NON-CONTACT AIR-COUPLED ULTRASONIC MEASUREMENT OF GEOMETRY PARAMETERS OF METALLIC STRUCTURES

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Basic parameter which characterizes technical state of metallic structures (MS) is thickness of its critical components. Thickness control is most common routine in technical inspection and is used for evaluation of residual operating life. Ultrasonic inspection is most efficient among existing non-destructive methods for thickness control. Almost all current ultrasonic inspection methods require the use of a couplant between transducer and the material to be inspected. Need of couplant is probably the most serious restriction of the method.

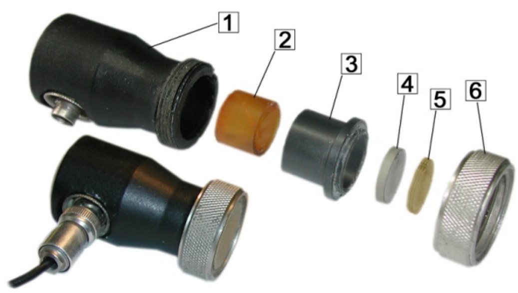
Non-contact ultrasonic inspection allows exclusion of the disadvantage and increase inspection efficiency. Great energy losses during non-contact air-coupled ultrasonic inspection disable using commercial ultrasonic transducers [1].

In this report there are given main results of theoretical and experimental research concerning air-coupled ultrasonic transducers design and experimental setup for non-contact ultrasonic measurement of geometry parameters of MS.

As a part of theoretical study, a range of problems which appears during design of air-coupled transducer for thickness control has been analyzed [2,3]. Mathematical modeling proved the need for use of neural networks aimed on clear allocation of noisy echoed signal [4]. It solves some problems of great energy the lost that appears at interfaces transducer-air and air-metal.

After accomplished reference analysis and performed mathematical modeling of the matching multilayer for air-coupled transducer [5], follow design of air-coupled ultrasonic transducer has been proposed (fig. 1). It consists of: body (1), damper (2), resonator body (3), piezo base (4) (f_{rez}*=1 MHz*, *D=20 mm*), matching multilayer 5 and O-ring 6. Damper, piezo base and multilayer matching layer are sticked together by epoxide resin and build up resonator, contained in resonator body. Electrical connections between piezo base and corresponding contacts are made of thin guides. Resonator is fixed in transducer body by O-ring.

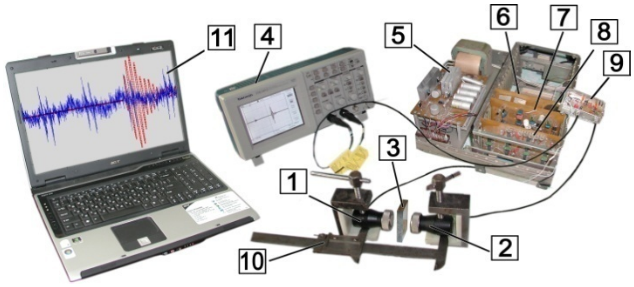
Matching multilayer consists of three disk-type form bases with diameter equal to piezo base diameter. The first one, fixed to piezo base, is made of aluminum and is *0.78 mm* thick. The second one, ethylene polymer and is *0.65 mm* thick. The outer base made of reworking cellulose and is *0.085 mm* thick. The bases are sticked together by epoxide resin.



1 – transducer body; 2 – damper; 3 – resonator body; 4 – piezo base; 5 – multilayer matching layer; 6 – O-ring;

Fig. 1. Design of air-coupled ultrasonic transducer

Overall view of experimental setup for air-coupled ultrasonic measurement of thikness of MS is shown the on fig.2.



1,2 – designed transmitting and receiving air-coupled transducer; 3 – inspeckt object; 4 – digital oscilloscope; 5 – electric power supply; 6 – high-voltage generator; 7 – ultrasonic oscillator; 8 – synchronizer; 9 – preamplifier; 10 – trammel; 11 – PC;

Fig. 2. Overall view of experimental setup for air-coupled ultrasonic measurement of MS thickness

Experimental setup includes of acoustic module, oscillator-reception moule, visualization and processing module. Acoustic module consists of two air-coupled transducers: transmitter and receiver. Oscillator-reception module consists of electric power supply, high-voltage generator, ultrasonic oscillator, synchronizer and preamplifier. Visualization and processing module consists of digital oscilloscope Tektronix TDS1012 and PC.

Laboratory investigation of experimental setup has been accomplished on 12 steel samples of different thickness (margins from *0.55 mm* to *9.53 mm*). Actual thickness of each sample has been measured by micrometer.

The investigation was done as the following. Air-coupled transducers installed one in front of another at the distance of *20 mm.* The distance was measured by trammel. After the setup assembly is turned on, the digitalization, oscillograph tracing and time recording of flight of pulse are accomplished. From digitalized selection the pass impulse was separated for cross-correlating function calculation and neural network training.

After the test specimen has beens placed between two transducers, the digitalization and recording of the pass impulse were accomplished. Calculated for each sample, cross-correlating functions and neural network outputs allowed locate pass impulses and calculate thickness of test specimens.

Thickness definition is made according to the formula:

$$h = (T_1 - T_2)\left(\frac{\tilde{n}_{co} \cdot \tilde{n}_a}{c_{co} - \tilde{n}_a}\right), \qquad (1)$$

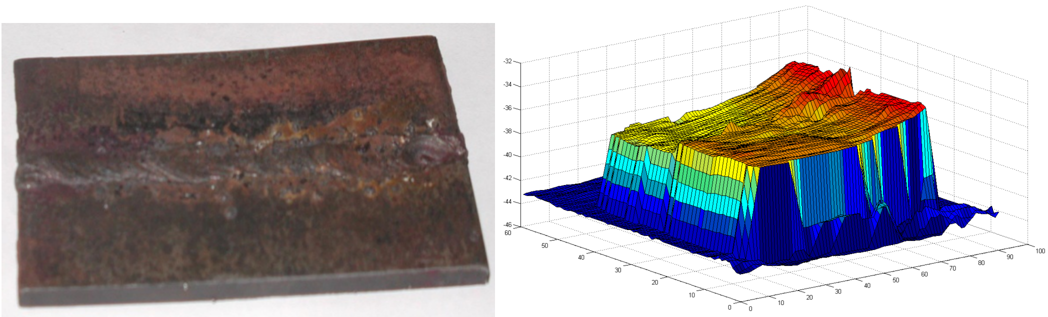
where, h – thickness of inspect object; c_{co}, c_a – ultrasound velocity in inspect object material and in air; T_1, T_2 - time of flight of pulse from transmitting transducer to receiving transducer without and with control object placed between them.

Test results and correspond errors are shown in the table 1.

Table 1 – Test results

		Real thickness of samples, mm											
		.5	0.82	1.2	1.5	1.9	2.96	3.8	3.93	5.01	5.94	6.9	9.53
Mean error Δ, %	2,32	Calculated thickness value (neural network approach), mm											
		.4	0.71	.33	1.66	.75	2.58	.61	3.89	4.89	4.94	.56	9.17
	6,88	Calculated thickness value (cross-correlating approach), mm											
		1.0	1.21	1.2	1.74	2.0	2.14	3.7	3.78	4.76	5.4	5.5	-

Some investigations for experimental setup cooperate with coordinate scanner for corrosive damage inspection of MS, have been accomplished. The fragment of gas pipeline with present corrosive damage on its body have been prepared for the investigations (fig 3,a). The surface of the sample was scanned with air-coupled transducer in *xy* coordinates in parallel to the surface area. A spatial 3-d pattern of the sample was received in designed software (fig 3,b).



a) b)

Fig. 3. Testing sample – a); spatial pattern of testing sample b)

As result of experimental investigation following conclusion can be done:

- experimental proving of non contact air-coupling ultrasonic method have been accomplished, it allowed evaluate thickness of steel samples in thickness diapason from *0.55 mm* to *9.53 mm*, with normalized to diapason mean error *2.32%* for neural network approach and *6.88%* for cross correlating approach;
- experimental setup can be used for inspection such geometrical characteristics of MS, as thickness and outer surface corrosive damage depth;
- experimental results showed that it is expedient to use neural network approach for noisy echoed signal processing, which provides smaller error.

References

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