EUROPEAN STANDARD

NORME EUROPÉENNE

EUROPÄISCHE NORM

EN 10160

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English version

Ultrasonic testing of steel flat product of thickness equal or greater than 6 mm (reflection method)

Contrôle ultrasonore des produits plats en acier d'épaisseur égale ou supérieure à 6 mm (méthode par réflexion)

Ultraschallprüfung von Flacherzeugnissen aus Stahl mit einer Dicke größer oder gleich 6 mm (Reflexionsverfahren)

This European Standard was approved by CEN on 3 March 1999.

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This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CEN member into its own language and notified to the Central Secretariat has the same status as the official versions.

CEN members are the national standards bodies of Austria, Belgium, Czech Republic, Denmark, Finland, France, Germany, Greece, Iceland, Ireland, Italy, Luxembourg, Netherlands, Norway, Portugal, Spain, Sweden, Switzerland and United Kingdom.

Contents

Foreword

This European Standard has been prepared by Technical Committee ECISS/TC 2 "Steel - Physico-chemical and non-destructive testing", the secretariat of which is held by AFNOR.

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of an identical text or by endorsement, at the latest by January 2000, and conflicting national standards shall be withdrawn at the latest by January 2000.

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

1 Scope

This European Standard describes a method for the ultrasonic testing of uncoated flat steel product for internal discontinuities. It is applicable to flat product in nominal thickness range of 6 mm to 200 mm of non-alloyed or alloyed steel, excluding austenitic or austenoferritic steels. However, this standard may be applied to the latter types of steels provided that the difference between the amplitude of the noise signal and that of the echo detection threshold is sufficient for the limit fixed.

This standard also defines four quality classes for the flat product body (classes S_0, S_1, S_2 and S_3) and 5 classes (E_0, E_1, E_2, E_3, E_4) for the edges in accordance with the criteria specified in clause 9.

Other methods of testing (e.g. by transmission) or other test equipments may be used at the manufacturer's discretion provided that they give identical results to those obtained under the conditions of this standard. In the event of a dispute, only the method defined in this standard shall prevail.

Testing of flat product of thickness less than 6 mm may be the subject of special agreements between the parties concerned.

The inspection is normally carried out in the place of production or on the premises of the supplier. If specified on the order, the inspection may take place in the presence of the purchaser or his representative [1)].

A list of equivalent terms in several European languages is given in annex A.

2 Normative references

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies.

EN 473, *Qualification and certification of NDT personnel - General principles*

prEN 1330-4, *Non destructive testing - Terminology - Part 4 : Terms used in ultrasoning testing*

3 Terms and definitions

For the purposes of this European Standard, the definitions given in prEN 1330-4 and the following definitions apply:

3.1
internal discontinuity
any imperfection lying within the thickness of the flat product, e.g planar or laminar imperfection, single-plane or multi-plane inclusion bands or clusters

NOTE It is referred in the text as discontinuity.

3.2
defect
unacceptable internal discontinuity, i.e. exceeding the specified maximum size or population density limits

3.3
Population density
the number of individual internal discontinuities of a size greater than a specified minimum size and less than a specified maximum size per specified area of body or length of edge zone

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1) In this case, all steps should be taken to ensure that the production process is not disturbed.

3.4
manual and assisted manual testing
testing by an operator applying an ultrasonic probe, or probes, to the flat product surface, manually executing the appropriate scanning pattern on the flat product surface and visually assessing ultrasonic signal indications on the electronic equipment screen either by direct viewing or by built-in signal amplitude alarm devices

3.5
automatic and semi-automatic testing
testing using a mechanized means of applying the ultrasonic probe or probes to, and executing the appropriate scanning pattern on the flat product surface, together with ultrasonic signal indication evaluation by electronic means. Such testing can be either fully automatic with no operator involvement, or semi-automatic when the operator performs basic equipment operation functions

4 Principle

The method used is based on the reflection of ultrasonic waves (generally longitudinal), the mean direction of which is perpendicular to the surface of the product. The examination consists of :

a) locating any discontinuity by comparing the amplitude of the discontinuity echo with the amplitude of the echo of a flat-bottomed hole of a given diameter and located at the same depth as the discontinuity.

NOTE Only those discontinuities giving an echo at least equivalent in amplitude to that of the echo obtained with the reference flat-bottomed hole are taken into consideration ;

b) then determining its area, the contour of the discontinuity being defined by the positions of the centre of the probe corresponding to a echo amplitude of half the maximum amplitude of the discontinuity under consideration (6 dB method).

The examination is carried out during the first ultrasonic scan for all the flat product thicknesses and from one side only.

5 Personnel

Testing is carried out by qualified personnel under the responsability of a level 3 individual certified in accordance with EN 473.

6 Apparatus

6.1 Description

The detection apparatus shall be equipped with an oscilloscope screen allowing the path of the ultrasonic waves in the flat product to be followed. The oscillograms shall be clearly visible, the peaks corresponding to the successive echoes being sharp and very clear ; the apparatus shall be suitably calibrated and shall be equipped with an amplifier marked in decibels.

Both ultrasonic testing apparatus with display monitor and amplifier control graduated in dB, or apparatus without display monitor can be used. Apparatus without display monitor shall be able to carry out automatic amplitude testing and evaluation and their unit of measurement shall be calibrated in dB.

It shall be possible to regulate amplification, power and time base.

The apparatus includes at least one probe which may be either a probe with a single transducer serving for both emission and reception (single probe) or a double transducer probe (separate emission-reception transducers). The mean direction of the waves emitted and received shall be perpendicular to the surface of the product.

The probe shall have a frequency and dimensions such that the required sensitivity can be guaranteed throughout the extent of the test field.

The single probes shall be such that their dead zone is as small as possible, i.e. 15 % of the flat product thickness or 15 mm whichever is the smaller. The focusing zone of the double transducer probes shall be adapted to the thickness of the flat product.

The main dimensions of probes are 10 mm to 25 mm in diameter and the probes shall have a nominal frequency in the range of 2 MHz to 5 MHz. Probes of larger dimension and of a nominal frequency that is outside the range of 2 MHz to 5 MHz may be used for automatic or semi-automatic testing and/or when the flat product exhibits high attenuation provided that the main requirements of this standard are met.

The type of the probe depends on the thickness of the flat product as given in table 1 :

Table 1 - Type of probe

Nominal thickness of the flat product (e) or depth of any discontinuity zone mm	**Type of probe**
$6 \leq e < 60$	Double transducer probe
$60 \leq e \leq 200$	Single or double transducer probe [a) b)]
a) In the event of a dispute, the type of probe to be used shall be the subject of an agreement. b) Where automatic testing is carried out using immersion or water column techniques, it is permissible to use single crystal probes < 60 mm thick.	

The probe may be either hand held, or mounted on a continuous testing apparatus with a scanning speed sufficiently low for the discontinuities to be easily located taking into account the display delay of the screen, or fitted with a device which indicates the discontinuity.

When double transducer probes are used, the orientation of the barrier separating the two transducers shall be perpendicular to the scanning direction.

The verification of the apparatus shall be carried out in accordance with the relevant national standards.

6.2 Adjustment of the apparatus

Adjustment of the apparatus for use particularly requires that the time base, power and amplification be determined.

The time base is adjusted to a value at which the distance, on the oscilloscope screen, between the emission echo and back-wall echo is sufficient to allow a defect echo to be clearly detected between them.

At least, two back-wall echoes should be displayed.

The power and amplification are adjusted in conjunction on a sound area which does not give any discontinuity echo. The first back-wall echo shall then be brought up to the maximum amplitude compatible with the height of the screen in the field of linearity of the apparatus (generally between 80 % and 100 % full screen height).

The system shall be checked at least once every 8 h.

7 Coupling conditions - Surface condition of the flat product

The coupling medium shall ensure an adequate contact between the probe and the surface of the flat product. Water is normally used but other coupling media (e.g. oil, paste) may be used at the discretion of the supplier.

The surface condition shall permit at least two successive back-wall echoes to be distinguished when the probe is placed on any area free from internal discontinuities. The flat products are normally examined without any special preparation of the surface.

8 Scanning plan

8.1 General

For the flat product body, the testing is based on statistical methods, unless otherwise specified in the order.

According to the quality class , scanning of the flat product shall be carried out in accordance with 8.2 and/or 8.3.

By agreement at the time of order, a scanning with a defined scan coverage or a scanning of all body part of the flat product may be provided, the operating conditions being included in the agreement.

8.2 Testing of the flat product body

8.2.1 Class S_0 and S_1 flat product

Scanning comprises continuous examination along the lines of a grid made of a 200 mm square parallel to the edges of the flat product, or along parallel or oscillating lines distributed uniformly over the area, giving the same degree of control.

8.2.2 Class S_2 and S_3 flat product

Scanning comprises continuous examination along the lines of a grid made of a 100 mm square parallel to the edges of the flat product, or along parallel or oscillating lines distributed uniformly over the area, giving the same degree of control.

8.3 Testing of the flat product edges

Scanning comprises a full examination of a zone in accordance with table 2 over the four edges of the flat product.

Table 2 - Zone width for flat product edges

Thickness of the flat product e mm	Zone width mm
$6 \leq e < 50$	50
$50 \leq e < 100$	75
$100 \leq e \leq 200$	100

9 Procedure

9.1 Sensitivity and range setting

For each type of probe, curves shall be used giving :

a) the change in the amplitude of the back-wall echo as a function of the thickness of the flat product ;

b) the change in the amplitude of the echo of the flat-bottomed hole as a function of its depth, for holes of diameter :

— 11 mm for classes S_0, S_1, E_0 and E_1 ;

— 8 mm for classes S_2, E_2 and E_3 ;

— 5 mm for classes S_3 and E_4.

The bottom of the hole shall be as flat as practicable, parallel to the ultrasound entry surface and free from pits or score markes that significantly degrade its ultrasonic reflectivity. The tolerance on the diameter of the flat bottomed hole or width of recess shall be + 5 %.

The use of rectangular recesses is permitted provided that the length and width of the recess are choosen to provide an ultrasonic signal response essentially equivalent to that obtained from the stipulated flat bottomed hole using the same equipment/transducer type combination.

When testing with a double-transducer probe, only the 5 mm diameter hole is used for all the qualities as the characteristic curves corresponding to the 8 mm and 11 mm diameter holes become confused with the curve of the back-wall echo.

These curves shall be determined using blocks (graduated block for the curve showing the variation in the amplitude of the back-wall echo and blocks comprising the flat-bottomed holes at different depths for the characteristic curves for 11 mm, 8 mm and 5 mm diameters). The blocks are made of carbon steel with a homogenous structure and each curve shall be determined from at least five points distributed over the entire field of use of the probe. All these curves can be supplied by the manufacturer of the probe.

Thus, for a flat product of given thickness, the method consists of adjusting the amplitude of the back-wall echo to the value given by the curve for the variation of the back-wall echo amplitude and comparing the amplitude of the discontinuity echo with the characteristics curves (for 11 mm, 8 mm and 5 mm diameters) in accordance with the class selected. Only discontinuities for which the amplitude of the echo is greater than that of the characteristic curve shall be taken into account.

9.2 Determination of the area of discontinuities

9.2.1 Testing the flat product body

9.2.1.1 Testing with double transducer probes

The area of all the discontinuities giving responses that exceeded the characteristic curve shall be determined using the 6 dB technique, i.e. the contour of the discontinuity being defined as the positions of the centre of the probe when the response from the discontinuity is equal to half the maximum amplitude. A rectangle that encompasses the whole of the discontinuity is then determined, the major dimension of which is called the length of the discontinuity and the minor dimension the width of the discontinuity. The area of the rectangle is also calculated.

The area of the rectangle defines the area S of the discontinuity. Two nearby discontinuities shall be considered to represent a single discontinuity, the area being equal to the sum of the two if the distance between them is less than or equal to the length of the smaller of the two.

9.2.1.2 Testing with single probes

The test consists of :

a) for class S_0 and S_1 flat product : determination of the area in accordance with the method defined in 8.2.1.1 ;

b) for class S_2 and S_3 flat product : simply counting of the discontinuities which can be done when they are detected using the characteristic curves for 5 mm, 8 mm and 11 mm diameter holes.

The following is thus determined :

— for class S_2 : the number of discontinuities giving echoes with an amplitude greater than the 11 mm diameter curve and the number N_2 of discontinuities (Table 4) giving echoes with an amplitude between characteristic curves for the 8 mm and 11 mm diameter holes ;

— for class S_3 : the number of discontinuities giving echoes with an amplitude greater than the 8 mm diameter curve and the number N_3 of discontinuities (Table 4) giving echoes with an amplitude between characteristic curves for the 5 mm and 8 mm diameter holes.

9.2.2 Testing the edges

The test consists of scanning the total area of the edges (or areas to be welded according to sketches) where discontinuities were located defined in 8.3 under the same conditions as for flat product body (9.2.1).

The following are determined :

— the maximum dimension (L_{max}) and minimum dimension (L_{min}) of the discontinuity in the direction parallel to the edge of the flat product ;

— the area (S) of the discontinuity ;

— the number of discontinuities smaller than the maximum area (S_{max}) and longer than minimum dimension (L_{min}) per 1m length.

The determination of these properties of the discontinuity is obtained using the 6 dB method.

10 Acceptance criteria

Tables 3 and 4 give the acceptance criteria for the four quality classes (S_0, S_1, S_2, S_3) for the flat product body, depending on the type of probe used and the table 5 for the five edge classes (E_0, E_1, E_2, E_3, E_4) (see figure 1).

Subject to agreement on ordering, the flat product may be supplied with different quality classes for flat product body and/or edges.

11 Test report

When requested, the manufacturer shall submit a test report which shall include at least the following points :

a) reference to the present European Standard ;

b) reference data of the flat product examined (identification of the grade, heat treatment condition, surface condition, dimensions) ;

c) the characteristics of the ultrasonic probe (type, dimensions, frequency) and of the apparatus ;

d) the operation conditions (coupling medium, scanning, method of area determination used, setting of the apparatus) ;

e) the test results ;

f) a list of special points which have been the subject of special agreement ;

g) date of test report.

Table 3 - Acceptance criteria for testing with double transducer probes for the body of flat products for thicknesses < 60 mm

Class	Unacceptable individual discontinuity mm^2	Acceptable clusters of discontinuities	
		Area [a] considered mm^2	Maximum density not greater than
S_0	$S > 5\,000$	$1\,000 < S \leq 5\,000$	20 in the most populated 1 m x 1 m square
S_1	$S > 1\,000$	$100 < S \leq 1\,000$	15 in the most populated 1 m x 1 m square
S_2	$S > 100$	$50 < S \leq 100$	10 in the most populated 1 m x 1 m square
S_3	$S > 50$	$20 < S \leq 50$	10 in the most populated 1 m x 1 m square

a) Area of each discontinuity in the cluster in question (see 9.2).

NOTE This table can be used for thicknesses ≥ 60 mm if an appropriate method other than the 6 dB method is used for the sizing of discontinuities.

Table 4 : Acceptance criteria for testing with normal probes for the body of flat products

Class	Unacceptable individual discontinuity	Acceptable clusters of discontinuities	
		Dimensions [a] (number) considered	Maximum number not greater than
S_0	$S > 5\,000\ mm^2$	$1\,000 < S \leq 5\,000\ mm^2$	20 in the most populated 1 m x 1 m square
S_1	$S > 1\,000\ mm^2$	$100 < S \leq 1\,000\ mm^2$	15 in the most populated 1 m x 1 m square
S_2	Discontinuities where the flaw echo has an amplitude greater than the characteristic curve Ø 11 mm	N_2 (between Ø 8 mm and Ø 11 mm)	10 in the most populated 1 m x 1 m square
S_3	Discontinuities where the flaw echo has an amplitude greater than the characteristic curve Ø 8 mm	N_3 (between Ø 5 mm and Ø 8 mm)	10 in the most populated 1 m x 1 m square

a) Dimensions of each discontinuity in the cluster in question (see 9.2).

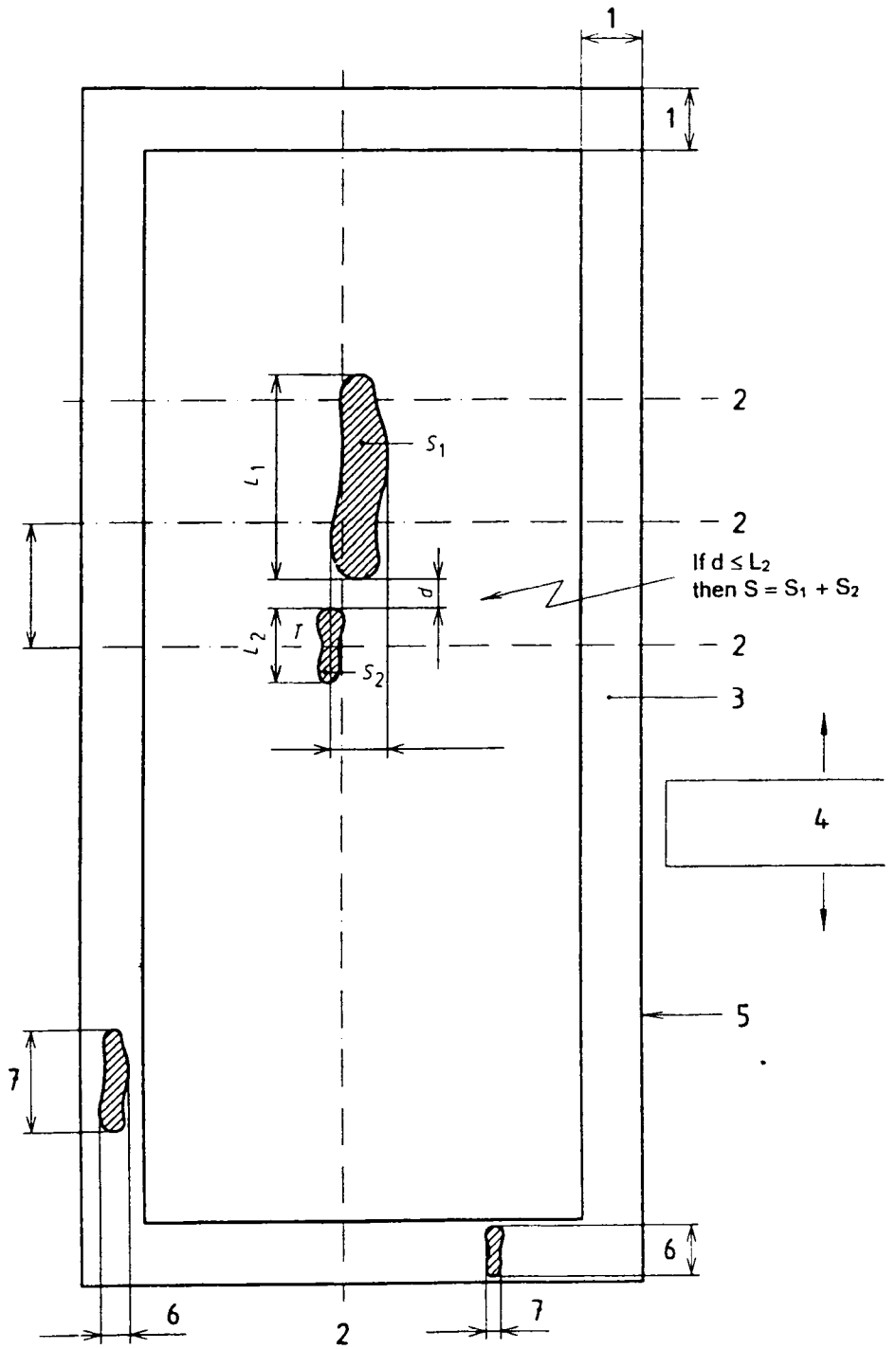
Table 5 - Acceptance criteria for flat product edge zone testing

Class	Permissible individual discontinuity size		Minimum discontinuity dimension considered L_{min} mm	Permissible number of discontinuities smaller than the maximum area S_{max} and longer than L_{min} per 1 m length
	Maximum Dimension L_{max} mm	Maximum Area S_{max} mm^2		
E_0	100	2 000	50	6
E_1	50	1 000	25	5
E_2	40	500	20	4
E_3	30	100	15	3
E_4	20	50	10	2

NOTE For product with thickness ≥ 60 mm, a counting of the discontinuities is carried out using the characteristics curves for the 11 mm, 8 mm and 5 mm diameters holes :

- E_3 number of discontinuities giving echos with an amplitude between characteristic curves for the 8 mm and 11 mm diameter holes : 3 ;

- E_4 number of discontinuities giving echos with an amplitude between characteristic curves for the 5 mm and 8 mm diameter holes : 2.



Key :

1 See table 2 for the value of the edge zone width
2 Scan line
3 Edge zone
4 Principal rolling direction
5 Flat product
6 Width
7 Length

Figure 1 - Schematic representation of terms used

Annex A

(informative)
List of equivalent terms in several european languages

Table A.1

English	French	German	Italian	Dutch
Time base	Base de temps	Zeitablenkung	Base dei tempi	Tijdbasis
Noise signal	Bruit de fond	Rauschanzeige	Rumore di fondo	Ruis
Discontinuity echo	Echo d'anomalie	Fehlerecho	Eco del difetto	Indicatie-echo
Back echo	Echo de fond	Rückwandecho	Eco di fondo	Bodemecho
Probe	Traducteur	Prüfkopf	Sonda	Taster
Double transducer probe	Traducteur émetteur et récepteur séparés	SE-Prüfkopf	Sonda ed emettitore e ricevitore separati (sonda doppia)	Dubbel-kristaltaster
Single probe	Traducteur normal	Einschwinger-Prüfkopf	Sonda normale	Rechtetaster
Transducer	Transducteur	Schwinger	Transduttore	Kristal
Flat bottomed hole	Trou à fond plat	Flachbodenbohrung	Foro a fondo piatto	Vlakbodemgat
Dead zone	Zone morte	Tote Zone	Zona morta	Dode zone