1.3.62. FEATURES OF THE ULTRASONIC WAVES REFLECTION FROM INHOMOGENEOUS BOUNDARY OF CONTACTING SOLIDS

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As it is known there are many articles belonging to the layered objects and it is actually to inspect their interface boundary and determine the quality of the materials contact. In spite of amplitude, spectral, phase and etc. methods of ultrasonic inspection applied to evaluate quality of adhesion, cohesion, "contact power" (and etc.) of joints of two materials [1], the problems are to be arise when contacting materials have substantially different elastic properties, non-constancy of its structure and ultrasonic attenuation, high roughness of external surface and there is only one-side access to inspected object. We are developing the method of evaluation of the joints quality of contacting materials, based on the principle of interference of reflected waves from the interface surface of solids with inhomogeneous boundary (IB) conditions. This method was firstly suggested by [1] and named as a method of the "Apertures and Phase Optimization of the Imaginary Sources" (APOIS), where "imaginary sources" (IS) are the interface surfaces S_i which reflect incident ultrasonic waves (UW) and "shift" their phases. The first part of this work is devoted, mainly, to the acoustical path analysis of the APOIS method inspection when the normal probe, or the pair of angle probes, are used to inspect the interface surface of contacting materials at which discrete ("free-slip", "slip-rigid", "rigid-free") and continuous inhomogeneous conditions are modeling. Using the famous classical formulas we analyzed in detail amplitude and phase characteristics of reflected waves, the incidence angle β, the modes used and elastic properties of contacting materials at which the phase shift φ between waves, reflected simultaneously from the former different boundaries, is nearly π. Amplitude of the waves reflected from IB surface at the angle θ = β(fig. 1), can be written as

$$P \sim K_D S_D \cos\beta \left[1 + \exp(i\varphi) \frac{K_N}{K_D} \left(\frac{S_A}{S_D \cos\beta} - 1 \right) \right], \qquad (1)$$

where K_D and K_N – are the integral coefficients, characterizing UW transformation when acoustical beam is reflected by defect (D) and non-defect (N) boundary surface and received by the probe; S_D ¯ is the defect surface and S_N – spot of the acoustical beam on the interface. As the theoretical analysis show, by varying parameters $\Xi_I = \{K_D, K_N, \beta, S_N\}$ it is possible to decrease UW amplitude P reflected at angle θ = β from IB surface by ~ 20 – 40 dB and obtain the sensitivity maximum of the ultrasonic measurements. By analyzing two-dimensional IS diagram directivity Φ(θ) vs. ultrasonic emitter position (or beam position, fig. 1) we study in detail Φ(θ) evolution and its angular extremums behavior, when the former boundary conditions on the interface surface arise. It was shown, that inspection of the objects with IB surface can be realized at determined angles θ_i which magnitude are more or less than $\theta_i = \beta$. The θ_i choice and its quantity, used in inspection, depends on required sensitivity, used apparatus and testing rate, wave frequency and, especially, on the UW pulse duration.

An experimental installation has been designed to check the results of the qualitative theoretical analysis, including:

a) study of the possibilities of the longitudinal, head, surface and transverse waves using in APOIS method;

b) to check the $\Phi(\theta)$ evolution when the boundary line, separating surface regions with different IB conditions, is translating or rotating. The objects of experimental study are interface boundaries: metal (Al, Steel)–Plexiglas, Plexiglas–Plexiglas and resin–Plexiglas. The nominal frequency used was 1 – 5 MHz.

As our laboratory finding show, the data of theoretical analysis are in good qualitative accordance with experimental data independently on the mode and probe used. Partially, as seen in fig. 2, dependence of amplitude of the surface waves, reflected from inhomogeneous boundary (straight corner of rejection – rib of rectangular bar) has minimum P_R vs. position of the surface wave probe, caused by interference phenomena. So, the higher the wave frequency the deeper the minimum of P_R. Such tendency takes place and for another modes. Fig. 3 illustrates how up-to day dual probe works when it scanning along the interface with artificial defects or the inhomogeneous boundary "free-rigid".

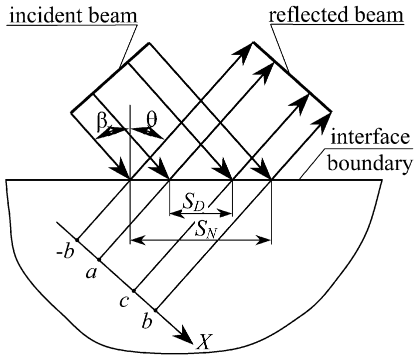

Fig. 1. Illustration for theoretical analysis

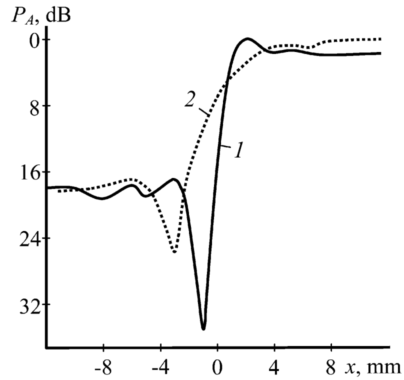

Fig. 2. Amplitude of Rayleigh wave, reflected from inhomogeneous boundary, vs. probe position *x* (experiment):
frequency *f*, MHz = 5 (1); 1.8 (2)

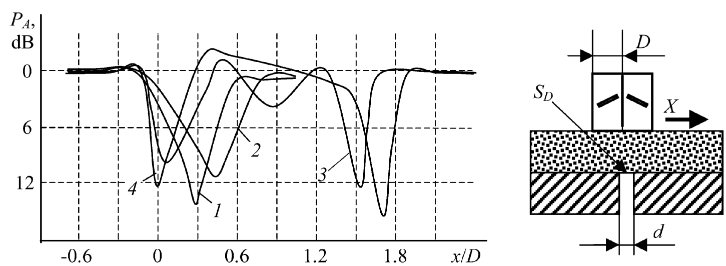

Fig. 3. Amplitude of the longitudinal wave, reflected from IB surface (free – rigid), vs. dual probe position *x*:
d / D = 0.36 (1); 0.54 (2); 1.44 (3); 1.8 (4)

The obtained data can be used for development of the APOIS inspection methodic and be useful for understanding of the results of two-layered materials testing made by the traditional way.

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References:

1. **Baev A.R.** Abstracts of Int. Conf.: Ecology and Waves. – Belarus, Minsk, 1993. – P. 95.