Inspection of Topography of Cracks Using Scanning Acoustic Microscopy

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Abstract – **Scanning acoustic microscopy is an analysis tool mainly used for detecting inhomogeneities inside the inspected samples, but it is also capable for measuring the thickness of a given layer. A standard method for thickness measurements is based on observing a so called A-mode echo signal. In this paper the authors present pilot results of a method for thickness measurements based on analyzing the grayscale value of the C-mode image. The method can be used only under certain circumstances, but has the advantage to estimate the thickness of a layer using only the C-mode image.**

Keywords – **Scanning Acoustic Microscopy, measuring thickness, grayscale image processing**

I. Introduction

Scanning acoustic microscopy (SAM) is a commonly used non destructive inspection method in electronic failure analysis. One major advantage of this method is that with the help of ultrasonic signals it is capable to detect cracks or delaminations inside the sample under test.

In case of using SAM in a reflexive mode the so called A-mode signal gives the fundamental information about the inner structure of the inspected sample. The A-mode signal is an oscilloscope type signal which displays the reflected echoes as a function of time. The amplitude of the main peaks in the reflected signal provides information about the inner interfaces of the sample as follows [1]:

$$R = \frac{Z_2 - Z_1}{Z_2 + Z_1} \qquad (1)$$

where R is the fraction of the reflected amplitude from an interface, Z_1 and Z_2 are the acoustic impedances of the primary and secondary materials of the given interface, respectively. Acoustic impedance values of materials mentioned in this paper are summarized in Table I.

Measuring the time elapsed between the main peaks gives the possibility to estimate the thickness of the given layer:

$$d = \frac{v \cdot t}{2} \qquad (2)$$

where d is thickness of the layer, v is the velocity of the ultrasonic signal in the layer and t is the time elapsed between the appearance of the main peaks.

The accuracy of measuring the elapsed time between the adequate peaks determines the accuracy of the thickness measurement. In case the peaks are too close to each other the measurement of the thickness of the layer becomes inaccurate; in case of overlapping peaks the measurement is not performable. By applying transducers with higher operational frequencies higher depth resolution can be achieved because of the shorter wavelengths, however the penetration depth into the given material will decrease.

In this paper we present the results of the pilot measurements of a method which uses the value of a specific amplitude of the reflected signal, that is the grayscale value of the C-mode image for predicting the thickness of the given layer. The principles of the method are as follows: the value of the acoustic impedance of air is approximately 0, thus when the inspection signal reaches a crack or delamination filled with air the total amount of the incident wave will be reflected according to Eq. (1). If during the inspection the ultrasonic wave propagates though only one material before reaching the air-gap then the attenuation of the signal will be proportional with the thickness of this inspected material. Thus the thickness of the layer above the air-gap can be estimated from the grayscale value of the C-scan image.

TABLE I
ACOUSTIC IMPEDANCE VALUES USED (@ 25 °C)

Material	Z ($kg \cdot s^{-1} \cdot m^{-2} \cdot 10^6$)	Reference
Air	0.00041	[2]
Water	1.49	[2]
Aluminum	17	[3]
Copper	42	[3]

II. Experimental Setup

Measurements were performed by a scanning acoustic microscope Sonix HS1000 equipped with a transducer of operational frequency of 50 MHz.

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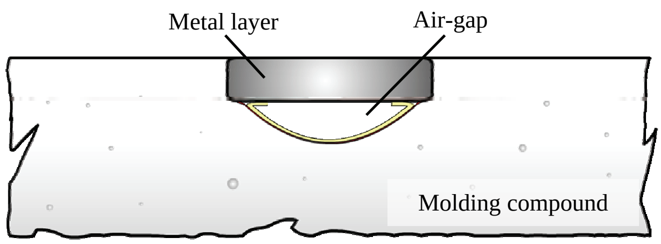

Fig. 1: Virtual cross-section of a sample

Aluminum and copper samples of different thicknesses were used for measurements. The thickness value of the inspected samples was formed by grinding the base material.

On the back of the inspected samples air-gaps were formed using a paper spacer and foil. After that the samples were molded into a two component acrylic compound. The mold compound gave a mechanical stability to the samples, and prevented the air-gaps from filling with water during the inspections. A virtual cross-section image of one sample is shown in Fig. 1.

From samples with the same composition the thickest one was measured firstly. The transducer was focused to the air-gap under the sample, then the value of the gain of the acoustic microscope was set in such a way that the amplitude of the reflected peak from the sample – air-gap interface would not overdrive the evaluation system during the C-scan imaging. All other samples with the same composition were measured using the same value of gain and focusing the transducer to the sample – air-gap interface. In these cases the ultrasonic wave was propagated though a higher thickness of water and a smaller thickness of metal, thus the attenuation of the wave was higher and these samples appeared darker in the C-scan images.

III. Results and Discussion

Results of measuring the aluminum samples are shown in Fig. 2. It can be seen that by decreasing the thickness of the samples the grayscale value of the C-scan images is linearly decreases. The attenuation of the ultrasonic signal in case of any material should be exponential, however in case of such a narrow thickness interval the linear approximation can be acceptable. Determining the slope of the approximation line gives the possibility to estimate the thickness of any layer of the same composition above an air-gap if using the same value of gain. Additional limitations are that the thickness of the layer must be lower that the penetration depth of the inspection wave, but also should be high enough to significantly attenuate the propagating wave.

Fig. 3 shows the results of measuring the copper samples. In contrast to aluminum samples there is no significant difference among the grayscale values of the measured copper samples. This result possibly can be explained by the higher acoustic impedance of copper according to aluminum. The propagating signal was not able to significantly attenuate in the sample because of the relatively high wavelength of the transducer.

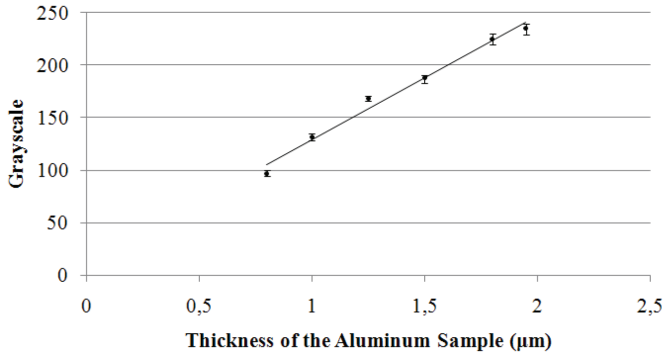

Fig. 2: Results of measuring the aluminum samples

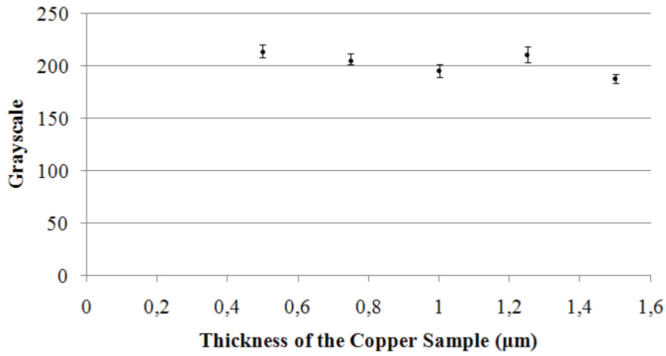

Fig. 2: Results of measuring the copper samples

IV. Conclusion

This paper presents the results of the pilot measurements of a method which estimates the thickness of a given material above an air filled crack or delamination by the grayscale value of the C-mode image.

Results show that under certain circumstances it is possible to estimate the thickness value of a material by the grayscale value, however the inspection frequency of the transducer significantly limits the available interval and accuracy of the thickness measurement similarly to measuring the thickness from the A-mode signal.

The main advantage of this method could be that thickness measurements can be done without the A-mode echoes by applying simple image processing steps. The generalization of the method and revealing its limits are the following tasks of the authors.

References

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