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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

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 17641-2 was prepared by the European Committee for Standardization (CEN) in collaboration with Technical Committee ISO/TC 44, *Welding and allied processes*, Subcommittee SC 5, *Testing and inspection of welds*, in accordance with the Agreement on technical cooperation between ISO and CEN (Vienna Agreement).

Throughout the text of this document, read “...this European Standard...” to mean “...this International Standard...”.

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]

Annex ZA provides a list of corresponding International and European Standards for which equivalents are not given in the text.

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## Foreword

This document (EN ISO 17641-2:2005) has been prepared by Technical Committee CEN/TC 121 "Welding", the secretariat of which is held by DIN, in collaboration with Technical Committee ISO/TC 44 "Welding and allied processes".

This European Standard shall be given the status of a national standard, either by publication of an identical text or by endorsement, at the latest by September 2005, and conflicting national standards shall be withdrawn at the latest by September 2005.

EN 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<sup>1</sup>

According to the CEN/CENELEC Internal Regulations, the national standards organizations of the following countries are bound to implement this European Standard: Austria, Belgium, Cyprus, Czech Republic, Denmark, Estonia, Finland, France, Germany, Greece, Hungary, Iceland, Ireland, Italy, Latvia, Lithuania, Luxembourg, Malta, Netherlands, Norway, Poland, Portugal, Slovakia, Slovenia, Spain, Sweden, Switzerland and United Kingdom.

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<sup>1</sup> Part 3 will be published as a Technical Report with the same general title.



## 1 Scope

This standard 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.

The standard applies primarily to fully austenitic stainless steels; nickel, nickel base and nickel copper weld metals. The standard can also be used for other weld metals.

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

## 2 Normative references

The following referenced documents are indispensable for the application 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.

EN 876, *Destructive tests on welds in metallic materials - Longitudinal tensile test on weld metal in fusion welded joints*

EN 910, *Destructive tests on welds in metallic materials - Bend tests*

EN 1597-1, *Welding consumables - Test methods - Part 1: Test piece for all-weld metal test specimens in steel, nickel and nickel alloys*

EN 10002-1, *Metallic materials - Tensile testing - Part 1: Method of test at ambient temperature*

EN 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 15614-1:2004)*

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

## 3 Terms and definitions

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

## 4 Symbols, designations and units

For the purposes of this European Standard, 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 beat 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 <sup>a</sup>	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) <sup>b</sup>	mm/mm <sup>2</sup>
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) <sup>c</sup>	mm/mm <sup>2</sup>
<sup>a</sup> $X_1+X_2=L_e$ , see Figure 4 <sup>b</sup> $MSI = L_{MF} / L_o \times d \times \pi$ <sup>c</sup> $MSI = L_{MF} / b \times l_o$		

## 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
	Liquation		Production weld coupon test
	Ductility dip		Qualification of consumables Qualification test for welding consumables
Longitudinal bend test	Solidification	Qualitative or quantitative if $MSI_{(LBT)}$ is used	Welding procedure qualification
	Liquation		Production weld coupon test
	Ductility dip		Qualification of welding consumables Qualification test for welding consumables

## 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.

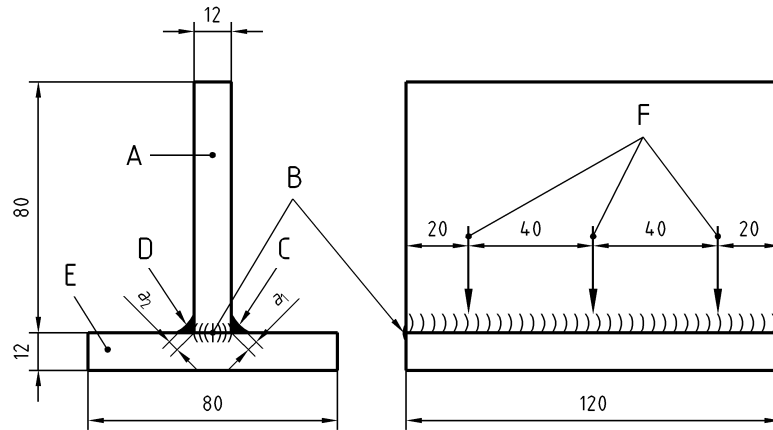
#### 6.1.2 Dimension of the test pieces

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).

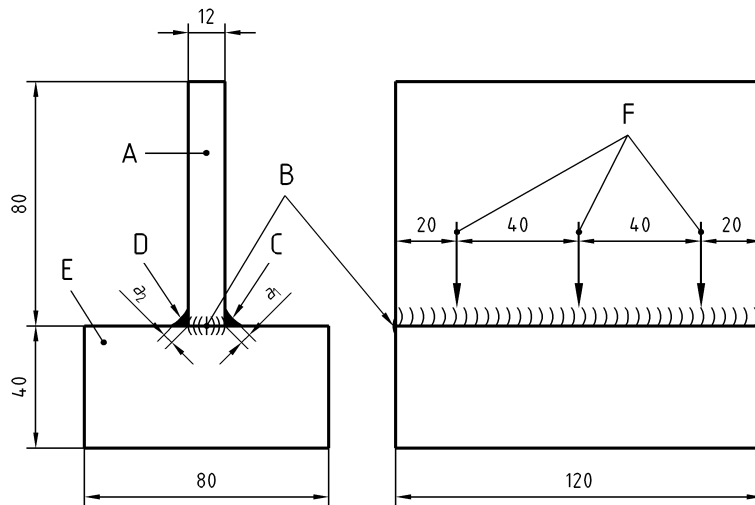
Type B requires the use of a 40 mm thick horizontal plate. If this is not available, then Type C, which uses 10 mm thick stiffeners welded on the horizontal plate, may be used. The thickness of the horizontal and vertical plate and/or the stiffeners can be modified.



**Key**

- A Vertical plate
- B Tack welds
- C Weld bead 1
- D Weld bead 2
- E Horizontal plate
- F Measuring points

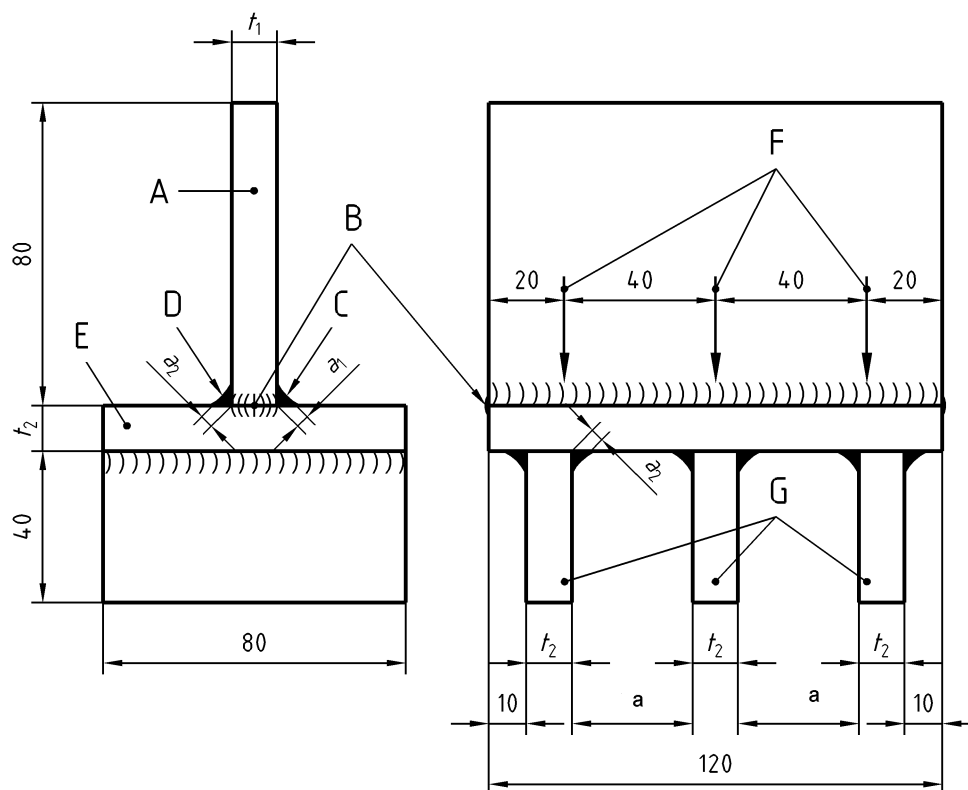
Figure 1 a) Type A



**Key**

- a Throat thickness (6 mm)
- A Vertical plane
- B Tack welds
- C Weld bead 1
- D Weld bead 2
- E Horizontal plate
- F Measuring points

Figure 1 b) Type B



### Key

- A Vertical plane
- B Tack welds
- C Weld bead 1
- D Weld bead 2
- E Horizontal plate
- F Measuring points
- G Stiffeners
- a Variable, depending on  $t_2$

NOTE  $t_1$ ;  $t_2$  It is recommended to use the thickness which is available or requested.

Figure 1 c) Type C

Figure 1 — T-joint weld cracking test type A, B and C

### 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 EN 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 x5. Liquid dye penetrant testing may 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 standard. 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.

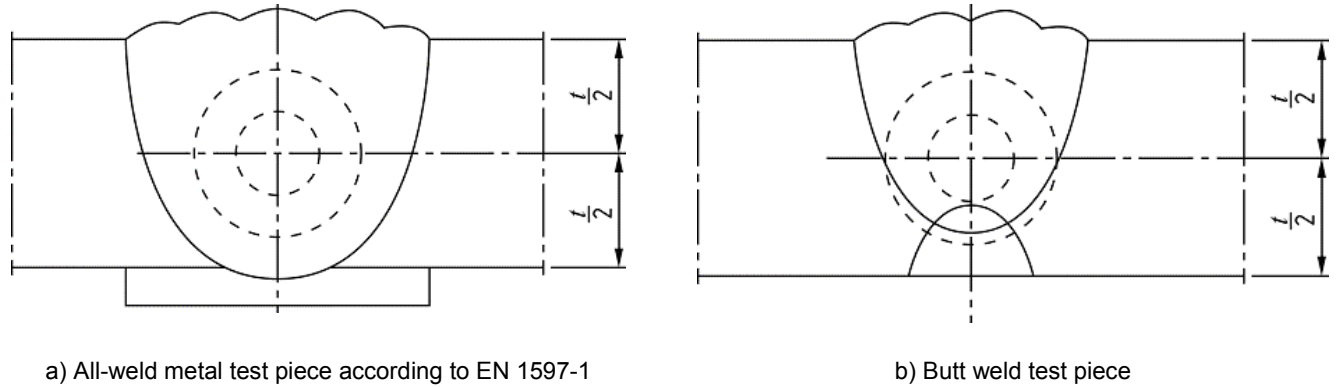
#### 6.2.2 Test specimen

##### 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 may 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 EN ISO 15614-1.

**6.2.2.2 Test specimen**

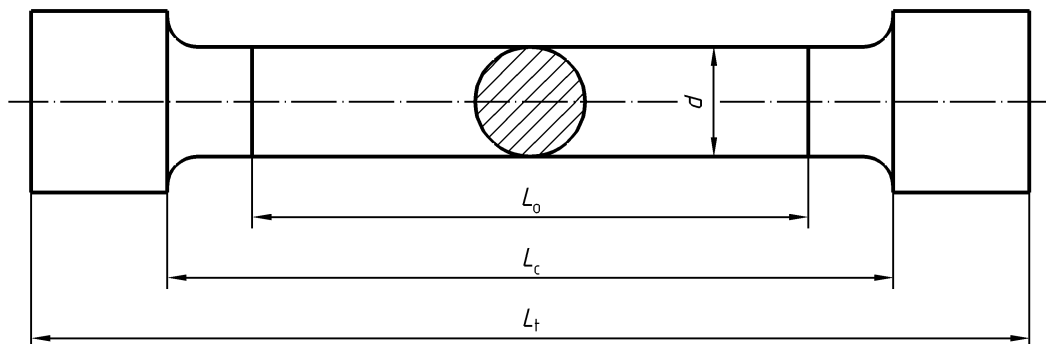
A 10 mm diameter standard tensile specimen in accordance with EN 10002-1 and EN 876 shall be machined from the test weld (Figures 2 and 3). The parallel gauge length of the specimen shall consist entirely of weld metal. The test plate cross sections can be macro-etched to ensure that only weld metal is tested. The specimen shall be clearly identified using a method and in a position which will not affect the test results.



**Key**

t Plate thickness

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



NOTE  $d = 10 \text{ mm}$   
 $L_0 = 50 \text{ mm}$   
 $L_c = 55 \text{ mm}$   
 $L_t > 75 \text{ mm}$

**Figure 3 - Weld metal tensile specimen**

**6.2.2.3 Testing**

Unless otherwise specified, the tensile test shall be carried out in accordance with EN 876.

**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  $L_0$  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 0,1mm. The position, length and orientation of such cracks shall be noted on a test report (see Annex B).

## ISO 17641-2:2005(E)

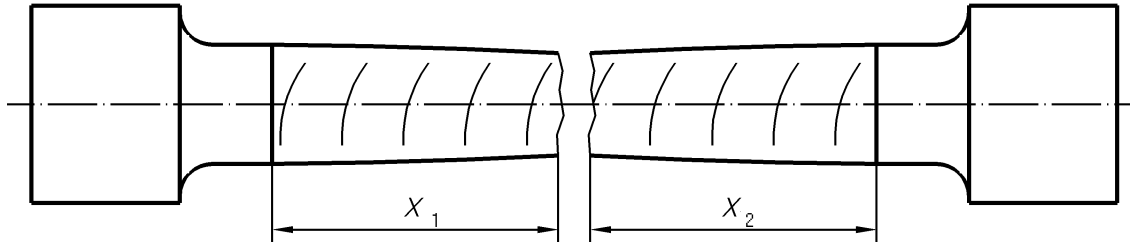
The Microcrack Sensitivity Indicator (Tensile Test) ( $MSI_{(TT)}$ ) may be used to provide a quantitative measure of cracking sensitivity. The  $MSI_{(TT)}$  is calculated as follows:

$$MSI_{(TT)} = L_{MF}/L_o \times 10\pi$$

where

$L_{MF}$  is the total length of all cracks of length 0,1mm 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 standard. 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.

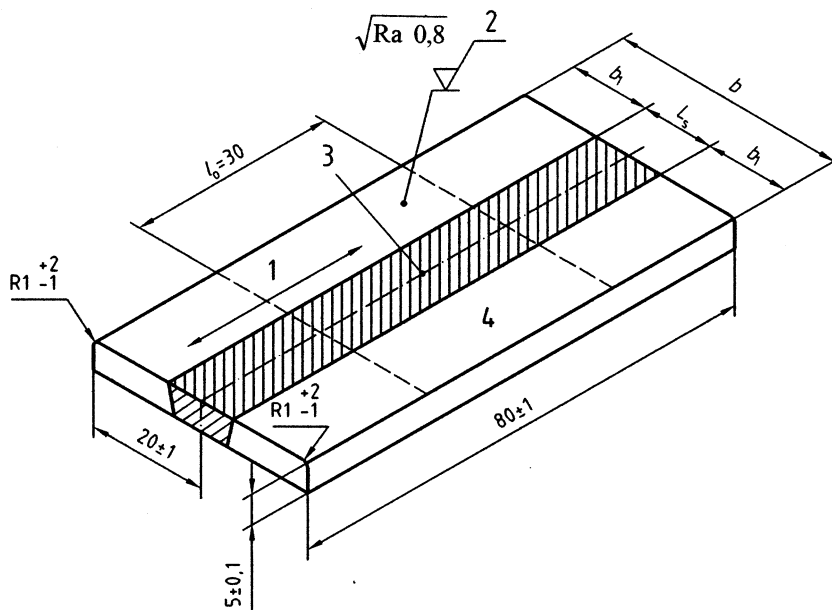
### 6.3.2 Test weld

The test specimen shall be taken from a suitable butt weld large enough to accommodate the test specimen. The butt weld may 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 EN ISO 15614-1.

### 6.3.3 Test specimen

The specimen having dimensions shown in Figure 4 shall be machined from the test weld (Figures 5 and 6) in accordance with the requirements of EN 910 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**

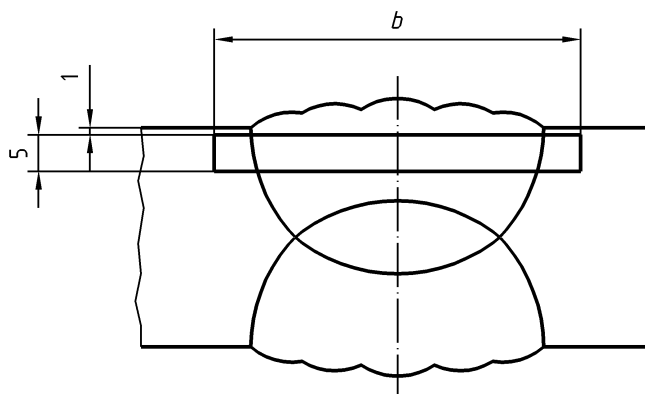
- 1 Direction of grinding
- 2 Ground
- 3 Area of hot cracks examination
- 4 Surface

NOTE 1 For specimen bending: Bending mandrel  $\varnothing = 20$  mm, bending angle  $\geq 120^\circ$

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  $\mu$  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 4.

Light etching may be used to reveal the weld area.

### 6.3.5 Testing

The bend testing shall be carried out in accordance with EN 910 except that the bending mandrel diameter shall be 20 mm (4 x 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 4 (This region is defined by the original  $L_0$  prior to the test). The examination shall be carried out using suitable magnifying equipment at a magnification range of x 10 to x 25. The magnification chosen shall be sufficient to resolve cracks with a length of at least 0,1mm. 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)  $MSI_{(LBT)}$  may be used to provide a quantitative measure of cracking sensitivity.

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

$$MSI_{(LBT)} = L_{MF}/b \times l_0$$

Where

$L_{MF}$  is the total length of all cracks of 0,1mm or greater and  $b$  is the initial width of the specimen (undeformed) = 40 mm and  $l_0$  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 standard. An example of a suitable test report for the longitudinal bend test is given in Annex C.



## Annex A (informative)

### Test report for T-joint weld cracking test

According to WPS

No.

Manufacturer:

Purpose of examination:

Parent metal:

Filler metal:

Magnification used:

**Table A.1 — T-joint weld cracking test**

Test Specimen No./form	Dimensions				Cracks		
	Plates		Fillet welds		Number	Length, $L_1$	Positions
	$t_1$ (mm)	$t_2$ (mm)	$a_1$ (mm)	$a_2$ (mm)			

Examiner or examining body:

Verified by:

(name, date and signature)

(name, date and signature)

**Annex B**  
(informative)

**Test report for weld metal tensile test**

According to WPS

No.

Manufacturer:

Purpose of examination:

Parent metal:

Filler metal:

Magnification used:

**Table B.1 — Weld metal tensile test**

Specimen No./position	Dimensions		Cracks		$L_{MF}$ (mm)	$MSI=L_{MF}/L_0 \times d \times \pi$ (mm/mm <sup>2</sup> )
	$d$ (mm)	$L_0$ (mm)	Number	Length, $l_1$ (mm)		

Examiner or examining body:

Verified by:

(name, date and signature)

(name, date and signature)

NOTE  $d = 10$  mm for standard specimen

## Annex C (informative)

### Test report for longitudinal bend test

According to WPS

No.

Manufacturer:

Purpose of examination:

Parent metal:

Filler metal:

Magnification used:

**Table C.1 —Longitudinal bend test**

Test Specimen No./position	Dimensions				Cracks		$L_{MF}$ (mm)	MSI = $L_{MF}/L_O \times b$ (mm/mm <sup>2</sup> )
	$L_s$ (mm)	$b_1$ (mm)	$b = 2 \times b_1 + L_s$ (mm)	$l_o$ (mm)	Number	Length, $l_1$ (mm)		

Examiner or examining body:

Verified by:

(name, date and signature)

(name, date and signature)

**Annex ZA**  
(normative)

**List of corresponding European and International Standards for which  
equivalents are not given in the text**

EN 876	ISO 5178, <i>Destructive tests on welds in metallic materials - Longitudinal tensile test on weld metal in fusion welded joints</i>
EN 910	ISO 5173, <i>Destructive tests on welds in metallic materials - Bend tests</i>
EN 1597-1	ISO 15792-1, <i>Welding consumables - Test methods - Part 1: Test methods for all-weld metal test specimens in steel, nickel and nickel alloys</i>
EN 10002-1	ISO 6892, <i>Metallic materials - Tensile testing at ambient temperature</i>



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