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VELOCITY OF ULTRASONIC WAVES PROPAGATING IN COMPOSITES: DEPENDENCE ON CONCENTRATION.

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This paper is devoted both to experimental studies of ultrasonic waves (USW) velocity dependence on concentration of glass spheres inserted as despersed particles into polymeric matrices and to solution of the reverse problem of obtaining information about dependence of the elastic properties of composites on concentration and structure configuration of inserted particles.

With developing new technologies an interest to composite materials steady increases. The physical properties of composites can be widely changed by varying the particles size, their concentration and distribution in matrix.

In this study the 10% gelatine solution (composites 1) and epoxide resin (composites 2) were used as matrix. The concentration of inserted particles varied from 0.01% up to 50% by volume. Measurements were held at 3 MHz frequency of USW. Glass spheres were glass shell with gas inside it. The thickness of the glass shell was 1 – 3 μm. To determine the particles distribution by sizes, 1000 particles was measured with microscope and histogram, presented at Fig. 1 has been drawn. The range of particles size variation, as it can be seen from the graph, was from 3 up to 40 μm, average radius of particles being ≈ 10 μm. Glass spheres have been inserted into 10% gelatine solution at temperature ≈ 80°C and distributed by mixing all over the volume of the sample, placed inside a container. Then the container has been cooled, the composite extracted from it and placed into cuvette for measurements.

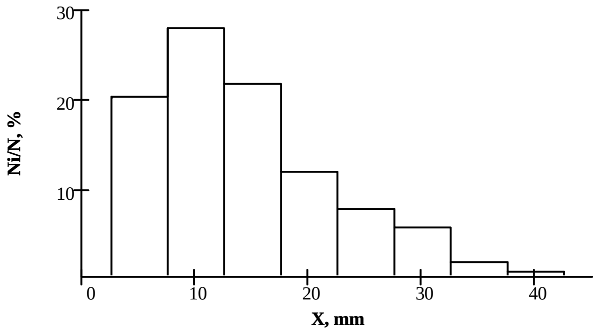

Fig. 1 Particles sizes histogram.

The sample under research has been positioned in the center of the cuvette inside the transducer`s ray-zone. The cuvette has been filled with distilled water. The reflecting surface of the sample was positioned parallel to emitting-receiving surface of the quartz, which could be displased it. That allowed measureing the reflection coefficient for different parts of the sample [1,2]. In Fig. 2 the results of measurements of reflection coefficient for composites with variation of particles concentration are presented. From this experimental data one can see that reflection coefficient increases with growth of particles concentration. It can be noted also rather significant scatter of experimental points, exceeding the inaccuracy of measurements. To study the cause of this phenomena we measured reflection coefficient for composites formed by the same inserted particles, but with their distribution

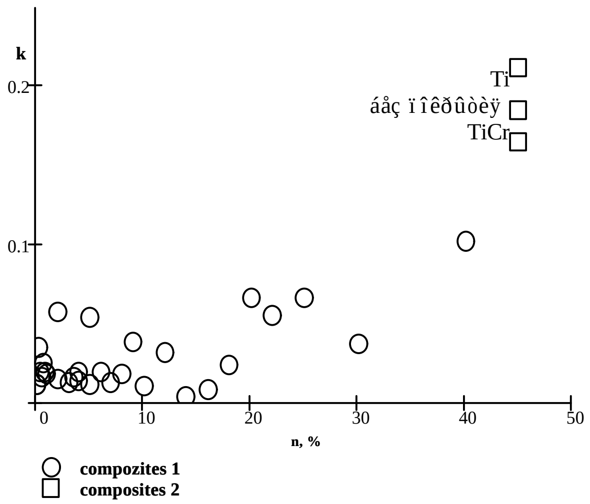

Fig. 2 Reflection coefficient

changed by remelting the sample. The results of these measurements are presented in Fig. 3. On abscissas are the values of the transducer displacement along the sample are and the ordinates are ratio of pressures in incident and reflected waves. As it can be seen from the graph the remelting of the sample leads to spreading of reflection coefficient values at the same positions of the transducer. So, reflection coefficient fixes every particles configuration. With growth of particles concentration the spread of reflection coefficient values diminishes as a result of stabilization the particles structure configuration [3].

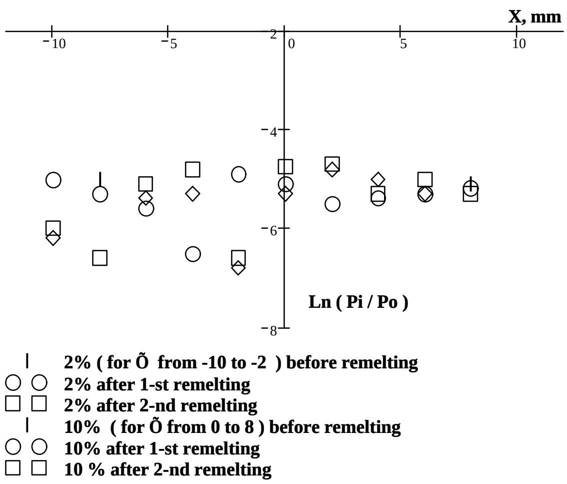

Fig. 3 Remelting of the samples 2%, 10%

In Fig. 2 also values of reflection coefficient for composites, formed by epoxide resin and glass spheres (volume concentration 50%) are presented. At such concentration, as it has been mentioned above, stabilization

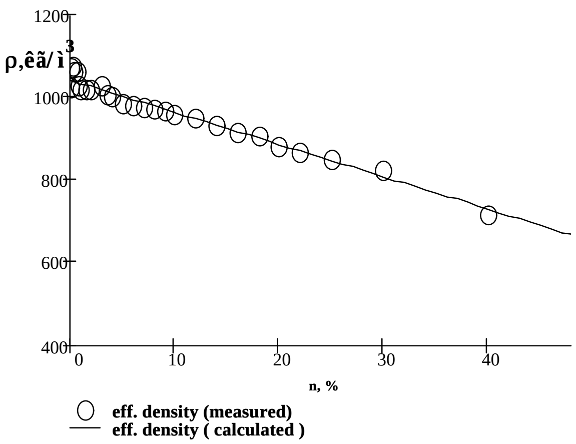

Fig. 4 Effective density

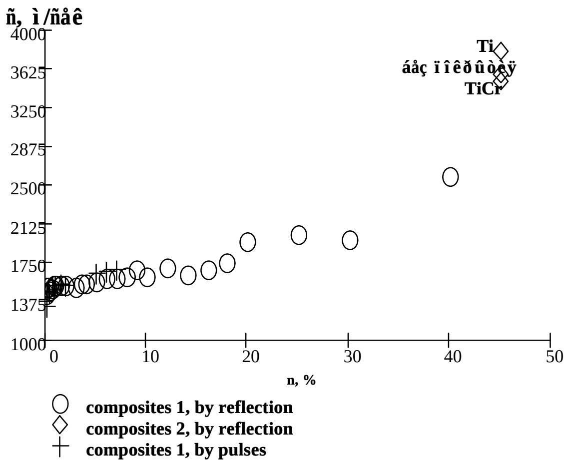

Fig. 5 USW velocity in composites

of the particles structure configuration takes place, so the variations of reflected signal, presented in Fig. 2, can be explained as variation of the surface interaction forces between the phases forming the composite. Let us consider the formula for calculating the reflection coefficient k: $k = (Z_k - Z_1)/(Z_k - Z_1)$, where $Z_k = \rho_{eff} c_k$ – the composite wave impedance, $\rho_{eff} = (1-n)\rho_1 + n\rho_2$ – the composite effective density, c_k – velocity of USW in composite, Z_1 – the water wave impedance[4].

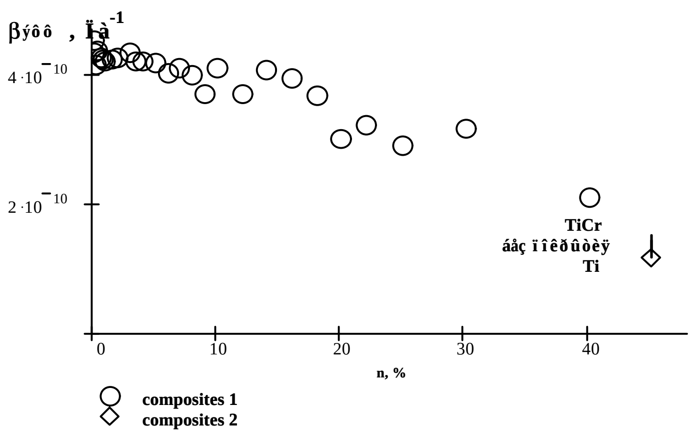

Fig. 6 Effective compressibility

Fig. 4 and 5 respectively show dependence of effective density and USW velocity on concentration of inserted particles in composite. One can see the increasing of velocity with growth of particles concentration. In region of low concentrations (n ≈ 0.01 – 7%) USW velocity has been measured by the time lag between pulses, reflected from the front and back surfaces of the sample.

Measured values (in fig. 5 shown as +) coincided with data, calculated by reflection coefficient, which confirms the possibility to determine the USW velocity by reflection coefficient. Fig. 5 also presents the values of USW velocity calculated by reflection coefficient for composites " epoxide resin – glass spheres". The variation of particles surface properties influences the valurs of USW velocity.

Obtained values of USW velocity in composites and effective density allowed to calculate effective compressibility $\beta_{eff} = 1/c_k^2\rho_{eff}$ of composites. The results of calculations are presented in Fig. 6. One can see from the graph the decreasing of β_{eff} with growth of particles concentration. In the same figure the values of effective compressibility for composites formed by epoxide resin and glass spheres are presented. The variation of particles surface properties influences the effective compressibility. Thus the measurements of reflection coefficient allowed to demonstrate the increasing of USW velocity in composite with growth of dispersed particles concentration. The elastic parameters of composites depend on particles structure configuration inside of the matrix. Variation of elastic parameters decreases with growth of particles concentration.

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