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Electromagnetic diagnostics of composite materials

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Abstract: It was studied the main regularities of mechanoelctric transformations in composites and developed electromagnetic methods of control of quality.

Key words: mechanoelectric transformations, defects, strength, deflected mode.

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The large volume of researches was carry out in order to interrelate parameters of mechanoelectric transformations [MET] with mechanical characteristics of composites affected MET effectiveness and to study the main factors affecting MET effectiveness.

Gain-frequency characteristics of electromagnetic response on impact excitation of composites, consisting of cement and aggregate, depend on location the last in the sample [1].

It was determined that magnitude of electromagnetic response increases proportionally inclusion size[2]. In result of mathematical calculates it was obtained the following expression:

$$A=a+b\cdot S^{0.5},$$

where A is electromagnetic response magnitude, b*is* the inclusion square; a and b are constants.

It was shown that improvement of adhesion contact between matrix and inclusion due to changing surface consistency results in increasing level of electromagnetic response on impact excitation and decreasing adhesion strength. The more inclusion surface is developed, the higher is its surface energy, and, hence, the above adhesion contact in composite is stronger. On the other hand, the more the inclusion surface is heterogeneous, the below is MET effectiveness due to decrease square of double electrical layer synchronously excited acoustic wave [3]. Consequently, surface state of the inclusion, placed in concrete, affects MET effectiveness, what may be used for adhesive strength control in composites.

MET effectiveness in composites, composed of quasi-homogeneous matrix and inclusions having other elastic constants then matrix, described by the equation:

$$A(n)=A_0\cdot n\cdot e^{-kn}$$

where A_0 is constant; $n$is inclusions concentration; k is coefficient characterized dispersion of the impact excitation energy.

Consiquenly, the process of MET in composites is superposition of two processes: decrease of electromagnetic signal intensity as an result of dispersion of acoustic waves on conclusions and increase one due to extension of the double electric layers effective square, excited an acoustic wave.

Under impact excitation of composites the MET effectiveness reflects character scattering and dumping acoustic

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energy and depends on correlation impedances of composites components. A sensor of electromagnetic signals, in contrast to acoustic one, perceives changing dipole electric moments from each of double electric layers in moment of passing acoustic wave through the sample. Therefore, electromagnetic response gives more full information about internal heterogeneity of composites in comparison with the acoustic signal.

Using methods of mathematic and physical simulation it was shown, that the main resources of MET in composites under elastic impact mechanical excitation are double electrical layers, located on the boards of heterogeneities. Electromagnetic field arises because of shifting charges of double electric layers relatively the capacity sensor.

The main factor, affected MET effectiveness in composites, was studied. Particularly, change of impact energy and duration was shown to transform spectral characteristics of electromagnetic responses in concrete. Decreasing impact duration results in broadening the spectrum of an electrical signal and shifting it to the high—frequency range. Increasing impact energy gives rise to growth of spectral maximums. Duration of the first pulse of the electromagnetic response was determined to define length the active stage of impact excitation[5].

Using the climate system, effects of temperature and moisture of environment on effectiveness of applying MET were investigated. It was determined that electromagnetic response level was decreasing in process of increasing moisture from 20% to 100%. The dependence is described satisfactorily the square polynomial. Essential decrease of signal (when moisture is became above 50%) maybe explained considerable damping the specimen. In the range from 20% to 90% of moisture it is not sizeable changes in electromagnetic response spectrum. When moisture exceeds 90%, the spectrum becomes distorted. It can be due to change of impact excitation characteristics because of specimen surface damping.

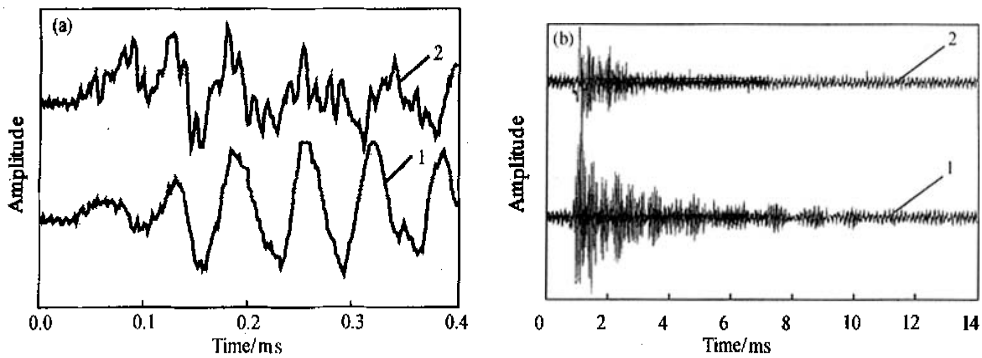

Fig. 1 Typical electromagnetic responses from concrete specimens

Curve 1: free of defects; Curve 2: defective

As to temperature influence, increasing level electromagnetic response is observed when temperature becomes below 0℃. It maybe associated with changing elastic properties of the material. Complex response-temperature relationship in area of positive temperatures is connected both conductivity and elastic properties of the material.

Obtained the main regularities of MET and factors, affected its effectiveness, was as a basis for development of nondestructive check methods of mechanical characteristics of composites. Let us view more detail character of changes of electromagnetic response parameters on pulse mechanical excitation in dependence of its defect, strength and degree of its deflected mode.

Researches shows that appearance high-frequent components in spectrum of signa(Fig. 1(a)) and level of damping electromagnetic response(Fig. 1(b))is evidence of defects occurrence in the specimen. It may be explained in the following way: appearance of high-frequent components in the spectrum is dictated reflection of acoustic waves from heterogeneities; more increased damping in defect samples is due dispersion of excitation energy on heterogeneities.

Change of spectrum characteristics of model specimens under mechanical loading is shown on Fig. 2.

One can see that loading growth causes redistribution of spectral components energy and spectrum distribution center displacement to low-frequent range while the main spectrum maximums shift to high-frequent range.

Under loading specimens, conditions of passing acoustic waves and state of composites components adhesion contacts are changed. It has effect on electromagnetic response characteristics in accordance with above shift charge mechanism.

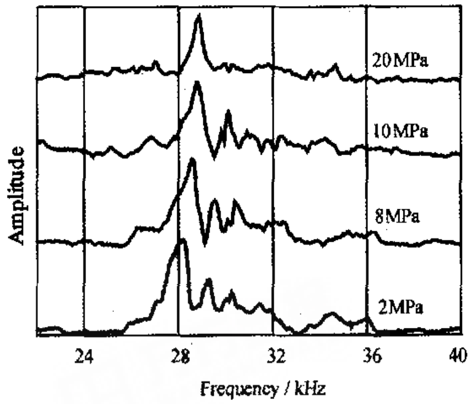

Fig. 2 Gain—frequency characteristics of electromagnetic responses under different levels of mechanical loading

Correlation analysis method was used for obtain of quantity estimation of changes, taking place in electromagnetic response depend on deflected mode degree: it is shown on Fig. 3. that meanings of maximum correlation coefficient depends on applied loading. One can see that under increase of loading and, consequently, degree of deflected mode cross-correlation function maximum decrease.

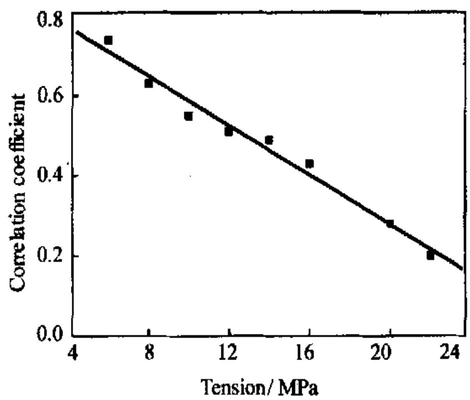

Fig. 3 A graph of maximum correlation coefficients of electromagnetic responses versus applied loading

On base of received resultes it was elaborated algorithms of nondestructive electromagnetic methods of defect control in composites and degree of deflected mode.

Criteria and algorithm of nondestructive methods of mechanical strength control in composites are posed in patents [6, 7]

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