Characterization of Poly-isoprene Rubber Layer Backed with Porous Material as Sound Absorber and Vibration Damper

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Abstract: There are several methods to decrease acoustic noise. Sound absorption is one of the noise control methods, commonly, multi-layer sound absorbers are applied to absorb broad band noise. , the sound absorption coefficient of different materials are measured in impedance tube using two-microphone transfer-function method according to ISO 10534-2 and ASTM E1050-98 international standards. Multi-layers sound absorbers effectiveness depends on their construction. The effects of different porous materials (R, S &F), and layers backing on the sound absorption and of poly isoprene rubber will be studied**.** The treatment for Multi-layered with sponge and rubber increasing the sound absorption coefficient value at about 0.9 and shifted towards a lower frequency range 315-800 Hz.

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Keywords: Characterization; Poly-isoprene; Rubber Porous; Material; Vibration Damper

1. Introduction:

With the increase in public awareness and concern for noise pollution, many kinds of sound absorbing or isolating materials, such as glass wool, polymeric fibrous materials, and various types of foams, alone or with viscoelastic materials. These materials are used to absorb airborne noise and to optimize the transmission loss (TL) and damping coefficient in multi-layer systems, may be found in trim lining, under carpets, in seats, cavity interior, etc. It is interesting to measure the acoustical properties, and moreover to be able to predict the noise control impact of these materials in the design stage. Associated with the characteristic impedance and propagation constant, the absorption ratio and TL that represent sound reflection and penetrating capability of a sample material, are usually considered as the most important acoustical properties, and may be measured by a standing wave-duct system. It is essentially an impedance tube with a loudspeaker at one end, a test specimen at a certain location inside and a specifically designed terminator at the other end. Several microphones are mounted along the wall of the tube. Based on the one-dimensional wave equations, the measurement process may be performed by decomposing the standing wave in the tube, and frequency analysis or transfer function techniques may be applied to compute the normal incidence absorption coefficient, characteristic impedance, propagation constant, TL, and other acoustical properties of the noise control materials. According to the comparison results, a concept so-called experimental hybrid multi-layer prediction was proposed and applied to predict absorption and transmission characteristics of a set of multi-layered treatments of different materials, and some useful results were obtained. In actual application, by adding the hybrid prediction function into standing wave-duct, one can measure any material sample, regardless of its consisting layers, thickness, etc.; moreover, optimize the acoustical properties of a multi-layer treatment by replacing one or several layers with some new materials with known transfer matrix information in absorption and transmission characteristic design. It should be mentioned that the work done in this paper may be extended to study other types of noise control configurations or equipment, such as measuring or predicting the acoustical properties of automotive muffler. [1]. the absorption coefficient (α) of metallic hollow sphere structures (MHSS) was measured in the range from 500 Hz to 3500 Hz. The detailed form and frequency dependence is influenced strongly by material parameters like sample thickness, pore size, porosity and sphere diameter. It is possible to reach high absorption over a wide range of frequencies by variation of different technological parameters. The ability of sound absorption can be adapted to different noise spectra. These parameters include thickness, sphere diameter, packing density, mixture of different sphere diameters and others. Thus the material can be used for an efficient and new design of noise control systems [2]. Multi-layer acoustic absorbers composed of perforated plates, airspaces or porous materials are commonly applied to absorb broadband noise. However, the acoustic absorption of these multi-layer acoustic absorbers is strongly dependent on their constructions. It was suggested that the outer-layer porous material with appropriate impedance should encourage the incident sound to enter the composite structure, but the inner-layer porous material was selected to attenuate the sound energy and prevent the incident sound from recombining. The acoustic impedance and acoustic absorption coefficient for a realistic multi-layer acoustic absorber containing several compartments with perforated plates, airspaces and porous materials can be calculated. The drawback of the equivalent electrical circuit approach in analyzing multi-layer acoustic absorbers, (which always assumes the back surface acoustic impedance of airspaces or porous materials as that of the rigid wall), is compensated. Besides, several acoustic features of the multi-layer acoustic absorber are also discussed in detail. This provides a reliable guidance for the design of multi-layer acoustic absorbers [3]. Both combinations of putting perforated plates (PP) before or after the fiber layer were eligible to improve the absorption. When coir fiber was backed by (PP) and air gap, porosity of the plate had small influence in adjusting the amount of low frequency absorption. In the condition that PP was in front of coir fiber, low porosity of plate caused the most incident sound to reflect from the plate. Therefore sound waves could not reach the fibers and medium and high frequency absorption were greatly reduced. Coir fiber is naturally a good acoustical absorption in medium and high frequency bands. Observation of different arrangements showed that utilization of (PP) may help to improve low frequency absorption of coir fiber while medium frequency values vanished [4]. This paper puts forward a simple extended acoustic model that can be used to calculate the sound absorption coefficients of porous sintered fiber metals and then briefly discuss its characteristics. At last, the sound absorption coefficient and surface impedance of fiber metals and multi-layer-assembled sound absorbing structures are theoretically calculated using the extended model and Biot–Allard model and compared with the measured results. By comparisons, it is shown that the values calculated by using the extended model fit the measured ones better, in particular at the higher frequencies. This work would provide references and guides for the future studies of sound absorption in porous sintered fiber metal under the high temperature conditions as well as the optimization of sound absorption characteristics of grade-assembled sound absorbing structures. [5]. The tea-leaf-fibre (TLF) waste material is natural, renewable and is a waste produced during processing of tea leaves which does not pose harm to human health. The backing of TLF with a single layer of cotton cloth increases its sound absorption properties significantly. For the samples with 10 mm thickness, TLF exhibits a better sound absorption when compared with polyester and poly-propylene based non-woven fiber (PNF) material. When compared to PNF, samples of backed TLF with 20 and 30 mm thickness yield comparable sound absorption over the frequency ranges of 500–3200 and 500–2400 Hz, respectively. One should note that, TLF test samples utilized throughout this work were not pressurized as PNF materials, which may affect the sound attenuation properties.[6].

2. Materials and methods

Table 1: Material properties of the tested samples

Material	Thickness (cm)	2	4	6
Foam (F)	Mass (Kg/m^2)	3.2	6.4	9.6
	Density (Kg/m^3)	143	----------	---------
Rubber (R)	Mass (Kg/m^2)	21.15	42.3	63.6
	Density (Kg/m^3)	1057	----------	---------
Sponge(S)	Mass (Kg/m^2)	3	5.7	8.6
	Density (Kg/m^3)	150	----------	--------
Wood(W)	Mass (Kg/m^2)	103	---------	-----------
	Density (Kg/m^3)	5098	----------	-----------

Table 2: Multi-layered material treatment of the tested samples

Multi-layer material Construction	Explanation
R2cm +W	2 layers formed from 2cm of rubber faced to incident sound and backed with wood layer
R2cm +S1cm +W	3 layers formed from 2cm of rubber faced to incident sound, backed with 1cm of sponge layer and the last layer is wood

R2cm +F1cm +W	3 layers formed from 2cm of rubber faced to incident sound, backed with 1cm of foam layer and the last layer is wood
R1cm +S2cm +W	3 layers formed from 1cm of rubber faced to incident sound, backed with 2cm of sponge layer and the last layer is wood
R1cm +F2cm +W	3 layers formed from 1cm of rubber faced to incident sound, backed with 2cm of foam layer and the last layer is wood
R2cm +S2cm +W	3 layers formed from 2cm of rubber faced to incident sound, backed with 2cm of sponge layer and the last layer is wood
R2cm +F2cm +W	3 layers formed from 2cm of rubber faced to incident sound, backed with 2cm of foam layer and the last layer is wood

In this section, the sound absorption coefficient of different materials is measured in impedance tube, using two-microphone transfer-function method according to ISO 10534-2 and ASTM E1050-98 international standards. The experimental apparatus (Fig. 1) include: B&K BZ 5050 & 5051 software, B&K3550 analyzer, B&K4260 impedance tube, 1/4 in. B&K4187 condenser microphones cartridge with B&K 2670 preamplifier, and B&K 2706 power amplifier. The experimental frequency ranges between 50 and 6400 Hz, and the span is 2 Hz. [7].
The used samples are: one-layer of different materials (the parameters of samples are listed in Table1), two-layers assembled, and three-layer-assembled. During measurements, the single layered sample is backed by stiffness piston in the impedance tube and the multi-layer-assembled are all backed by wood in the impedance tube.

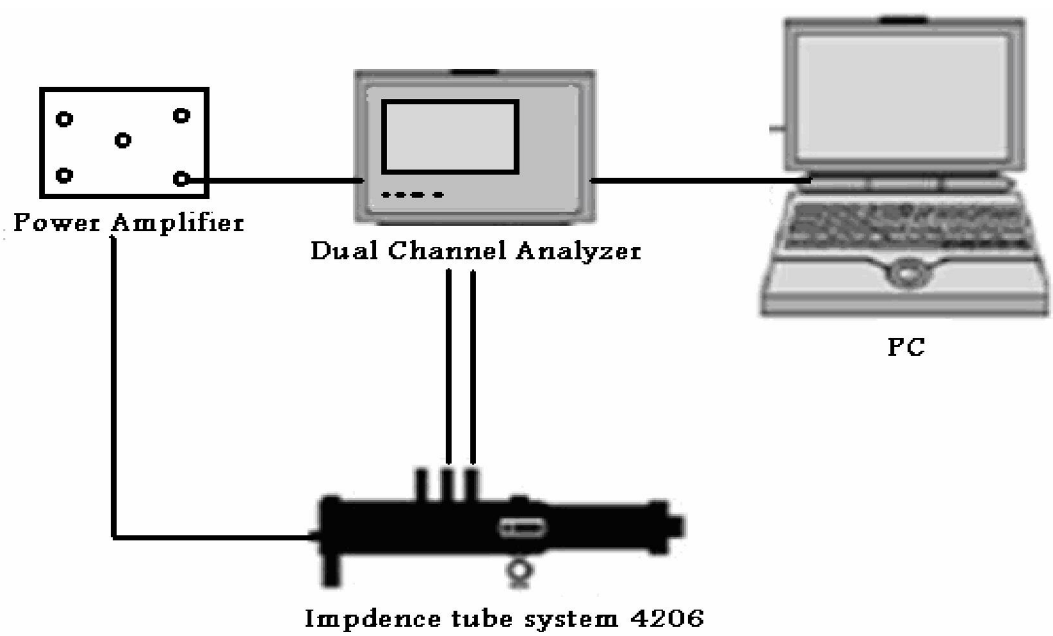

Figure. 1. Impedance tube setup for testing measurements.

The absorption coefficients for different materials (foam, rubber, wood and sponge) and combination layers (Multi-layered material treatment) with varying thickness were measured in the frequency range from 100 Hz to 2000 Hz.

3- Results and discussion

An optimal set of parameters is shown in Table 1&2. Porous absorptive materials used as sound absorbers are usually fuzzy. If the absorption efficiency of materials depending on the trapping and dissipating of sound energy in tiny pores, this can be seriously impaired if the surface pores are filled. For example, (foam, coarse concrete block), has many such pores and is a fair absorber of sound. If the pores of surface are filled, a painted surface can reduce porosity [8]. A greatly reducing in sound penetration occurs, and thus absorption is reduced.
In figure 2, porosity of foam and rubber had small influence in absorption (the surface pores are filled). In wood had no porosity but for foam samples it has more porosity but filled so it has better sound

absorption than wood, sponge has higher porosity than foam and wood, so it has higher sound absorption than foam and wood in frequency range higher than 1300Hz. For rubber samples it has a good sound absorption than wood, foam, rubber and sponge especially in the frequency range from 800Hz up to 2000Hz.

Greater sound absorption occurs from thicker material, but this absorption holds primary for the lower frequencies. Figures (3, 4 and 5), shows the effect of varying absorbent thickness. From Figs. 3 to 5 one can clearly see the effect of increasing samples thickness on its sound absorption coefficient of different materials F (foam), R(rubber) and S (sponge).

From figure 3, as increasing in foam thickness the maximum value of the sound absorption shifted toward the low frequency range. The sound absorption of 2cm foam reach its maximum value (0.25) at 800Hz. As foam thickness increased from 2cm to 4cm, the sound absorption coefficient of foam reaches its maximum value (0.48) at 630Hz. And for 6cm foam thickness, the sound absorption reaches its maximum value (0.38) at 500Hz.

For sponge samples in Figure 4, it is clear that, as increasing in the sponge thickness the maximum value of the sound absorption shifted toward the low frequency range. The sound absorption of 2cm sponge thickness reaches its maximum value (0.52) at 2000Hz. The sound absorption of 4cm sponge reaches its maximum value (0.85) at 1250Hz, and for the 6cm sponge thickness, the sound absorption reaches its maximum value (1.00) at 1000Hz. And for rubber samples in Figure 5, the maximum value of the sound absorption shifted toward the low frequency range. as increasing in the rubber thickness, the sound absorption of 2cm rubber reach its maximum value (0.68) at 1630Hz. When rubber thickness increases from 2cm to 4cm the sound absorption is shifted to a lower frequency 1000Hz and its value is 0.56. And for 6cm rubber the sound absorption reaches its maximum value (0.34) at 400Hz. Several acoustic features of the multi-layer acoustic absorber are also discussed in detail. This provides a reliable guidance for the design of multi-layer acoustic absorbers.

Figure 6, appears the sound absorption of foam layer backed with wood and exhibits lower sound absorption at all frequencies from 100 to 2000 Hz. For the samples of (R1+F2+W) and (R2+F2+W), the sound absorption properties of them were comparable for the frequency range 100–1300 Hz, with a small deviation at 1300Hz between them. But if we compare between the samples with rubber and without rubber layer in Figure 6, the sample (F2cm+W) with foam of thickness 2cm faced the sound and backed with wood, appears the same behaviour of F2cm in Fig3. For the sample (R1cm+F2cm+W), a higher sound absorption in high frequency range especially at 1600Hz, it reaches 0.85. Increasing in the sound absorption of (R1cm+F2cm+W) is due to rubber layer addition (see fig.5). As rubber thickness increases its sound absorption values increases in the frequency range (100 -2000Hz), and due to foam effect as attenuator, an increasing in sound absorption values appears. For (R2cm+F2cm+W), an increasing in sound absorption values appears but in the frequency range (100 - 1250Hz).

In Fig.7 it is clear that the sample (S2cm+W), sponge of thickness 2cm facing the sound and backed with wood, appears the same behaviour of S2cm in Fig4. The sample (R1cm+S2cm+W), has a higher sound absorption coefficient in low frequency range especially at 800Hz it reaches 0.98. An increasing in sound absorption values for (R2cm+S2cm+W) appears also, but shifting at a lower frequency at 400Hz., Figure 8 reveals that, the resonance frequencies of this multi-layers acoustic absorber are respectively higher than those of their individual compartments. It is noted that the lower porosity of the perforated plate has a lower acoustic resonance frequency and higher sound absorption [3].

Figure 8, appears a comparison between a multi-layers material treatment, a higher absorbing sample especially in frequency range higher than 1000Hz is (S4cm+W), and for frequency range lower than 1000Hz, the higher absorbing sample is (R2cm+S2cm+W).

Vibration damping

The system of vibration damping test consists of, an exciting vibration source, a compressor machine of mass 36Kg, to produce a vibration on the floor, this vibration transmitted directly from point to other [8]. To detect the vibration level, using a vibration meter type 2511 B&K with accelerometer type B&K 4173 to measure the transmitted vibration at a point. Firstly the vibration velocity transmitted from compressor directly to floor without any isolator (Comp.), see Fig.9. For damping this vibration, different materials construction layers were used.

Studying each damper under the compressor base and recording the results of each damper. These records are illustrated in fig.9, where the higher velocity level appears due to signal of compressor alone (Comp.), this vibration signal is transmitted directly to the floor under compressor without any isolated material.

Using a wooden layer (2cm thickness) under compressor legs, appears a damping in vibration level of compressor signal especially at peaks of compressor vibration signal. Using a foam layer of 2cm thickness under the wooden layer, a little increasing in damping for the vibration signal occurs with the same behavior of wooden layer. But when inserting a sponge layer of 2cm thickness under wooden layer, a remarkable increasing in damping for the vibration signal occurs, in the interested frequency rang.

Table 3. Multi-layer material Construction Explanation

Multi-layer material Construction	Explanation
Compressor without damper	Comp.
Compressor over Wood (W)	A wooden layer of 1cm thickness
Compressor over (W/F2)	A wooden layer over 2cm thickness foam
Compressor over (W/S2)	A wooden layer over 2cm thickness sponge

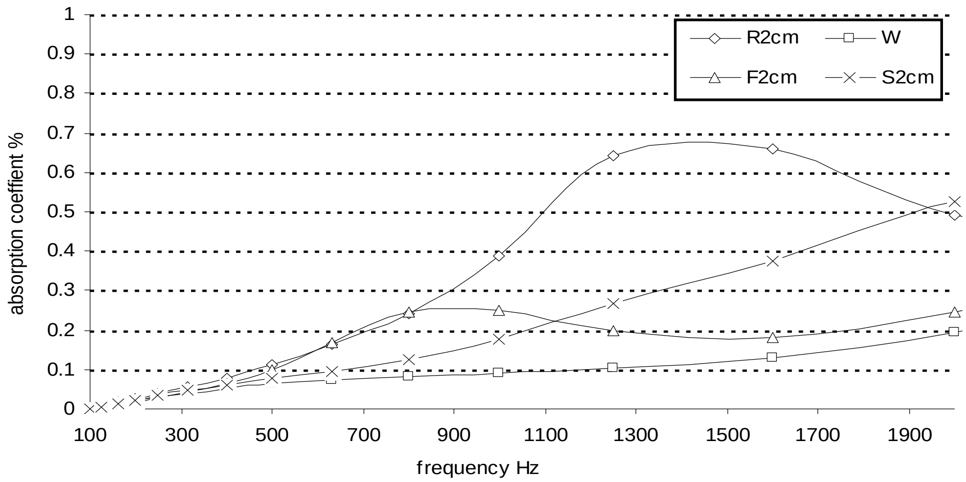

Figure 2; Effect of materials properties on sound absorption

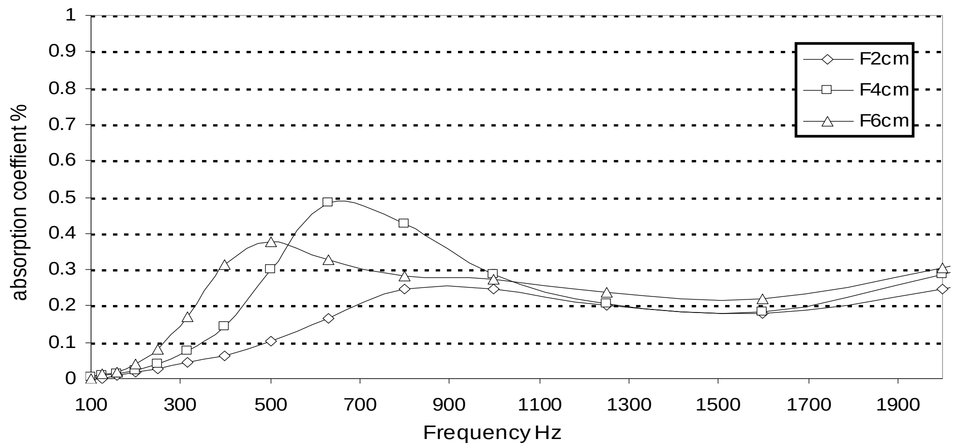

Figure 3; Effect of Foam thickness on sound absorption

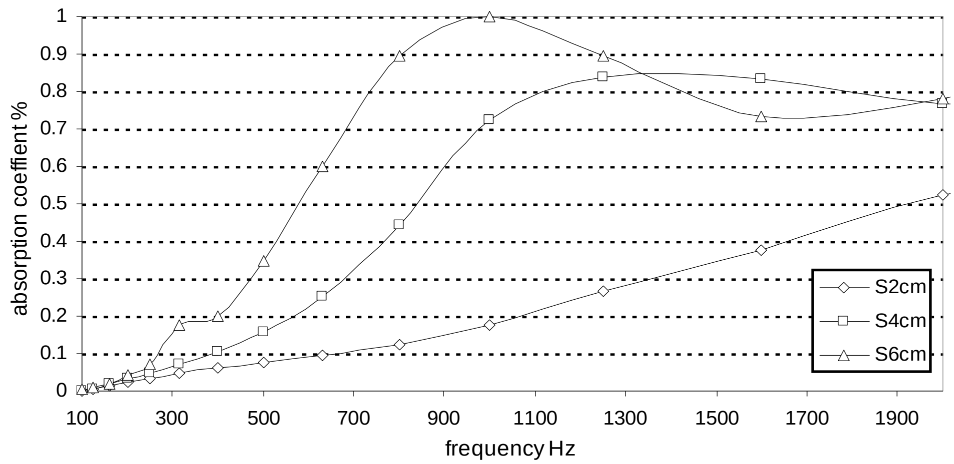

Figure 4; Effect of sponge thickness on sound absorption

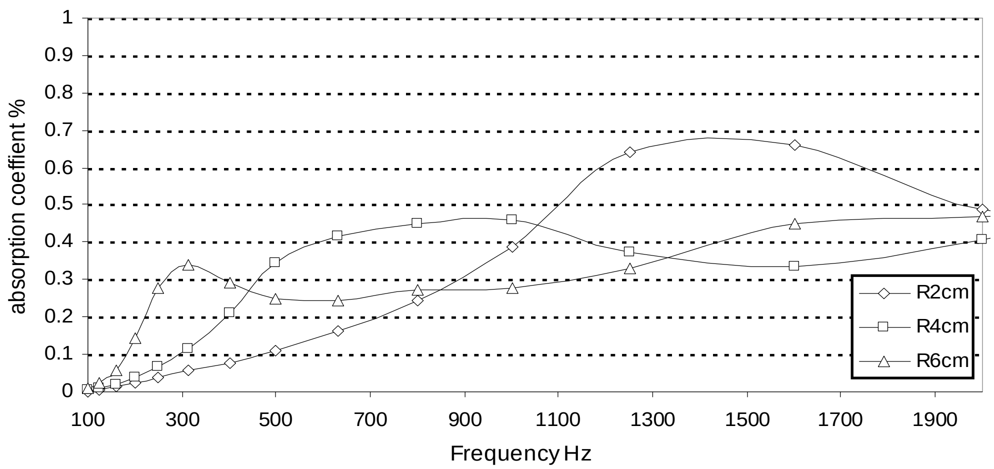

Figure 5; Effect of rubber thickness on sound absorption

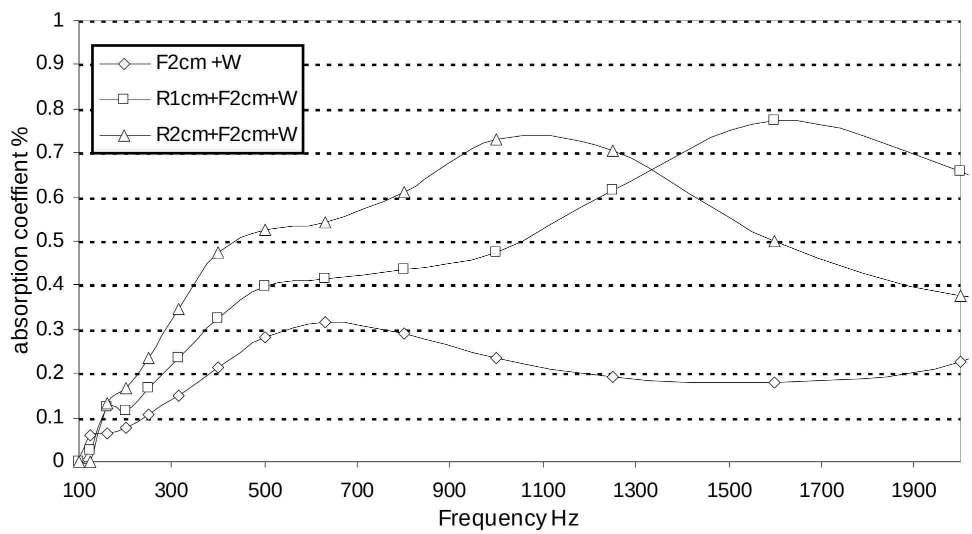

Figure 6; Effect of Rubber and Foam materials as a multi-layers on sound absorption

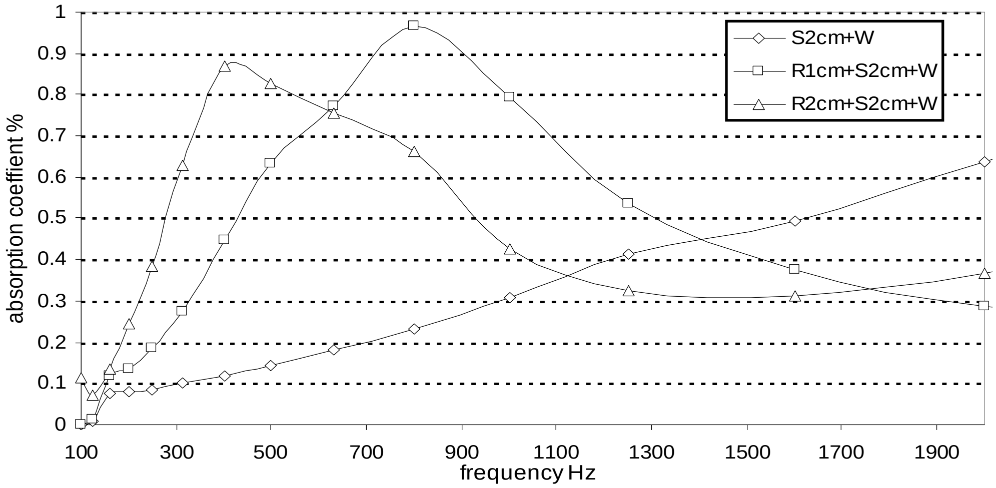

Figure 7; Effect of Rubber and sponge materials as a multi-layers on sound absorption

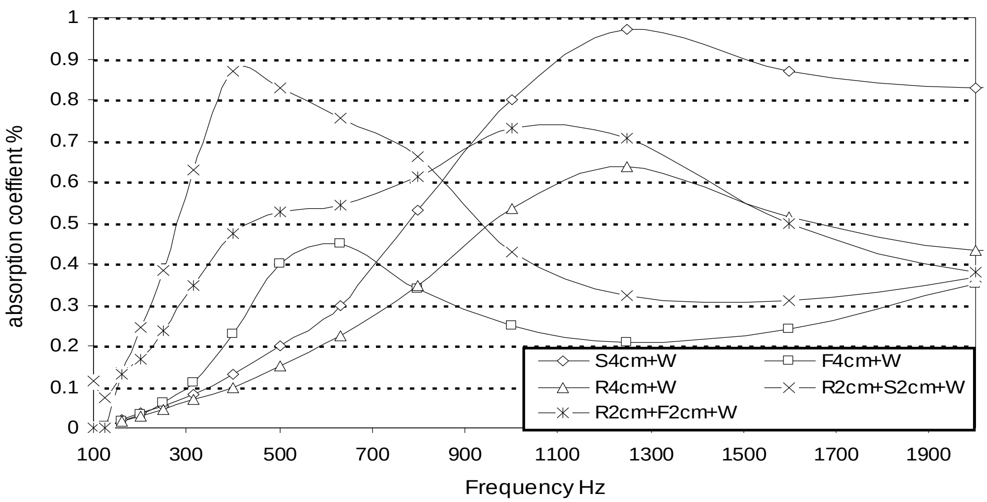

Figure 8; Comparison between different materials of multi-layered at constant thickness

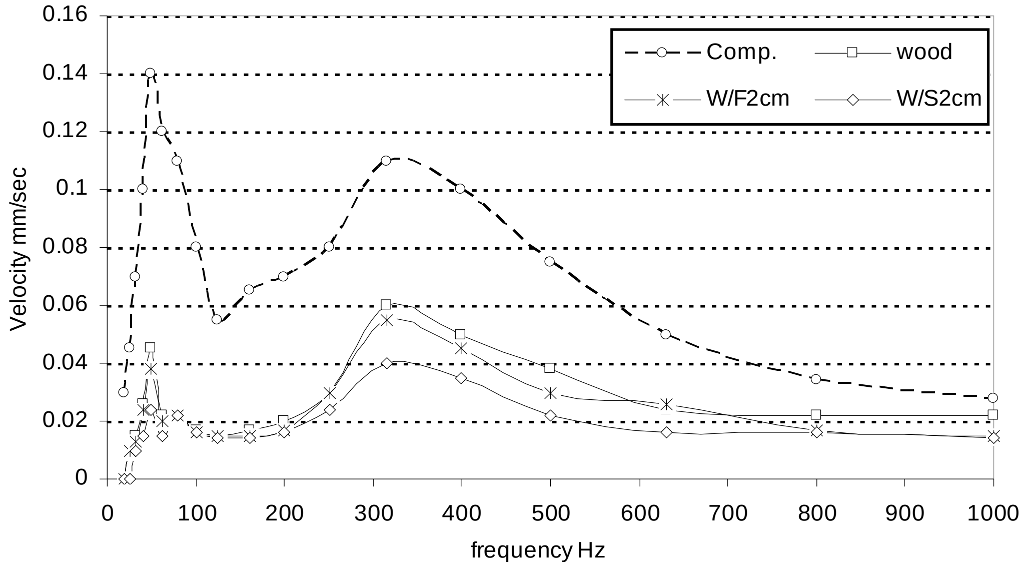

Figure 9; Effect of different materials as a damper for vibration (velocity)

4- Conclusion

The experimental data indicates that, porous layer (sponge), significantly increases sound absorption coefficient at low frequencies and improve it. 6cm thick layers of (R2cm +S2cm +W) exhibits peak value at frequencies between 315-800 Hz, with maximum value of 0.88 sound absorption coefficient. The experimental results of (S4+W) sample, gives a higher value for sound absorption coefficient at a higher frequency range from 1000-1600 Hz. The optimum values for Multi-layered sponge treatment is around 0.9 for sound absorption coefficient at frequencies between 315-800 Hz. Sound absorption coefficient of sponge layer was increased, and shifted to a lower frequency range when using Multi-layered sponge treatment. Using a rubber sample alone (R), appears a 0.67 of sound absorption coefficient at frequencies between 1150 - 1650 Hz. Using a sponge sample alone (S), appears a 0.35 of sound absorption at frequencies between 1150 - 1650 Hz

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