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Method and Apparatus of Measuring Velocity and Sound Attenuation Coefficient in Bulk Materials Based on the Analysis of the Structure of Sound-Insulation Materials on the Basis of Perlite

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Abstract. This paper presents the results of research and describes the apparatus for measuring the acoustic characteristics of bulk materials. Ultrasound, it has passed through a layer of bulk material, is further passes through an air gap. The presence of air gap prevents from measuring tract mechanical contacts, but complicates the measurement technology Studies were conducted on the example of measuring the acoustic characteristics of the widely used perlite-based sound-proofing material.

1. Introduction
Various types of bulk materials widely used in industry, construction, agriculture for heat shield and sound insulation [1]. Their properties are described by the following characteristics: the bulk density $(\frac{T}{m^s})$; the particle size (mm); the friction coefficients (internal, with steel, with wood, with rubber); the angle of inclination of the slope (degree). They describe operation properties of bulk materials, their use for various technical purposes and in different industry sectors [2-3]. However, exactly acoustic properties – the speed of propagation and attenuation of sound, must be defined for determination of sound insulation properties. Such instruments and methods of measurement of acoustic characteristics of bulk materials are missing currently. This is due to physical difficulty sounding samples due to the very large ultrasound attenuation in them. Instrument sounding method implementation presupposes the existence of various structural elements. The appearance of any mechanical contact between them leads to acoustic noise, the amplitude of which significantly exceeds the levels of acoustic signals after passing through a layer of bulk material.

2. Expanded Perlite
Perlite is a highly efficient heat-and sound ecologically clean material, reliable servant in the temperature range from -200° to +900° C. Swelling perlite is carried out in furnaces by thermal shock at 900-1100° c. the presence of constitutional water attached Perlite's ability to Slough when heated. Bound water, evaporating, creates countless tiny bubbles in the softened mass. The breed is divided into spherical grain with an increase in volume 4÷20 times and porosity of up to 70÷90%. Change

thermal expansion mode allows to produce various materials ranging from fractional composition of Perlite powder (less than 0.14 mm) to perlite crushed stone (10-20 mm). Depending on the size of grains of wood flour are distinguished (0.1 mm), perlite (0.16 mm), agroperlite (1-5 mm). Perlite sand is widely used in insulation fillings walls, floors and ceilings. Perlite bulk density ranges from 75 to 200 kg/m^3 use of Perlite reduces the thickness of the thermal insulation filling compared to the widely used ceramic concretes in Russia in 2-3 times. Compared to other thermal insulation materials, ecologically pure sand expanded perlite, incombustible, does not age, it does not live pests. Perlite is also used in glass, metal, chemical industries, agriculture (agroperlite).

Heat and sound insulating properties of expanded perlite defines its structure. For control of technological process, as well as to obtain different fractions of material structure analysis becomes necessary at different stages of production.

To get an idea of the internal structure of the material using x-ray computed tomography was used to capture the image slicer (tomogramma) perlite powder (Figure 1A) and 3-D image volume Ø5 x 5 mm (Figure 1B). Picture shows that expanded perlite is a combination of particles and their shape is close to areas of different diameters are available "stick together" sphere; also of different diameters are enclosed fields. A significant portion of the volume of matter takes the air. The term "structure" describes characteristics: diameter range of spheres; average diameter volume areas; thickness of individual areas; the relative content of material and air.

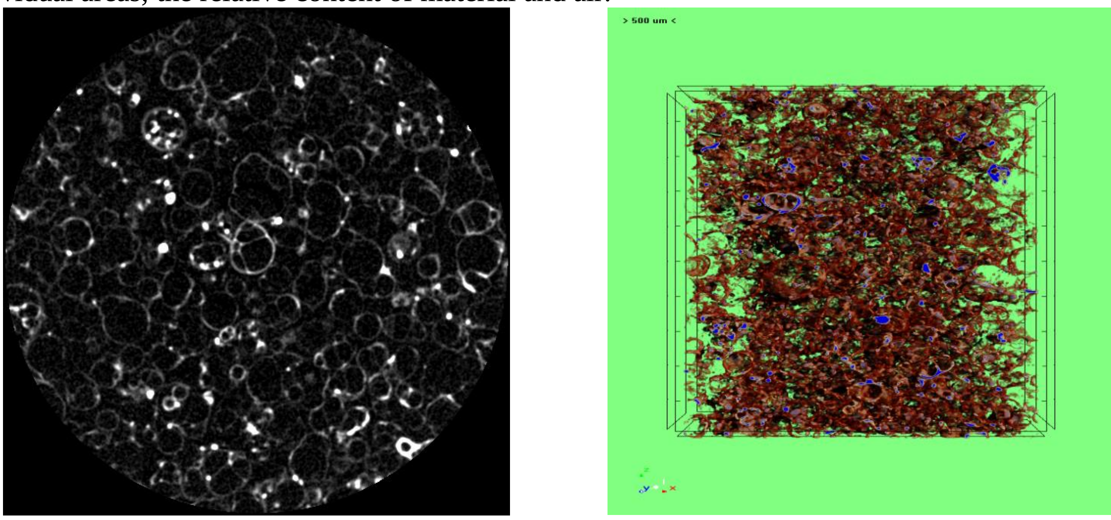

Figure 1. Tomograms, where a) tomogramma sample of expanded perlite; b) 3D-image element volume of expanded perlite.

In the work we investigated the possibility of application of ultrasound to monitor the structure of expanded perlite. The analysis showed that the information about the characteristics of the structure of the material can be obtained through measurement of sound velocity in it and its attenuation. However, measuring the speed and attenuation of sound in bulk materials using available modern equipment and measurement techniques impossible. This is due, primarily, with a very large attenuation in any bulk material. Secondly, it is impossible to carry out acoustic emitter and receiver at the same time contact with the powder. Or input or reception must attend an air gap, which excludes mechanical contact between the individual elements of design.

3. Installation

For measurement of velocity and attenuation of sound installation was developed for measuring the acoustic characteristics of granular materials. Installation work is based on the measuring time and attenuation of the wave in a layer of material known thickness, when passing the sound further, through well-known layer of air. Speed and sound attenuation in bulk material are determined by comparison with speed and attenuation of sound in air. Structural diagram of an apparatus for measuring speed and ultrasound attenuation in bulk material is shown in Figure 2.

The installation consists of the following units: a piezoelectric emitter (1), piezoelectric receiver (2) with integrated preamp. Probe excited by pulse generator output-device UK-14PM (3) and creates an acoustic pulse that passes through the material (h) and (H) and arrives at the receiver (2), passing through the zone control $(L)_0 = (h) + (H)$.

At the output of the receiver Crystal (2) there is an electrical impulse that, amplifying preamplifier fed to the input Attenuator (4). The Attenuator (4) is used to measure the amplitude of the past through the control zone of the acoustic pulse and adjust the signal level at the input connector of the device of the UK-14PM (3) material is controlled in the cell height (h). The ditch is installed on the radiator. PROBES through the contact layer of oil.

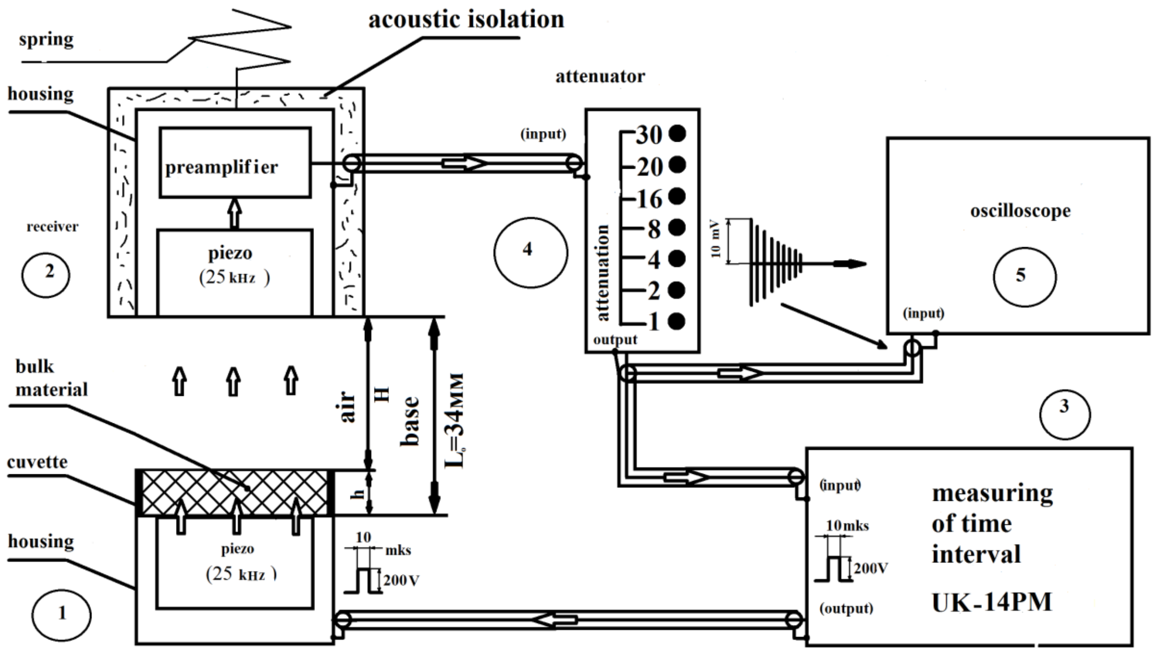

Figure 2. Block diagram of the Setup for the measurement of velocity and attenuation of sound in bulk materials.

Receiving the converter cannot be installed on the top surface of the material, because controlled amplitude spurious signal passing through the walls of the cells is much higher than the amplitude of the signal passing through the measured material. The only possibility of measurement is the measurement of acoustic signals from the top surface of the controlled material thickness (h) and passed through the layer of air H. While receiving the Converter requires a very effective sound insulation from all elements of the installation. The high attenuation of sound in bulk material and in the air receiving signal from preamplifier gain not less than 10^3. To measure time intervals used appliance UK-14PM. It is designed to work with converters from 20 kHz to 1 MHz and is designed for measuring the propagation time of longitudinal ultrasonic oscillations shadow method. The device provides the measuring range the propagation time of 20 μs up to 8800 μs and time measurement accuracy 0.01 t.

3. Sound velocity measurement.

The process of measuring the speed of sound consists of the following steps:

• Calibration time interval meter UK-14PM;

To calibrate the meter is used with State standard sample SO-2 with time passing longitudinal wave 10 μs. The sample is installed between the emitting and receiving transducers and with potentiometer "mouth. 0 "On the display of the device is set reading" 10.0 μs.

• Measurement of the speed of sound in air;

Measurement of the time passing (t_{air}) ultrasonic pulse through air gap (L_0) without measurable material. Of values (t_{air}) and (L_0) is speed of sound in air is defined as

$$C_{air} = L_0 / t_{air} \tag{1}$$

• Is poured into the cavity height (h) bulk material. To move full time is measured **t**. At a known velocity value. sound in air full time is

$$t = t_{mat} + H/C_{air} \tag{2}$$

• Determined by the moving sound through a layer of granular material (h) and calculated the speed of sound in it.

$$t_{mat} = H/ C_{air} \quad \text{and } C_{mat} = h/(t - H/ C_{air}). \tag{3}$$

Table 1 shows the average results of measurements of the speed of sound in expanded perlite for a fraction of 0.1-0.2 mm (filtroperlite).

Table 1. Speed of Sound in Perlite.

L_0, [mm]	h, [mm]	H, [mm]	C_{air}, [m/s]	T, [μs]	t_{mat}, [μs]	C_{mat}, [m/s]	Error, Δc, [m/s]	Error Δt, [μs]
34	10	24	322	114	39.7	252	± 5	± 0.3

As expected, the speed of sound in any bulk material must be less than the speed of sound in air, since the passage of ultrasound through the loose material describes the movement of sound through air gaps between grains resulting trajectory. US produces a curved, its length is greater than the geometric thickness of material (h). Through the grain themselves sound practically does not pass, because grains have solid sides, on which there is a scattering of sound. Evidently, the speed of sound propagation in bulk material depends on its structural characteristics, in particular medium-sized grains. Studies on the different fractions are represented in Figure 3. They show that with the increase of the average grain size of ultrasound velocity increases, since less effective length of trajectory of sound in the material [4-7].

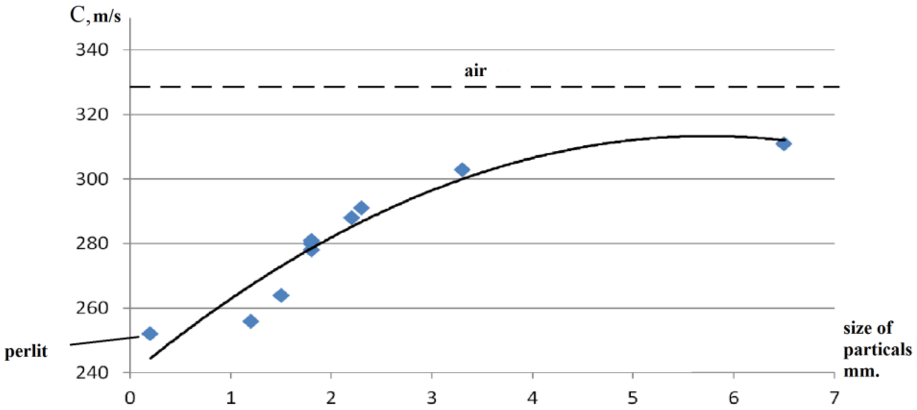

Figure 3. Dependence of the velocity of sound in perlite to different fractions.

Size fractions of 0.1- 0.2 mm corresponds to the speed of sound, 252 m/s. Thus, by measuring the velocity of sound, you can control the average grain size, i.e. the fraction of Perlite. Used information allows you to control (regulate) thermal process technology "heaving".

For the measurement of sound attenuation in the installation Figure 2 used attenuator (4). The measurement process is based on the fact that the full sound attenuation measured in dB (N) consists of attenuation in the material N_{mat} and attenuation in the air N_{air} [4, 8]. I.e. you can write

$$N=\delta_{mat}*h+\delta_{air}*H, \tag{4}$$

where δ_{mat} is an attenuation in the material (dB/mm); δ_{air} is attenuation in the air (dB/mm); (h) and (H) are in millimetres.

4. Measurement Attenuation

Attenuation measurement technique consists of the following steps:

- Determination of the coefficient of attenuation in the air;

Instead of bulk material installed steel sample thickness (h).

The used frequency 25 kHz attenuation in steel is negligible [9, 10] sound will take place with the attenuation layer of air (H) and the attenuation will be $N(H_{air})$.

Therefore, if you change the path of the sound L_0 –H=h, changing the attenuation will be

$$\Delta N_{air} = N(L_0)_{air} - N(H)_{air} \text{ (dB)}$$

and damping factor in air determined

$$\delta_{air=} \; \Delta N_{air}/(L_0 - H) \quad \text{(dB/mm)}. \tag{5}$$

- Determination of the coefficient of attenuation in the material.

For this loose material is poured into the cavity height (h) and measured total attenuation (N) (dB). Attenuation in the material will be defined as

$$\delta_{mat} = (N - \delta_{air}*H)/h. \tag{6}$$

Measured average attenuation coefficient US perlite 25 kHz frequency is 19 dB/cm or in relative units 2.185 Np, that far exceeds the damping factor at the same frequency in the air
5.42 dB/cm (0.624 Np) [11-13].

5. Summary

The developed method and installation of measure speed of propagation and attenuation of sound in bulk materials. On the example of perlite it is shown, that for the purpose of monitoring its structure and determine the fraction can be used ultrasound velocity through the material and its attenuation. It has been shown that with increasing grain size of the material, the speed of sound increases, but it cannot exceed the speed of sound in air. A method for measuring sound velocity and attenuation in perlite (and other loose materials) is. Analogues of such installations do not. Installation and measurement technology of the speed of sound and attenuation can be used by developers of heat and noise insulating materials to improve their technologies.

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