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COMPOSITE MATERIAL SOUND ABSORPTION DETERMINATION BY MEANS OF STANDING WAVE TUBE MEASUREMENT

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ABSTRACT

The sound absorption material property knowledge, opens new application possibilities of material. Absorptive materials can be used for sound pressure level attenuation in interior spaces (usually acoustic diffuse field), as well as exterior spaces (free acoustic field). The presented work is focused on sound absorption coefficient measurement techniques. In respect to this purpose, the standing wave impedance tube measurement device was assembled. Reference samples from composite based EVA (ethylene vinyl acetate) material were created. Samples were used for interlaboratory comparative sound absorption measurement test. Measurement results comparison is presented here.

INTRODUCTION

The material sound absorption is usually expressed by sound absorption coefficient α(-). Generally, it is the ratio of incidence sound power entering (irreversible) into the material surface, to the total incidence sound power [Vigran, 2008]. In the practice, sound absorptive materials found their place mainly in cases, when acoustic sound pressure level attenuation is needed, whether in a bounded areas or in a near sound field of a sound source. As is clear from definition, sound absorptive materials are absorbing acoustic energy. The sound absorption is frequency dependent. Usually is expressed in one third octave or full octave frequency band. With sound waves absorption, we are dealing in full range of acoustics domains [Beranek, 2012; Kuttruf, 2008; Beranek, 1965; Hopkins, 2012]. The acoustic absorptive materials are usually also porous. The theory of sound propagation within the porous materials is actually still hot topic and is partially described in the literature [6]. Sound absorption property can be expressed also by impedance of material surface. One of most frequently used technique for sound absorption determination is by means of impedance (standing wave) tube. There are plenty of measurement techniques to determine sound absorption. Part of them are standardized.

Standard methods can be generally divided to the laboratory measurement techniques e.g. by means of impedance tube (Standing wave method [ISO, 1996] or Transfer-function method [ISO, 1998]) or by means of reverberant room [ISO, 2003; BS EN, 2017] and in situ techniques for determining the acoustic performance of road traffic noise reduction devices [DIN EN, 2016] and road surfaces [ISO 2002; ISO, 2010].

Research in field of innovative material development based on industry waste is an integral part of sustainable development in society. The Department of material engineering at STUBA is constantly dealing with research in this field. One of the fields, where was the lack in their expertise, was the research in sound propagation within material, especially the sound absorption determination of small prototype samples. Motivated by possible collaboration with Departments of Physics and Building construction from STUBA, TGM Vienna, CTU in Brno and A&Z Acoustics s.r.o., the small comparative interlaboratory test in sound absorption measurement in accordance to ISO 10534-1 [ISO, 1996] was organized. The additional value of the work was on one hand the verification of measurement technique quality of the measurement setup temporally borrowed to department of Material engineering of STUBA, on the other hand the active involving students in development of new sound absorptive industrial waste based material.

DESCRIPTION OF THE REFERENCE SAMPLE

Ethyl vinyl acetate (EVA), also called expanded or foam rubber, was used as a sample filler. It is a copolymer comprised of monomers of ethylene and vinyl acetate, wherein the ethylene content is about 60-90%. Elasticity, impact resistance and good thermal insulating properties can be distinguished from the basic properties of the EVA material. We usually compare EVA with elastomeric materials. As a binder the Conipur 360, known as MDI (methylene diphenyl disocyanate) was used. MDI is a one-component adhesive mainly used in industry and has a reinforcing effect. A small amount of water was added that acts as a pouring accelerator. The composition of material mixture consisted of 4l of filler (EVA), 0.3l of binder (MDI) and ca. 5ml of water. The components were thoroughly mixed. Subsequently cylindrical molds of 10cm diameter and 3cm and height 6.5 cm (+ -1 mm) were filled. After the solidification process (24h), samples were removed from molds (Figure 1). For interlaboratory comparative tests, just samples of diameter *d*=10cm were used.

Figure 1. The reference sample (cylinders with diameter 10cm and height 6.5cm).

MEASUREMENT DESCRIPTION

As was mentioned above, for the comparative test was used measurement technique explained in standard ISO 10534-1 [ISO, 1996]. The big advantage of the impedance tube measurement techniques (also so called the fast measurement techniques) in general is the fact, for sound absorption properties determination just relatively small size measurement sample is needed (the size of specimen can be smaller than wavelength of the sound waves in frequency spectrum of interest). Therefore, impedance tube measurement methods are often used for absorption material development. However, the objective parameter, sound absorption coefficient, is determined just for perpendicular incidence of acoustic plane wave.

The measurement principle by means of impedance tube and standing wave method based on sound pressure level measurement inside of the tube is based on seeking for nodes, or superposition, of standing wave in tube (maximal, and minimal value of pressure in impedance tube, also so-called the Kundt's tube). The standing waves are generated by acoustic plane wave source (loudspeaker) mounted on the one end of the tube. On the other side of the tube is mounted the specimen under investigation [Vigran, 2008]. This measurement technique is used in practice since 40ties of 20th century. The performed measurements can be divided to two groups here.

- The comparative test between 3 labs (STUBA, TGM and CTU in Brno). Measurements were performed in frequency range from 100 to 1800 Hz. The excitation signal was time stationary sine signal tuned in step of 1/3rd frequency generated by external sine generator.
- Measurement in range from 100 to 5000 Hz performed in one of the labs by means of 3 ways of absorption determination, extended by calculation of theoretical sound absorption for diffuse field. The first of three techniques was the same as in previous approach. For the second and third technique the random noise generator was used. In the 2nd approach, resulting values were get from single values in the spectrum. For case 3, resulting sound absorption coefficient was achieved by averaging values in 1/3rd octave band spectrum.

RESULTS

In the fist step, the comparison of sound absorption measurement results achieved by interlaboratory test were compared. Three EVA based composite material were distributed (traveling) between three laboratories. In both cases, the excitation measurement signal was sine signal generated by sine tone generator. The tone was gradually tuned in 1/3rd octave step. The average values of sound absorption coefficient spectra in frequency range from 100 to 1800Hz are compared in Figure 2. One can see the similar trend of absorption spectra shape. Measurements from both laboratories verified the significant sound absorption in spectrum from 400 to 700Hz. However, there is deviation in results in low and high frequency range. The deviation is usually caused by background noise, tightness of specimen mounting in the device but also by used filter. It is not unusual to have deviation in low frequency spectra. Difference between laboratories was up to $\Delta\alpha = 0.15$.

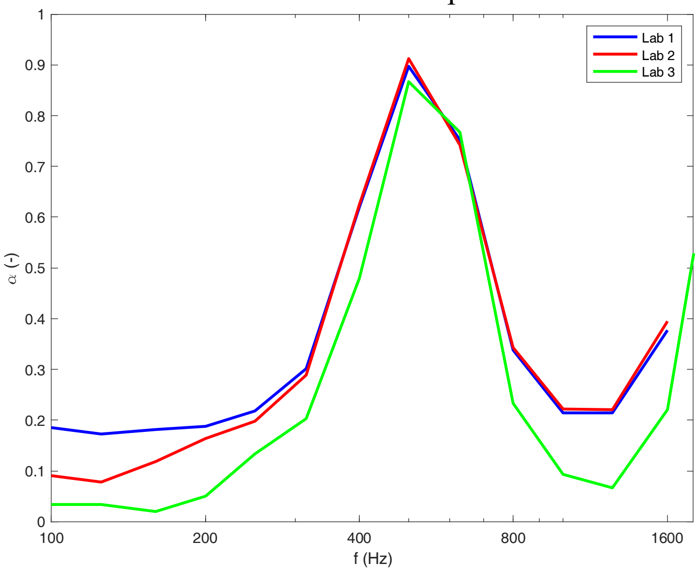

Figure 2. The interlaboratory results comparison (average results for EVA cylinders with diameter 10cm and height 6.5cm in rage from 100Hz to 1800Hz).

In the second step, in one of laboratories, the sound absorption measurement in frequency range up to 5kHz was performed (for frequencies above 1kHz the small impedance tube was used). Three variants of data processing were used (Figure 3.).

Variant 1- measurement was performed in the same way as explained above. Large and small impedance tube were used. The signal was generated by sine tone generator in step of 1/3rd octave.

During measurement, the superposition of maximum and minimum sound pressure level was seeking for by microphone probe moving in the tube.
In variants 2 and 3, the excitation signal was random noise (created in Matlab). In both cases, the full length of tubes was scanned by the probe. Subsequently the standing acoustic waves for each frequency were evaluate. In variant 2, the sound absorption was determined by choosing single pressure values on the middle frequencies of 1/3rd octave band. In case of variant 3, the sound pressure energy was averaged in 1/3rd octave bands. From average values the absorption was determined. Resulting spectra are differ significantly in range above 2500Hz. In other parts is deviation less than $\Delta\alpha$= 0.1.

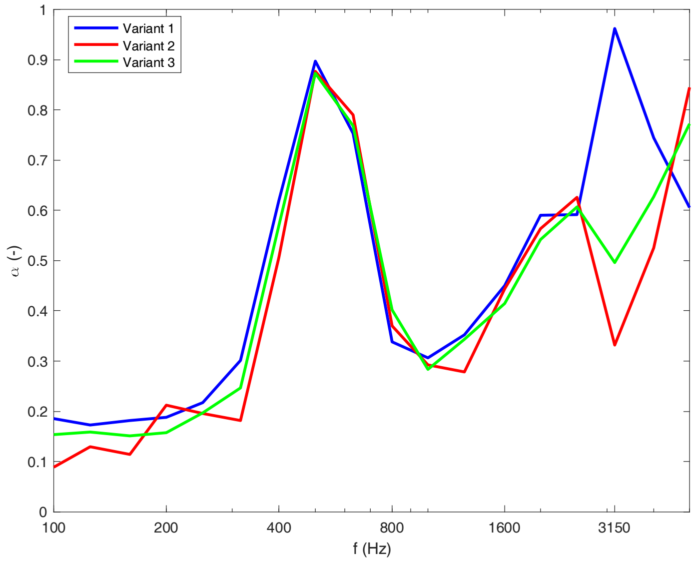

Figure 3. Sound absorption spectra of variants 1 to 3.

In the last step, results from variant 3 were chosen, to calculate the theoretical sound absorption in diffuse field in according to the standard ISO 10534-1 [ISO, 1996]. The relation between perpendicular acoustic plane wave incidence absorption and diffuse sound field is shown on Figure 4. It is every time very important to realize this difference between results.

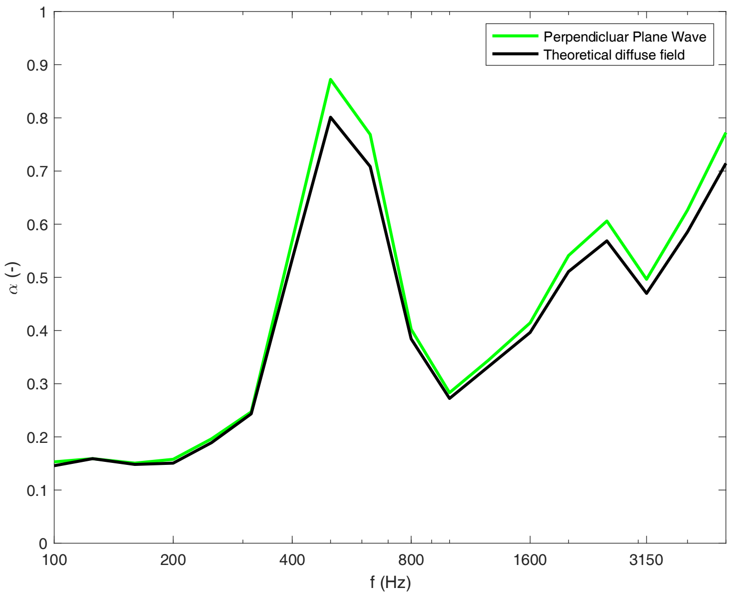

Figure 4. Comparison of measured sound absorption coefficient spectrum for perpendicular plane sound wave and a theoretical spectrum for case of diffuse sound field excitation.

CONCLUSIONS

From the measurement results comparison is clear that, the differences occurred between laboratories measurement results. Generally most sensitive are low frequencies. In presented results, the biggest difference was $\Delta\alpha$= 0.15. There was also shown, if the same measurement device and specimen is used, and the same data are processed in the different ways, the results can differ. As more objective measurement approach was the variant 3, where the sample was excited by random noise and results were obtained based summing and averaging the energy of frequency bands. Of course, the integrated impulse response approach would be even more sophisticated approach and would neglect the stationary background noise during measurement. Also important is to mention, measurements presented here were performed on large samples (diameter 10cm). There were made also samples of diameter 3cm, but their material properties were not comparable with bigger samples (caused by fraction of EVA filler). Therefore, for high frequency measurements the large specimen was used, mounted in the way to tightly press to the small tube blinded from the rare side by massive steel plate.

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