# USING MODELING TECHNIQUES TO IMPROVE INFORMATION OPPORTUNITIES FLAW METHOD DETECTION FOR HETEROGENEOUS MATERIALS, BASED ON THE PHENOMENON OF MECHANOELECTRICAL TRANSFORMATIONS

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The problem of flaw detection in technological structures, which are constructed from heterogeneous dielectric materials (e.g., concretes) and operated in conditions under which high reliability requirements are imposed on them, is important in practice.

Techniques that can detect and characterize the damage using non-destructive evaluation (NDE) techniques are of great interest to practicing structural engineers [1]. The NDE techniques such as Ultrasonic Pulse Velocity or Echo [2], Surfaces Waves [3] are commonly used. The existing methods are characterized by an insufficient accuracy and low sensitivity to internal defects and inhomogeneities.

This problem can be solved by using the phenomenon of mechanoelectrical transformations (METs) in heterogeneous dielectric materials under quasielastic impact excitation [4,5]. Its essence is that when acoustic waves exert an influence on sources of mechanoelectric transformations, an alternating electric field arises. Acoustic waves are formed in a sample of finite dimensions that is subjected to an impact excitation. An electric field is produced owing to the occurrence of charges on faces of piezoelectric quartz crystals, which are contained in heterogeneous dielectric materials, during their deformations and owing to displacements of these charges and charges of double electrical layers, which are localized at the boundaries of components in the heterogeneous material, relative to a receiver of electric signals. The electric measuring receiver is positioned quite close to a sample and within the coverage of this field.

Therefore, on the one hand, the electric signal parameters are determined by the elastic characteristics of an object under study and, on the other hand, by the number and efficiency of the sources of mechanoelectric transformations. The prospect for using the parameters of electrical responses to elastic impact excitations of materials for testing imperfections in concrete was confirmed by the results of previous investigations.

The objective scientific work is to search for new informative parameters of non-destructive testing of heterogeneous materials defects in the parameters of the electromagnetic response to a pulsed mechanical excitation using numerical simulation methods.

Using classical electrodynamics and mechanical relations, a model of the acoustoelectric transformations in heterogeneous materials containing piezoelectric inclusions was developed.

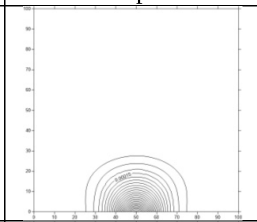
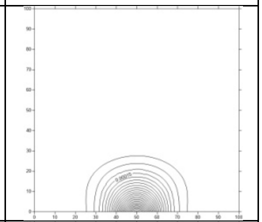
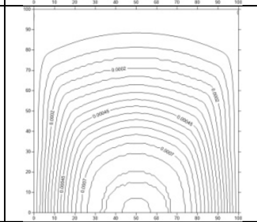
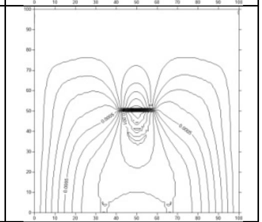
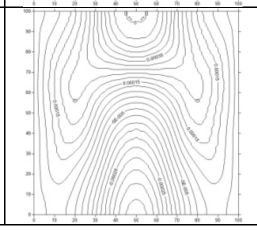
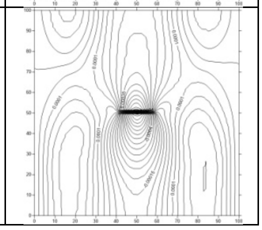
| Time, μs | Defect-free sample | Defective sample |
|---|---|---|
| 10 |  |  |
| 30 |  |  |
| 60 |  |  |

**Fig. 1.** Distribution offset pattern at regular intervals for a homogeneous sample, and the sample with a cut length of 20 mm.

Within this model, the bias current was calculated. This current defined the rate of change of the electric field due to acoustic excitation of the piezoelectric sources. The bias current equation is

$$I_{sm}(t) = \frac{d \cdot S \cdot E \cdot l}{L} \int_{S_d} \frac{V_y(t)}{r^3} \left( \frac{3h^2}{r^2} - 1 \right) dS_d$$

where *Sd* measures the electrode area; *E* is the elastic modulus; *L* is the model size in the excitation direction; *Vy*(*t*) is the displacement rate in the excitation direction; *h* is the depth of the piezoelectric source position; *r* is the distance from the source to the receiving electrode; *l* is the thickness of the piezoelectric quartz crystals; *d* is the piezoelectric modulus of quartz; and *S* is the sample cross-sectional area.

As we can see from the equation, the bias current is proportional to the displacement velocity of the piezoelectric source under the effect of elastic waves. Therefore, the parameters of electric response and elastic waves are interrelated. In ref. [6], a detailed calculation is performed based on the mathematical model of electric response.

The analysis of elastic waves distribution processes in the concrete sample in case of pulse mechanical excitation is performed using the computing mechanics of continuous medium. Numerical calculations were carried out using non-central difference scheme of the second order accuracy concerning steps by the space and time. The correctness of numerical results was evaluated by the internal results convergence in case of changing the parameters of finite-difference grid and integration steps on time and by the model tasks calculations.

The advantages of the non-central schemes in comparison to the most of normal central schemes consist in program logic simplification, the non-uniform members are easily turned on, and multivariate tasks are directly generalized. The numerical algorithm is based on the Runge–Kutta method for the solution of ordinary differential equations. Such approach arises from the effective non-central scheme of the second order offered by McCormack's [7].

The experimental researches were carried out at laboratory hardware-software complex, which performs pulse mechanical excitation of samples and records electrical response signals.

The sample size was 100x100x100 mm$^3$. Artificial defect length of 20mm and a thickness of 1 mm was created using a cutting machine. Fig. 1 shows the results of mathematical modeling of elastic waves by a defect-free samples and defective . The first figure shows that while the wave front has not reached the defect , the wave pattern is similar for both samples. After rounding wave front defect, different processes is obvious.

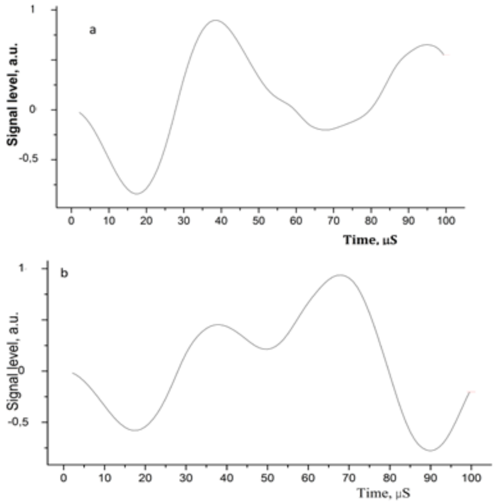



**Fig. 2.** Calculated signal a) defect-free sample and b) defective sample sample.

Fig. 2 shows the initial moment of the calculated signals from a sample. As can be seen from Fig. 2 in the sample the presence of a defect leads to a change in electrical response of the theoretically calculated.

Fig. 3 shows the experimental results of the initial moment of the signal time realization.

A good correspondence the nature of changes in theoretical and experimental data in the presence of a defect in the sample is an indication of the prospects of using modeling in the non-destructive testing. On the basis of the results obtained can be developed additional new opportunities NDT defects by solving inverse problems.

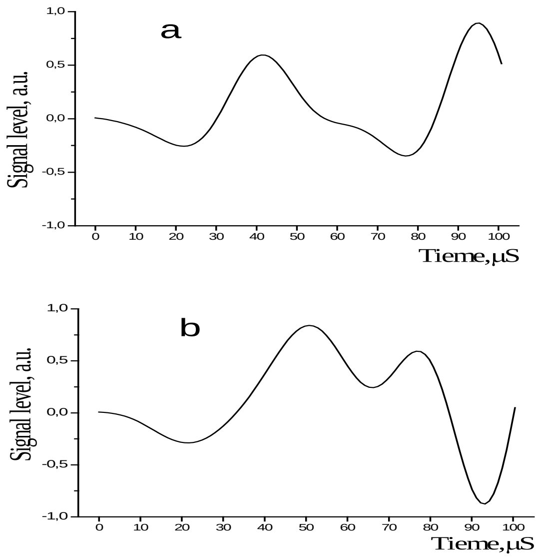



**Fig. 3.** Electric response a) defect-free sample and b) defective sample sample.

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