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PROPOSALS OF METHODOLOGY FOR MEASURING SELECTED ACOUSTIC DESCRIPTORS

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ABSTRACT: In spite of existing European and national legislation aimed at noise abatement, public interest and concern about noise are high. The EU Directive 70/157/EEC [15] for setting and controlling environmental noise is aimed at creating less noisy and more pleasant environment for European residents within "Sustainable Development in Europe". The authors are presenting a methodology for measuring selected acoustic descriptors (sound absorption coefficient and sound transmission loss) for acoustic materials, which are currently in process of development. Verification results of the proposed methodology are presented.
KEYWORDS: environmental noise, transportation, noise wall, sound absorption coefficient, sound transmission loss

INTRODUCTION

In spite of existing European and national legislation, aimed at noise abatement, public interest and concern about noise are high. Directive of EU 70/157/EEC [15] for setting and controlling environmental noise is aimed at creating less noisy and more pleasant environment for European residents within "Sustainable Development in Europe".

Harmful effects of environmental noise are various and they can be produced in various ways. They can be categorized into three main categories: effects influencing health, impacts on quality of life and financial implications on affected persons.

In the European Union, about 80 million persons are exposed to high noise levels, which are unacceptable or result in sleep disorders and other undesirable influences. There are approximately 170 million people living in the so-called "grey regions", where noise is very annoying.

Transportation causes the main problem in the sphere of noise. In Europe, the first limits of protection against noise were specified for transportation. In this respect, the most important directive is 70/157/EEC [15], limiting noise for vehicles. The EU has only recently started to regulate noise emissions from railway transportation (2002). Limits for air transport are specified mainly at international levels ICAO (International Civil Aviation Organization).

Noise protection measures for reducing the effect of noise caused by transportation (road, railway and air transport) can be passive and active. Active measures try to prevent the origination of noise, while passive measures are adopted only then, when noise arises. Passive noise protection measures can be divided into two groups, namely: measures preventing acoustic noise propagation (noise barriers and/or walls, noise protection embankments and the like) [6]. Attention is paid to the design process and materials used for construction of noise walls and to their properties. The authors focus their attention on development of new acoustic materials manufactured by recycling raw materials. The paper presents a proposed methodology for measuring selected acoustic descriptors (the sound absorption coefficient α and the sound transmission loss TL) [1].

PROPOSAL OF METHODOLOGY FOR MEASURING SELECTED ACOUSTIC DESCRIPTORS OF ACOUSTIC MATERIALS, WHICH ARE CURRENTLY IN PROCESS OF DEVELOPMENT

Out of several possible acoustic descriptors, the authors have focused their attention on the two following descriptors:

- □ sound absorption coefficient (α),
- □ transmission loss (TL).

For measuring the sound absorption coefficient (α) and the transmission loss (TL) there are two theoretically available methods, namely: the method of standing wave ratio and the method of transfer function. The authors have used in their work the method of transfer function. This method can be used *for measuring the sound absorption coefficient, the reflection factor, the normal impedance and the normal admittance. Based on this method is the impedance tube (Figure 1).*

Figure 1. The impedance tube

The proposed methodology of measurement includes the use of the impedance tube, two positions of positioning the microphones and the system of numerical frequency analysis for determining the sound absorption coefficient of sound absorbers for normal incidence of sound. It can also be applied for determining acoustic surface impedance or acoustic surface admittance for sound absorbing materials, due to the fact that the impedance ratios of sound absorbing materials are proportional to their physical properties, such as airflow resistance, porosity, elasticity and density.

The proposal of methodology for measuring selected acoustic descriptors by using an impedance tube and by applying the method of transfer function is presented in Figures 2, 3, 4 and 5.

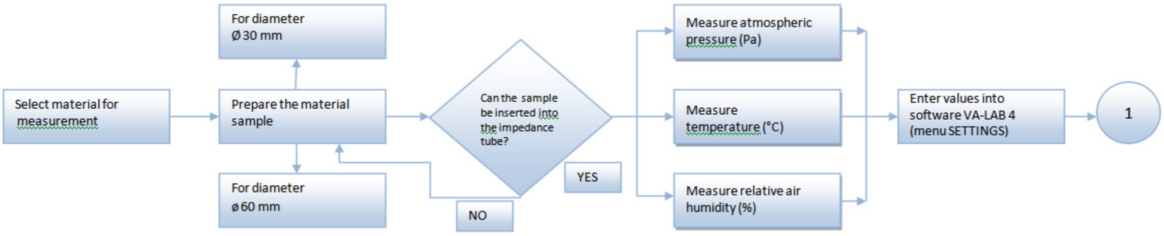

Figure 2. Methodology for measuring selected acoustic descriptors

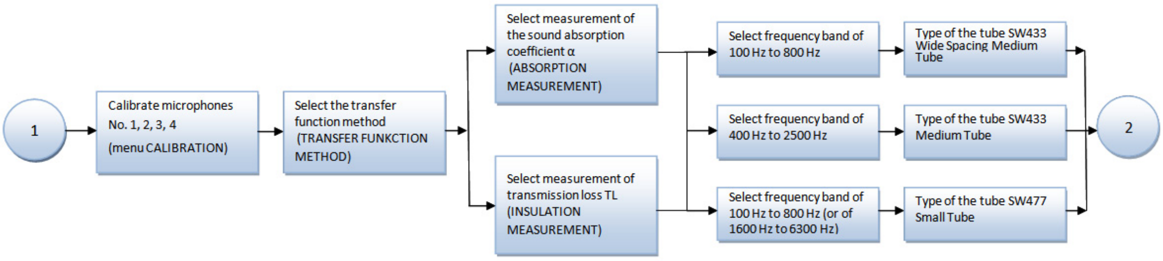

Figure 3. Methodology for measuring selected acoustic descriptors (continued)

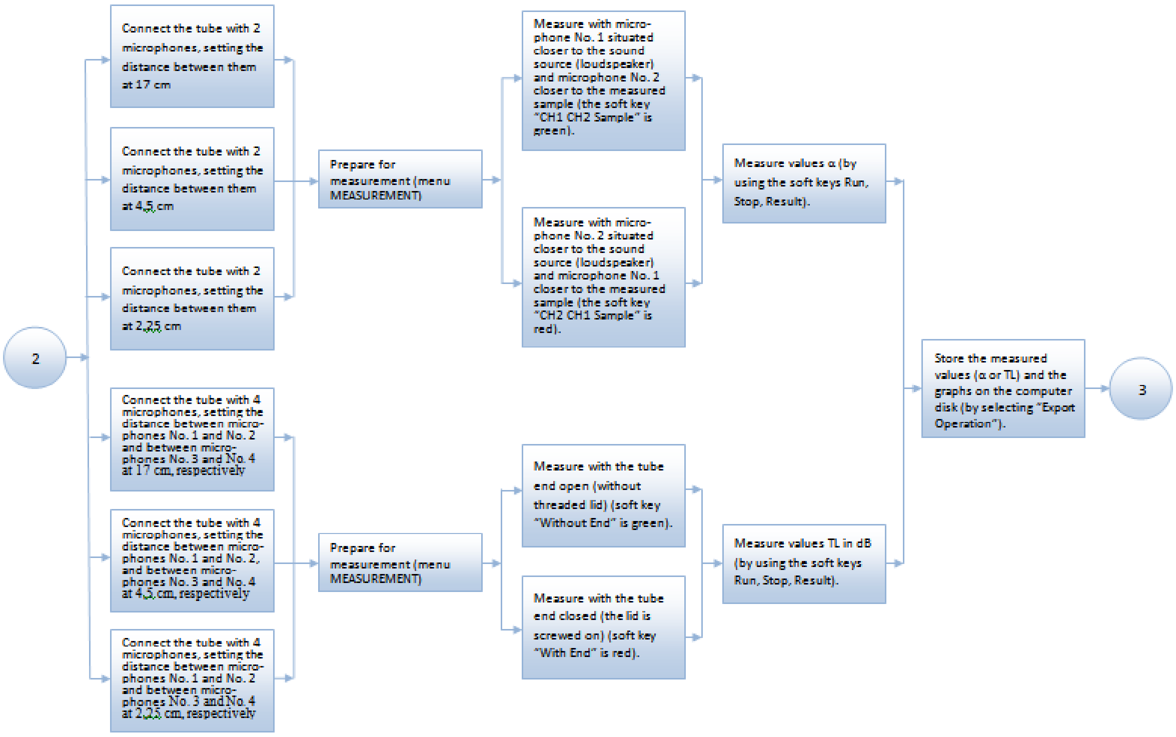

Figure 4. Methodology for measuring selected acoustic descriptors (continued)

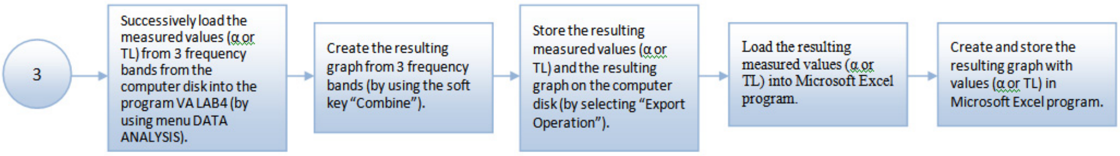

Figure 5. Methodology for measuring selected acoustic descriptors (continued)

This test method is similar to the test method specified in STN EN ISO 10534-1 [7] in terms of using an impedance tube with a sound source connected to one of its ends and a test specimen mounted into the tube at its other end. However, the actual test method is different. In this test method the plane waves are generated in the tube by the sound source and the decomposition of the interference field is achieved by measuring acoustic pressures in two fixed positions of microphones mounted on the wall of the tube or by a microphone shifted in the tube and the subsequent calculation of the complex acoustic transfer function, by absorption at normal incidence and by impedance ratios of the acoustic material. This test method is designated to provide an alternative method of measurement, in general much faster than that included in STN EN ISO 10534-1[7].

VERIFICATION OF THE PROPOSED METHODOLOGY FOR MEASURING ACOUSTIC DESCRIPTORS FOR ACOUSTIC MATERIALS, WHICH ARE CURRENTLY IN PROCESS OF DEVELOPMENT

The proposed methodology of measurement was verified by measuring selected acoustic descriptors, namely: the sound absorption coefficient (α) and the transmission loss (TL) for the materials, which are currently in process of development.

Instruments, software and other equipment

The system for measuring the sound absorption coefficient (α) (for the frequency bands of 100 Hz to 800 Hz and 400 Hz to 2500 Hz, respectively) is shown in Figure 6. It is comprised of a tube with inner diameter of 60 mm – SW060-L and of a holder of the tested sample with inner diameter of 60 mm – SW060-S.

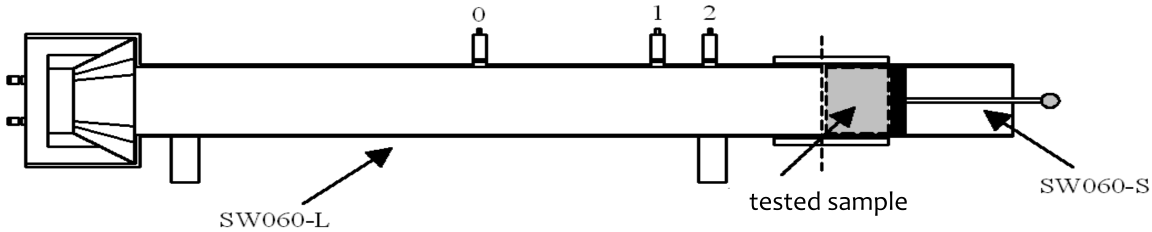

Figure 6. The system for measuring the sound absorption coefficient (100 Hz to 800 Hz and 400 Hz to 2500 Hz, respectively). Legend: 0, 1, 2 – mounting sockets for microphones

The system for measuring the sound absorption coefficient (α) (for the frequency bands of 800 Hz to 6300 Hz) is shown in Figure 7. It is comprised of a tube with inner diameter of 60 mm – SW060-L, of a tube with inner diameter of 30 mm – SW030-L and of a holder of the tested sample with inner diameter of 30 mm – SW030-S.

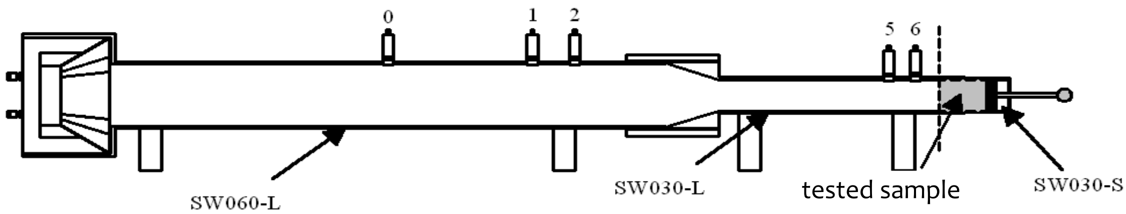

Figure 7. The system for measuring the sound absorption coefficient (800 Hz to 6300 Hz). Legend: 0, 1, 2, 5, 6 – mounting sockets for microphones

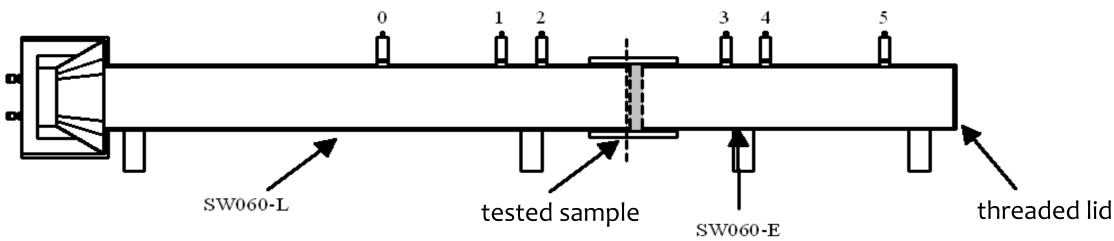

Figure 8. The system for measuring the transmission loss TL (100 Hz to 800 Hz and 400 Hz to 2500 Hz, respectively). Legend: 0, 1, 2, 3, 4, 5 – mounting sockets for microphones

The system for measuring the transmission loss (TL) (for the frequency bands of 100 Hz to 800 Hz and 400 Hz to 2500 Hz, respectively) is shown in Figure 8. It is comprised of a tube with inner diameter of 60 mm – SW060-L and of an extension piece of the tube with inner diameter of 60 mm – SW060-E.

The system for measuring the transmission loss (TL) (for the frequency bands of 1600 Hz to 6300 Hz) is shown in Figure 9. It is comprised of a tube with inner diameter of 60 mm – SW060-L, of a tube with inner diameter of 30 mm – SW030-L and of an extension piece of the tube with inner diameter of 30 mm – SW030-E.

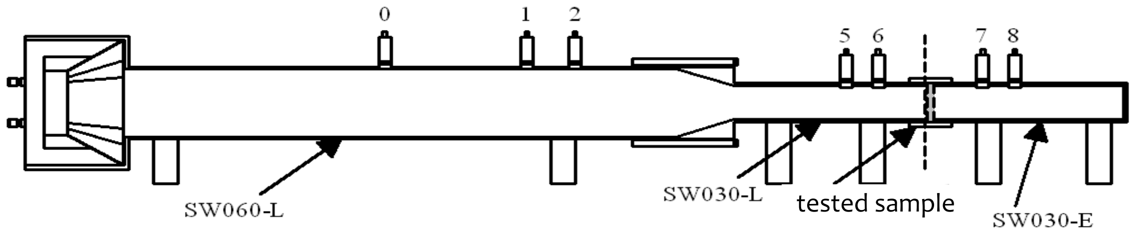

Figure 9. The system for measuring the transmission loss TL (1600 Hz to 6300 Hz). Legend: 0, 1, 2, 5, 6, 7, 8 – mounting sockets for microphones

Selection of materials for the experimental part

The selected acoustic descriptors (the sound absorption coefficient α, the transmission loss TL) were measured for the following acoustic materials, which are currently in process of development:

- *Ekomolitan (Figure 10)*
- *Recycled rubber (Figure 11)*

Measurement were also carried out, for comparison, for the material Nobasil (Figure 12), which is a component part of various sandwich structures of noise walls (barriers).

Figure 10. Ekomolitan

Figure 11. Recycled rubber

Figure 12. Nobasil

Preparation of test samples

The test samples, with different thickness (see Figs. 13. and 14.), were prepared from three materials (Ekomolitan, recycled rubber and Nobasil).

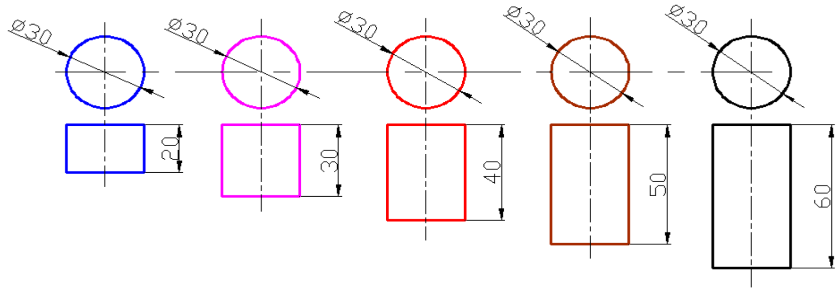

Figure13. Sample sizes

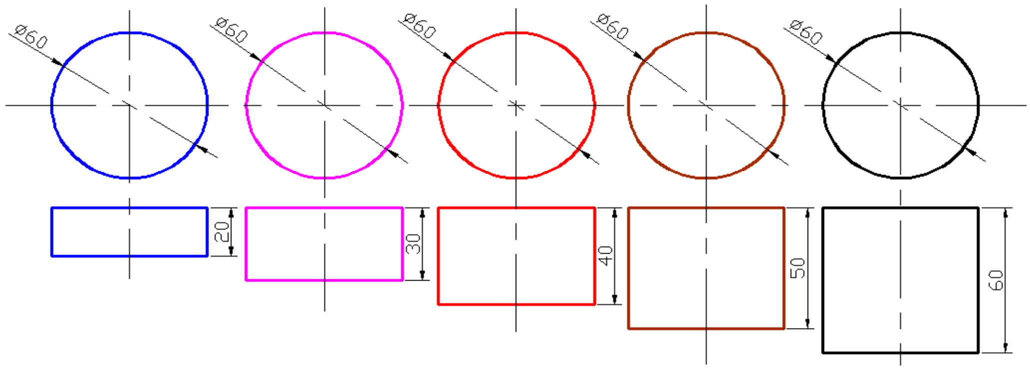

Figure14. Sample sizes

The measured values of the sound absorption coefficient and of the transmission loss

In this part of our paper we present the outputs from the measurement of the sound absorption coefficient for the material Ekomolitan with thickness of 2 cm (Figure 15.) and the outputs from the measurement of the transmission loss for the material Ekomolitan with thickness of 2 cm (Figure 16). For other outputs see [1].

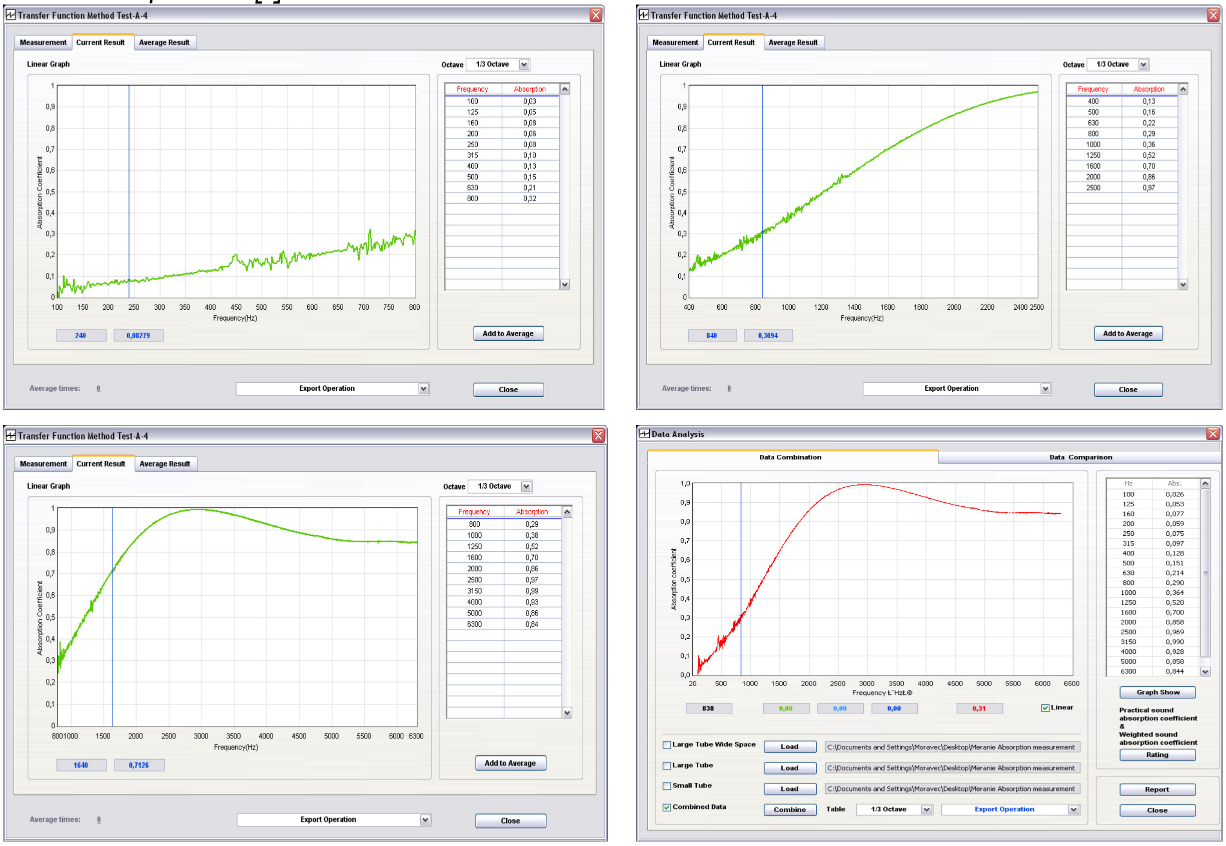

Figure 15. The sound absorption coefficient displayed for the material Ekomolitan with thickness of 2cm

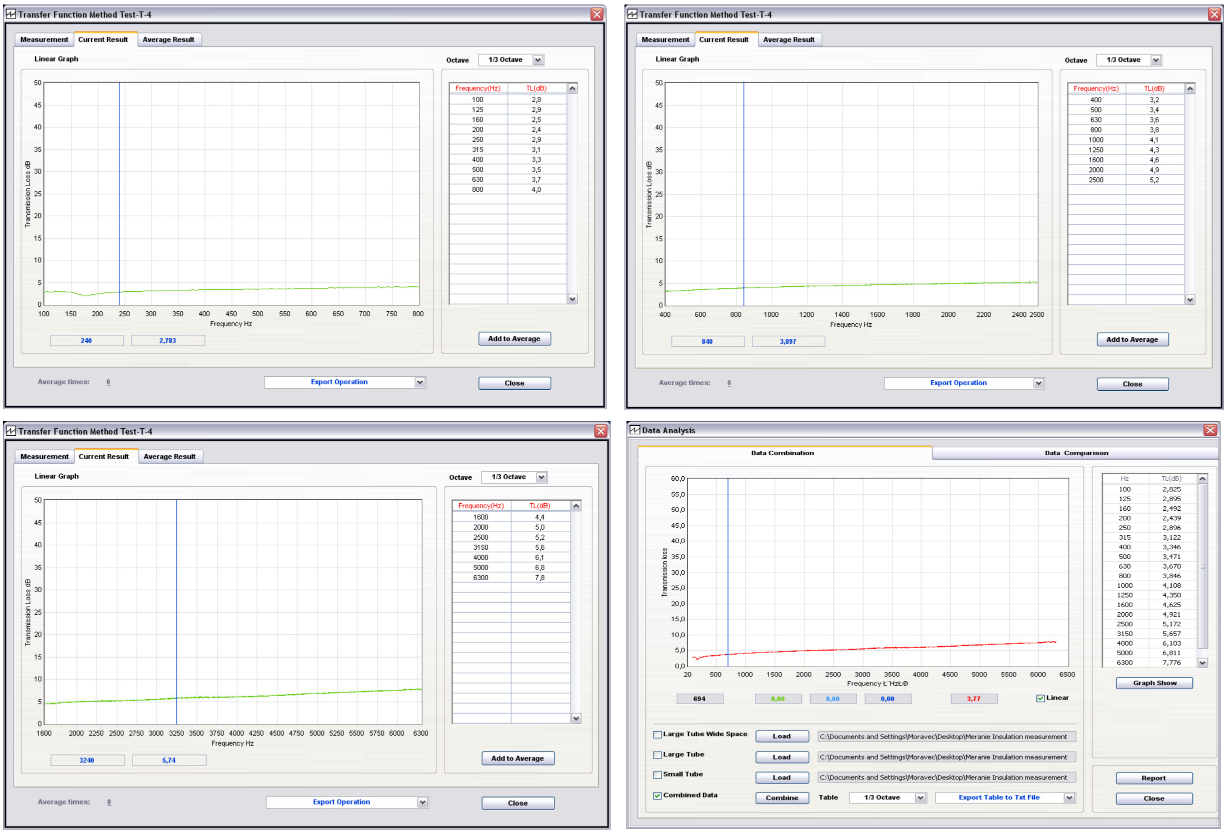

Figure 16. The transmission loss displayed for the material Ekomolitan with thickness of 2cm

CONCLUSIONS – EVALUATION OF MEASURED VALUES

The sound absorption coefficient (α) is a dimensionless number varying from 0 to 1. The closer is the measured value to 1 or is equal to 1, the sample of the measured absorber, and thus the absorber itself, will have a better (higher) sound absorption.

We have also measured the transmission loss (TL). It is a value in dB, based on the ratio of the sound wave incident at the front side of the acoustically absorbing material to the sound waves transmitted from the rear side. TL represents the sound damping properties of the material, i.e. the higher that value is, the more efficient is the damping of the sound.

The authors carried out measurements of the sound absorption coefficient (α) and of the transmission loss (TL) for various materials (Ekomolitan, recycled rubber and Nobasil) and for thickness of samples of 2 cm, 3 cm, 4 cm, 5 cm and 6 cm, respectively. As an illustration, outputs of measurements carried out for material thickness of 4 cm are presented (see Table 1).

Table. 1. Measured values of selected descriptors

Frequency f [Hz]	Sound absorption coefficient (α)			Transmission loss (TL)		
	Ekomolitan	Recycled rubber	Nobasil	Ekomolitan	Recycled rubber	Nobasil
100	0,022	0,017	0,151	5,668	9,062	17,552
125	0,093	0,108	0,196	5,879	9,267	17,513
160	0,139	0,057	0,252	6,220	9,554	17,687
200	0,189	0,088	0,305	6,559	9,892	17,839
250	0,258	0,113	0,355	6,139	10,277	18,154
315	0,330	0,153	0,402	5,934	10,750	18,584
400	0,508	0,228	0,443	6,785	11,341	19,291
500	0,650	0,324	0,480	7,218	11,686	19,850
630	0,780	0,479	0,511	7,660	11,877	20,985
800	0,881	0,727	0,541	7,820	12,199	22,644
1000	0,921	0,771	0,576	8,379	12,232	24,677
1250	0,917	0,593	0,610	8,990	11,804	28,070
1600	0,879	0,419	0,681	9,883	11,128	22,026
2000	0,830	0,345	0,657	10,945	11,739	25,474
2500	0,797	0,359	0,753	12,083	13,752	26,920
3150	0,836	0,607	0,761	13,350	15,357	32,679
4000	0,933	0,497	0,810	14,624	15,189	21,184
5000	0,924	0,625	0,840	15,958	16,118	35,281
6300	0,931	0,624	0,875	18,708	17,485	30,942

The frequency spectrum of noise caused by transportation reaches its maximum in the frequency range of 500 Hz to 1500 Hz, and the most intensive noise is caused at the frequency of 1000 Hz.

On the basis of values of the sound absorption coefficient (α) measured for selected materials (Nobasil, Ekomolitan and recycled rubber) with varying thickness of samples at frequencies ranging from 500 Hz to 1500 Hz, it was found that the best results for a sample with thickness of 2 cm were achieved for the material Nobasil. Less favorable results were measured for the material Ekomolitan and the worst results were identified for recycled rubber. When measuring sound absorption (α) of material samples with thickness of 3 cm, excellent results were achieved for the materials Nobasil (at frequencies from 500 Hz to 630 Hz) and Ekomolitan (at frequencies from 800 Hz to 1600 Hz). Again, the least favorable results were achieved for the material made from recycled rubber. By increasing the thickness of the measured material its sound absorption coefficient (α) was increasing substantially also for the material Ekomolitan. An example of the results measured in the frequency band from 500 Hz to 1500 Hz is presented in Figure 17.

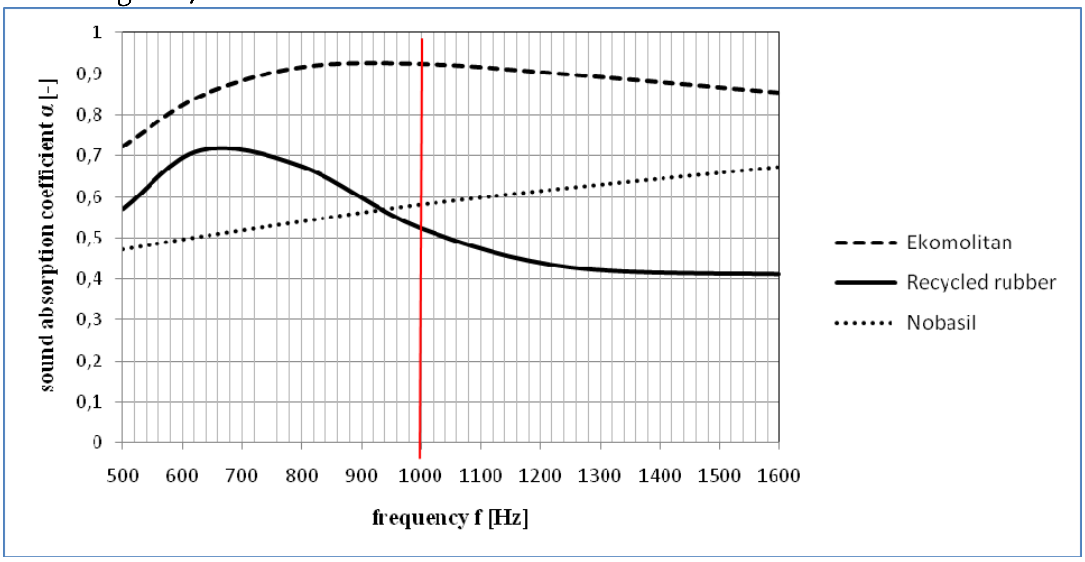

Figure 17. Sound absorption coefficient (α) (thickness of materials 5 cm)

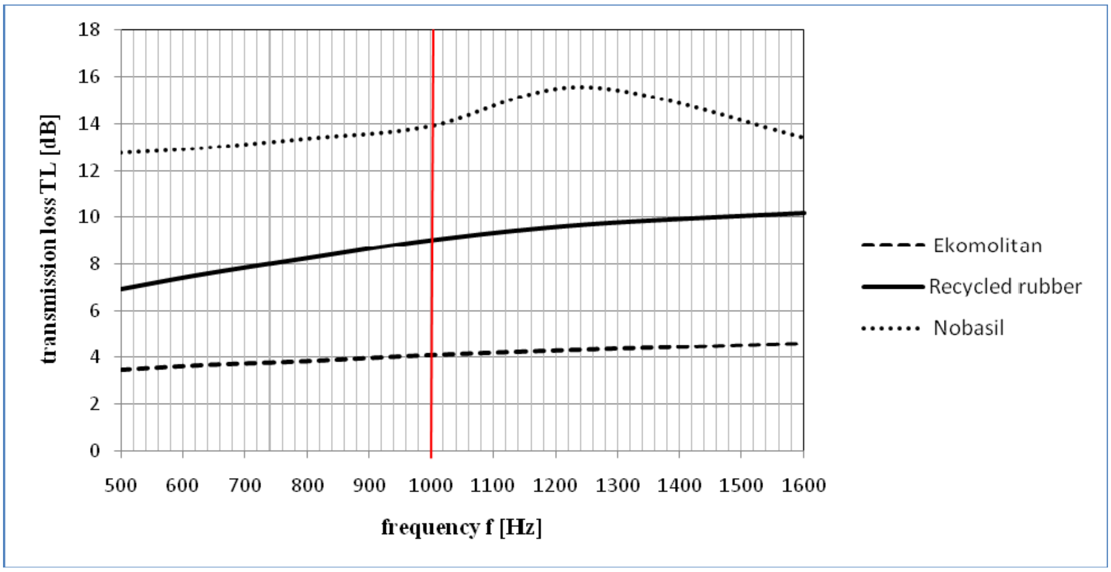

Figure 18. Transmission loss (TL) (thickness of materials 2 cm)

On the basis of values of the transmission loss measured for selected materials (Nobasil, Ekomolitan and recycled rubber) at different thickness of samples (2 cm, 3 cm, 4 cm, 5 cm and 6 cm, respectively) for frequencies ranging from 500 Hz to 1500 Hz, it was found that the best results for samples of all sizes were achieved for the material Nobasil. Then followed the recycled rubber and the least favourable results were measured for the material Ekomolitan. Selected results of measurement in the frequency band from 500 Hz to 1500 Hz are presented in Figure 18.

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