SIST

SLOVENSKI STANDARD
SIST ENV 583-6:2000

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Neporuġitveno preskuġanje - Ultrazvoļ ne preiskave - 6. del: Tehnika zvoļ ne poti kot metoda za odkrivanje in ugotavljanje velikosti diskontinuitet

Non-destructive testing - Ultrasonic examination - Part 6: Time-of-flight diffraction technique as a method for detection and sizing of discontinuities

Zerstörungsfreie Prüfung - Ultraschallprüfung - Teil 6: Beugungslaufzeittechnik, ein Technik zum Auffinden und Ausmessen von Inhomogenitäten

Essais non destructifs - Contrôle ultrasonore - Partie 6: Technique de diffraction du temps de vol utilisée comme méthode de détection et de dimensionnement des discontinuités

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ICS:

19.100 Neporušitveno preskušanje Non-destructive testing

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English version

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This European Prestandard (ENV) was approved by CEN on 21 May 1997 as a prospective standard for provisional application.

The period of validity of this ENV is limited initially to three years. After two years the members of CEN will be requested to submit their comments, particularly on the question whether the ENV can be converted into a European Standard.

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EUROPEAN COMMITTEE FOR STANDARDIZATION
COMITÉ EUROPÉEN DE NORMALISATION
EUROPÄISCHES KOMITEE FÜR NORMUNG

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Foreword

This European Prestandard has been prepared by Technical Committee CEN/TC 138 "Non-destructive testing", the secretariat of which is held by AFNOR.

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

EN 583 "Non-destructive testing. Ultrasonic examination" consists of the following parts:

EN 583-1, *Non-destructive testing - Ultrasonic examination - Part 1: General principles.*

EN 583-2, *Non-destructive testing - Ultrasonic examination - Part 2: Sensitivity and range setting.*

EN 583-3, *Non-destructive testing - Ultrasonic examination - Part 3: Transmission technique.*

EN 583-4, *Non-destructive testing - Ultrasonic examination - Part 4: Examination for discontinuities perpendicular to the surface.*

EN 583-5, *Non-destructive testing - Ultrasonic examination - Part 5: Characterization and sizing of discontinuities.*

ENV 583-6, *Non-destructive testing - Ultrasonic examination - Part 6: Time-of-flight diffraction technique as a method for detection and sizing of discontinuities.*

1 Scope

This European Prestandard defines the general principles for the application of the Time-Of-Flight Diffraction (TOFD) technique for both detection and sizing of discontinuities in low alloyed carbon steel components. It could also be used for other types of materials, provided the application of the TOFD technique is performed with necessary consideration of geometry, acoustical properties of the materials and the sensitivity of the examination.

Although it is applicable, in general terms, to discontinuities in materials and applications covered by EN 583-1, it contains references to the application on welds. This approach has been chosen for reasons of clarity as to the ultrasonic probe positions and directions of scanning.

Unless otherwise specified in the referencing documents, the minimum requirements of this Prestandard are applicable.

Unless explicitly stated otherwise, this Prestandard is applicable to the following product classes as defined in EN 583-2:

— class 1, without restrictions;

— classes 2 and 3, restrictions will apply as stated in clause 9.

The inspection of products of classes 4 and 5 will require special procedures. These are addressed in clause 9 as well.

2 Normative references

This European Prestandard 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 Prestandard 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.*

EN 583-1, *Non-destructive testing - Ultrasonic examination - Part 1: General principles.*

EN 583-2, *Non-destructive testing - Ultrasonic examination - Part 2: Sensitivity and range setting.*

EN 12668-1, *Ultrasonic examination - Characterization and verification of ultrasonic examination equipment – Part 1: Instruments.*

EN 12668-2, *Ultrasonic examination - Characterization and verification of ultrasonic examination equipment – Part 2: Probes.*

EN 12668-3, *Ultrasonic examination - Characterization and verification of ultrasonic examination equipment – Part 3: Combined equipment.*

3 Definitions and symbols

— TOFD : Time-Of-Flight Diffraction.

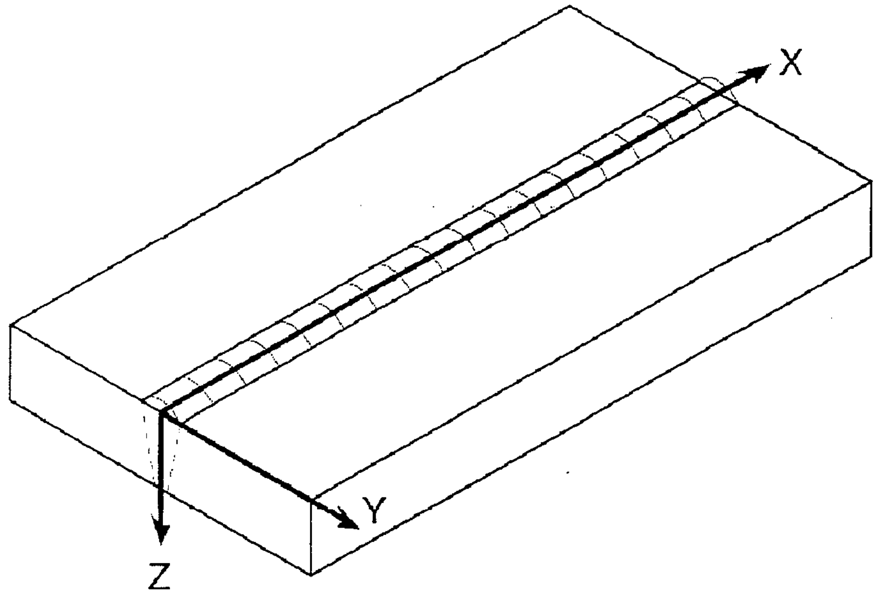


Figure 1 — Coordinate definition

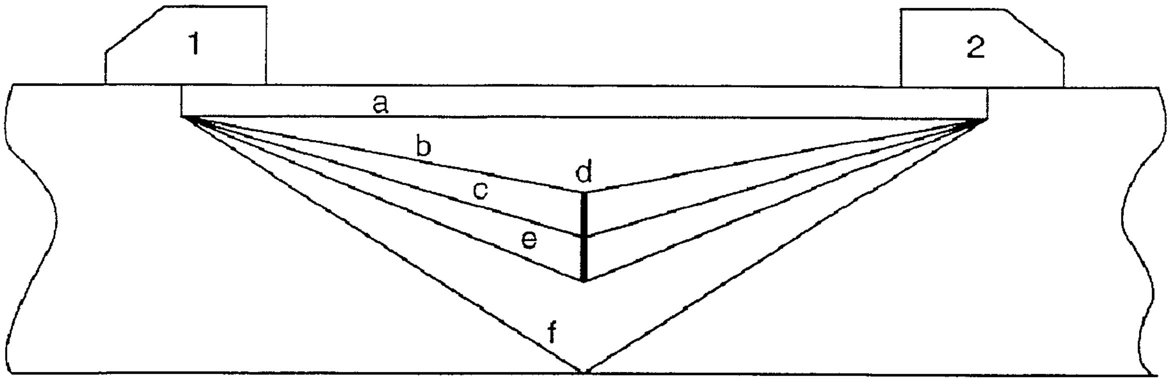
x	coordinate parallel to the scanning surface, and parallel to a predetermined reference line. In case of weld inspection this reference line should coincide with the weld. The origin of the axes may be defined as best suits the specimen under examination (see figure 1);
Δx	imperfection length;
y	coordinate parallel to the scanning surface, perpendicular to the predetermined reference line (see figure 1);
δy	error in lateral position;
z	coordinate perpendicular to the scanning surface (see figure 1);
Δz	imperfection height;
d	depth of a imperfection tip below the scanning surface;
δd	error in depth;
D_{ds}	scanning-surface dead zone;
D_{dw}	backwall dead zone;
c	sound velocity;
δc	error in sound velocity;
R	spatial resolution;
t	time-of-flight from the transmitter to the receiver;
Δt	time-of-flight difference between the lateral wave and a second ultrasonic signal;

δt	error in time-of-flight;
t_d	time-of-flight at depth d;
t_p	length (in time) of the acoustical pulse up to an amplitude of 10 % of the maximum;
t_w	time-of-flight of the backwall echo;
S	half the distance between the index points of two ultrasonic probes;
δS	error in half the probe separation;
W	wall thickness;
dead zone	zone where indications may be obscured due to the presence of signals of geometrical origin;
back wall dead zone	extra dead zone where signals may be obscured by the presence of the back wall echo;
A-scan	display of the ultrasonic signal amplitude as a function of time;
B-scan	display of the time-of-flight of the ultrasonic signal as a function of probe displacement;
non-parallel scan	scan perpendicular to the ultrasonic beam direction (see figure 4);
parallel scan	scan parallel to the ultrasonic beam direction (see figure 5).

4 General

4.1 Principle of the technique

The TOFD technique relies on the interaction of ultrasonic waves with the tips of discontinuities. This interaction results in the emission of diffracted waves over a large angular range. Detection of the diffracted waves makes it possible to establish the presence of the imperfection. The time-of-flight of the recorded signals is a measure for the height of the imperfection, thus enabling sizing of the defect. The dimension of the imperfection is always determined from the time-of-flight of the diffracted signals. The signal amplitude is not used in size estimation.



Legend

1 transmitter
2 Receiver
a lateral wave
b Upper tip
c Included angle
d Imperfection
e lower tip
f Back wall echo

Figure 2 — Basic TOFD configuration

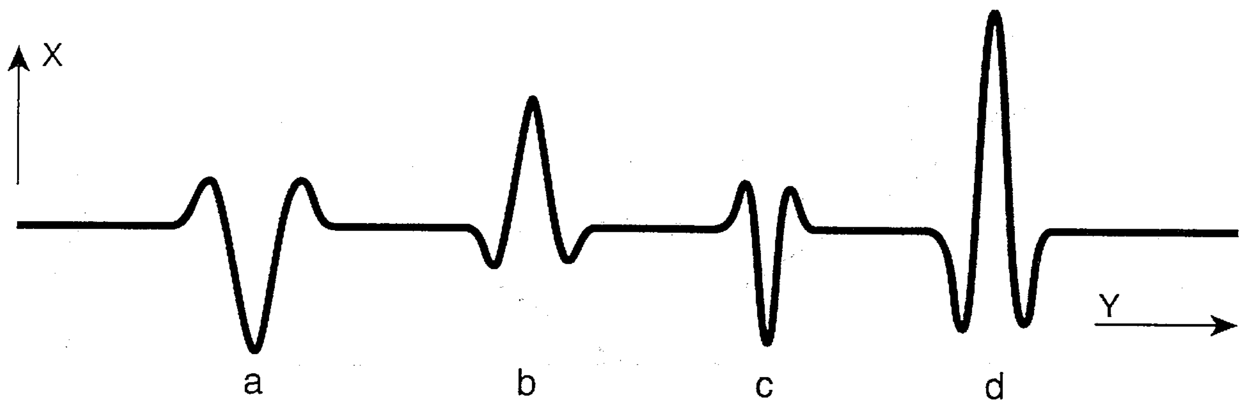
The basic configuration for the TOFD technique consists of a separate ultrasonic transmitter and receiver (see figure 2). Wide-angle beam compression wave probes are normally used since the diffraction of ultrasonic waves is only weakly dependent on the orientation of the imperfection tip. This enables the inspection of a certain volume in one scan. However, restrictions apply to the size of the volume that can be inspected during a single scan (see 7.2).

The first signal to arrive at the receiver after emission of an acoustic pulse is usually the lateral wave which travels just beneath the upper surface of the test specimen.

In the absence of discontinuities the second signal to arrive at the receiver is the backwall echo.

These two signals are normally used for reference purposes. If mode conversion is neglected, any signals generated by discontinuities in the material should arrive between the lateral wave and the backwall echo, since the latter two correspond, respectively to the shortest and longest paths between transmitter and receiver. For similar reasons the diffracted signal generated at the upper tip of a imperfection will arrive before the signal generated at the lower tip of the imperfection. A typical pattern of indications (A-scan) is shown in figure 3. The height of the imperfection can be deduced from the difference in time-of-flight of the two diffracted signals (see 8.1.5). Note the phase reversal between the lateral wave and the backwall echo, and between echoes of the upper and lower tip of the imperfection.

Where access to both surfaces of the specimen is possible and flaws are distributed throughout the specimen thickness, scanning from both surfaces will improve the overall precision, particularly in regard to flaws near the surfaces.



Legend

X	amplitude	b	upper tip
Y	time	d	back-wall echo
a	lateral wave	c	lower tip

Figure 3 — Schematic A-scan of embedded imperfection

4.2 Requirements for surface condition and couplant

Care shall be taken that the surface condition meets at least the requirements stated in EN 583-1. Since the diffracted signals may be weak, the degradation of signal quality due to poor surface condition will have a severe impact on inspection reliability.

Different coupling media can be used, but their type shall be compatible with the materials to be examined. Examples are: water, possibly containing an agent (wetting, anti-freeze, corrosion inhibitor), contact paste, oil, grease, cellulose paste containing water, etc.

The characteristics of the coupling medium shall remain constant throughout the examination. It shall be suitable for the temperature range in which it will be used.

4.3 Materials and process type

Due to the relatively low signal amplitudes that are used in the TOFD technique, the method can be applied routinely on materials with relatively low levels of attenuation and scatter for ultrasonic waves. In general, application on unalloyed and low alloyed carbon steel components and welds is possible, but also on fine grained austenitic steels and aluminium.

Coarse-grained materials and materials with significant anisotropy however, such as cast iron, austenitic weld materials and high-nickel alloys, will require additional validation and additional data-processing.

By mutual agreement, a representative test specimen with artificial and/or natural discontinuities can be used to confirm inspectability. Remember that diffraction characteristics of articial defects can differ significantly from those of real defects.

5 Qualification of personnel

Personnel performing examinations with the TOFD technique shall, as a minimum, be qualified in accordance with EN 473, and shall have received additional training and examination on the use of the TOFD technique on the product classes to be tested, as specified in a written practice.

6 Equipment requirements

6.1 Ultrasonic equipment and display

Ultrasonic equipment used for the TOFD technique shall, as a minimum, comply with the requirements of EN 12668-1, EN 12668-2 and EN 12668-3.

In addition, the following requirements shall apply:

— the receiver bandwidth shall, as a minimum, range between 0,5 and 2 times the nominal probe frequency at -6 dB, unless specific materials and product classes require a larger bandwidth. Appropriate band filters can be used;

— the transmitting pulse can either be unipolar or bipolar.The rise time shall not exceed 0,25 times the period corresponding to the nominal probe frequency;

— the unrectified signals shall be digitized with a sampling rate of at least four times the nominal probe frequency;

— for general applications combinations of ultrasonic equipment and scanning mechanisms (see 6.3) shall be capable of acquiring and digitizing signals with a rate of at least one A-scan per 1 millimetre scan length. Data acquisition and scanning mechanism movement shall be synchronized for this purpose;

— to select an appropriate portion of the time base within which A-scans are digitized, a window with programmable position and length shall be present. Window start shall be programmable between 0 and 200 µs from the transmitting pulse, window length shall be programmable between 5 and 100 µs. In this way, the appropriate signals (lateral or creeping wave, backwall signal, one or more mode converted signals as described in 4.1) can be selected to be digitized and displayed;

— digitized A-scans should be displayed in amplitude related grey or single-colour levels, plotted adjacently to form a B-scan. See figures 4 and 5 for typical B-scans of non-parallel and parallel scans respectively. The number of grey or single-colour scales should at least be 64;

— for archiving purposes, the equipment shall be capable of storing all A-scans or B-scans (as appropriate) on a magnetic or optical storage medium such as hard disk, floppy disk, tape or optical disk. For reporting purposes, it shall be capable of making hard copies of A-scans or B-scans (as appropriate);

— the equipment should be capable of performing signal averaging.

In order to achieve the relatively high gain settings required for typical TOFD-signals, a pre-amplifier may be used, which should have a flat response over the frequency range of interest. This pre-amplifier shall be positioned as close as possible to the receiving probe.

Additional requirements regarding features for basic and advanced analysis of discontinuities are described in clause 8.

6.2 Ultrasonic probes

Ultrasonic probes used for the TOFD technique shall comply with at least the following requirements:

— number of probes: 2 (transmitter and receiver);

— type: any suitable probe (see 7.2);

— wave mode: usually compression wave; the use of shear wave probes is more complex but may be agreed upon in special cases;

— both probes shall have the same centre frequency within a tolerance of ± 20 %; frequency: for details on probe frequency selection, see 7.2;

— the pulse length of both the lateral wave and the backwall echo shall not exceed two cycles, measured at 10 % of the peak amplitude;