SOUND DAMPING PROPERTIES OF PUR/NANO FABRIC SANDWITCH STRUCTURES

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Open cell polyurethane (PUR) foams (Gumotex, Břeclav, Czech Republic) of varying pore size distribution were tested for sound damping in the perpendicular incident sound wave geometry by means of Kundt´s tube measurements in the frequency range of 50-6400 Hz. Tested samples were modified by coating the top layer by nano non-woven fabric of PUR bases (SPUR, Zlin, Czech Republic) produced by means of Nanospider technology (ELMARCO, Liberec, Czech Republic) having varying air flow resistivity. Acoustic reactance of porous insulating materials is determined by layer thickness and in the lesser extent by surface density of the air permeable surface film coating. Acoustic resistance of the porous insulating material is determined by the air flow resistivity. This study allow to characterize the effect of the mutual influence of acoustic resistance and acoustic reactance components of the complex acoustic impedance on final sound damping characteristics of the studied sandwich like PUR based structures.

Key words: Polyurethanes, PUR, nano-fabric, sound absorption coefficient, acoustic impedance.

1. INTRODUCTION

Sound is an acoustic waving with frequencies ranging from 10 Hz to 16 kHz. Sonic wave is spreading in all directions from the source. On the bases of different points of view on problems of noise attenuation it is possible to distinguish following methods of sound and vibration damping [1]:

– *Reduction method* – attenuation at the noise source, e.g. during the machinery construction stage.
– *Sound isolation method* – covering the sound source by the material with high air born sound insulation characteristic.
– *Sound absorption method* – endeavour is to minimize sound reflections e.g. to absorb maximum of the incident acoustic energy.

In the matrix of the sound/vibration attenuating material dissipation of the sonic wave to the mechanical energy and heat took place. This proceeds by combination of the following processes [2-3]:

– By friction of the vibrating air particles on the walls during their penetration into the pores of the sound absorbing material. This is lowering kinetic energy of the incident sound field. Effectiveness of this process increases with growing porosity of the absorption material.
– By decreasing the potential energy of the sonic wave penetrating into the material. This is lowering acoustic pressure due to the heat exchange between air and the skeleton of the absorbing material during periodic pressure changes.
– By non–elastic deformation of the absorbing material body.

At the specifically aimed construction of the vibration or noise–isolation material it is therefore possible to utilize all from the above mentioned processes for their synergistic effect in obtaining maximum effectiveness of attenuation. This is possible by modelling the geometry of the damping material body as well as by proper selection of the main material matrix and adhesive system [1-3].

Most common construction types of sound and vibration damping materials can be summarized as follows: different types of laminates, composite fiber–loop materials, truss type plate systems, planar panel systems with variable thickness of the air gap, freely poured particulate systems, sandwich foam composite systems, sandwich composites with designed grooves at the contact surface (or without them), crosslinked polymeric systems[1]. In our experimental study main attention was focused on porous sandwich structures composed of PUR open cell foams with controlled pore size distribution and PUR nonwoven nano-fabric in the sandwich like configuration.

Acoustic reactance of porous insulating materials is determined by layer thickness and in the lesser extent by surface density of the air permeable surface film coating. Acoustic resistance of the porous insulating material is determined by the air flow resistivity. This study allow to characterize the effect of the mutual influence of acoustic resistance and acoustic reactance components of the complex acoustic impedance on final sound damping characteristics of the studied sandwich like PUR based structures.

2. EXPERIMENTAL

2.1 MATERIALS

Polyurethane (PUR) based open cell foams (see Table 1) (Gumotex, Breclav, Czech Republic) and PUR based nonwoven nano-fabric (SPUR, Zlin, Czech Republic) produced by means of Nanospider technology (ELMARCO, Liberec, Czech Republic) were used for testing in this study (see Figure 1). The latter materials are used in automotive, aerospace and building construction industries. Nonwoven nano-fabric was used as the air flow resistivity controlling component.

Table 1. Studied PUR based foam materials basic physico-chemical properties [4].

Type of foams	Color	Volume mass	Volume mass	Pressing resistance	Tensile strength	Elongation	Permanent deformation
		[kg/m^3]	[kg/m^3]	[kPa]	[kPa]	[%]	[%]
		brutto	netto	(40%)	(40%)	average	[50%, 23°C,72 h]
S3535F	grey	35	33	3.5	130	190	2.0
N2130	white	21	-	3.2	80	150	7.0
N2538	orange	25	-	3.8	150	230	2.5
N2529	blue	25	23	2.9	160	290	2.5
RE80	white	80	-	9.4	40	-	10.0

Table 2. Results of the porosity measurements of the studied PUR foams.

Material	m_1 [g]	P_1[vol.%]	m_2 [g]	P_2[vol.%]	m_3 [g]	P_3[vol.%]	$\overline{P}$ [vol.%]
S3535F	158.8	96.4	159.0	96.5	158.8	96.4	96.4 ± 0.1
N2130	159.1	96.6	159.0	96.5	159.1	96.6	96.6 ± 0.1
N2538	159.3	96.7	159.3	96.8	159.4	96.7	96.7 ± 0.1
N2529	155.0	99.1	154.9	99.0	155.1	99.1	99.1 ± 0.1
RE80	141.4	85.8	141.3	85.8	141.1	85.6	85.8 ± 0.1

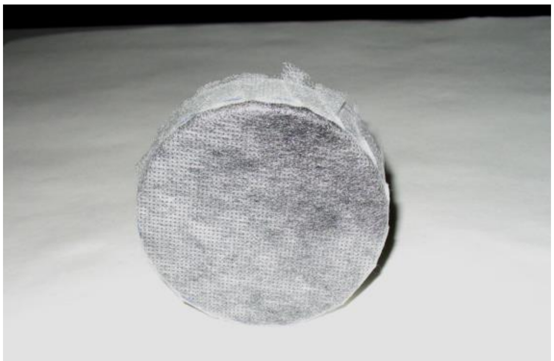

Figure 1. PUR sample (S3535F) coated with nano non-woven fabric.

2.2 METHODS

Samples were tested for their effective sound damping capabilities by means of Kund´s tube measurements (Brüel & Kjaer Impedance Tube (50Hz – 6.3 kHz) Type 4206 interconnected with multi-analyzer device PULSETM 3560-B-030). Measured parameter was normal incidence sound absorption coefficient α.

Porosity of the studied samples was measured by volume method [5] with water at 20 °C, 2 hours for 20 mm thick samples, maximum pressure 100 kPa (see Table 1 and Figures 1 and 2). Mean pore size was determined by microscopic observations on optical microscope Nikon Eclipse 50i, Japan followed by image analysis (NI IMAQ, National Instruments, USA).

3. RESULTS AND DISCUSSION

Sound absorbing properties of materials or of the whole construction can be described by sound absorption coefficient α:

$$\alpha = \frac{P_p}{P_{dop}} \qquad (1)$$

where P_p is absorbed acoustic power and P_{dop} is total incident acoustic power. For the case of the perpendicular incident sound wave a normal sound absorption coefficient is defined α_n:

$$\alpha_n = \frac{(4r/\rho c)}{\left[\left(\frac{r}{\rho c}+1\right)^2 + (x/\rho c)^2\right]} \qquad (2)$$

where $r/\rho c$ is acoustical resistance (real part of the acoustic impedance), $x/\rho c$ acoustical reactance (imaginary part of the acoustical impedance) and ρc is characteristic impedance of the air. The latter characteristic air impedance in general depends on sound velocity in the surrounding medium, which is a function of medium density, temperature and other parameters.

Sound absorption characteristics of the porous insulating materials depend on acoustical impedance. Acoustical impedance (Z_a) is a complex quantity, which consists from frequency dependent parts of acoustical resistance and acoustical reactance and is defined as a complex ratio of acoustical pressure and volume velocity:

$$Z_a = \frac{p}{q} \tag{3}$$

Acoustical pressure is defined as difference between pressure and static pressure. Volume acoustical velocity q (or flow of acoustical velocity) is defined as time changing of the volume acoustical displacement.

Acoustical reactance of porous insulating materials is governed by insulating layer thickness and in much lesser extent by surface density of the air permeable surface film, by which these materials are covered. For a given value of the acoustical reactance is existing an optimal value of the acoustical resistance. At this optimal value the maximum sound absorption is obtained. Because of the fact, that the porous material reactance is governed mainly by the layer thickness, adjusting of the acoustical resistivity is the most effective way of regulation of the sound absorption properties in this case. This can be achieved by decreasing mean pore size (i.e. by increasing material volume density), increasing bonding compound content, variant perforation etc. Disadvantage of this approach is in the increase of the material costs, hence also of the market price of the final product.

Results of the sound absorption coefficient measurements for selected PUR foam base materials covered with modifying top surface based on PUR nonwoven nano-fabric are shown in Figures 1 and 2. There is clear strong effect on the magnitude of the maximum value of the sound absorption coefficient, where the increase in its magnitude was ranging between 10 to 25 %. The maximum of sound absorption coefficient was observed at 3000 Hz for sample N2538, for remaining samples at 2200 Hz. Similar pattern was obtained for all studied types of foam and fabric combinations.

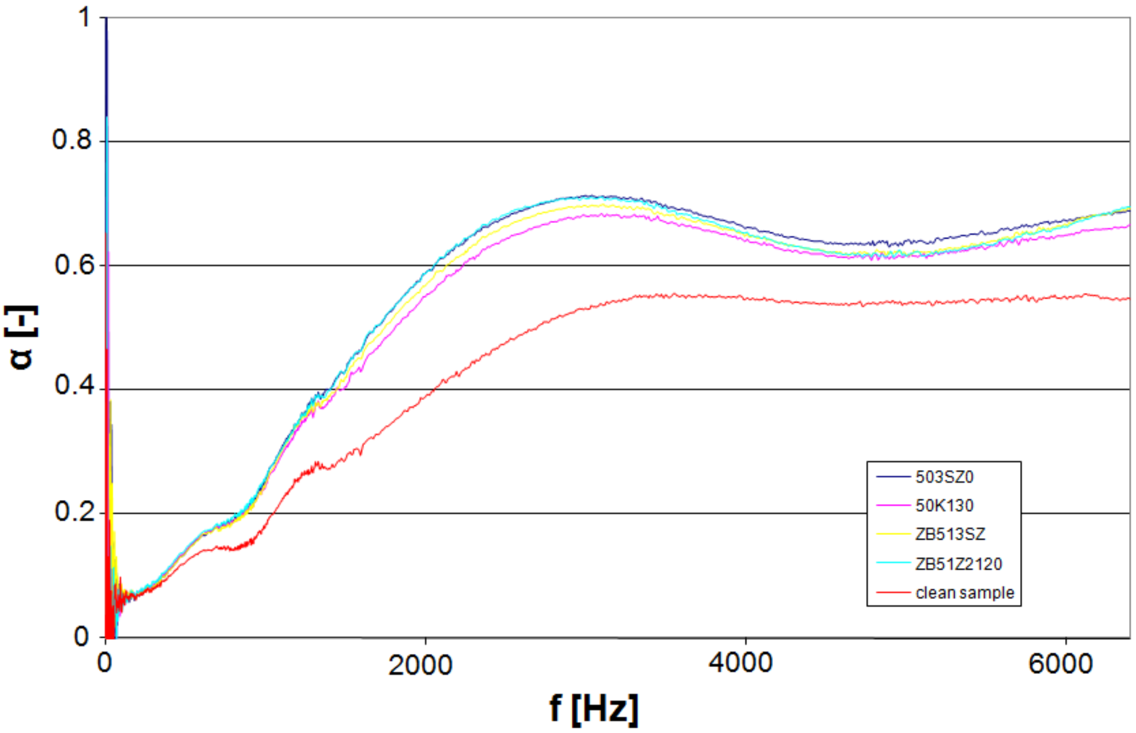

Figure 2. Frequency dependence of sound absorption coefficient of PUR open cell foam material N2538 covered with PUR based nonwoven nano-fabric of different air flow resistivity.

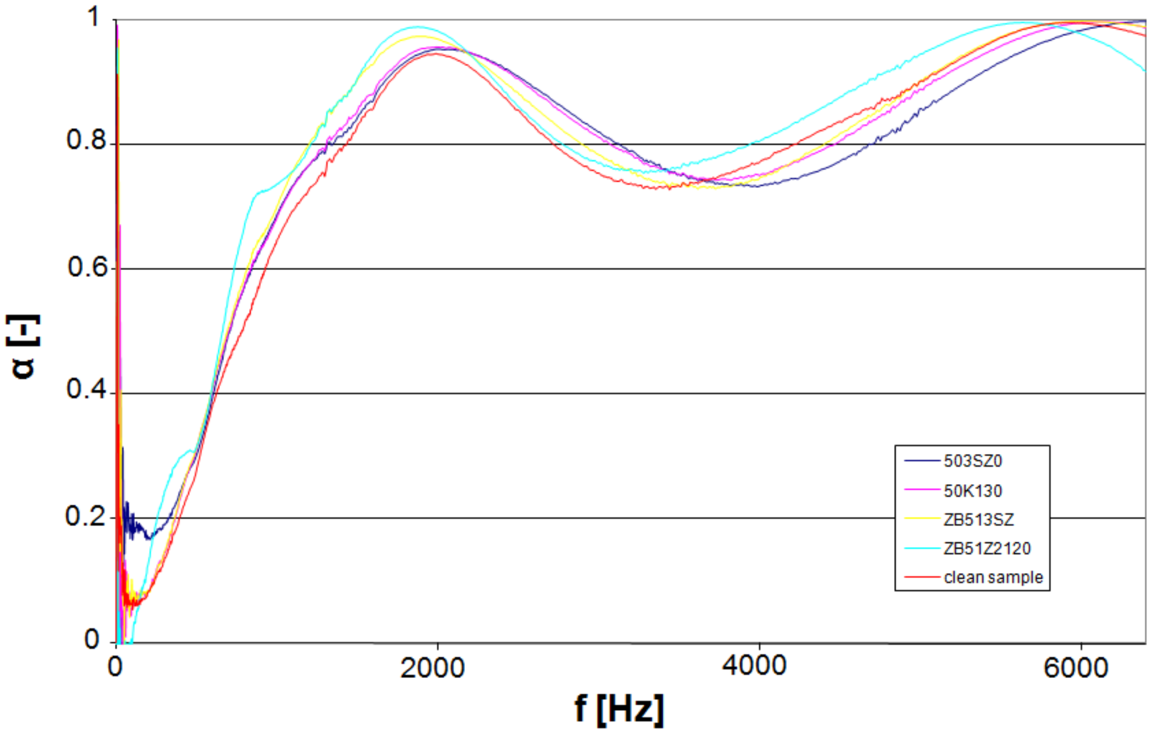

Figure 3. Frequency dependence of sound absorption coefficient of PUR open cell foam material S3535F covered with PUR based nonwoven nano-fabric of different air flow resistivity.

4. CONCLUSIONS

Acoustic reactance of porous insulating materials is determined by layer thickness and in the lesser extent by surface density of the air permeable surface film coating. Acoustic resistance of the porous insulating material is determined by the air flow resistivity. This study allowed characterize the effect of the mutual influence of acoustic resistance and acoustic reactance components of the complex acoustic impedance on final sound damping characteristics of the studied sandwich like PUR based structures. It was found, that studied PUR based open cell porous materials in combination with nano-size fabrics exhibit excellent sound damping properties. This is allowing application of the latter PUR based micro and nano sized matrices as effective sound damping materials for automotive and aerospace cabin or fuselage applications as was confirmed by our pilot testing [3].

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