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CHARACTERIZATION OF REFLECTORS BY ULTRASONIC METHODS

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ABSTRACT

This work is a comprehensive review of the methods being used at the present or under development, for qualitative interpretation of reflectors by means of pulse-echo techniques

1. Introduction

Ultrasonic inspection is used to determine whether or not a test piece may be used according to its intended purpose; that is, whether it is free of discontinuities or contains defects. The definition of "defects" cannot be determined solely from ultrasonic information: knowledge of construction of the test piece, its intended purpose, its material and its fabrication process is necessary. All this information is important to decide whether an inspected part may be used or not.
Therefore, in the following text the term "defect evaluation" will not be used if we are referring to the interpretation of ultrasonic pulse echoes.

2. The pulse echo method - general remarks

It is essential in the evaluation of a reflector that one has scanned for it and detected it [1].
The procedure can be divided into the following steps:

a) a reflector is detected;

b) a simple evaluation can be made of the pulse echo characteristics, for example, the transit time or the maximum echo amplitude;

c) a rough classification of the type of reflector can be made with additional effort. In this case o combination of different characteristics from a number of echoes during a scan procedure must be linked in order to determine the type of reflector;

d) a precise classification of the reflector according to type, position and size can be attempted by means of ultrasonic imaging.

Using the pulse echo method, in principle, all information about the reflector can be derived only from the echo signal. Simple evaluation methods use only part of the resulting information. According to fig. 1, the following will be available: the position of the transducer, when an echo occurs; the directional characteristics of the transducer; the transit time of the pulse echo; information based on the shape of the echo.
From the interaction between the sound waves and the reflector, three spheres of influence can be differentiated [1], [2]: the transducer influences the transmitted and received pulse. It has a directional characteristic; the reflector influences the shape and direction of propagation of the reflected pulse, and could even cause wave transformation; the material also influences the shape and amplitude of the echo pulse by sound absorption, anisotropy and scattering.
The interaction between the sound wave and the reflector does not always take place in an ideal manner as shown in fig. 1 (above). In most cases a portion of the sound beam strikes the reflector and sometimes only part of the reflected waves can be received. It is also possible that mode conversion has taken place and the wave type received is different from the transmitted pulse. Therefore, when using simple evaluation methods, the many possibilities of interaction sometimes lead to an uncertain or even wrong result.

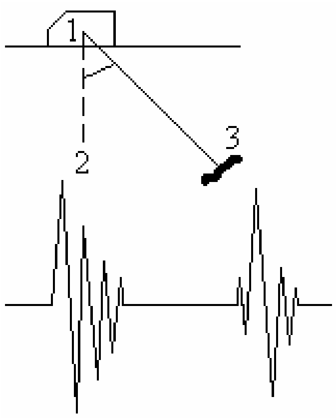


Figure. 1 Information of the pulse echo method (1 probe position; 2 directional characteristic; 3 echo response)

3. Simple evaluation methods

a) Evaluation of the transit time: with crack growth in tensile test pieces, the reflector type and position is known. The crack depth can be determined from the measurement of the transit time [3], [4] (fig. 2). Stress cracks on parts having simple shapes can be determined in a similar way if the direction of crack propagation is known.

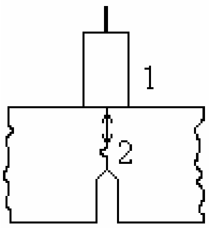


Figure 2 Simple transit time method (end-of-crack) (1 probe; 2 crack)

b) Reflector edge scanning: if information about transducer position is added to the transit time data, than one obtains a scanning method with which the dimensions of large reflectors can be determined. This method is used when the size of the detected reflector is distinctly larger than the sound beam diameter (fig. 3). From the transit time the depth position of the reflector can be derived, the measurement of the transducer scanning track will give reflector expansion. In most cases the projection of the reflector area on the surface of the test piece is used (C-scan method). However, the echo amplitude must also be considered in order to determine the reflector edge. It is assumed that the reflector edge is positioned under the center of the transducer when the echo amplitude has dropped below its maximum by a predetermined value of x dB [5], i.e. by 6 dB (the half value method). An amplitude decrease of 20 dB is also quite common.

c) Evaluation of the maximum echo amplitude: if the reflector area, contrary to b), is smaller than the sound beam diameter, then evaluation is accomplished using the maximum echo amplitude combined with appropriate transit time information. This is the most common evaluation method used today in manual testing.

The transit time determines the reflector position and the maximum echo amplitude determines a (fictitious) reflector size. The DGS-method uses the ideal circular reflector as an equivalent reflector. Independent of the actual reflector type and possible inclined position, the echo is evaluated as if it had come from a circular reflector of equivalent size, which was hit perpendicularly.

In addition to the uncertainties which the use of an equivalent reflector imply the rectified video signal is normally used rather then the RF-echo presentation (fig. 4). Properties of the electrical transmission line also influence the result (rectification, smoothing, filtering).

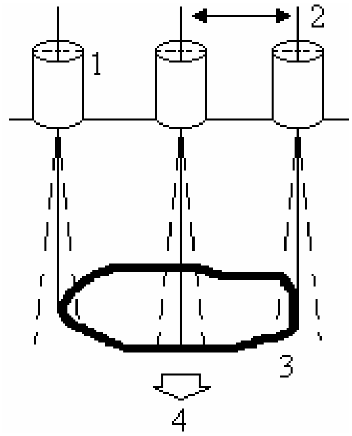


Figure 3 Simple reflector scanning (amplitude drop by x dB) (1 probe; 2 shift; 3 reflector; 4 bidimensional image of the reflector)

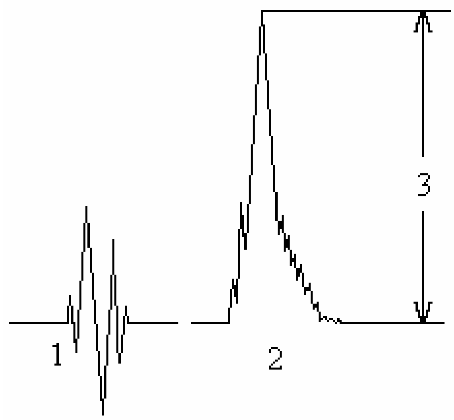
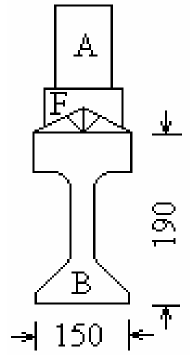
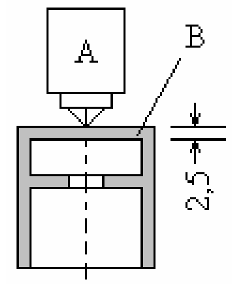
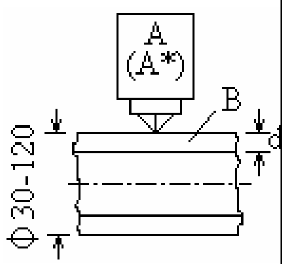
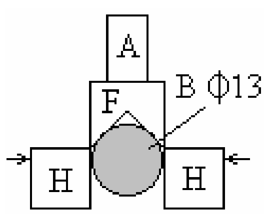


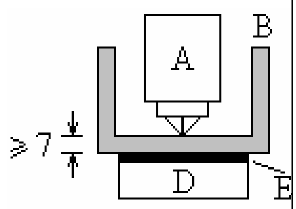
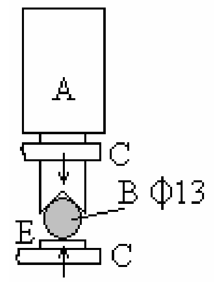
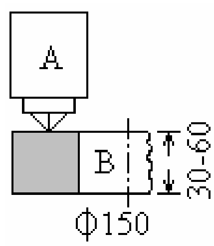
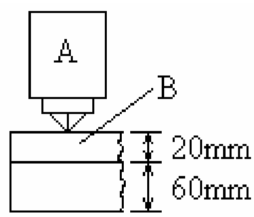
Figure. 4 Simple evaluation of an echo amplitude (1 RF-pulse; 2 video-pulse; 3 echo amplitude/DGS method)

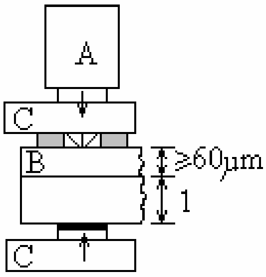
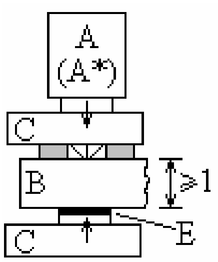
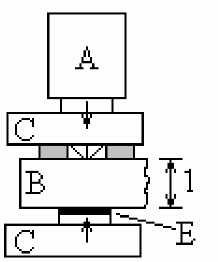
4. Interesting facts from test reports

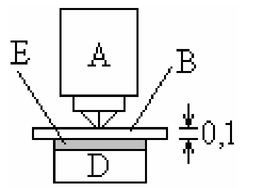
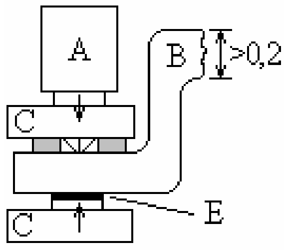
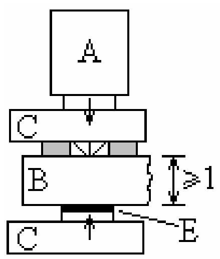
From the many technical subjects we have selected the field of hardness testing (Tab. 1)

Table 1 The hardness testing

Test problem and remarks	Measurement set-up
Hardness testing on the head of a rail in the production line *Essential*: Removal of the roll scale. *Recommended*: Prismatic adapter set MIC 100(F) for probe guidance along the surface.	
Hardness testing on cup tappets *Recommended*: By using the prismatic adapter set MIC 100 it is possible to determine the hardness on the cylindrical surface	
Hardness testing on hard chromium layers on steel *Required*: Application of probe MIC 101 (7,7N) on chromium layers of thicknesses < 60µm the probe MIC 102 (3N) on chromium layers 35 ≤ d < 60 µm; calibration using the hardness reference value for direct indication of the chromium hardness.	
Hardness testing on the cylindrical surface of steel bolts *Required*: Fixing the test object into a clamp (H) for acoustic damping; centering of the probe using the prismatic adapter set MIC 100 (F).	

Test problem and remarks	Measurement set-up
Hardness testing on sintered parts *Recommended*: The application of the Universal Interface MIC 350 for the entire recording and evaluation of measured data through computer/ printer, including averaging.	
Hardness testing on spring steel wires *Required*: Holder MIC 220 (C) with special prismatic guiding for acoustic damping and centering of the wire.	
Hardness testing on hard metal rings having 150mm *Required*: If hardness values exceed 1000HV the MICRODUR must be calibrated to half the hardness value. Matching to the different quality grades (E-moduli) must be done by done by calibration using corresponding hardness reference value.	
Hardness testing on chrome plated layers on steel *Required*: Probe MIC 102 (3N); MICRODUR - calibration to half the hardness value (hardness apporx. 1800HV).	

Test problem and remarks	Measurement set-up
Hardness testing on nickel layers on steel plates *Required*: Holder MIC 220 (C); probe MIC 102 (3N); calibration using the hardness reference value	
Hardness testing on soft copper plates *Required*: Holder MIC 220 (C) for acoustic damping in case copper hardness is < 50HV; calibration of the MIC 1 is made to double the hardness value taking the hardness reference value into consideration. *Recommended*: Probe MIC 102 (3N)	
Hardness testing on brass plates (strip material) *Required*: Holder MIC 220 (C) for acoustic damping and compensation of plate unevenness. Calibration ysing the hardness reference value.	

Test problem and remarks	Measurement set-up
Hardness testing on razor blades *Required*: Support DH 191 (D); probe with attachment sleeve; calibration using the hardness reference value.	
Hardness testing on small spring elements *Required*: Holder MIC 220 (C) for acoustic damping. Thickness of the test object ≥ 0,2 mm. In order to clamp the test object into the holder it is necessary to have a flat noninterrupted area ≥ 25 mm^2 (no holes). Calibration to the value.	
Hardness testing on steel plate parts *Required*: Holder MIC 220 (C). *Remark*: Due to unintentional surface hardening, causes by processing, higher hardness values can be obtained by using lowload hardness meters as with test loads of 50 or 100 N!	

References

[1] **Serabian, St.**, *An assesment of the detection ability of the angle beam interrogation method*, Mater. Eval. 39, 1243-1249, 1998

[2] **Wü stenberg, H., Erhard, A.**, *Development of ultrasoni techniques for sizing defects*, Appl. Sci. Publ., In Nondestructive Examination Relation Structural Integrity, London, 59-83, 2002

[3] **Winter, D.C.**, *End-on-crack measurement*, Ultrasonic Symposium Proceedings, New-York, 2001

[4] **Schlengermann, U.**, *Remarks on the practice of determining the size of reflectors by scanning*, Proceedings 8th WCNDT, Cannes, report 5 C 10, 2004

[5] **Jackson, B.**, *The use of edge-of-beam methods for the assesment of defect size*, Can. Soc. Nondestructive Testing J., 5, 48-50, 2003