INTERNATIONAL STANDARD

ISO 16828

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Non-destructive testing — Ultrasonic testing — Time-of-flight diffraction technique as a method for detection and sizing of discontinuities

Essais non destructifs — Contrôle par ultrasons — Technique de diffraction du temps de vol utilisée comme méthode de détection et de dimensionnement des discontinuités

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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 16828 was prepared by Technical Committee ISO/TC 135, *Non-destructive testing*, Subcommittee SC 3, *Ultrasonic testing*.

Introduction

This International Standard is based on EN 583-6:2008, *Non-destructive testing — Ultrasonic examination — Part 6: Time-of-flight diffraction technique as a method for detection and sizing of discontinuities.*

The following International Standards are linked.

ISO 16810, *Non-destructive testing — Ultrasonic testing — General principles*

ISO 16811, *Non-destructive testing — Ultrasonic testing — Sensitivity and range setting*

ISO 16823, *Non-destructive testing — Ultrasonic testing — Transmission technique*

ISO 16826, *Non-destructive testing — Ultrasonic testing — Examination for discontinuities perpendicular to the surface*

ISO 16827, *Non-destructive testing — Ultrasonic testing — Characterization and sizing of discontinuities*

ISO 16828, *Non-destructive testing — Ultrasonic testing — Time-of-flight diffraction technique as a method for detection and sizing of discontinuities*

Non-destructive testing — Ultrasonic testing — Time-of-flight diffraction technique as a method for detection and sizing of discontinuities

1 Scope

This International Standard 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 can 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 ISO 16810, 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 International Standard are applicable.

Unless explicitly stated otherwise, this International Standard is applicable to the following product classes as defined in ISO 16811:

— class 1, without restrictions;

— classes 2 and 3, specified restrictions apply.

NOTE 1 See Clause 9.

The inspection of products of classes 4 and 5 requires special procedures, which are also addressed.

NOTE 2 See Clause 9.

NOTE 3 Techniques for the use of TOFD for weld inspection are described in ISO 10863.

NOTE 4 The related acceptance criteria are given in ISO 15626.

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.

ISO 9712, *Non-destructive testing — Qualification and certification of NDT personnel — General principles*

ISO 16810, *Non-destructive testing — Ultrasonic testing — General principles*

ISO 16811, *Non-destructive testing — Ultrasonic testing — Sensitivity and range setting*

EN 12668-1, *Non-destructive testing — Characterization and verification of ultrasonic examination equipment — Part 1: Instruments*

EN 12668-2, *Non-destructive testing — Characterization and verification of ultrasonic examination equipment — Part 2: Probes*

EN 12668-3, *Non-destructive testing — Characterization and verification of ultrasonic examination equipment — Part 3: Combined equipment*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

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

3.1.1
scanning surface dead zone
zone where indications may be obscured due to the interface echo (lateral wave)

3.1.2
back wall dead zone
dead zone where signals may be obscured by the presence of the back wall echo

3.1.3
A-scan
display of the ultrasonic signal amplitude as a function of time

3.1.4
B-scan
display of the time-of-flight of the ultrasonic signal as a function of probe displacement

3.1.5
non-parallel scan
scan perpendicular to the ultrasonic beam direction (see Figure 4)

3.1.6
parallel scan
scan parallel to the ultrasonic beam direction (see Figure 5)

3.2 Abbreviations

— TOFD: time-of-flight diffraction

3.3 Symbols

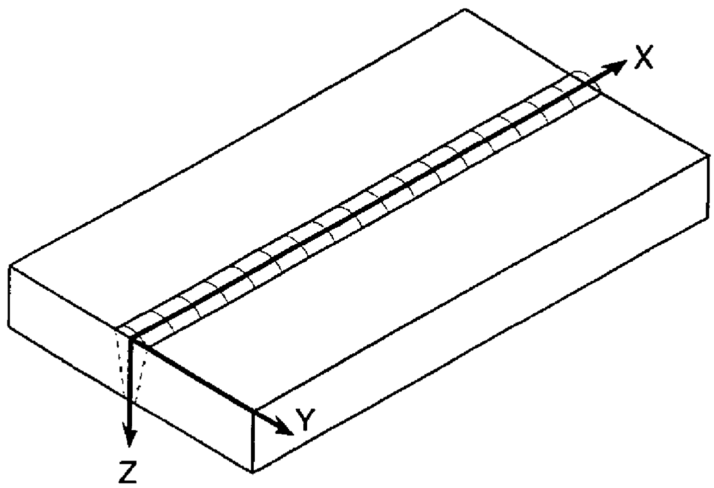


Figure 1 — Coordinate definition

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 discontinuity 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 discontinuity height;

d depth of a discontinuity tip below the scanning surface;

δd error in depth;

D_{ds} scanning-surface dead zone;

D_{dw} back wall 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 duration of the ultrasonic pulse measured at 10 % of the peak amplitude;

t_w time-of-flight of the back wall echo;

s half the distance between the index points of two ultrasonic probes;

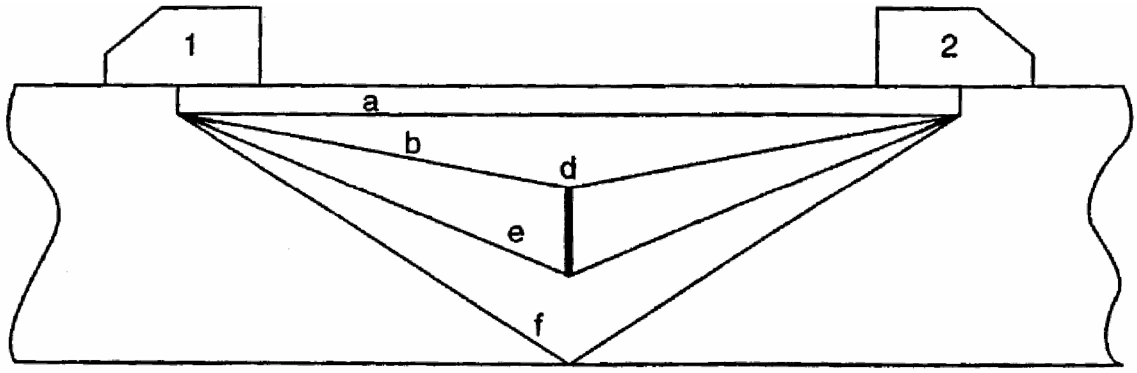
δs error in half the probe separation;

W wall thickness.

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 discontinuity. The time-of-flight of the recorded signals is a measure for the height of the discontinuity, thus enabling sizing of the defect. The dimension of the discontinuity is always determined from the time-of-flight of the diffracted signals. The signal amplitude is not used in size estimation.



Key

1 transmitter
2 receiver
a lateral wave
b upper tip
d discontinuity
e lower tip
f back wall echo

Figure 2 — Basic TOFD configuration

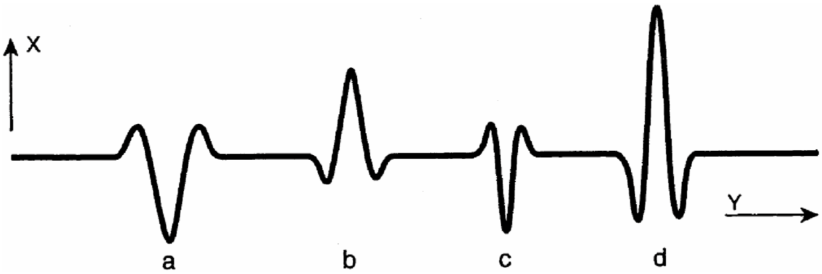
The basic configuration for the TOFD technique consists of a separate ultrasonic transmitter and receiver (see Figure 2). Wide-angle beam compression wave probes are normally used since the diffraction of ultrasonic waves is only weakly dependent on the orientation of the discontinuity tip. This enables 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 ultrasonic 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 back wall 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 back wall 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 discontinuity will arrive before the signal generated at the lower tip of the discontinuity. A typical pattern of indications (A-scan) is shown in Figure 3. The height of the discontinuity 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 back wall echo, and between echoes of the upper and lower tip of the discontinuity.

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



Key

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

Figure 3 — Schematic A-scan of an embedded discontinuity

4.2 Requirements for surface condition and couplant

Care shall be taken that the surface condition meets at least the requirements stated in ISO 16810. 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 e.g. 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 artificial 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 ISO 9712, 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.