SMALL-ANGLE ULTRASONIC TOMOGRAPHY WITH MILLS CROSS ARRAY FOR NDT: A SIMULATION STUDY

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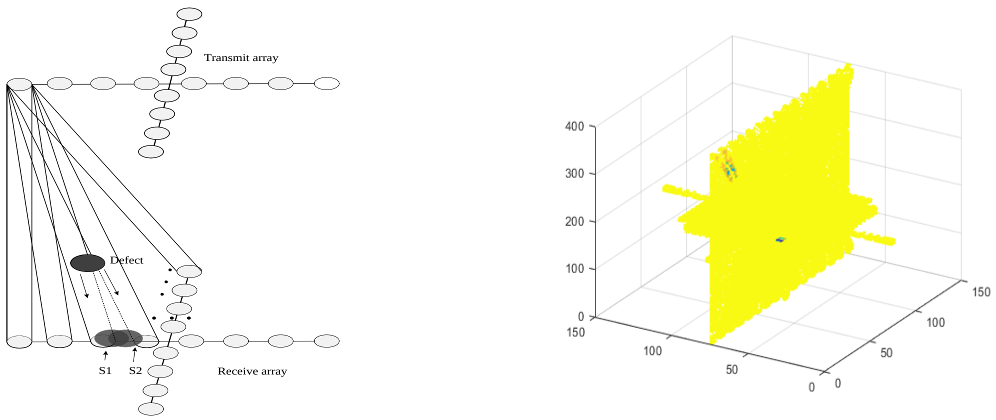
High attenuation and complex structures of some materials limit pulse-echo method inspecting engineered structures. Through-transition transmission method is particularly effective in the testing of highly attenuating and complex structured materials such as multi-layer composites, because it has a higher sensitivity noise immunity, deeper penetration depth and no dead area, in comparison with the pulse-echo reflection method. Traditional transmission method use one fixed transmitting and receiving transducer pair measurements, which make it impossible to determine the depth and shape of defects. Projections from different angles used to solve this problem, and anisotropy of acoustic impedance and shape of material limit large-angle tomography inspecting engineered structures. There are two methods of small-angle tomography are used to build two-dimensional model: mechanical scanning with two unfixed sensors and electronic scanning of with two linear arrays [1]. In order to build three-dimensional model quickly and efficiently, a new method, which use two Mills cross arrays is studied. Mills cross arrays consists of two vertical linear arrays. This method can worked in two modes: In two-dimensional scan, results that are more accurate obtained, in comparison with other methods; in three-dimensional scanning possibility to have a high-speed scanning. The disadvantages of this method - only can be used for the detection of materials with a fixed geometrical structure, complicacy control circuit, high cost of arrays, limited detection range and not necessarily more accurate test results in three-dimensional scanning.

On the basic of the Kirchhoff diffraction theory and the assumption of the existence of absolutely waves in a given acoustic path, it asserted that the diffraction integral in the shadow region very rapidly tends to zero. Thus, this digital model of the acoustic path is valid for the high-frequency case of the transmitting of the wavelength and the perimeter of the defect model [2]. In addition, it should be emphasized that the distance between the transmitter and the receiver is assumed sufficiently large. Consequently, the piezoelectric transducers composing antenna arrays are located in the Fraunhofer diffraction zone, and their working surface is much smaller than the first Fresnel zone. This makes it possible to consider the distribution of ultrasonic pressure on the elementary receiving element to be uniform, and the amplitude of the received signal of a directly proportional “sounded” surface. In addition, the size of elements is bigger than the wavelength of the sounds. Therefore, the shape and dimensions of each pair of transmitter-receiver acoustic path determine by the elements of the antenna arrays and the distance between the receiver and the transmitter.

A three-dimensional model of the acoustic path with the emitting and receiving arrays is shown in Fig1,a.



a) b)

Figure 1. (a) the acoustic paths of transmission method with Mills cross arrays; (b) result of simulation.

In this work, ignore diffraction, scattering and upper surface reflection. Each linear array consist of N same size round sensors with area S. The transmitters sequentially transmit the ultrasonic waves, and receivers receive signals in parallel. The projected area along the direction of the acoustic paths on the second receive transducer is S1 and on the third transducer is S2. The coefficients for image reconstruction are calculate in accordance with the formula:

$$k=A/A0 \tag{1}$$

Where A amplitude of received signal when there is defect in defected object, A0 signal amplitude received by the same sensor when there is not defect in defected object.

A defect in the model is simulated by a disc that is parallel to the x axis, and it is located in the testing zone with the coordinates X1, X2, Y. The defect supposed to be opaque. The defect attenuation depends on the overlap of radiation tape (Figure 2). Therefore, the transmission ratios are calculate in accordance with formula:

$$k = 1- Sm/S \tag{2}$$

Where Sm – the shadow area along the direction of the acoustic paths on the receive sensor, S – the sensor area. Due to the superposition effect, we can calculate and obtain the reconstruction of defect by back projecting data.

The shadow area along the direction of the pair of sensor path on its receiver Sm, then calculated coefficient k and assign the area covered by this acoustic path a value of k. Then sum all the path coverage areas to get the reconstructed image. Tomography reconstruction of defect showed on fig 1,b.

The paper describes a method of three-dimensional small-angle tomography for highly attenuation materials with Mills cross array. Due to the superposition effect, obtained the reconstruction of object by back projecting data, optimized simulation results by weight coefficient. Simulation results prove the theoretical feasibility of this method. However, the detection area is limited and the results are not accurate enough.

References

1. Soldatov, A., Soldatov, A., Kostina, M., Bakanov, P., Polonskaya, M. Small angle tomography algorithm for transmis-sion inspection of acoustic linear array (2016) MATEC Web of Conferences, – P. 2.

2. Provost J., Lesage F., The application of compressed sensing for photo-acoustic tomography//IEEE Trans. Med. Imaging. 2009. – T. 28. – № 4. – P. 585-594.