Paper No.339/2021

BUCKWHEAT HUSK AND EPOXY RESIN BASED COMPOSITES FOR NOISE ABATING

[a)]**Victor V. Kozhushko,** [a)]**Sergey N. Bukharov,** [b)]**Alexander R. Alexiev,** [b)]**Roumen Iankov**

[a)]*V. A. Belyi Metal-Polymer Research Institute of National Academy of Sciences of Belarus, Kirov 32a street, Gomel, 246050, Republic of Belarus, e-mail: vkozhushko@mail.ru*
[b)]*Institute of Mechanics at the Bulgarian Academy of Sciences, Acad. G. Bonchev Str., block 4, Sofia, 1113, Bulgaria, e-mail: alexiev@imbm.bas.bg*

Abstract*: The paper discusses promising way of utilization of the buckwheat husks for production of noise abating epoxy based composites for transport infrastructure and buildings industry. Composites of different densities from 400kg/m^3 up to 650 kg/m^3 have been prepared. The measurements of normal coefficient of sound absorption and sound transmission loss in the range from 500 Hz up to 6400 Hz are carried out. The absorption coefficient posses local maximum depending on the density of composites approaching the value of 0.99 at 3120 Hz for the density 400 kg/m^3. The sound transmission loss of composites increases with density from the mean value of 10 dB for 400kg/m^3 up to 60 dB for 650 kg/m^3 that is comparable with well-developed artificial materials. The pristine buckwheat husks is thermally stable of up to 200-250°C that gives thermogravimetric analysis in the range from 30°C up to 500°C. The husks is suggested as the filler for production of epoxy resin based noise abating composites.*

Keywords: *Fagopyrum esculentum, buckwheat husk, noise reducing composites, normal acoustical absorption, transmission loss*

DOI: *10.36336/akustika20214018*

1 INTRODUCTION

Rapid transport development has led to a steep increase in environmental pollution, which has received increasing attention from society. Among different kinds of environmental issues are vibration and noise. They are kind of pollution which have become main type in cities. In actual engineering, noise and vibration issues are closely related and often accompany each other. The noise exposure can cause not only hearing problems (acute or chronic ear diseases) but also cardiovascular disease, thereby seriously affecting health and quality of life.

The noise reducing composites encompass a class of materials which can be applied to the ceiling, floor and walls to decrease as much reflected sound as possible so that the room appears to be like a free space. Moderate reflection and good sound absorption can be achieved with porous materials which show considerable air flow resistance. The porous acoustic materials possess a cellular structure of interlocking pores. The oscillations of air molecules induced by elastic waves experience the friction with the solid material. Due to the friction the part of mechanical energy of motion is converted to the heat. Larger free surface of open pores of material lead to stronger losses. The foam elastomers are widely used in the automotive industry for solving the task of noise abating in vehicle cabins. In order to meet the requirements to mechanical strength it is necessary to use fillers among numerous technical demands for safety. There is a wide range of fillers from nanosize graphite and carbon nanotubes to silica particles [1]. The ecological issues attract attention to natural fibers, sawdust and other biomass-derived materials since they are less hazardous to human, than those made out of synthetic fibers. Natural fibers have many advantages compare to synthetic fibers, for instance low weight, low density, low cost, acceptable specific properties and recyclable or biodegradable [2, 3]. Fibers form open pores structure which possess flow air flow resistance while other biomass-derived materials such as rice of buckwheat husks can be used as filler in composite. As a relatively large size of particles reduces the strength of the materials the dispersed husks can be used [4]. Sowing buckwheat (Fagopyrum esculentum) is a valuable, widely cultivated cereal crop, the cultivation of which is of great economic importance. Buckwheat is one of the most popular food crops not only in the Republic of Belarus, but also abroad. The large-tonnage wastes in the form of straw, husk and bran are produced after processing of buckwheat. The waste amount of buckwheat husk is about 200 kg for each ton of groats [5].

Sakamoto et al. measured the sound absorption of pristine buckwheat husk in tubule of acoustic interferometer [3]. The goal of the paper to evaluate the sound absorption, sound transmission loss and heat resistance of buckwheat husk for possible use as a filler of epoxy based composites for noise abating tasks. To the authors' knowledge, the epoxy based buckwheat composites were not considered before.

2 MATERIALS AND RESEARCH METHODS

The buckwheat husk was obtained from cereal mill company located in Gomel (Belarus). The measured density of buckwheat husk was about 145 kg/m^3. The measurements were carried out after one week storing at room temperature of about 20^{o}C and relative humidity of 40%.

As pure husk is limited by floor application the noise abating composite of buckwheat husk and epoxy resin was suggested. The composite material was produced by blending epoxy resin in amount of 60-75 wt.%. with buckwheat husk. The amount of buckwheat husk was fixed by 1.2 gram while the weight of epoxy resin varied yielding composites with different densities. The blend was placed in 12 mm thick forms of 29 mm diameter for 24 hours polymerization at room temperature. The image of composites is in Fig.1. After polymerization the composites were weighted and the densities were calculated. The obtained composites had the densities from 400 kg/m^3 up to 650 kg/m^3 .

Fig. 1: Photograph of buckwheat husk epoxy resin based composites

It is noteworthy that the relative epoxy resin amount of composite is changing due to the gravity flow during the polymerization. The bottom of the specimens has the denser structure while the top of the specimen has more pores thus a kind of material with gradient of density can be produced.

In order to study heat resistance and application possibilities at elevated temperatures the degradation processes of buckwheat husk was investigated by thermogravimetric (TGA) and differential heat (DTA) analyzes using Simultaneous thermal analyzer STA-6000 (Perkin Elmer, USA). The simultaneous thermal analysis of pristine husk was carried out in the temperature range from 30°C up to 500°C at a heating rate of 5 °C/min in a neutral (nitrogen) gas medium. When carrying out thermal analysis sample of the test material weighing 8.0 ± 2.0 mg was placed in a pan made of oxide ceramics (Al_2O_3).

The TGA-DTA results are presented in Fig. 2. Two endothermic peaks at 260°C and 340°C are result of organic decomposition and gas evaporation. The husk burns with significant gas evolution and requires special conditions for utilization. The mass loss is 64%. Thus, the thermal stability of buckwheat husks up to 200-250 ˚C allows its employment as filler for a polymer composite for a wide range of tasks, in which noise-reducing materials and structures are used.

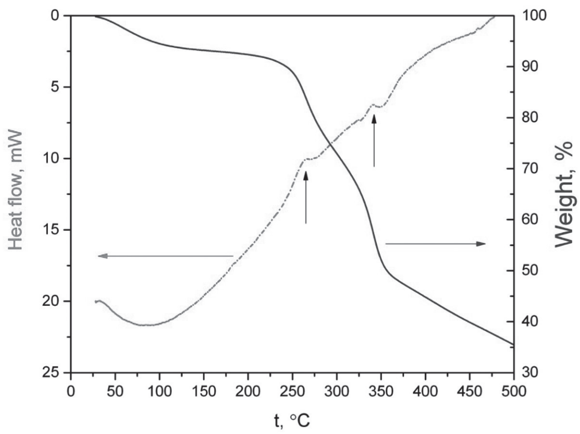

Fig. 2: STA of pristine buckwheat husk

Two-microphone impedance tube produced by Brüel&Kjær was used to measure the normal incident sound absorption coefficients of pristine buckwheat layers of three different thicknesses 10 mm, 20 mm and 40 mm. The small impedance tube of the kit 4206 was used in measurements. The impedance tube was vertically oriented and the loudspeaker was on the top. The fixed amount of buckwheat husk was enclosed into the small tube with 29 mm inner diameter. The thickness of the layer was defined by marked rod. A loudspeaker radiated white noise signal, generated by the built-in function generator unit. The normal absorption coefficients were obtained in the frequency range from 500 Hz up to 6400 Hz according to the two microphones method described in ISO 10534-2:1998 [6].

The results of the measured absorption coefficient are presented in Fig. 3. The absorption of layers is frequency dependent and shows a maxima of magnitude above value of 0.6. Increasing the thickness of buckwheat shifts the first local maximum of sound absorption to the lower frequency; thus, thicker layer of buckwheat possesses better absorption at lower frequencies.

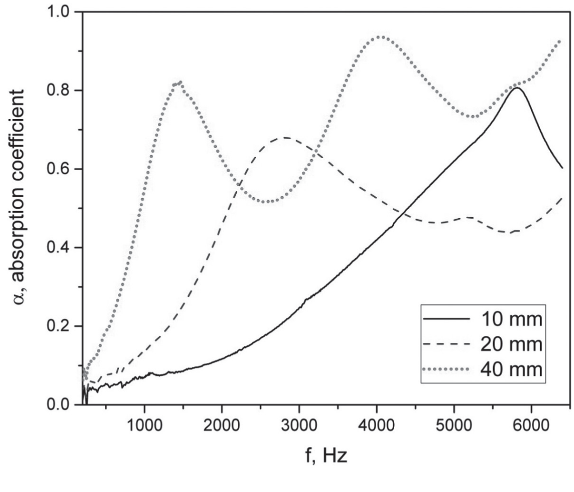

Fig. 3: Absorption coefficient of pristine buckwheat husk layers

The results of measurements of sound absorption of buckwheat husk epoxy based composite are presented in Fig. 4. The specimens were oriented by porous part to the loudspeaker.

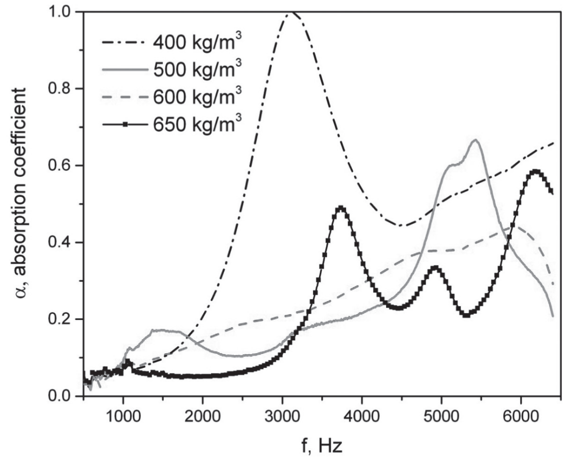

Fig. 4: Absorption coefficient of buckwheat husk epoxy based composite

The sound absorption of composites changes significantly from low density composite to denser specimens. The low density composite shows local maximum of absorption of about 0.99 at frequency 3120 Hz while the absorption of the denser composite has local maxima of magnitude below 0.6. It is well known that the sound absorption is directly related to the porosity since the composites with high porosity (low density) have higher sound absorption in contrast to the materials with low porosity (high density). It also proofs the necessity of good air flow resistance of material for performance sound absorption.

The insulation relates to the task of outer surrounding noise reduction. The sound transmission loss was measured by four microphone methods according to ASTM E2611-17 [7]. The results are presented in Fig. 5. The obtained transmission loss of low density composite is nearly 10-12 dB in the considered frequency range. The composites were also oriented by porous side to the loudspeaker. The sound transmission loss gradually increases with the density of composites. The value of transmission loss increases up to 60 dB for the denser composite that can be explained by decreasing of the free air volume in specimens.

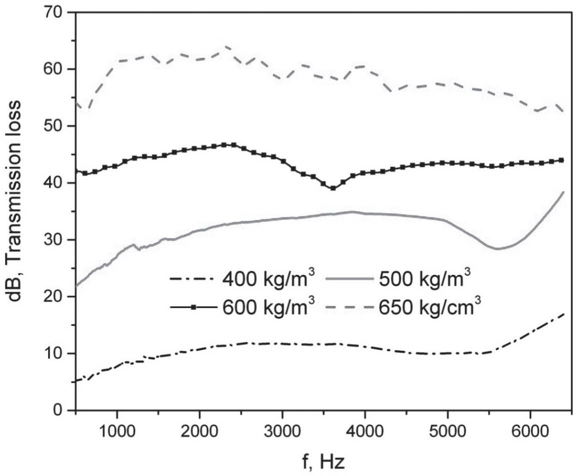

Fig. 5: Sound transmission loss of buckwheat husk epoxy based composites

3 CONCLUSION

The pristine buckwheat husk and samples of epoxy resin based composites demonstrated strong dependence from the thickness and density, respectively, with a local maxima of sound absorption in the range 500-6400 Hz. The measurements of sound transmission loss show also dependence from the density of composite. The composite with the density 650 kg/m^3 achieves value of about 60 dB. It is assumed that the technology of epoxy resin based buckwheat husk composites could be used for solution of both noise absorption and noise insulation tasks. For instance, the composites can be used in production of noise reflectors around railway humps for the insulation of the high frequency squeal caused by retarding system. In this case the units of composite in the form of plates can be assembled on the steel frame near the railway. As the sound absorption coefficient of lower density composites possesses local maximum therefore these composites can be used inside rooms at the walls and ceiling for selective absorption of sound frequencies in defined range. The thermal stability of buckwheat husks up to 200-250 °C allows its employment as filler for a polymer composite for a wide range of tasks, in which noise-reducing materials and structures are used. The lower density composites are promising for sound absorbing construction while more denser for echo boards. The last decade showed increased interest to the vegetable fibers [8] that produced their deficit and conditions for search of alternative types of natural filler. The utilization of significant amount of waste is applied task. The use of husk for composite production decreases the emission of CO_2 as it avoids combustion.

ACKNOWLEDGEMENT

This research was sponsored by the NATO Science for Peace and Security Programme under grant SPS G5790.

REFERENCES

[1] Ayub M., Zander A.C., Howard C.Q., Cazzolato B.S., Huang D.M., Shanov V.N., Alvarez N.T Normal incidence acoustic absorption characteristics of a carbon nanotube forest / Applied Acoustics. V. 127, P.223-239, 2017.
[2] Balasubramanian D., Rajendran S., Srinivasan B., Angamuthu N. Elucidating the sound absorption characteristics of foxtail millet (Setariaitalica) husk / Materials. V.13, P. 5126, 2020.
[3] Sakamoto S., Takauchi Y., Yanagimoto K., Watanabe S. Study of sound absorbing materials of biomass tubule etc. (Measured results for rice straw, rice husks, and buckwheat husks) / Journal of Environment and Engineering. V.6, No 2, P. 352-364, 2011.
[4] Kornev Yu.V., Eymelaynov S.V., Lukyanova A.Yu., Semenov N.A., Spiridonova E.Ch., Gus'kov D.V. Investigation of influence of dispersion of rice husk recycling products on the properties of elastomer composites / Kauchuk & rezina, V. 77, No 1, P. 20-24, 2018.
[5] Klintsavich V.N., Flyrik E.A. Methods of use of buckwheat husk sowing (Review) / Proceedings of BNTU, V. 2, No 1, p. 68-81, 2020.
[6] ISO 10534-2-98, Acoustics — Determination of sound absorption coefficient and impedance in impedance tubes — Part 2: Transfer-function method.
[7] ASTM E2611-17, Standard Test Method for Normal Incident Determination of Porous Material Acoustical Properties Based on the Transfer Matrix Method, ASTM International, West Conshohocken, PA, USA, 2017.https://doi.org/10.1520/E2611-17.
[8] Tang X., Yan X. Acoustic Energy Absorption Properties of Fibrous Materials: A Review / Composites Part A: Applied Science and Manufacture , V.101, P. 360-380, 2017.

Victor Kozhushko *is senior researcher at V.A. Belyi metal-polymer research institute in Gomel (Belarus). Ph.D. degree was obtained in Russia at Moscow State University named after M.V. Lomonosov. He hold postdoc positions at Heidelberg (Germany) and Graz (Austria) Universities. The main field of interests relates to the application of laser-induced ultrasound in properties evaluation, material science and non-destructive testing. Recent researches are aimed to the development of sound absorbing and sound insulating composites. Victor Kozhushko is co-author of more than 70 papers.*

Sergey Bukharov, *Ph.D. of Engineering Science, Head of the sector «Vibroacoustics of materials and friction units of machines», Department of Frictional Material Science, V.A. Belyi Metal-Polymer Research Institute of National Academy of Science of Belarus, Member of International Council on Materials Education (ICME).*
Sergey Bukharov is a specialist in the field of Tribology and Frictional Material Science, is a developer and co-author of the frictional composite materials on polymer base with improved noise and vibration performance for operation in dry friction conditions and in oil, environmentally friendly noise-reducing materials and structures for vehicles.
Sergey Bukharov is the author of over 110 scientific publications, including 4 monographs, 30 journal articles and 12 patents.

Alexander Alexiev, *M.Sc., Eng., Department of Solid Mechanics, Institute of Mechanics, Bulgarian Academy of Sciences, Sofia, Bulgaria .*
Alexander Alexiev is a specialist in field of Ultrasonic methods; Acoustics methods; Acoustic emission; Nondestructive characterization of materials; Low frequency acoustic methods; Ultrasonic spectral analysis; Analysis of non-destructive information using signal processing tools; Development of NDT procedures and methods for materials characterization; Alexander Alexiev is the author of over 50 scientific publications

Roumen Iankov, *Ph.D., Professor, Department of Solid Mechanics, Institute of Mechanics, Bulgarian Academy of Sciences, Sofia, Bulgaria*
Roumen Iankov is a specialist in field of Fracture Mechanics; Theory of Plasticity; Damage Mechanics; Solid Mechanics, Numerical simulation of metal forming processes and powder metal forming processes; Identification of material properties based on hybrid numerical-experimental approach; Material characterization by nanoindentation; Interval arithmetic; Interval finite element; Finite element application to the coupled problems. Roumen Iankov is the author of over 90 scientific publications