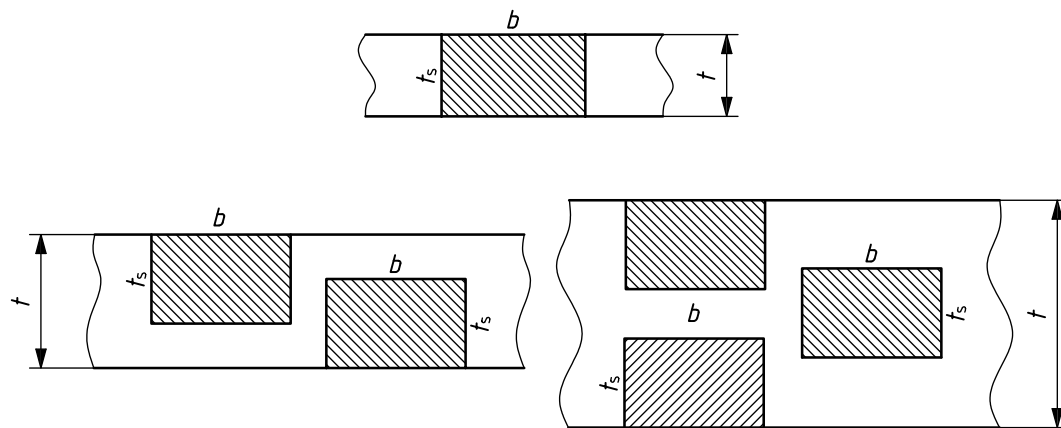


Figure 9 — Root and face bend test specimens for a butt weld (TFBB, TRBB, LFBB and LRBB)

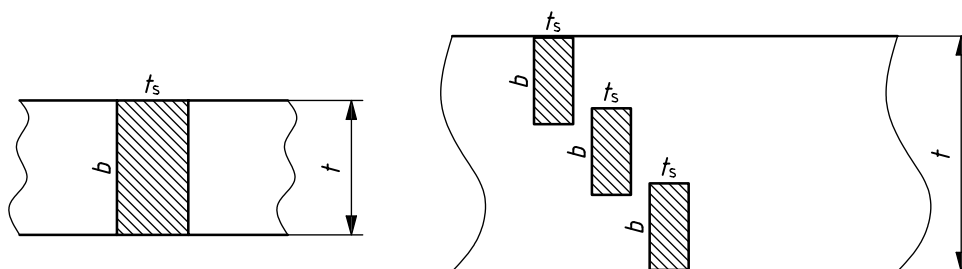


Figure 10 — Side bend test specimens for a butt weld (SBB)

5.6.7 Dimensions

5.6.7.1 Length

The total length, L_t , of test specimens shall be equal to the required value and shall fulfil the requirements of the appropriate application standards.

5.6.7.2 Thickness

The thickness of test specimens, t_s , shall be in accordance with 5.6.1 to 5.6.6.

5.6.7.3 Width

a) Transverse root or face bend tests:

1) For plates:

the width, b , of the test specimen shall be $4t_s$ or greater, unless otherwise specified in the relevant application standard.

2) For pipes, the width, b , of the test specimen shall be at least:

— for pipe diameter ≤ 50 mm:

$$b = t + 0,1 D$$

(minimum diameter 8 mm);

— for pipe diameter > 50 mm:

$$b = t + 0,5 D$$

(minimum diameter 8 mm, but should not exceed 40 mm).

For an outside diameter, D , $> 25 \times$ the wall thickness of the pipe, the specimen may be taken as required for the flat plates.

b) Transverse side bend tests:

The width, b , of the test specimen shall generally be equal to the thickness of the base material near the welded joint.

c) Longitudinal bend tests:

The width, b , of the test specimen shall be

$$b = L_s + 2 b_1$$

where $b_1 = 15$ mm, unless otherwise specified in the relevant application standard and/or by agreement between the contracting parties.

5.6.7.4 Edges

The edges of the test specimen on the face in tension shall be rounded by mechanical means to a radius, r , not exceeding $0,2 t_s$ to a maximum of 3 mm (see Figures 1 to 8).

5.6.8 Surface preparation

The final stages of preparation shall be obtained by machining or grinding, taking suitable precautions to avoid superficial strain hardening or excessive heating of the material. Within the length l (see Figures 11 to 13), the surface shall be free from scratches or notches transverse to the test specimen direction, except for undercuts, which shall not be removed unless required by the relevant application standard.

The surfaces of the test specimen shall be machined in such a way that, unless otherwise specified in the relevant application standard and/or by agreement between the contracting parties, all excess weld metal is removed. Unless otherwise specified, the penetration bead may be left intact inside pipes of small diameter on the opposite side of the former.

6 Conditions of testing

6.1 Etching

Before starting the bend test, the shape and the position of the fusion zone or fusion line may be established by lightly macroetching the surface of the test specimen to be tested in tension.

6.2 Testing

6.2.1 Testing with a former

See Figures 11 to 14.

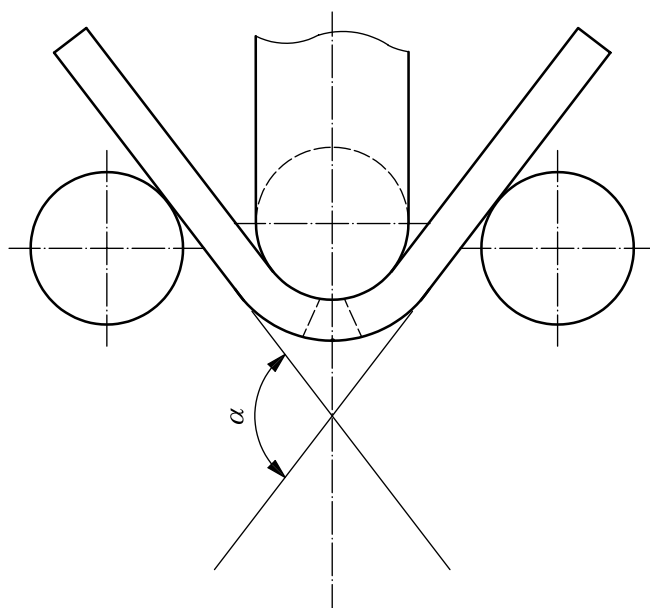
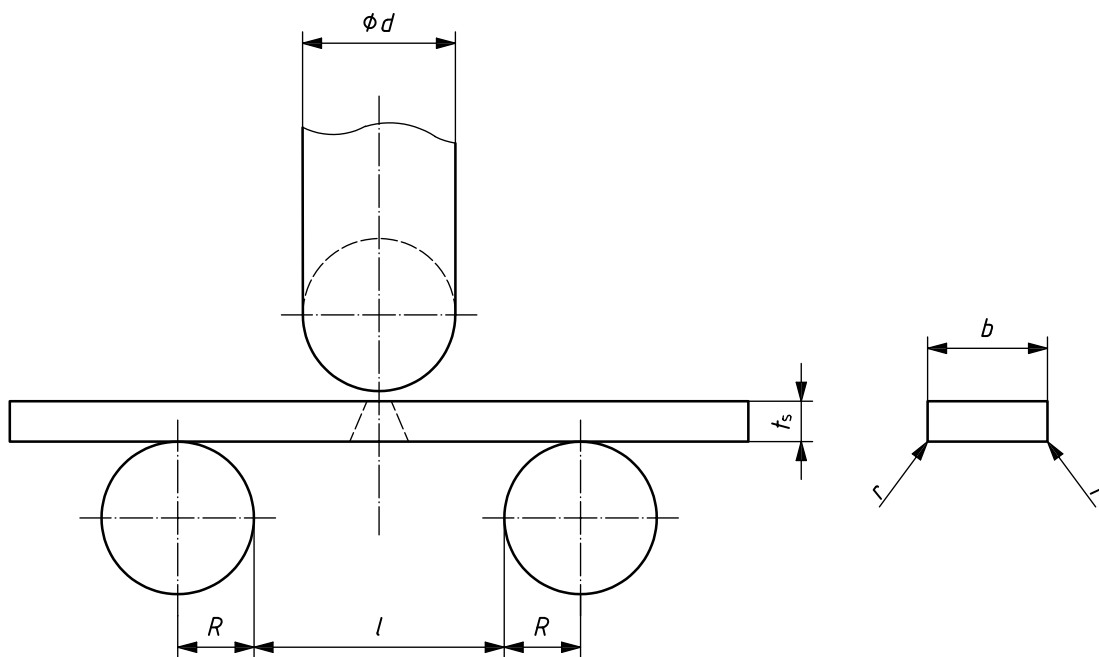
The test shall be carried out by placing the test specimen on two supports consisting of parallel rollers (see Figures 11 to 13) or U-type jig (see Figure 14).

The weld shall be at the mid-point between the rollers, except for longitudinal bend tests. The test specimen shall be bent by loading gradually and continuously in the middle of the span, on the axis of the weld, with a load applied by a former (three-point bending) perpendicular to the test specimen surface.

The radius of the plunger and die for the U-type jig shall be in accordance with Table 2.

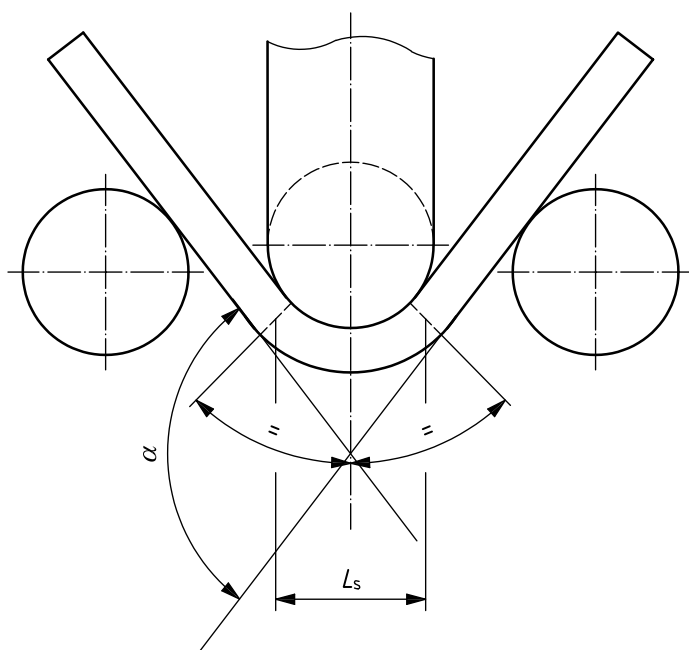
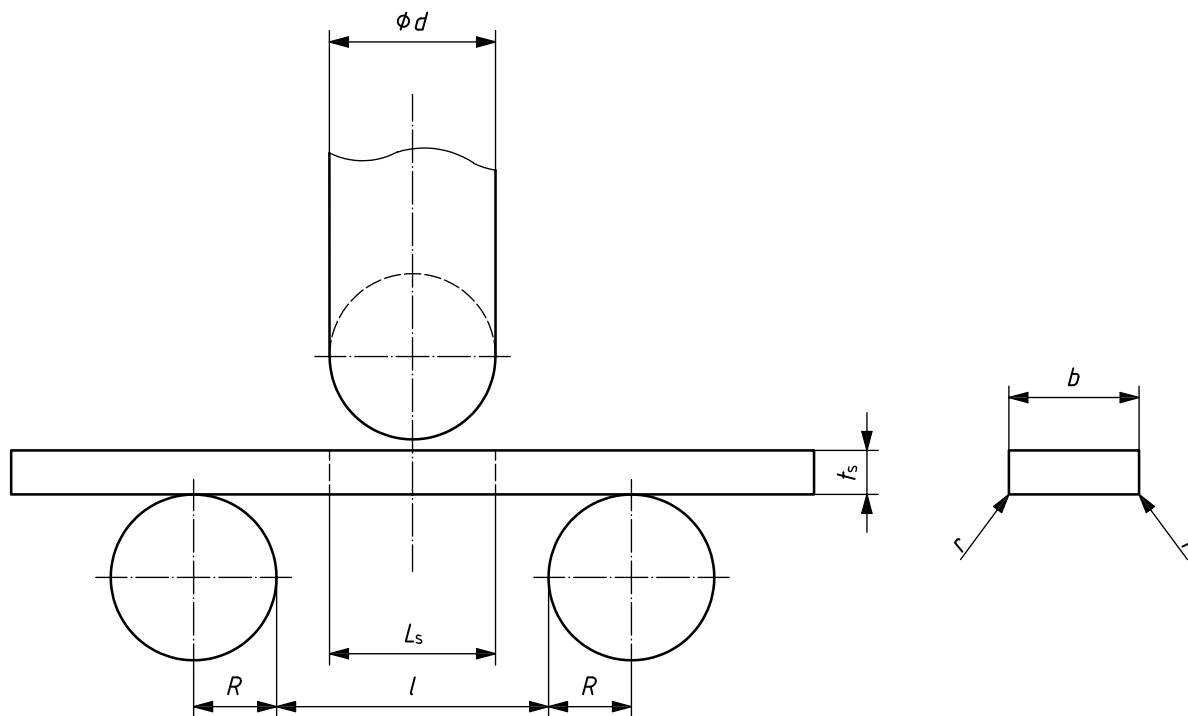
Table 2 — Fixture dimensions — U-type jig

Specimen thickness mm	Plunger radius mm	Die radius mm
10	20	32
t_s	$2 t_s$	$r_P + t_s + 2$



$$d + 2t_s + 3 \leq l \leq d + 3t_s$$

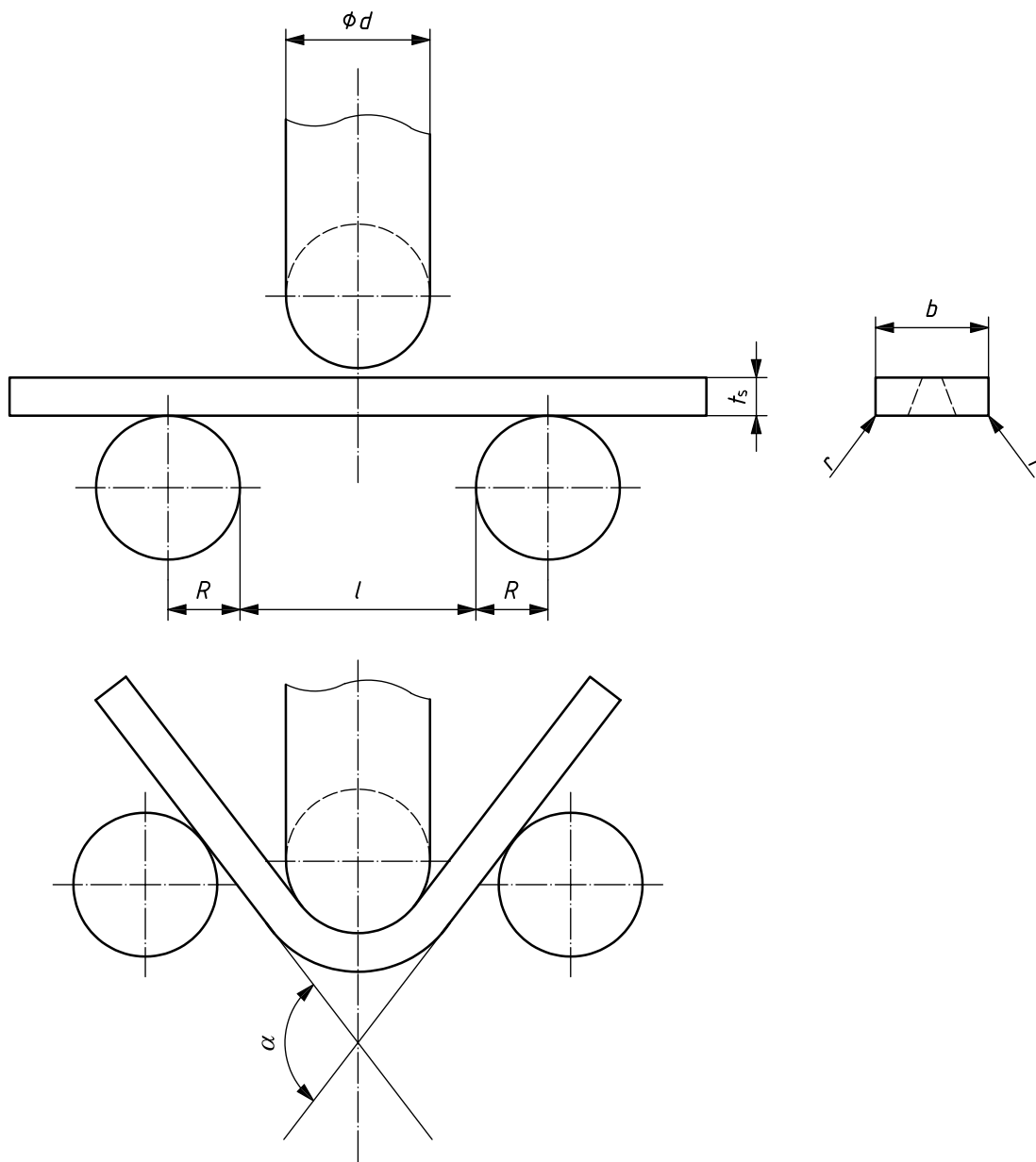
Figure 11 — Transverse face or root bend test



$$d + 2t_s + 3 \leq l \leq d + 3t_s$$

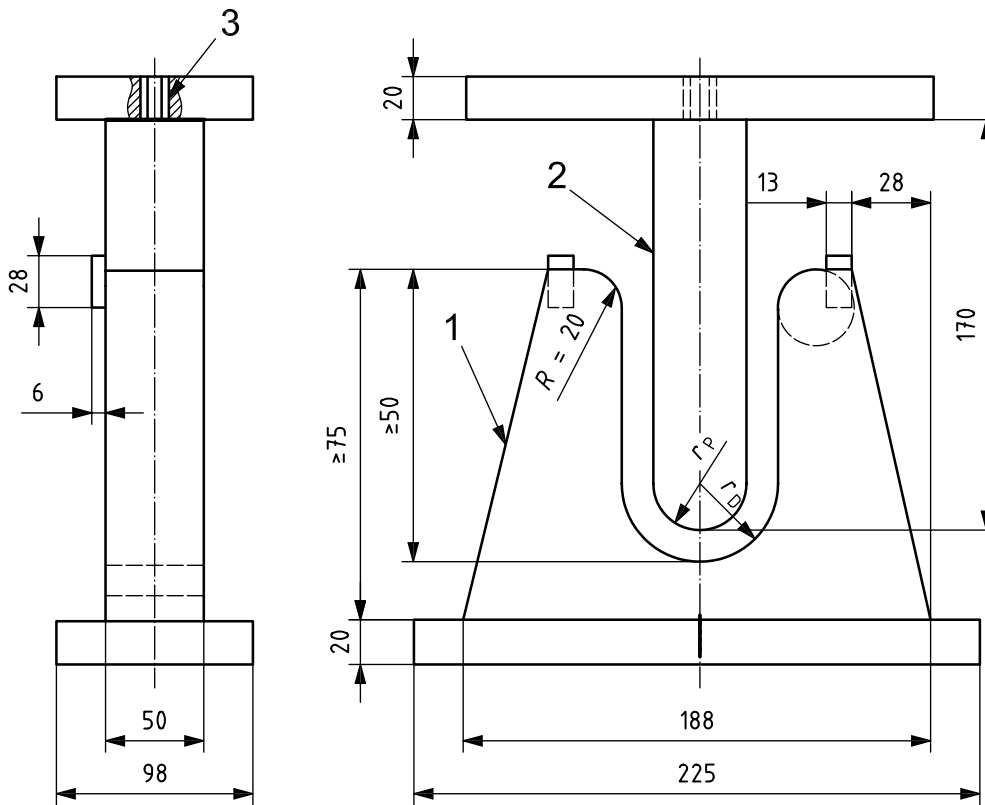
$$d \geq 1,3L_s - t_s$$

Figure 12 — Transverse side bend test



$$d + 2t_s + 3 \leq l \leq d + 3t_s$$

Figure 13 — Longitudinal bend test



Key

- r_P plunger radius
- r_D die radius
- 1 die
- 2 plunger
- 3 tapped hole for attaching plunger to test machine

Figure 14 — Example of shape of U-type jig for bend test of thin specimens (tentative)

6.2.2 Testing with a roller

See Figure 15.

The guided bend test with a roller is an alternative method of testing that may be used for aluminium alloys and for joints in other materials where the weld metal, or one of the materials being joined, has a lower yield point or proof strength than the (other) base material.

The test shall be carried out by firmly clamping one end of the test specimen in a testing device having a roller parallel to a former. The test specimen shall be bent by loading, gradually and continuously, by means of the rotation of the outer roller through an arc centred on the axis of the former.

Dimensions in millimetres

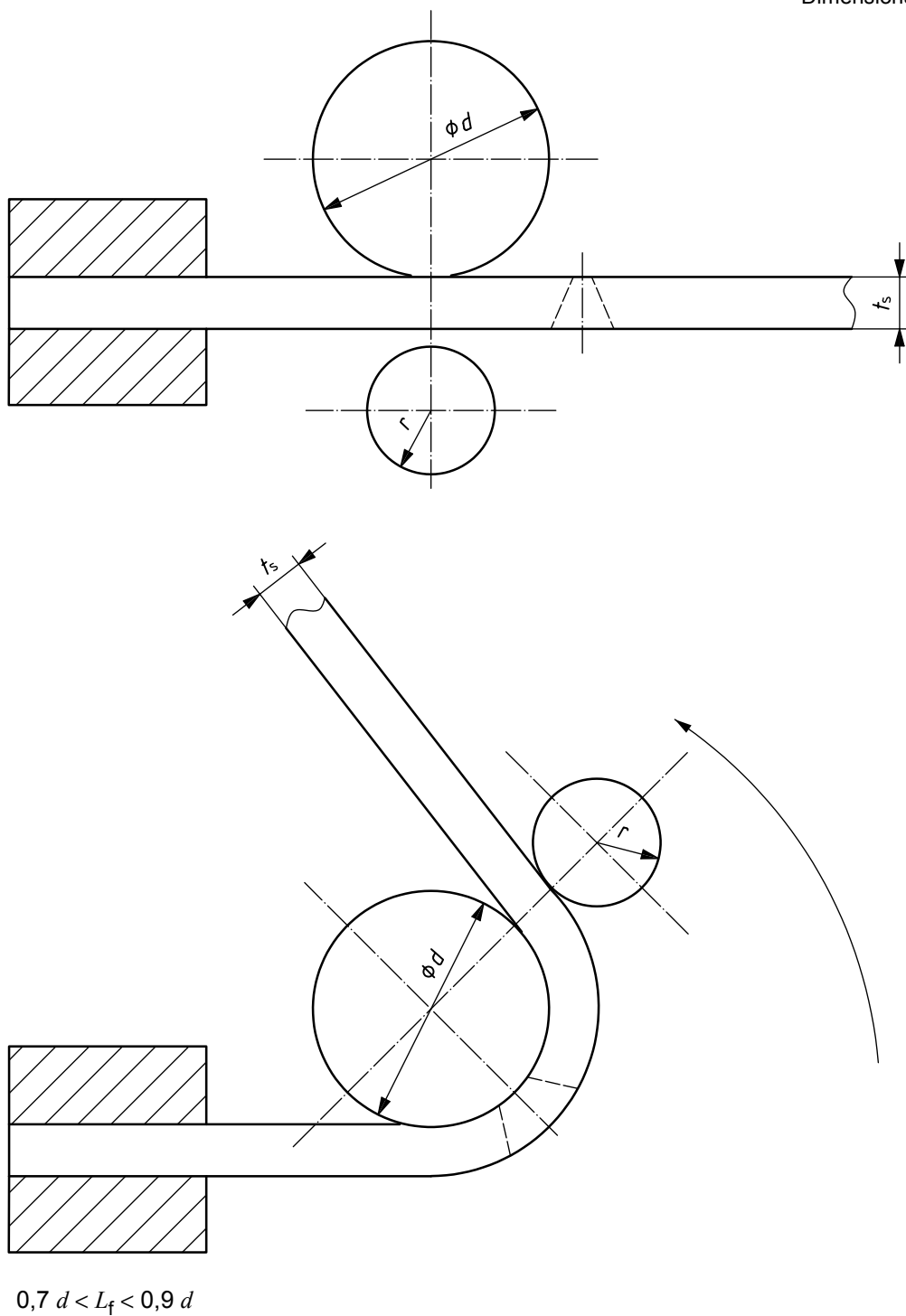


Figure 15 — Method of bend testing using a roller

6.3 Diameter of former and roller

The diameter of the former or the inner roller shall be equal to $4 t_s$ for parent metal with elongation $A \geq 20 \%$. For parent metal with elongation $A < 20 \%$, the following formula shall be applied unless otherwise specified in the relevant application standard:

$$d = \frac{100 \times t_s}{A} - t_s$$

6.4 Distance between rollers

See Figures 11 to 13.

6.5 Bending angle

The test is completed when the test reaches the definition of test completion given in the relevant application standard. Otherwise the following definitions may be applied:

- for Figures 11 to 13, the test is completed when the specimen is ejected from the bottom of the fixture;
- for Figure 14, the test is completed when a 3 mm wire cannot be inserted between the specimen and the lower fixture;
- for Figure 15, the test is completed when the outer roller has been moved 180° from the starting point.

6.6 Bending elongation

When required for measuring elongation, the root or face bend test specimens of steel shall have a gauge length of:

- for fusion welds:

$$L_0 = L_s$$

or

$$L_0 = 2L_s$$

or

$$L_0 = L_s - t_s$$

- for pressure welds, electron beam welds and laser welds:

$$L_0 = t_s$$

or

$$L_0 = 2t_s$$

7 Test results

After bending, both the external surface and the sides of the test specimen shall be examined.

The evaluation of the bend test specimen shall be made and reported in accordance with the relevant application standard.

8 Test report

The test report shall include at least the following information:

- a) reference to this International Standard, i.e. ISO 5173:2009;
- b) identification of the test specimen (marking, type of base material, heat treatment, etc.);
- c) shape and dimensions of the test specimen;
- d) type and symbol of bend test (root and face, transverse or longitudinal, side transverse bend test);
- e) conditions of testing (see Clause 6):
 - test methods (former or roller);
 - diameter of the former;
 - distance between rollers.
- f) testing temperature if not in the temperature range $(23 \pm 5) ^\circ\text{C}$;
- g) type and dimensions of imperfections observed;
- h) bending angle.

An example of a typical test report is given in Annex A.

Annex A
(informative)

Example of a test report

N°

According to pWPS

According to test result “bend test”

test result “.....”

Manufacturer:

Purpose of the examination:

Form of product:

Base material:

Consumable:

Test temperature:

Table A.1 — Bend test in accordance with ISO 5173

Specimen N°/position	Type of test	Dimensions mm	Former diameter mm	Distance between rollers mm	Bend angle °	Original gauge length mm	Elongation %	Remark e.g. fracture appearance

Examiner or examining body:

.....

(name, date and signature)

Approved by:

.....

(name, date and signature)

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