Determining the effect of the duration of alternating acoustic excitation on electromagnetic response parameters of the composite

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Abstract. The paper presents the results of the experimental investigation dealing with the effect of the alternating excitation acoustic pulse duration on the parameters of the electromagnetic emission caused by interaction of acoustic vibrations with inhomogeneities in the sample structure, piezoelectric inclusions and media interfaces of different dielectric properties. The model sample was epoxy resin with quartz sand as filler. The electrical component of the response was recorded with a capacitive transducer. The acoustic pulse was generated by piezoelectric transducer at frequencies of 57 kHz, 65 kHz, 74 kHz, 87.5 kHz and 94.5 kHz with the pulse duration varying from 10 μs to 100 μs. It is shown that the reduced duration of the acoustic action leads to dominance of the intrinsic frequency in the spectrum. A contribution of tensile pulses to acoustic electromagnetic transformation response generation is revealed.

1. Introduction

The phenomenon of electromagnetic emission was first used in Tomsk Polytechnic University to develop methods of geodynamic phenomena forecasting (earthquakes, rock bursts and landslides) [1–5]. Later studies were aimed at using this phenomenon in nondestructive detection of defects and stress-strain state testing [6–8]. In [9–11], the authors showed the efficiency of the characteristics of electromagnetic emission under pulsed acoustic excitation to detect changes in the stress-strain and the degree of sample imperfection.

To further advance the method and develop the proposed non-destructive testing criteria by the parameters of the electromagnetic response (EMR) of solid nonmetallic materials to acoustic impact, including composite materials, the optimal conditions of EMR excitation under acoustic electromagnetic transformations (AET) are to be studied and determined. The impact of the geometry of acoustic excitation and EMR measurement, as well as excitation pulse parameters, frequency and duration in particular, is to be found out.

This paper presents the results of the experimental studies of electromagnetic responses under excitation with pulses of different duration and frequency.

2. Materials and experimental technique

The model sample was epoxy resin with a size of 60.5×78×87.5 mm with quartz sand filler. The volume fraction of the filler was 35%. The electrical component of the response to the acoustic excitation was recorded with a capacitive transducer. A PZT-19 ceramic based piezoelectric transducer located on the edge of the sample with a size of 60.5×87.5 mm was used to generate ultrasonic vibrations. The acoustic pulse was initiated by an electric harmonic pulse generated by the master generator at fixed frequencies of

57 kHz, 65 kHz, 74 kHz, 87.5 kHz and 94.5 kHz. The pulse duration varied from 10 μs to 100 μs. The capacitive transducers were installed parallel to the edges of the sample 87.5×78 mm in size at a distance of 1 mm from the surface. The signals from the capacitive transducer were amplified by the differential amplifier. The data acquisition board NI PCI-6133 recorded the electromagnetic responses from the AET sources excited by 140 acoustic pulses spaced with an interval of 7 ms. For further analysis, the responses were averaged over the entire time period. The experimental error did not exceed 5%. A detailed description of the measurement technique is provided in [6,8].

3. Results and discussion

The results obtained in measuring the amplitude-frequency parameters of the electromagnetic responses to acoustic excitation tend to be identical for all the pulse frequencies used in the experiments. Fig. 1 shows the EMR amplitude changes at a frequency of 57 kHz, which feature this tendency under discretely changing duration of the ultrasound packet: 10; 30; 70 and 100 μs.

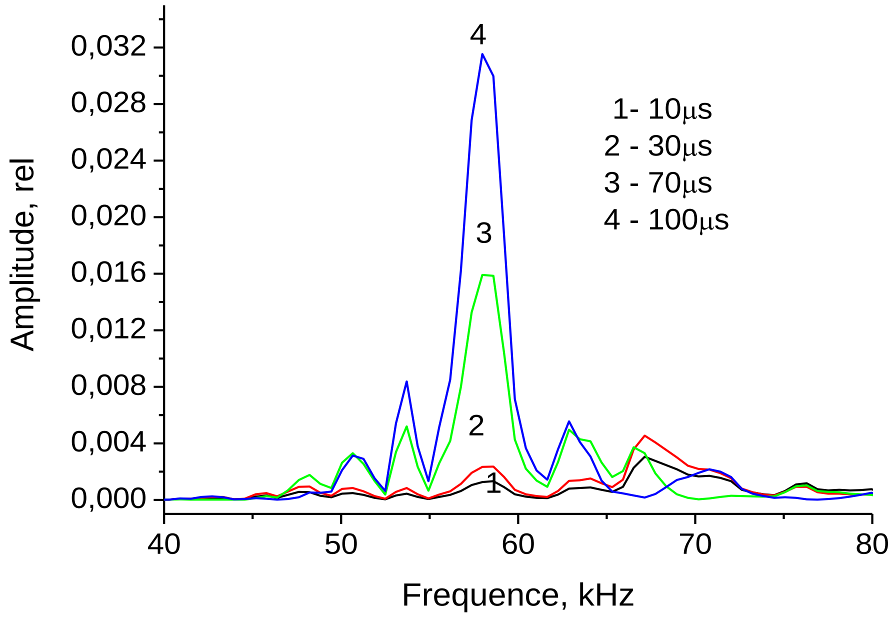

Figure 1. Spectra of the response power at a pulse frequency of 57 kHz for different pulse durations

The acoustic pulses were excited by piezoelectric transducer. The diameter of the contact surface of the transducer with the sample was 20 mm. As a result, the vibrations at the frequency of the master generator and forced vibrations at the intrinsic frequencies of the test object were initiated in the model sample. It is known that the electromagnetic signal parameters are determined by the characteristics of the acoustic impact [5,8]. Under excitation pulse duration of 10 μs and 30 μs, the vibrations at intrinsic frequencies are dominant in the spectrum. As pulse duration increases, the maximum at the frequency of the excitation pulse becomes dominant.

Fig. 2 shows the matched dependence of the integral of the response vibrational energy on the excitation pulse duration (Curve 1) and the sinusoidal voltage of a definite duration of the piezoelectric radiator from the master generator (Curve 2). To determine the energy of the integrated signal, the amplitude for each point was squared and the resulting values were summed over the entire response duration. The compression maximum in the generated acoustic wave corresponds to the positive voltage pulse maximum, and the tension maximum corresponds to the negative voltage pulse minimum. Curve 1 exhibits a number of "steps" with the duration equal to the period of the vibrations generated by the master generator with a sharp jump in the amplitude values. The amplitude jump coincides with the leading edge of the negative half-wave of the generator responsible for generation of the tensile stress in the acoustic wave.

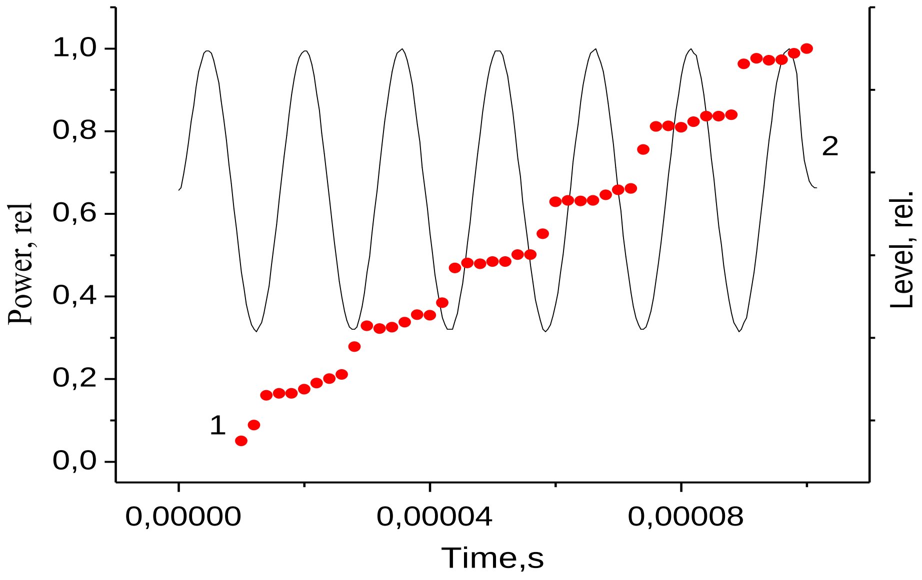

Figure 2. The integral of the vibrational energy in the electromagnetic response of the model sample versus excitation pulse duration (1); excitation pulse at 65 kHz generated by piezoelectric radiator (2).

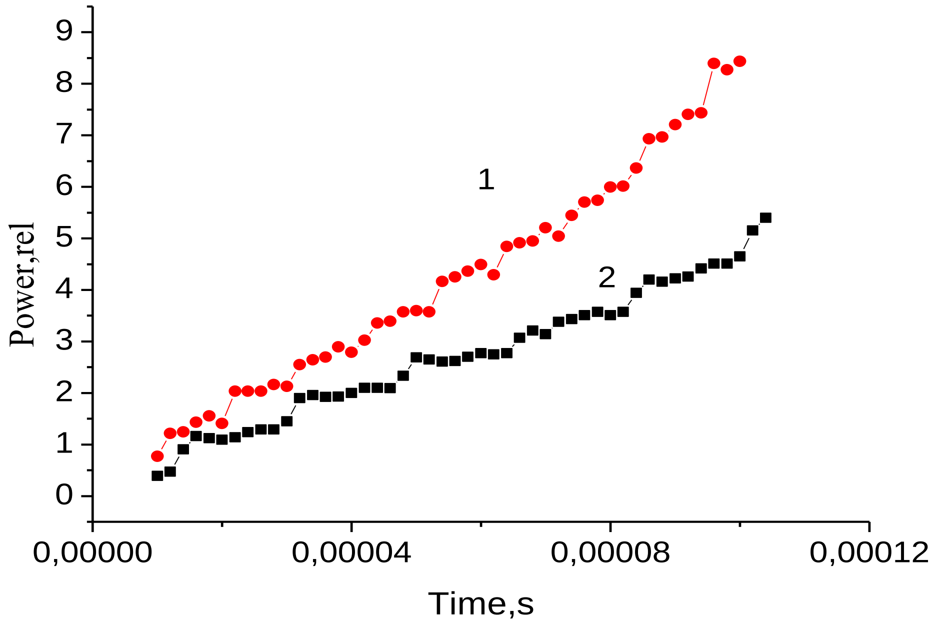

Figure 3. The integral of the vibrational energy in the electromagnetic response of the model sample versus pulse duration of the acoustic excitation at 94.5 kHz (1) and 57 kHz (2)

Fig. 3 shows the dependences of the integral of the electromagnetic response vibrational energy on the excitation pulse duration for frequencies of 94.5 kHz and 57 kHz. The dependencies indicate alternating sections with a smooth rise within the time equal to the period of the vibrations from the master generator with a sharp jump in the amplitude values coinciding with the emergence of the tensile pulse in the sample.

In order to eliminate the impact of the superposition of vibrations on the shape of the dependencies (Figures 2 and 3), the control measurements were performed with non-differential circuit when all the measurements were performed with one capacitive transducer (Fig. 4).

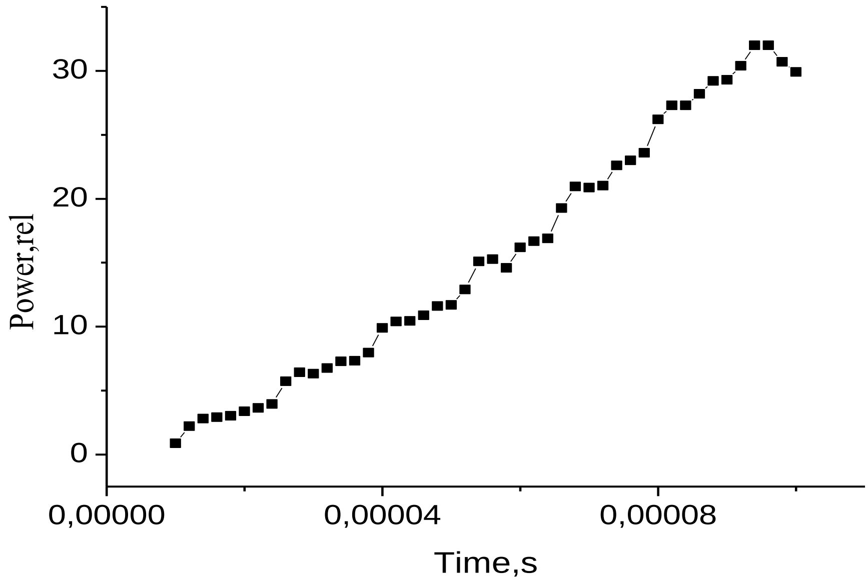

Figure 4 The integral of the vibrational energy in the electromagnetic response of the model sample versus the acoustic excitation pulse duration at 74 kHz (for non-differential amplifier input)

It can be seen that in this case, the feature of the integral dependence of the vibrational energy in the electromagnetic response of the model sample on the acoustic excitation duration is similar to that obtained via the differential measurement circuit as well. The steps in the curve under short excitation pulse durations become more distinct. This may be due to the fact that under short acoustic pulse durations, the electromagnetic response at intrinsic frequencies becomes dominant in the spectrum.

4.Conclusions

Thus, simulation of the impact of the alternating acoustic excitation duration on the parameters of the electromagnetic response of the model composite sample made of epoxy resin with quartz sand filler indicated non-linear dependence of the electromagnetic signal vibrational energy integral on the action time. The change in pulse duration causes redistribution in the AET response spectrum. Reduced duration of the acoustic excitation makes the intrinsic frequencies of the electromagnetic signal dominant in the spectrum. It is found that under alternating acoustic excitation, tensile pulses greatly contribute to the formation of the AET response. The obtained results can be used for development and application of the techniques to detect defects in solid dielectric materials by the parameters of the electromagnetic responses to alternating acoustic impact.

Acknowledgments

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