Study of vibro-acoustic properties of composite materials based on polyurethane injection

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Annotation. Modern standards of noise and vibration make the manufacturers of vehicles, machines and construction materials take into account the high demands in the design process. Often there is a need both in vibrations absorbing and in effective sound absorbers. Therefore there was a research on the concentrations of matrix components, fillers and modifiers impact on the absorbing and elastic properties of the polyurethane composites. The evaluation of sound-absorbing and elastic properties was in determination of sound absorption coefficient Cs and dynamic elasticity modulus Ed of developed composite materials. The aim of this work is to study changes in the properties of composite materials based on polyurethane matrix to identify compounds with the highest sound absorption and vibration absorbing properties simultaneously.

Urethane composition was used as matrix components, consisting of component A (mass fraction of hydroxyl groups, 4.4%); Component B (mass fraction of isocyanate groups, 21.4%). A polyurethane matrix selection is due to the high popularity of polyurethanes in modern industry due to a number of valuable properties, such as resistance to mechanical and chemical influences, a wide range of physical and mechanical properties and others.

Fillers and modifiers used:

1. Aerosil - colloidal silicon dioxide (SiO2), very light micronized powder with strong adsorption properties. "Aeros" is a trade name, coined by the German chemical company «Evonik Degussa AG». The technical name is pyrogenic silica.

2. Expanded clay - lightweight porous building material, produced by the burning of fusible clay.

3. Aluminum hydroxide - alumina compound with water. The white gelatinous substance poorly soluble in water, has amphoteric properties. Prepared by reaction of aluminum salts with aqueous solutions of alkalis, avoiding their excess.

The dried aluminum hydroxide is a white crystalline substance, insoluble in acids and alkalis. It is used as a flame retardant (suppressor burning) in plastics and other materials.

4. The organic silicon compound. There is a connection between the silicon and carbon atoms its
molecules. It is used for the production of lubricants, polymers, rubber, rubbers, silicone fluids and emulsions.

Directional control of the chemical structure of the polymers is a method of improving them. This process can be carried out by copolymerization of polymers with other monomers. Their introduction (injection) increases the mobility of macromolecular segments and increases the sound-absorbing properties.

In order to enhance the elastic and sound-absorbing properties the two-component polyurethane matrix was modified by the introduction of silicon organic compound (CO).

As a result of a chemical reaction of the polyethylenepolyamine with the polyisocyanate gel fraction was formed which subsequently serves as an additional source of dissipation of vibrational energy.

Figure 1. shows the effect of modifying agent (10 parts by weight) on dynamic modulus of elasticity (Ed) polyurethane CM with different concentrations of matrix components.

![Graph showing dynamic modulus of elasticity](image)

**Figure 1.** Effect of modifying agent (10 parts by weight) on Ed PU matrix CM with different concentrations of matrix components

As can be seen from the graph in Figure 1, the dynamic modulus of elasticity of the modified polyurethane CM varies extremely from a sharp decrease to an increase. The dynamic modulus of elasticity of nearly all the unmodified compositions is higher than of unmodified ones. This indicates that the modification has improved elastic properties of the PU matrix.

Table 1 shows that the sample with the concentration of the matrix components A: B is equal to 125: 100 and a modified CO with additive in volume 10 weight parts has a Cs greater than the unmodified composition. The sound absorption properties increase with the introduction of the complex reactive additive is connected with decreased velocity of wave propagation in the polymer. In addition, such a content of CO compound (10 parts by weight) helps to reduce the flammability of the material and expands the scope of its application.

**Table 1.** The effect of modifier (10 parts by weight) on the sound absorption coefficient of matrix polyurethane CM

| modifier | component A | component B | sound absorption coefficient Cs |
|----------|-------------|-------------|--------------------------------|
|          |             |             | 630 Hz 1000 Hz 1600 Hz       |

|          |             |             | 630 Hz 1000 Hz 1600 Hz       |
It is known that water is a widespread intumescent agent of PU. The amount of water required for active gassing of polyurethane matrix is 1%. The porous structure effectively absorbs sound waves and dampens vibration.

The interaction of a certain ratio of matrix components with the modifying additive forms PU foam. Foamed CM shows the isocyanate component sensitivity to moisture, which is initially in urethanoforming polyester and is absorbed from the environment.

The analysis of data obtained as a result of the study showed the feasibility of modifying the PU matrix by one-component modifying additive at 10 parts by weight and the introduction of 1% water to obtain the CM with higher sound-absorbing and elastic properties compared with the PU matrix composites. All subsequent CM filled compositions are based on PU composition modified by 10 parts by weight of the compound CO and 1% water.

Table 2 shows the compositions of CM samples with different ratios of fillers and the study results of their sound absorption coefficient and the dynamic modulus of elasticity.

| № samples | Components ratio of modified matrix, parts by weight | Filler and its content (parts by weight) | Sound absorption coefficient Cs, in Hz | Dynamic modulus of elasticity Ed Mpa |
|-----------|-----------------------------------------------------|----------------------------------------|----------------------------------------|-------------------------------------|
| A(GSS)  | Б(PFP) | 630 | 1000 | 1600 | | |
| 1 | 186 | 100 | – | – | 0.07 | 0.07 | 0.05 | 426 | |
| 2 | 175 | 100 | – | – | 0.04 | 0.11 | 0.04 | 364 | |
| 3 | 150 | 100 | – | – | 0.06 | 0.11 | 0.01 | 207 | |
| 4 | 125 | 100 | – | – | 0.15 | 0.3 | 0.06 | 93 | |
| 5 | 100 | 100 | – | – | 0.08 | 0.14 | 0.03 | 371 | |
| 6 | 125 | 100 | Aerosil; 0.1 | – | 0.35 | 0.12 | 0.08 | 761 | |
| 7 | 125 | 100 | Aerosil; 0.2 | – | 0.43 | 0.37 | 0.26 | 165 | |
| 8 | 125 | 100 | Aerosil; 0.3 | – | 0.48 | 0.57 | 0.46 | 95 | |
| 9 | 125 | 100 | Expanded clay; 0.1 | – | 0.25 | 0.27 | 0.017 | 328 | |
| 10 | 125 | 100 | Expanded clay; 0.3 | – | 0.42 | 0.28 | 0.22 | 110 | |
| 11 | 125 | 100 | Expanded clay; 0.4 | – | 0.36 | 0.22 | 0.17 | 41 | |
| 12 | 125 | 100 | Aluminum hydroxide, 0.2 | – | 0.25 | 0.21 | 0.2 | 338 | |
| 13 | 125 | 100 | Aluminum hydroxide, 0.3 | – | 0.33 | 0.75 | 0.05 | 326 | |

Considering the results of samples tests of 1-5 we see that with increasing concentration of the matrix component A there is a growth dynamic modulus of elasticity, which is connected with an increase in the degree of PU monomer crosslinking.

The study of unfilled modified PU compositions with different ratio of components A: B shows that the modified matrix composition in a ratio of 125: 100 has the greatest Cs. The same composition showed the smallest elastic modulus Ed, and thus the best vibration-absorbing properties among the rest of the samples.

The subsequent filling of the composition with aerosil, expanded clay and aluminum hydroxide increased sound absorption and reduced dynamic modulus of elasticity. It should be noted that with an increase in the filler volume content, the sound-absorbing and vibration-absorbing properties of the
samples are increasing at the same time. But the growth is uneven.

The material with the best sound absorption (Ed = 41 MPa), sample №11, but the Cs in the entire investigated audio range did not exceed the value of 0.36. This means that being a good vibration-absorbing material, this material is not enough an efficient sound absorber.

The material with the best sound absorption properties is sample № 13. Maximum Cs occurs at a frequency of 1000 Hz and is 0.75. It should be noted that at other frequencies Cs of this sample shows much lower values. The storage modulus is 326 MPa, that indicates the lowest vibration damping capability.

The best of the investigated CM filled on the basis of the modified PU matrix is sample № 8, since in the entire frequency range from 800 Hz to 1600 it showed a stable performance of Cs, increasing with the filler weight increase to a value of 0.57. The modulus of elasticity of sample number 8 is 95 MPa, that means good vibration-absorbing ability.

The analysis of the data obtained showed the advisability of PU matrix modification by one-component modifying additive in a concentration of 10 parts by weight and its subsequent filling for vibro-acoustic CM obtain.

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