INTERNATIONAL STANDARD

ISO 17641-2

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Destructive tests on welds in metallic materials — Hot cracking tests for weldments — Arc welding processes —

Part 2: Self-restraint tests

Essais destructifs des soudures sur matériaux métalliques — Essais de fissuration à chaud des assemblages soudés — Procédés de soudage à l'arc —

Partie 2: Essais sur éprouvettes auto-bridées

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Foreword

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

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For an explanation on the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the WTO principles in the Technical Barriers to Trade (TBT) see the following URL: Foreword - Supplementary information

The committee responsible for this document is ISO/TC 44, *Welding and allied processes*, Subcommittee SC 5, *Testing and inspection of welds*.

This second edition cancels and replaces the first edition (ISO 17641-2:2005), of which it constitutes a minor amendment.

ISO 17641 consists of the following parts, under the general title *Destructive tests on welds in metallic materials — Hot cracking tests for weldments — Arc welding processes*:

— *Part 1: General*

— *Part 2: Self-restraint tests*

— *Part 3: Externally loaded tests* [Technical Report]

Destructive tests on welds in metallic materials — Hot cracking tests for weldments — Arc welding processes —

Part 2: Self-restraint tests

1 Scope

This part of ISO 17641 specifies the required specimens, the test piece dimensions, and the procedures to be followed to carry out self-restraint hot cracking tests.

The following tests are described:

— T-joint weld cracking test;

— weld metal tensile test;

— longitudinal bend test.

The tests are designed to provide information about the hot cracking sensitivity of weld metals. The tests are not suitable for the assessment of parent materials.

This part of ISO 17641 applies primarily to fully austenitic stainless steels, nickel, nickel base, and nickel copper weld metals. This part of ISO 17641 can also be used for other weld metals.

This part of ISO 17641 describes only how to carry out the tests and report the results. It does not give any acceptance criteria.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 5173, *Destructive tests on welds in metallic materials — Bend tests*

ISO 5178, *Destructive tests on welds in metallic materials — Longitudinal tensile test on weld metal in fusion welded joints*

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

ISO 15614-1, *Specification and qualification of welding procedures for metallic materials — Welding procedure test — Part 1: Arc and gas welding of steels and arc welding of nickel and nickel alloys*

ISO 15792-1, *Welding consumables — Test methods — Part 1: Test methods for all-weld metal test specimens in steel, nickel and nickel alloys*

ISO 17641-1:2004, *Destructive tests on welds in metallic materials — Hot cracking tests for weldments — Arc welding processes — Part 1: General*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 17641-1:2004 apply.

4 Symbols, designations, and units

For the purposes of this part of ISO 17641, the symbols and units given in Table 1 apply.

Table 1 — Symbols, designations, and units

Symbol	Designation	Unit
T-joint weld cracking test		
a_1	Throat thickness of weld bead 1	mm
a_2	Throat thickness of weld bead 2	mm
t_1	Thickness of vertical plate, form C	mm
t_2	Thickness of horizontal plate, form C	mm
Weld metal tensile test		
d	Specimen diameter	mm
L_c	Test length	mm
L_o	Measuring length on the test specimen	mm
L_e	Measuring length on the test specimen after fracture[a]	mm
L_t	Total length	mm
L_{MF}	Total crack length of all detected cracks >0,1 mm	mm
l_1	Length of an individual crack	mm
$MSI_{(TT)}$	Microcracks sensitivity indicator (tensile test)[b]	mm/mm^2
Longitudinal bend test (LBT)		
R	Radius of the test specimen edges >1	mm
B	Width of the test specimen	mm
b_1	Width of outside fusion line	mm
l_1	Length of an individual crack	mm
l_o	Length of crack examination area before bending	mm
L_{MF}	Total crack length of all detected cracks >0,1	mm
L_s	Maximum width of the weld after machining	mm
$MSI_{(LBT)}$	Microcrack sensitivity indicator (longitudinal bend test)[c]	mm/mm^2

[a] $X_1 + X_2 = L_e$ (see Figure 4).

[b] $MSI = L_{MF}/(L_o \times d \times \pi)$.

[c] $MSI = L_{MF}/(b \times l_o)$.

5 Principle

Three test methods are described which are designed to measure the sensitivity of weld metals to the types of hot cracking described in Clause 3. These test methods are described in Table 2.

In all cases, the cracks are generated during the welding of the test pieces. The tensile test and longitudinal bend test are subjected to additional straining which does not generate any new cracks, but widens the cracks formed during the welding which enables them to be more easily detected and measured.

Table 2 — Self-restraint hot cracking tests and applications

Type of test	Types of cracking	Results	Applications
T-joint weld cracking test	Solidification	Qualitative	Qualification of welding consumables Qualification test for welding consumables
Weld metal tensile tests	Solidification	Qualitative or quantitative if microcrack sensitivity index, $MSI_{(TT)}$, is used	Welding procedure qualification Production weld coupon test Qualification of consumables Qualification test for welding consumables
	Liquation		
	Ductility dip		
Longitudinal bend test	Solidification	Qualitative or quantitative if $MSI_{(LBT)}$ is used	Welding procedure qualification Production weld coupon test Qualification of welding consumables Qualification test for welding consumables
	Liquation		
	Ductility dip		

6 Description of the tests

6.1 T-joint weld cracking tests

6.1.1 General

The test procedure applies to a single pass restrained fillet weld. It can be used with the manual shielded metal arc, gas metal arc and tungsten arc welding processes. It is not suitable for high current processes such as submerged arc.

The test method only provides a qualitative assessment (cracks or no cracks) and has a comparatively low sensitivity.

6.1.2 Dimension of the test pieces

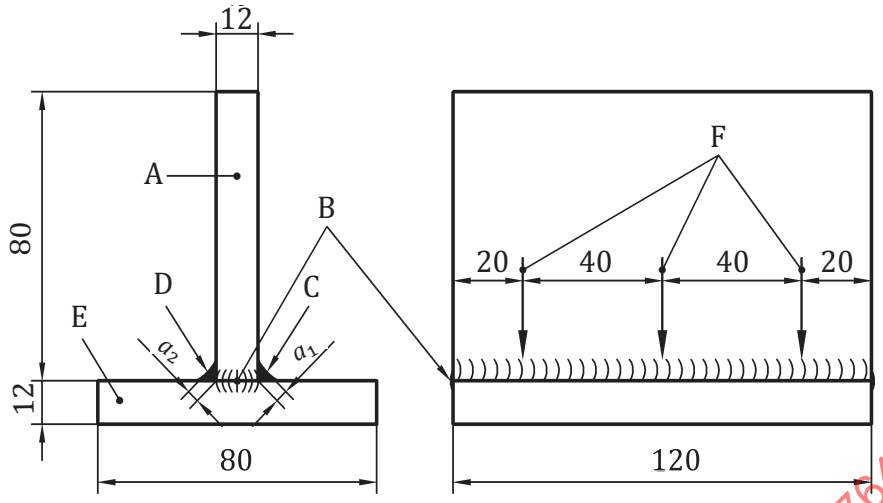
Three types of test (A, B, and C) are specified. Type A is the standard test piece. Types B and C are more highly restrained and are used to simulate more severe conditions.

The dimensions of the test pieces shall be as shown in Figure 1.

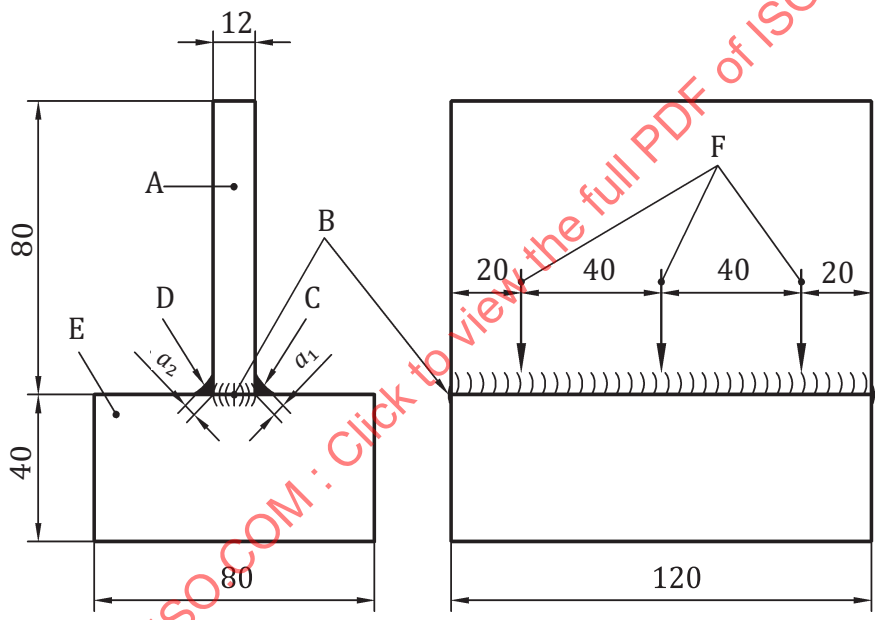
The test pieces shall be made from the parent material for which the consumable is designed (consumable approval test) or that which is to be used in a fabrication (procedure qualification test).

Type B requires the use of a 40 mm thick horizontal plate. If this is not available, then Type C which uses 10 mm thick stiffeners welded on the horizontal plate may be used. The thickness of the horizontal and vertical plate and/or the stiffeners can be modified.

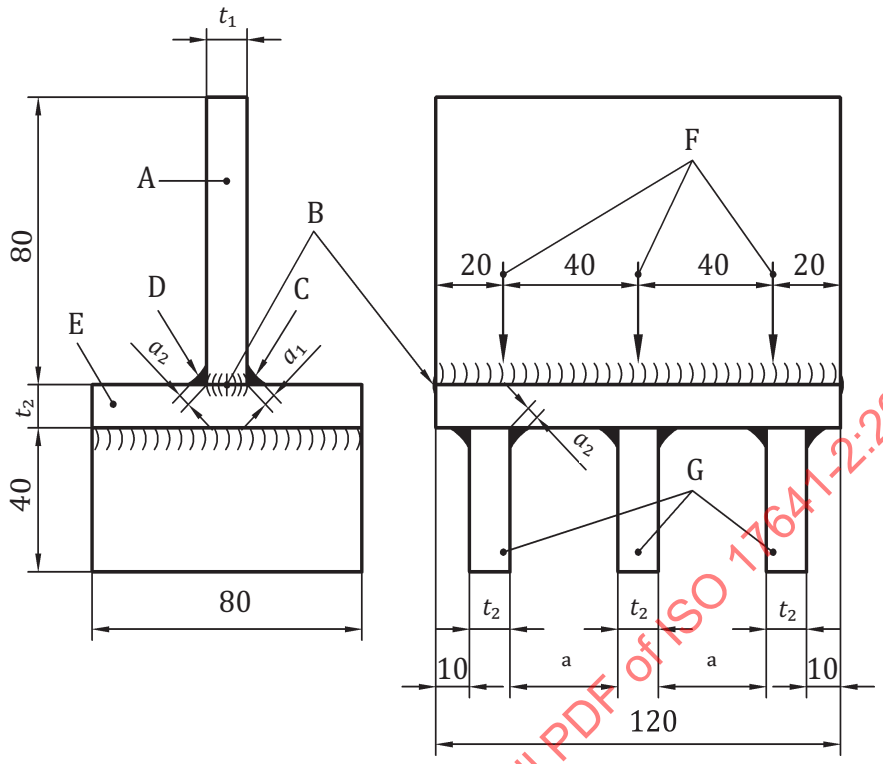
Dimensions in millimetres



a) Type A



b) Type B



c) Type C

Key

A vertical plane
B tack welds
C weld bead 1
D weld bead 2
E horizontal plane
F measuring points
a throat thickness (6 mm)
a Variable, depending on t_2.

For t_1 and t_2: it is recommended that the thickness which is available or requested be used.

Figure 1 — T-joint weld cracking test

6.1.3 Preparation of the test pieces

Any gap between the vertical and horizontal plates will increase the risk of cracking in the test welds. It is therefore important to obtain consistent contact between the two. Grinding or machining the contact faces prior to welding may achieve this.

The test plates in the areas to be welded shall be clean and free from any grease, cutting fluids, paint, or rust which could affect the test results.

6.1.4 Welding of the test pieces

A sound tack weld shall be made on both end surfaces (see Figure 1) to fix the horizontal and vertical plates at the correct 90° angle.

The test welds shall be made in accordance with a written welding procedure specification (WPS). This shall be as specified in ISO 15614-1 or unless otherwise specified. The welding conditions and

parameters shall be appropriate to the parent materials and the welding consumables being used and shall be designed to achieve the minimum specified dimensions of the weld beads. Run-on and run-off plates may be used in order to achieve a consistent weld profile along the overall specimen length.

The first weld bead, a_1, shall be made as a continuous run in the horizontal vertical position PB with a throat thickness of not less than 5 mm. The second weld bead, a_2, shall be started at an interval not exceeding 20 s after completion of the first weld bead.

On completion of welding the slag (if any) of both fillet welds shall be removed. If hammering or grinding is used to help slag removal, care should be taken to ensure that the surfaces of the welds are not damaged to the extent that any cracking is obscured.

6.1.5 Examination of the test piece

Prior to examining the test welds for cracks, the throat thickness of the welds a_1 and a_2 shall be checked at the measuring points specified in Figure 1. Both welds shall satisfy the minimum dimensions given in 6.1.4 and in addition, the throat thickness of weld bead a_1 shall not exceed that of the second bead, a_2, by more than 120 %. Failure to meet the weld bead dimensional requirements shall invalidate the test.

The fillet weld of a valid test piece shall be examined for cracks. This shall be carried out visually at a magnification not exceeding ×5. Liquid dye penetrant testing can be used as an aid to crack detection. The first weld bead, a_1, shall be crack free.

Any cracks found in the second weld bead, a_2, shall be reported. The position, orientation, and length of each crack shall be noted on a test report (see Annex A).

6.1.6 Test report

The test results may be reported in any agreed form and shall make reference to this part of ISO 17641. An example of a suitable test report for T-joint weld cracking tests is given in Annex A.

6.2 Weld metal tensile test

6.2.1 General

The test procedure applies to a multi-pass weld metal. It is suitable for all arc welding processes. The test method provides qualitative assessment and quantitative assessments if the microcrack sensitivity index, $MSI_{(TT)}$, is used.

Applying a load to rupture to a cylindrical all-weld metal test specimen taken from a butt weld opens cracks initiated during welding.

6.2.2 Test specimen

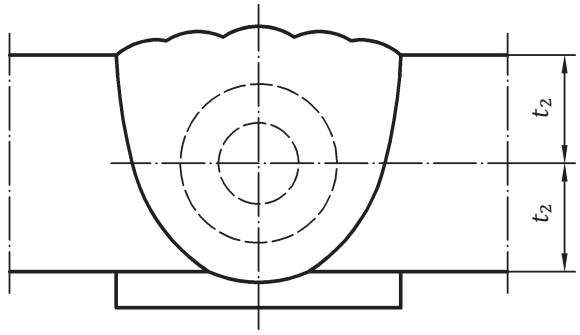
6.2.2.1 Test weld

The test specimen shall be taken from any suitable butt weld large enough to accommodate the test specimen. The butt weld can be that used for other tests, e.g. standard mechanical tests. It shall be made in accordance with a written welding procedure specification (WPS). Unless otherwise specified, this shall be as specified in ISO 15614-1.

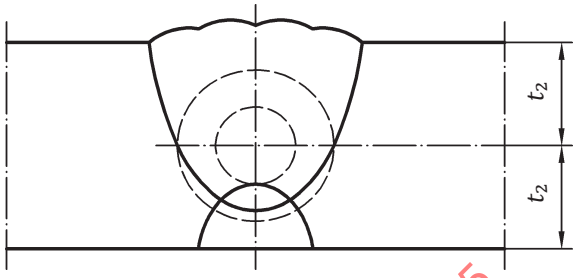
6.2.2.2 Test specimen

A 10 mm diameter standard tensile specimen in accordance with ISO 6892-1 and ISO 5178 shall be machined from the test weld (Figure 2 and Figure 3). The parallel gauge length of the specimen shall consist entirely of weld metal. The test plate cross sections can be macro-etched to ensure that only

weld metal is tested. The specimen shall be clearly identified using a method and in a position which will not affect the test results.



a) All-weld metal test piece according to ISO 15792-1

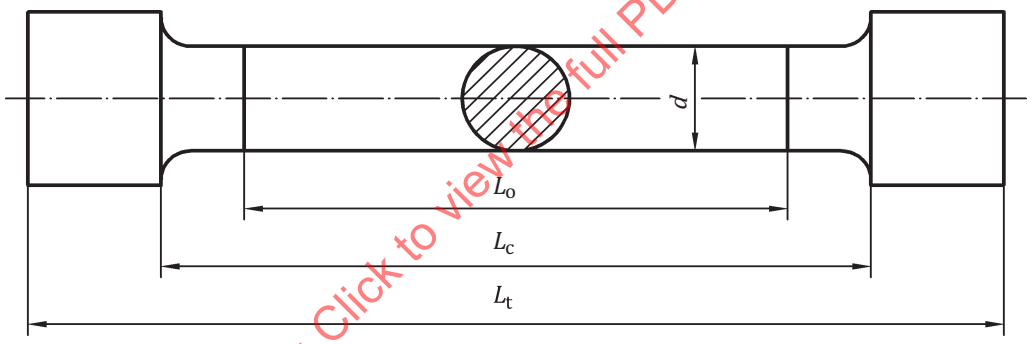


b) Butt weld test piece

Key

t plate thickness

Figure 2 — Extraction of weld metal tensile test specimens from test pieces



Key

d = 10 mm

L_o = 50 mm

L_c = 55 mm

L_t = >75 mm

Figure 3 — Weld metal tensile specimen

6.2.2.3 Testing

Unless otherwise specified, the tensile test shall be carried out in accordance with ISO 5178.

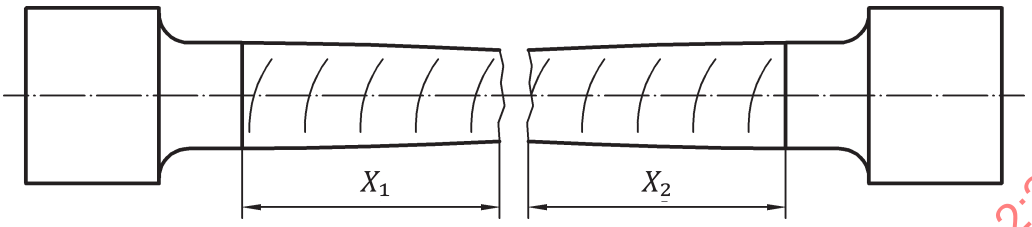
6.2.3 Examination of the test specimen

The examination shall be carried out in the area of the extended gauge length, L_e, as shown in Figure 4 (this region was the original L_o prior to the test). It shall be carried out using suitable magnifying equipment which shall be sufficient to resolve cracks with a length of at least 0,1 mm. The position, length, and orientation of such cracks shall be noted on a test report (see Annex B).

The microcrack sensitivity indicator (tensile test), $MSI_{(TT)}$, can be used to provide a quantitative measure of cracking sensitivity. $MSI_{(TT)}$ is calculated as follows:

$$MSI_{(TT)} = \frac{L_{MF}}{L_o \times 10\pi} \quad (1)$$

where



L_{MF} is the total length of all cracks of length 0,1 mm or greater;

L_o is the measuring length on the test specimen.

NOTE $L_e = X_1 + X_2$

Figure 4 — Area of examination, L, in a tested weld metal tensile specimen

6.2.4 Test report

The test results may be reported in any form and shall make reference to this part of ISO 17641. An example of a suitable test report for weld metal tensile test is given in Annex B.

6.3 Longitudinal bend test

6.3.1 General

The test procedure applies to a multi-pass weld metal. It is suitable for all arc welding processes. The test method provides qualitative assessments and quantitative assessments if the microcrack sensitivity index, $MSI_{(LBT)}$, is used.

Bending a test specimen taken longitudinally from a butt weld opens up cracks initiated during welding. The bending is carried out in a manner which places one surface of the test specimen in tension.

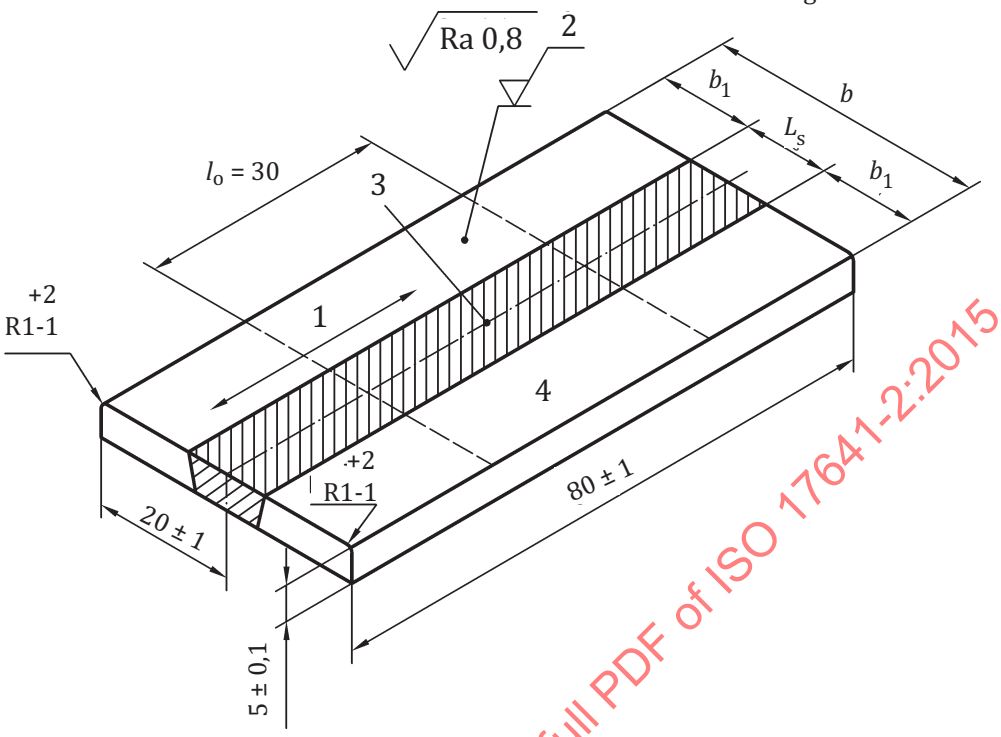
6.3.2 Test weld

The test specimen shall be taken from a suitable butt weld large enough to accommodate the test specimen. The butt weld can be that used for other tests, e.g. standard mechanical tests. The butt weld shall be made in accordance with a written welding procedure specification (WPS). Unless otherwise specified, this shall be according to ISO 15614-1.

6.3.3 Test specimen

The specimen having dimensions shown in Figure 5 shall be machined from the test weld (see Figure 6) in accordance with the requirements of ISO 5173, unless otherwise specified. The specimen shall be clearly identified using a method and in a position which will not affect the test results.

Dimensions in millimetres
surface roughness values in micrometres



Key

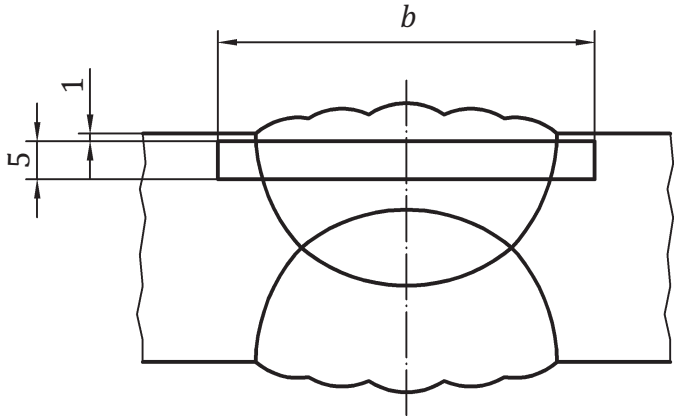
1 direction of grinding
2 ground
3 area of hot cracks examination
4 surface

NOTE 1 For specimen bending: bending mandrel Ø = 20 mm, bending angle ≥120°.

NOTE 2 For specimen investigation: under stereomicroscope 10 fold to 25 fold.

Figure 5 — Longitudinal bend specimen

Dimensions in millimetres



Key

b butt weld test piece

Figure 6 — Extraction of longitudinal end test specimens from test piece

6.3.4 Surface preparation

The specimen surface shall be prepared by machining and grinding in the longitudinal direction to a finish of 6,3 µm or better. Surface marks perpendicular to the direction of welding which might initiate spurious cracks shall be avoided. Corners shall be radiused as shown in Figure 5.

Light etching may be used to reveal the weld area.

6.3.5 Testing

The bend testing shall be carried out in accordance with ISO 5173, except that the bending mandrel diameter shall be 20 mm (4 × specimen thickness). The bend angle shall be a minimum of 120°.

6.3.6 Examination of the test specimen

The examination for cracks shall be carried out in the specified test area as shown in Figure 5 (this region is defined by the original l_o prior to the test). The examination shall be carried out using suitable magnifying equipment at a magnification range of ×10 to ×25. The magnification chosen shall be sufficient to resolve cracks with a length of at least 0,1 mm. The magnification should be included in the test report. The position, length, and orientation of such cracks shall be noted on a test report (see Annex C).

The microcrack sensitivity index (longitudinal bend test), $MSI_{(LBT)}$, can be used to provide a quantitative measure of cracking sensitivity.

$MSI_{(LBT)}$ is calculated as follows:

$$MSI_{(LBT)} = \frac{L_{MF}}{b \times l_o} \tag{2}$$

where

L_{MF} is the total length of all cracks of 0,1 mm or greater;

b is the initial width of the specimen (undeformed) = 40 mm and l_o is the initial length of the test area (undeformed) = 30 mm.

6.3.7 Test report

The test results may be reported in any agreed form and shall make reference to this part of ISO 17641. An example of a suitable test report for the longitudinal bend test is given in Annex C.