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UNCERTAINLY ESTIMATION IN PHASE ULTRASOUND METHOD

The new multi-layer materials widely be used in aircraft. In the article present the new method of multi-layer material thickness measurement, which is based on the digital Hilbert transformation and the signal unwrapped phase analysis and offered uncertainly estimation for two-layers materials.

The work is devoted to issues of testing of the thickness of layers of multi-layer objects and environments, such as composite materials, etc. bimetals. In [1,2] proposed a new way to control the thickness of layers of multilayer media based on the echo–pulse ultrasonic method thickness measurement, which is based on the analysis phase characteristic of the signals. As an informative parameter determines the time position of the time jump of phase characteristic, which is due to the imposition probing and reflected signals.

The new method of a ultrasonic control of multi-layer structure method is based on usage Hilbert transform and signal phase unwrapping analysis. Hilbert transform gives possibility to find the unwrapped phase of a signal. When echo signals coincide, the unwrapped phase of signal is distorted. The moment of its distortion corresponds to a phase jump. The time definition of a phase jump gives a chance to estimate a time delay and find a material thickness.

Testing thickness h is calculated according to $h = 0,5c\tau$, where c is the ultrasonic longitudinal waves pulse velocity in the layer, τ is impulse duration in test object (TO). In ultra-sound method τ is determine by amplitude characteristic [3], in phase ultrasound method – moment of phase jump.

If analytical expressions determining the thickness of layers of multilayer objects of control and accuracy of measurement indicators in the proposed method, taking into account the acoustic properties of environments.

In the case of TO (fig.1), the thickness of first layer is determined by the velocity of ultrasonic waves and the time interval distribution in this layer, which is limited by envelopes of the probe and the reflected signals; thickness of the second layer is determined from the known velocity of ultrasonic waves in the second layer and the time interval, which is limited by envelope of the reflected signal and the reflected signal jump of phase. In fig.1 U_{pr} – probing signal in TO, U_{ec} – echo signal, τ_1 – delay time in layer 1, τ_2 – delay time in layer 2.

The budget of uncertainty for phase ultrasound method for the case of double-layered TO is based on the analysis of Ishikawa diagram [4] (fig.2):

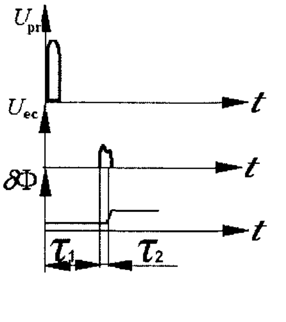

Figure 1. Allocation of time interval for case of two-layered TO

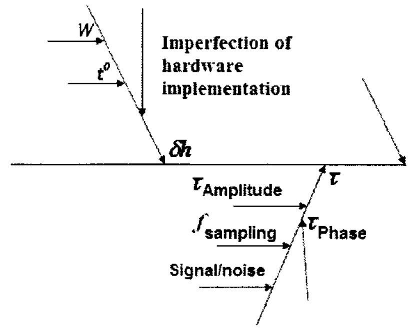

Figure 2. Ishikawa's diagram

According to Ishikawa's diagram (fig.2) is built a budget of uncertainty which is represented in tabl.1.

An alternative way of evaluating the propagation velocity of ultrasonic waves is evaluation of C by additional measurements on the reference sample, that sample with exactly known geometric dimensions.

The uncertainty is the case of the value of the time delay.

Uncertainty of time delay measurement has three main independent components:

1) the uncertainty due to sampling rate of the ADC (category B)

2) the uncertainty caused by the shape and position of Phase (Category B). The resulting of jump moment of Phase, indicating that the imposition reflected from the bottom of the TO signal.

The beginning of the time interval is known, so the error is determined by the jump moment detection.

Also this uncertainty include uncompensated component of methodical measurement errors, which caused by physical and mechanical properties of structural materials, resulting in a ratio of amplitudes of the probe and reflected m signals with a uniform distribution law and range.

3) the effect from value of the ratio S / N (Category A).

Counting uncorrelation for components of the error definition τ, its standard uncertainty is represented by standart formula.

In determination of σ_τ for double-layered TO is taken into account yet time allocation time of arrival of the envelope to determine the thickness of the first layer. This uncertainty is due to a form of ACS and is estimated by the formula:

$$\sigma_{\tau l} = \frac{\sigma_n}{S_l},$$

Where σ_n – RMS of noise on comparator input (V), S_l – slope of amplitude characteristic (V/s).

Table 1. Budget of uncertainty to determine the thickness of two-layered TO

Magnitude	RMS	Affecting factor	Type of uncertainty estimation	Distribution law	Total uncertainty	Affecting Coefficient
c	σ_c	c – passing velocity of ultrasonic waves in the thickness of the material	B	Uniform	$u_c^2 = \sigma_c^2$	$\frac{\tau}{2}$
τ	σ_τ	$\tau_{\text{amplitude}}$ – A form	B	Normal	$u_\tau^2 = \sigma^2_{\text{A}} + \sigma^2_{\text{P}} + +\sigma^2_{\text{S/N}} + \sigma^2_{\text{d}}$	$\frac{c}{2}$
		τ_{phase} – P form	B			
		f_{sampling} – sampling rate	B			
		S/N	A			
	$\sigma_{\delta h}$	t^0 – temperature	A	Uniform	$u_{\delta h}^2 = \sigma^2_{tem} + \sigma^2_{hum} + \sigma^2_{imp}$	1
		W – humidity	A			
		Imperfec-tion of hardware implementation	A			

2) the uncertainty caused by the sampling rate of the ADC (category B), which has a uniform distribution law:

$$\sigma_\tau = \frac{1}{f_{\text{sampling}}\sqrt{6}}.$$

The total root mean square error of the measurement time interval is equal to:

$$u_\tau = \sqrt{\sigma_{\text{A}}^2 + \sigma_{\text{P}}^2 + \sigma_{\text{sampling}}^2 + \sigma_{\text{S/N}}^2},$$

here: σ_{A} –RMS allocation of time interval for amplitude characteristic,

σ_{P} – RMS allocation of time interval for phase response,

$\sigma^2_{\text{sampling}}$ – RMS due to sampling ADC

$\sigma_{\text{S/N}}$ – Uncertainty due to the signal / noise ratio.

The uncertainty is caused due to the value of δh

The value δh incorporates the influence factors of temperature, humidity, imperfection of hardware implementation. Direct estimation of parameters should be carried out by the results of measurements and can be reduced by multiple repeat measurements. Here are the possible factors of influence:

1) The change in temperature. The speed of ultrasound in the material varies depending on the temperature, usually increasing on cooling and decreasing when heated. For maximum measurement accuracy of ultrasound speed setting should be carried out at a temperature at which the measurements will be carried out.

2) Setting and measurement. Arises from device calibration and gives a systematic error in following measurements.

3) The error of indicator device. Determined by the accuracy of the indicator.

4) Surface curvature of TO. In unsteady transducer echo signals are distorted, which also leads to inaccurate indications. In such cases, it is convenient to use the V- shaped spring holder clamp, which regulates a clip and creates the correct orientation of the transducer to the surface of the device.

5) The length of the cable. In some cases, it is need for long cables. Cable length, which affects the operation of thickness gauge is determined by the terms of the measurement and depends on the frequency of transducer, as well as the accuracy requirements and minimum measuring range. We assume that the impact δh is measured by the uniform law.

Conclusions and Future Work

In proposed work the uncertainly analysis of the method is conducted, estimation of uncertainly develops for two-layers materials. Ishikawa's diagram build and budget of uncertainly to determine the thickness of two-layed TO.

In the near future the experimental research of this method will be proceeded with wide band ultrasonic transducer. More experimental and modelling work will commence on real multi-layer material structure to provide a comprehensive study of unwrap phase for ultrasound nondestructive examination.

References

1. V.S. Yeremenko, Y.V. Kuts and O.V. Monchenko, Ukraine Patent #18441, (15 November, 2006).

2. V.S. Yeremenko, Y.V. Kuts, A.G. Protasov, O.V. Monchenko, *Ultrasound Method of Multi-Layer Material Thickness Measurement*, Review of Quantitative Nondestructive Evaluation Vol. 28, University of Illinois – Chicago (UIC), July 2008. P.1115

3. J.L. Rose, *Ultrasonic Waves in Solid Media,* Cambridge University Press, Cambridge, 1999.

4. *Uncertainty of measurement. Part 3: Guide to the expression of uncertainty in measurement (GUM:1995) : ISO/IEC Guide 98–3:2008. – [Accepted 2008-09-30]. – Geneva : ISO, 2008. – 120 p. – (International standard).*