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OPTIMIZED SOUND ABSORPTION OF A RIGID POLYURETHANE FOAM

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In this study, cast panel received as sound insulator was implemented as sound absorber. The panel is composed of prepainted metal skins with a rigid self extinguishing polyurethane foam. For the achievement of such material as sound absorber, holes are uniformly drilled in the sample to allow relatively easy access of sound to the interior structure. Using the two microphone impedance measurement tube, the sound absorption coefficient was studied for samples of different, coverings, opening pores (2 mm, 3 mm), open areas (0.04, 0.16), and at air space depths: 0, 5, 10, 20 and 40 mm from the reflected wall. The normalized acoustic impedance was also studied. The results revealed that when the sample was uniformly drilled with pores of opening 2 mm each to have 0.16 mm open area, and positioned at air space depth (5 mm), it showed optimum sound absorption greater than 0.80 in the frequency range from 700–1600 Hz. In dealing with noise reduction, this absorption gives, 6.9 dB drop in noise level.

1. Introduction

Porous materials used in noise control problems, are generally characterized by open cells where the sound dissipates through the air passages inside the material. Several works [1–4] were carried out for studying the acoustical properties of such porous materials. SHENODA *et al*. [5] studied the acoustical properties of Egyptian cotton either in its loose form or in a compressed bulky form. Although cotton showed high absorption coefficient even when it was exposed to high temperature up to 220°C, it could not be used in many applications because of its lower stiffness. New class of metallic foam was developed in which the absorption coefficient and mechanical stiffness of the material make it useful to replace the acoustical porous material. Cellular metal foam was developed for structural, thermal and acoustical applications [6–8]. T. J. LU *et al.* [6] stated that metal foams having open or semiopen cells are said to have sound absorbing capacity. They have higher damping capacity and natural vibration frequencies than solid of which they are made sandwich panels with metal foam cores offer significant potential for vibration and acoustic management. LU *et al.* [9] measured the absorption coefficient and static flow resistance for Aluminum foams with semiopen cells to be used in many applications. For his developed material, he found that a sound absorption coefficient larger than 0.8, in the frequency range of 800–2000 Hz, can be achieved in selected samples.

Cellular metals with closed cells are, in general, poor sound absorber owing to the difficulty of sound having access to the interior cellular structure. As denoted by T. J. LU [6], significant sound absorption enhancement in uncompressed Alporas foams is achieved via hole drilling.

In this investigation, a two-microphone impedance measurement tube was used for measuring the absorption coefficient and acoustic impedance of samples composed of prepainted metal skins with a rigid self extinguishing polyurethane foam core. The absorption coefficient was studied as a function of diameter and number of pore opening, open areas, and the air space depth behind the sample. The object of this work is the implementation of polyurethane materials as sound absorbers. An optimized absorption coefficient (> 0.8) in the frequency range from 700–1600 Hz was achieved.

2. Materials and preparation

Materials used for this investigation were received as panels of thickness 38 mm. These panels, which are used for sound insulation, are composed of two prepainted metal skins, or two layers one is metal and the other is wood with a rigid self extinguishing polyurethane foam core. Features of such panels are, the average density: 35–42 kg/m^2, compressive stress: ≥ 1 kg/cm^2, tensile strength: ≥ 1 kg/cm^2. Circular samples of diameter 100 mm (the interior diameter of the sample holder), were prepared thoroully from the received panels. Preparation of samples were carried out in the testing laboratory of National Institute for Standards (NIS). To allow relatively easy access of sound to the interior cellular structure, numbers of holes were drilled uniformly through the sample. Some samples were drilled with 2 mm opening pores and other with 3 mm.

3. Experimental procedure and calibration

The assembly used in the measurements of this study is consists of: the two microphone impedance measurement tube B&K type 4206 (Fig. 1), analyzer B&K type 3550 which generates a random signal amplified by a power amplifier by B&K type 2706, frequency weighted by the frequency weighting unit and then applied to the sound source. The data were transferred to PC as a screen picture, and then to the printer. At the beginning of each measurement, calibration procedure was carried out to ensure that the measurement results were not affected by phase or amplitude mismatch between the two measurement channels.

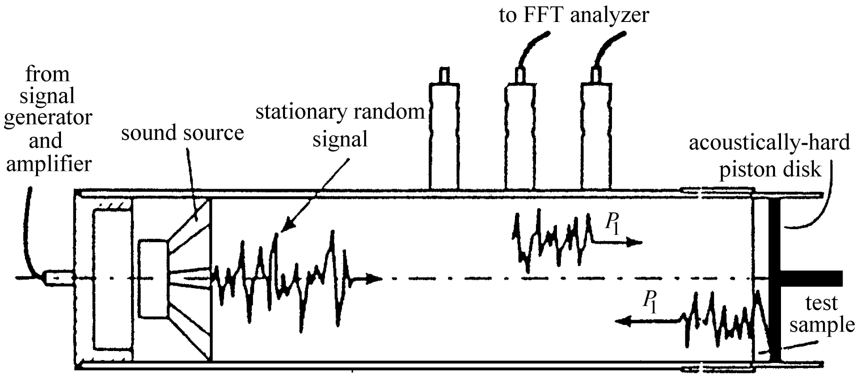

Fig. 1. Cut-away diagram of the impedance measurement tube, showing the incident and reflect component of the stationary-random signal.

4. Results and discusion

4.1. Absorption coefficient

Absorption coefficient was determined for two conditions of the composed material; a) two prepainted metal skins and, b) one prepainted metal skin and the other was a wooden skin, with a rigid self extinguishing polyurethane foam core for both conditions. The sample of constant thickness 38 mm was placed in the sample holder with its metal skin at the reflected wall, and no air space between them. Figure 2 shows the measured normal sound absorption ceefficient for two such samples with two different conditions of covering. The measurements were carried out in the frequency range 125–1600 Hz. The figure shows that the absorption coefficient is generally poor at low frequencies up to 500 Hz, and sharply increases at certain frequency depending upon each condition. The absorption curve corresponding to the sample with two metal skins is flatter than the other, and the peak point is shifted toward lower frequencies. Regarding to these results and the fire resistance of the covering metals, samples with two metal skin were preferred for further study.

Two samples of polyurethane with covering metal skins were drilled uniformly with the same number of circular holes, the first sample with pore opening 2 mm, and the second with 3 mm. The absorption coefficient was determined In the frequency range 125–1600 Hz where the sample was backed by the rigid wall with no air cavity between them. The obtained data are shown in Fig. 3 which reveal that the absorption coefficient increases sharply in the frequency range 1100–1400 Hz. The resonance frequency is reduced by decreasing pore opening i.e. the absorption is enhanced to the lower frequency range.

As denoted by T. J. Lu, *et al.* [6] the hole drilling alters the cellular structure of the cast foam panels that they become more transparent to air motion, and may lead to enhancement in sound absorption. The above results of this study showed that sample drilled with 2 mm pore opening could be used to establish more definite trends.

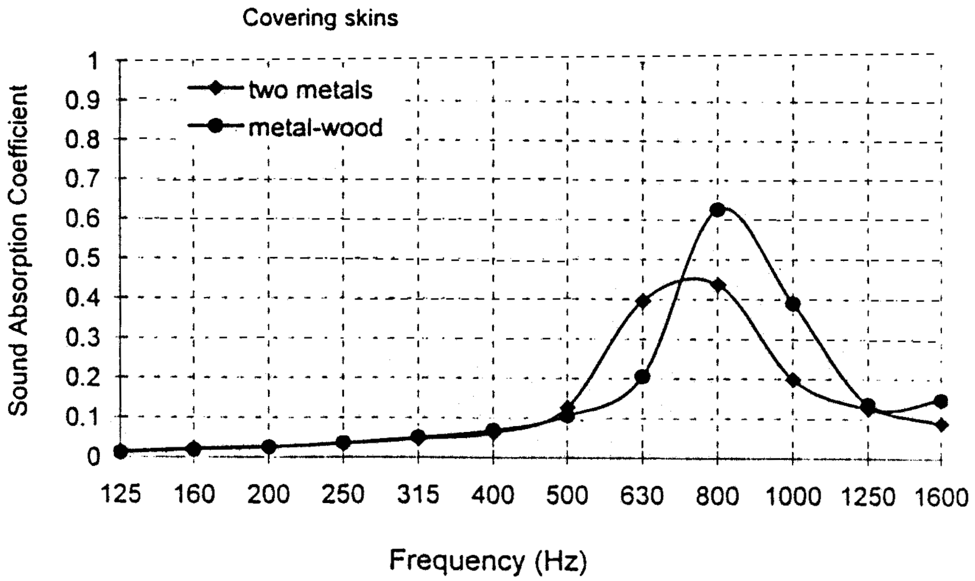

Fig. 2. Sound absorption coefficient as function of frequency for two conditions of covering (a) two metal skins, (b) one metal and the other wooden skin.

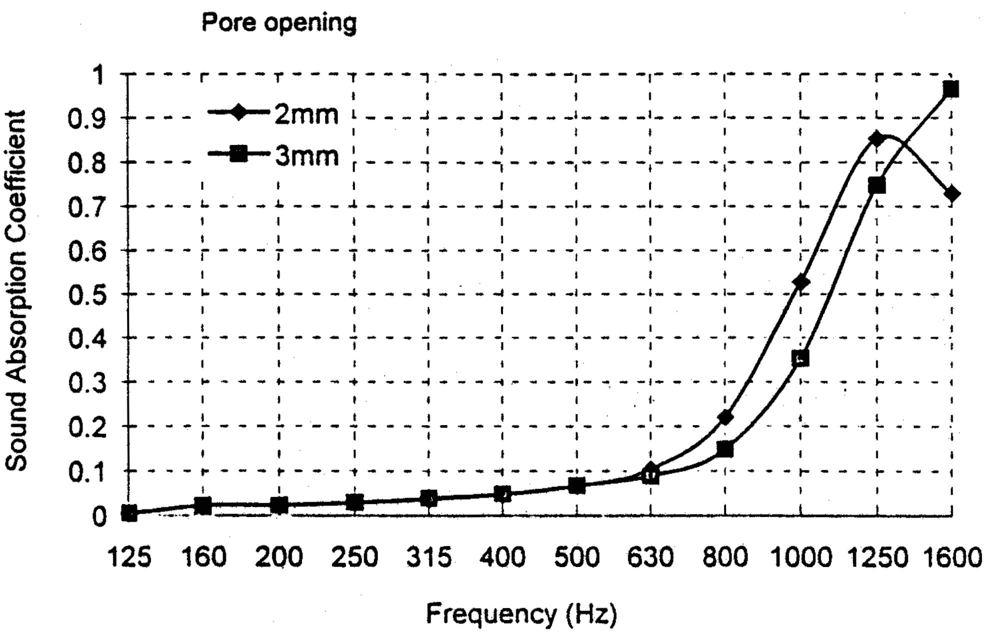

Fig. 3. Sound absorption coefficient as function of frequency for two samples: (a) pore opening 2 mm and (b) pore opening 3 mm.

Figure 4 represents the variation of sound absorption with frequency for two samples drilled uniformly with the same pore opening (2 mm) for two different pore opening areas 0.04 and 0.16 relative to the surface of the sample. In each measurement, the sample was backed directly to the reflected wall. From the figure, one can see that the sample with larger pore opening area (0.16) shows higher absorption coefficient.

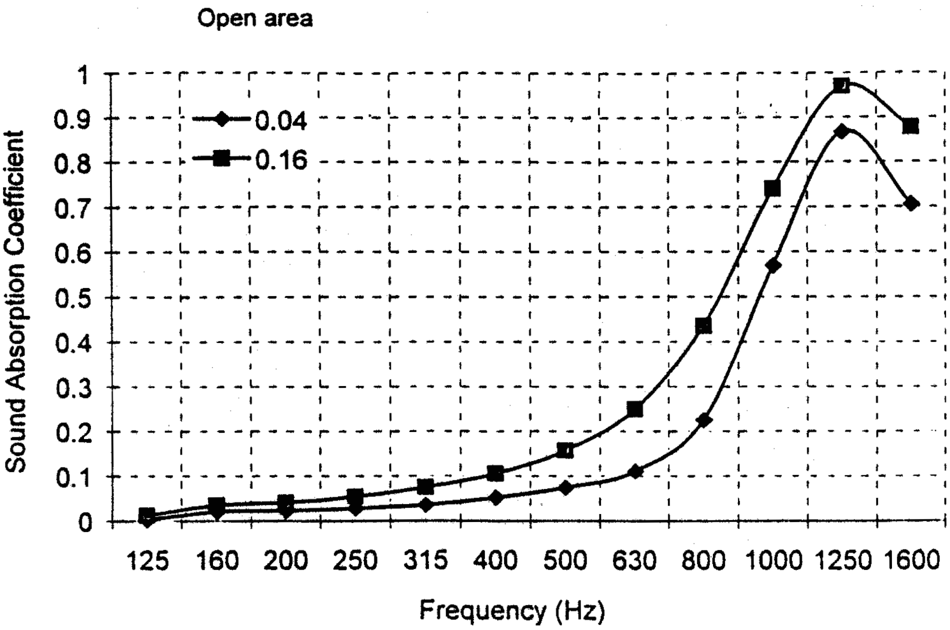

Fig. 4. Sound absorption coefficient as function of frequency for two samples: (a) pore opening 0.04 and, (b) pore opening 0.16.

As denoted by HIDEFUSA [10], an increase of the bulk thickness might be undesirable in terms of the weight increment and hence cost implication. However, the absorption coefficient in the lower frequency region can be improved by backing air gap between the sample and the reflected wall.

To determine the ideal air space depth which gives the optimum sound absorption, the normal sound absorption of a sample with higher opening area (0.16) was measured at different air space depths: 0, 5, 10, 20 and 40 mm between the sample and the reflected wall. Figure 5 represents the obtained data in the frequency range from 125–1600 Hz. As expected, increasing the air space depth shifts the peak point of sound absorption towards lower frequencies, namely, the sound absorption performance was improved in the lower frequencies. One can see from this figure that the optimum absorption among these conditions is achieved with 5 mm air space depth, where the values of sound absorption coefficient are higher than 0.8 in the frequency range from 700–1600 Hz. In dealing with noise reduction [6], this absorption gives 6.9 dB drop in noise level.

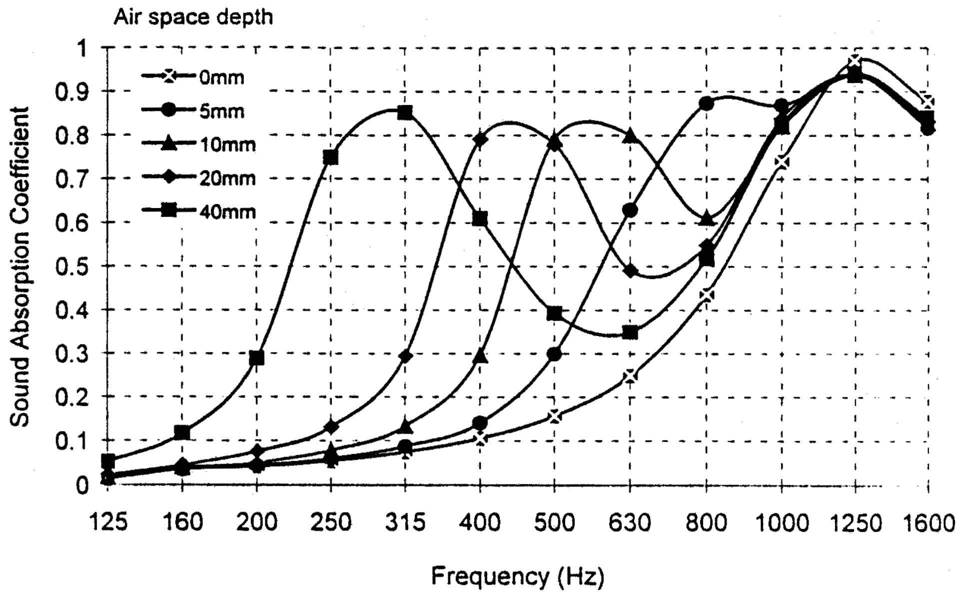

Fig. 5. Sound absorption coefficient as function of frequency for the sample of 0.16 open area placed at: 0, 5, 10, 20 and 40 mm, from the reflected wall.

4.2. Normalized impedance

The two microphone impedance measurement tube was also used for the determination of the real and imaginary components of the normalized impedance for a sample of 38 mm thickness of polyurethane foam covered with two metal skins. This sample

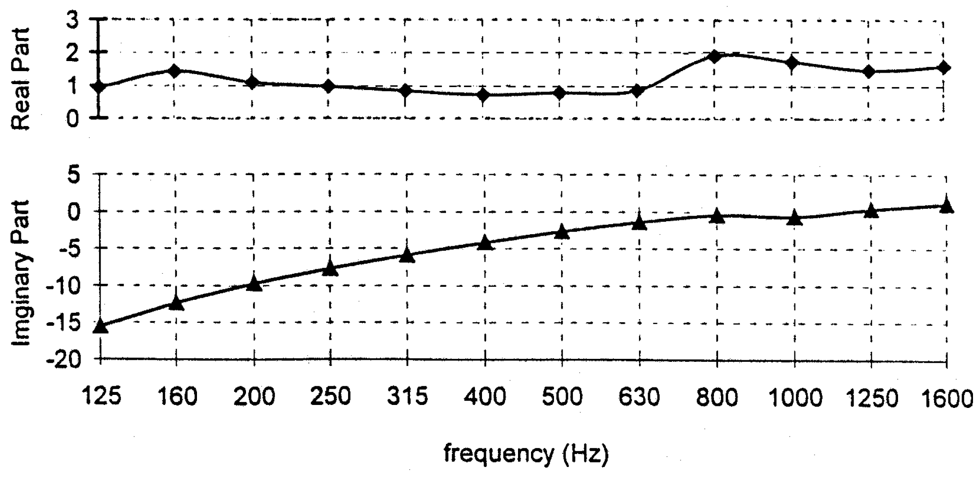

Fig. 6. Real and imaginary parts of the normalized acoustic impedance as a function of frequency for the sample of 0.16 open area, placed at 5 mm from the reflected wall, (optimum sound absorption condition).

with pore opening area (0.16) was placed at: 5, 10, 20 and 40 mm from the reflected wall. The measurements were carried out in the frequency range from 125–1600 Hz in third-octave bands, and the obtained data are given in Table 1. Figure 6 represents the values of real and imaginary components of the normalized impedance for the sample placed at 5 mm from the reflected wall, namely, the case which gave optimum sound absorption. From the table one can see that in the lower frequency range (from 125–500 Hz), the imaginary part of acoustic impedance increases with air space depth, while at higher frequencies (around 1250 Hz) the discrepancies are not great.

Table 1. Values of the real and imaginary components of the normalized impedance for the sample of 0.16 open area and placed at: 5, 10, 20 and 40 mm air space depth from the reflected wall.

F (Hz)	5 mm		10 mm		20 mm		40 mm	
	Re	Im	Re	Im	Re	Im	Re	Im
125	0.937	−15.6	0.676	−11.6	0.514	−9.045	0.442	−5.619
160	1.422	−12.4	0.85	−9.294	0.59	−6.997	0.497	−3.917
200	1.087	−9.785	0.794	−7.513	0.585	−5.384	0.583	−2.433
250	0.963	−7.741	0.707	−5.903	0.578	−3.921	0.755	−0.933
315	0.836	−5.91	0.634	−4.388	0.622	−2.484	1.402	0.853
400	0.71	−4.214	0.646	−2.919	0.922	−0.853	3.273	1.729
500	0.776	−2.73	0.812	−1.51	2.468	0.894	6.957	2.285
630	0.851	−1.419	1.915	−0.054	5.009	−1.362	5.802	−4.069
800	1.903	−0.47	2.762	−1.446	2.135	−2.409	2.103	−2.622
1000	1.722	−0.715	1.474	−0.831	1.383	−0.923	1.456	−0.988
1250	1.465	0.3	1.53	0.195	1.544	0.09	1.522	0.112
1600	1.588	1.035	1.783	0.971	1.878	0.866	1.669	0.899

5. Conclusion

The optimum absorption coefficient for a panel of thickness 38 mm, composed of rigid polyurethane foam of density about 40 kg/m^3 and covered with two metal skins, is achieved by uniformly drilling pores in this panel of opening 2 mm each (0.16 open area) and positioning it at 5 mm from the wall. This absorption was greater than 0.8 in the frequency range from 700–1600 Hz. In dealing with noise reduction, this absorption gives 6.9 dB drop in the noise level.

Acknowledgment

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