CORROSION ASSESSMENT USING ULTRASOUND

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Summary
Measurement and determination of the corrosion in the material is an important aspect of the structure safety. For that purpose article presents amplitude and time-of-flight C-scan method for thickness evaluation with single ultrasonic transducer. Test was performed using immersion setup with automated two-axis scanner.

Keywords: corrosion, thickness measurement, C-scan

OCENA KOROZJI PRZY UŻYCIU ULTRADŹWIĘKÓW

Streszczenie
Pomiar i ocena korozji materiału jest istotnym aspektem dla zachowania bezpieczeństwa konstrukcji. Artykuł przedstawia dwie metody, C-scan amplitudowy i time-of-flight do pomiaru grubości przy użyciu jednego ultradźwiękowego przetwornika. Pomiar został dokonany w trybie zanurzeniowym przy użyciu dwu-osiowego skanera.

Słowa kluczowe: korozja, pomiar grubości, C-scan

1. INTRODUCTION

Corrosion is an electrochemical degradation of a material by its environment. Reduces integrity of materials and highly influence structure lifetime, which might be dangerous for the whole structure.
It may have various forms and be divided into following types:

- Uniform (general corrosion) - proceeds at nearly at the same rate over the whole surface usually due to chemical reaction, the most common form of corrosion
- Pitting - results in pits on the metal surface caused by chloride and chlorine ions localized corrosion
- Crevice corrosion - occurs when a corrosive liquid is confined to a tight space
- Galvanic corrosion [1].

Corrosion can be evaluated by means of destructive methods but nondestructive methods commonly applied for corrosion detection are eddy current and ultrasound techniques [2],[3]. Ultrasound, due to its capability of thickness determination can be used for corrosion detection in thick plates and structures.
Short electrical discharge in the piezoelectric element results in ultrasonic wave induced in specimen (fig. 1). On the other hand, reflected wave from the object is received by probe, generating electrical signal registered by acquisition card [4].

Ultrasonic data can be expressed in form of three presentations - A-scan, B-scan and C-scan. A-scan is a plot of energy, from the reflected wave. B-scan presents a time-of-flight (TOF) of sound energy along specimen cross-section. While a C-scan is a two dimensional graphical representation of registered echoes, as a top view on the test surface. It is evaluated according to gates set on the A-scan (as shown in fig. 2 - from 2.1 mm thick element). Paper presents two method for evaluation C-scans - amplitude and time-of-flight.

This article is organized as follows. Firstly, thickness measurement and the equipment used in the experiment are briefly explained. Subsequently, experimental results and conclusions are given.

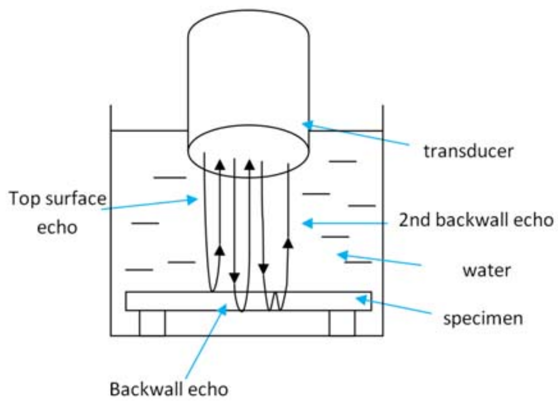

Fig. 1. Echo reflections in the specimen in immersion test

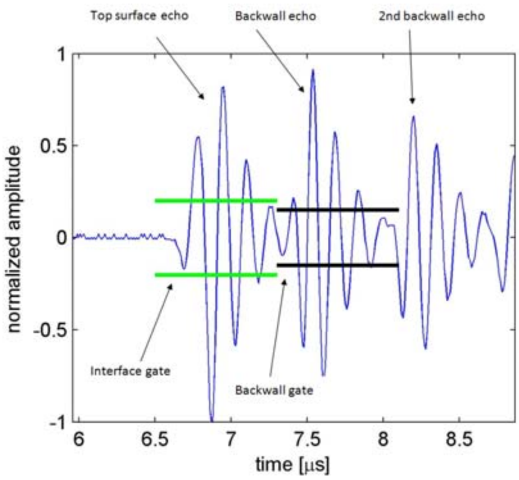

Fig. 2. A-scan with gates

2. THICKNESS MEASUREMENT

C-scan can be expressed in two forms, as amplitude relation, or time-of-flight of consecutive echoes. The principle of the first method is to measure change in attenuation while for second one, elapsed time between repeated echoes. Eventually C-scan generates horizontal representation, in contrary to B-scan which results in cross-section of specimen [5].

Time-of-flight (TOF) C-scan is a time difference between consecutive echoes (equation 1) [6].

$$h = \frac{v\Delta t}{2} \quad (1)$$

where h is the thickness, and t is the time between top and bottom surface echoes, while v is the longitudinal wave velocity in the specimen. As ultrasonic wave travels twice the thickness of the specimen, it must be divided by two. In the following article steel velocity was assumed to be 5900 m/s.

Amplitude C-scan, calculated, here on the other hand is a relation between maximum amplitude of the top surface waveform and back-wall echo. In article relation is presented in form of logarithm with dB unit.

$$h = 10 * log10\left(\frac{Y1}{Y2}\right) \quad (2)$$

where Y1 and Y2 are top surface echo and backwall echo, respectively.

3. EQUIPMENT

During research, ultrasonic signals were acquired by at ultrasonic transducer from Panametrics - with center frequency of 10MHz, and element diameter .375". Transducer was immersed into water tank (coupling medium) to allow efficient transmission of wave energy into examined object. In order to induce only longitudinal wave in the material, the transducer was aligned perpendicularly to the specimen, at a near field distance (18 mm). At this point half angle spread between -6dB points in water, was equal to 4,64^{o}.

Data was recorded in form of B-Scans at maximum sampling frequency allowed by acquisition card (100MHz - time resolution 0.01 us). Signals were digitized with 8-bit resolution. A mechanized X-Y scanner performed the probe scanning. Eventually signals were converted to C-scans by a script in Matlab software. Simplified scheme of the setup is shown in fig. 3.

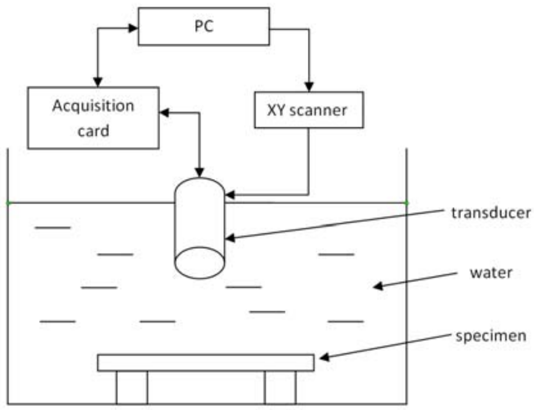

Fig. 3. Equipment setup

4. MEASUREMENTS

First experiment was conducted on corroded plate with use of TOF C-scan. For that purpose healthy plate was partially exposed to highly concentrated sulfur acid. The plate and its thickness mapped using amplitude C-scan are shown in fig. 4.

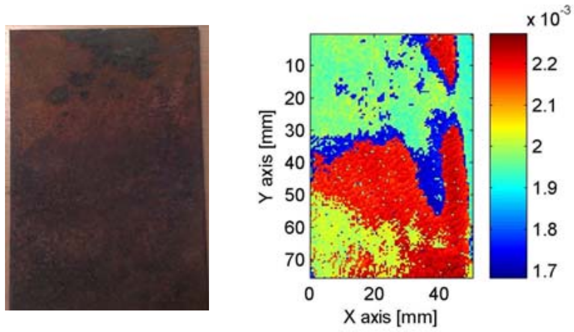

Fig. 4. Corroded plate (left) and the TOF C-scan in mm (right)

Material was scanned with 0.5mm step in both, x and y direction.

Second experiment was conducted in order to determine if it is possible to determine corrosion under layer of paint. For that purpose, element shown in fig. 5 was examined with amplitude C-scan. Mapped thickness using amplitude C-scan, is shown in fig. 6. Material was scanned with the following parameters: 0.5mm step in both, x and y direction. It is easy to notice how amplitude C-scan is highly affected by attenuation at corroded spots.

Fig. 5. Corroded element

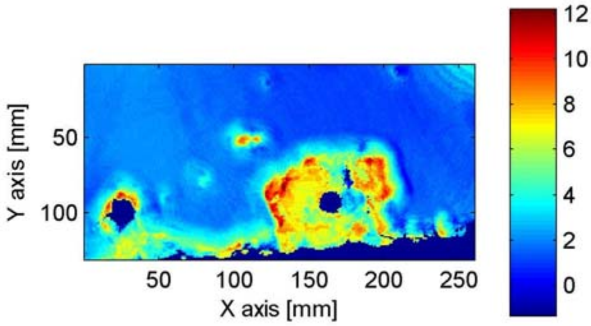

Fig. 6. Corrosion under paint - mapped in dB

5. CONCLUSIONS

This paper has described the use of amplitude and TOF C-scan measurement with single-transducer. Results were shown for a corroded plate and an element where corrosion occurred between metal and paint. It was shown that amplitude C-scan is capable of determining corrosion spots under layer of paint due to the increased back-wall attenuation while TOF C-scan is a reliable to for thickness determination of uniform elements.

6. ACKNOWLEDGEMENT

Research was performed within the project "*Development and implementation of an innovative, integrated system for anti-corrosive coating testing*" realized by EC Electronics Sp. z o.o., subsidiary of EC Systems Sp. z o.o. funded within the Operational Programme of Innovative Economy POIG.01.04.00-12-085/10-00.

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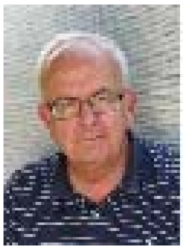

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