WELDS ULTRASONIC TOMOGRAPHY BASED ON THE PHASED ANTENNA ARRAYS WITH SMALL-APERTURE TRANSDUCERS.

A. M. Lutkevich[1], A. A. Samokrutov[2]
[1] "Acoustic Control Systems Ltd.", Moscow, Russia, [2] JSC "SPECTRUM" – RII", Moscow, Russia

Abstract: The article describes the main results in development of the manual ultrasonic tomograph for testing of welds in metallic objects. For development of small-size system it is appropriate to use the antenna array with direct excitation of shear wave in the testing object without using refracting prism. The system reconstructs the acoustic image of the defect using the SAFT-C algorithm.

Introduction: During the last years tomographic methods is a very developing direction of ultrasonic non-destructive testing. Tomography lightens the methodology of testing and interpretation of signals. This is especially important at distinguishing the signals from the defects from the signals determined by the weld form (internal roller, facets and other). Besides the tomography enlarges the possibilities in developing flaw detection and gauging methods.

The specificity of welds testing requires sending the ultrasonic beam from the near-weld area. For that sending and reception of shear waves, propagating under the angle to the object's surface is necessary. In existing antenna arrays angle prisms from Plexiglas or polyisterol are used for these purposes. But it is better to use the direct excitation of shear waves in the testing object with the elements of antenna array without the use of refracting prisms. In this case there are no noises from signal reflection in prism and no looses at wave transformation on prism-object border. The direct excitation of shear wave in object removes the limitations on angle of scanning. In this case it is determined by a maximal depth of shear waves directivity diagram for single array element and not by prism/object velocities relation.

Such antenna array is able to work with different wave types: both longitudinal and shear; the choice of wave type can be made through a program. And it is able to control not only metals, but also plastics.

Building of antenna arrays and of equipment based on them requires the exact knowledge of parameters and characteristics of small-aperture probes, which are the elements of antenna arrays. The distinctive feature of small-aperture probe is in size of its aperture, which is equal or smaller, then the longitudinal wavelength in the testing object at the operation frequency. This determines the creation of several commensurable in levels elastic wave types in the object of testing. In elastic half-space the small-aperture probe forms longitudinal, shear, lateral and surface (Rayleigh) waves. At the reception of oscillations the small-aperture probe has analogue characteristics. At that the small apertures of probes allow the electronic control of directivity function in the plane of antenna array.

Results: To build the optimal in-phase antenna array it is necessary to know the meanings of acoustical characteristics of its each element. To solve that problem the authors have made theoretical and experimental researches, develop the simulator, describing the acoustic field of every single element.

The base for these calculations was solving of Lamb problem for normal harmonic power source, active on the border of elastic half-space [1]. There was developed a simulator, describing the field, created by a normal load on a rectangular area [2-3].

Basing on the received equations were done the calculations and received the directivity diagrams for longitudinal and shear waves of the rectangular elements. The calculations were made both for harmonic and pulse disturbance. Figure 1 represents the calculated and received experimentally directivity diagram for shear waves.

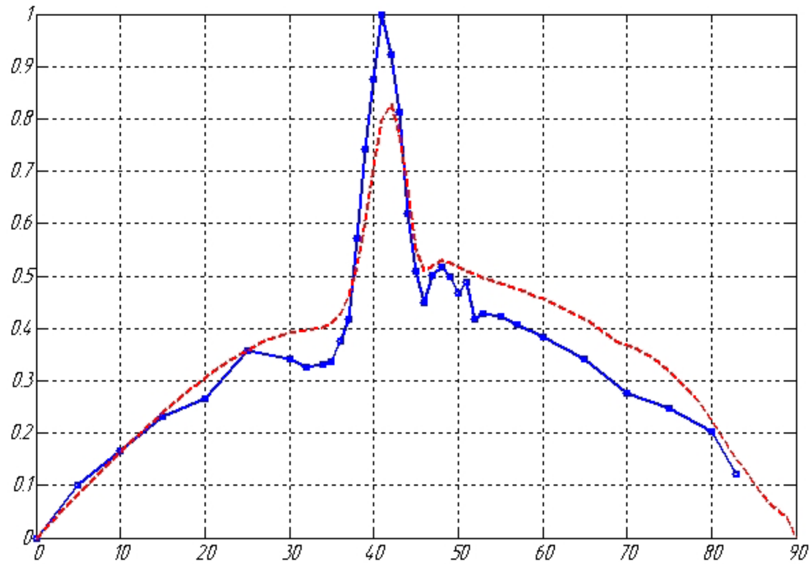

Fig. 1. Directivity diagram of small-aperture probes for shear waves in pulse mode. The firm line – the experimental, dotted line - calculated data.

On the base of numerical calculations was built the following diagram (figure 2). The diagram shows the relation between the normalized shear wave meaning module (as a function of element's width a) and an angle of propagation direction.

Discussion: The made calculations allowed determining the optimal parameters of a single element of antenna array. Thus for an element working at 2.5 MHz frequency at testing the steel objects the optimal width is 0.4-0.6 mm. At that the fall of shear wave level does not exceed 6 dB.

Using such elements was built the antenna array, consisting of 24 damped elements with active parts on contacting to surface side and wear plate. It is necessary to damp the standoff between the elements; that improves the correlation between the longitudinal and shear waves amplitudes. At other similar parameters the use of protector worsen the correlation of amplitudes on 3-6 dB. The figure 3 represents the echo-signal, received from the 8^{th} elements of 24-element antenna array on standard block-3.

The developed antenna array consists of 24 elements, made by sawing from a ЦТС-19 plate and glued to the protector. Inside the case there are multiplexor, amplifiers and commutation scheme (figure 4). This allowed to reduce the number of cables from the array to proceeding unit, reduce the electromagnetic pickup and rather simply to organize the commutation of elements.

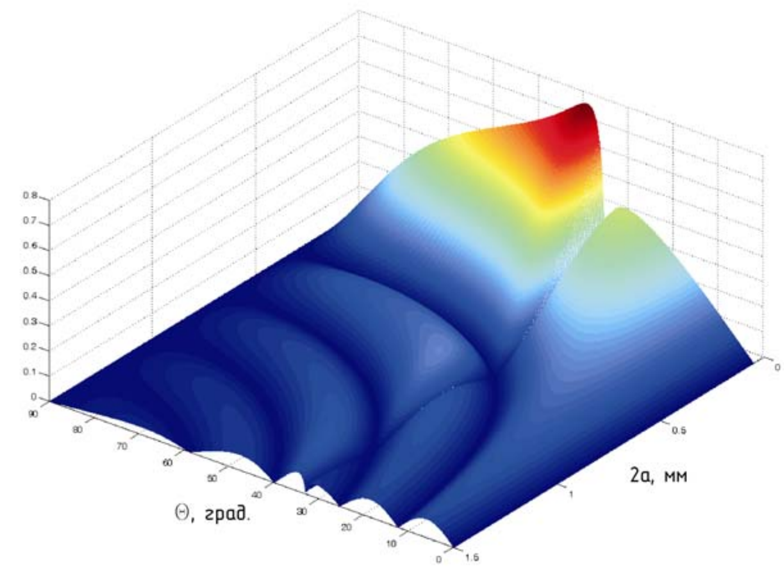

Fig. 2. Diagram of relation between the normalized shear wave meaning module (as a function of alternatives of element's width 2*a*) and angle of propagation direction θ .

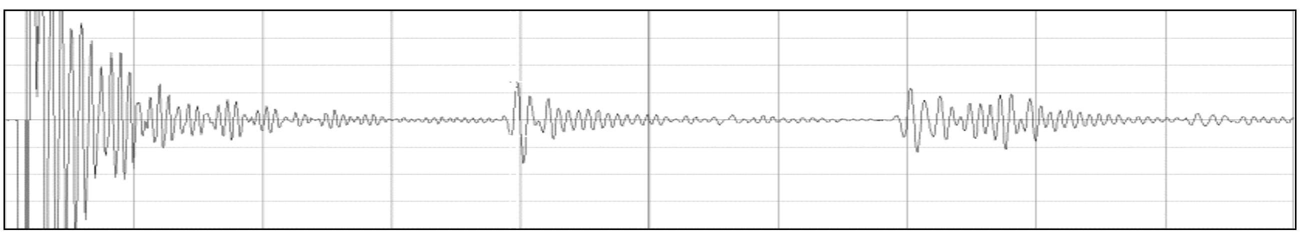

Fig. 3. Echo-signals from the backwall on the standard block-3 from the 8th element of 24 elements ЦТС-19 antenna array.

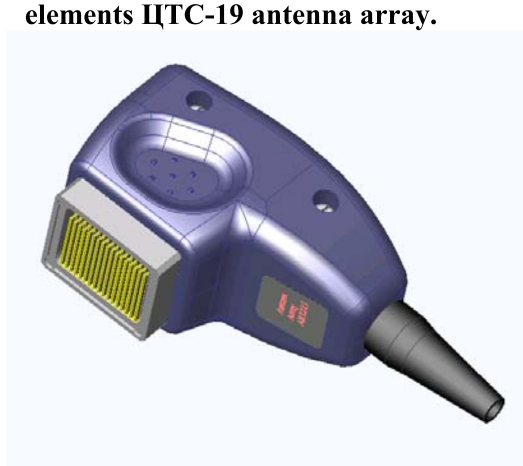

Fig. 4. Antenna array.

The SAFT-C algorithm is realized on 2 programmable logic matrixes (FPGA). This allows screening the acoustic images with the frequency of not less then 5Hz. The device allows choosing the wave type, under which the image is being built. On the figure 5 is represented the tomogram, received from standard block-1 on the longitudinal waves. In the middle left there are the acoustic images of 2 mm in diameters flaws, on the lower part of the picture there is an image of backwall.

Fig. 6 represents the results of synthesis on the standard block-2 in the area of hole 6 mm in diameter. There is an image of the hole, formed with the shear waves. The antenna array was directed 45° to the hole. At synthesis the attention was paid to the directivity diagrams of the elements.

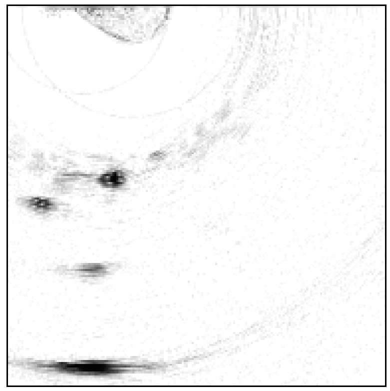

Fig. 5. Tomogram, made with the longitudinal waves on the standard block-1.

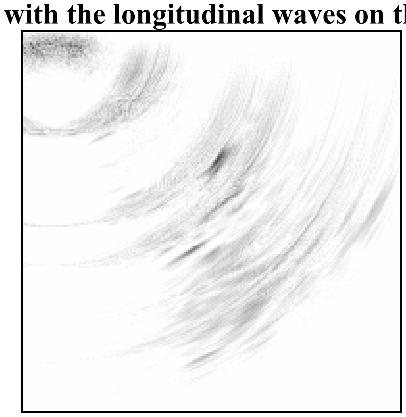

Fig. 6. Image of the hole in standard block-2, received with shear waves.

Conclusions: The made researches resulted with the following conclusion:

1. The number of rectangular piezo-elements of small size commensurable to wavelength without intermediate prisms, combined into antenna array in combination with SAFT-C algorithm of signals proceeding allow detection of defects with simultaneous use of both longitudinal and shear waves;
2. Were chosen the optimal parameters of antenna array for welds testing in steel objects: 18-24 number of elements with the step between the elements of not more then 1 mm;
3. Was developed a portable small-sized ultrasonic tomograph for welds testing, allowing on-line reception of flaws images in welds.
4.

References:

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