23rd International Congress on Sound & Vibration
Athens, Greece 10-14 July 2016

INVESTIGATION OF ACOUSTIC PERFORMANCE OF COMPRESSED WOOL CARPETS

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Sound absorbers including porous materials are used widely for noise control. The most widely-exploited and acknowledged absorption mechanism in porous materials is viscous friction due to relative motion between solid and fluid. Acoustical performance of carpet made of wool by using a traditional compression technique has been investigated. The results are very interesting.

1. Introduction

In this paper, a sample of compressed wool (knows as Kurdish/Mesopotamian felt) having 10 mm thickness has been characterized. Felt is a non-woven material produced by matting, condensing and pressing woollen fibres together. Natural fibres such as wool or synthetics fibres such as acrylic can be used to make felt. Felt material can vary in terms of fibre content, colour, size, thickness, density and more factors depending on the use of the felt. Felt making is still practised by nomadic peoples in Central Asia and northern parts of East Asia [1-2]. This material is used for heat insulation and building sound absorption in Mesopotamia. It is also used in automotive industry, casinos, musical instruments, and home construction as felt paper. It can be used to damps the vibrations between interior panels. The material characterised in this paper is produced using wet felting method. The felt is produced from animal hairs. Hot soapy water is spread over the wool when the wool is being stressed and compressed to weave hairs together into single piece of fabric.

Sound absorbing porous materials are used widely for noise control applications. The most widely-exploited and acknowledged absorption mechanism in porous materials is viscous friction due to relative motion between solid and fluid. If the frame of the porous material is viscoelastic then other dissipative mechanisms are possible. To obtain good low frequency absorption, exploiting this mechanism alone may require using an unacceptably large thickness of material. In designing passive sound absorbers based on porous materials or membranes, it is known that the presence of a backing air gap with properly chosen dimensions can enhance their low frequency performance. If a porous plate is elastic then a backing air cavity will allow bending modes which could lead to significant absorption at relatively low frequencies. The coupling between airborne sound and bending vibrations in the plates is increased if the flow resistivity is high. Depending on its thickness, the presence of an air-gap has been thought previously to favor or hinder structural vibration, but not to change the resonance frequencies which are considered to be solely dependent upon the plate's mechanical properties, the clamping conditions and the microstructural parameters (porosity, tortuosity and flow resistivity) [3].

2. Measurements

2.1. Absorption coefficient measurement by standing wave tube.

An impedance tube having a loudspeaker mounted at one end and a sample of acoustic material backed by a rigid perfect reflector at the other end is used to produce acoustic standing waves. This Standing Wave Tube of Type: 4200 and Serial Number: 878323 is specially designed to determine the absorption coefficient of the materials at normal incidence. The loudspeaker which is fed by a NTI noise generator produces an acoustic plane wave travelling through the tube. The sound pressure maxima and minima are detected by a microphone probe tube which is led through an axial hole in the loudspeaker. The other end of the microphone probe tube is connected to a microphone inside the microphone car. The microphone is connected to a two-channel digital oscilloscope. The measurement set-up is shown in Figure 1.

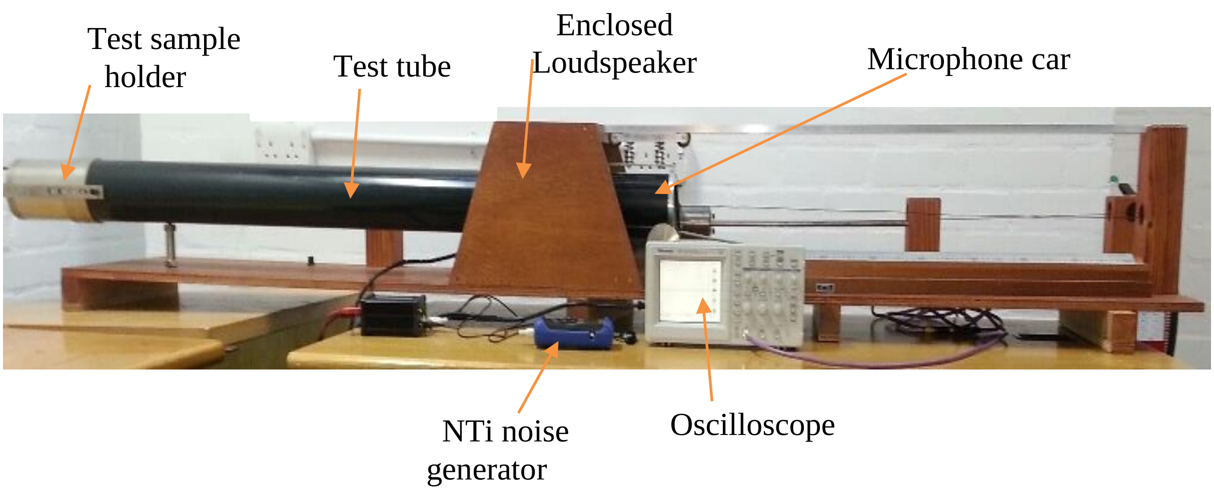

Figure 1: Measurement set-up.

The incident acoustic wave produced by loudspeaker is reflected from the rigid backing (perfect reflector). When the tube is terminated with an absorptive material then a part of sound energy will be absorbed by porous material and other part of the sound energy will be reflected back into same medium. A test procedure given in EN ISO 10534-1:2001 [4] is followed. The absorption coefficient of the sample can be determined by using the relationship between pressure maxima and pressure minima which is called the standing wave ratio (SWR) given by:

$$SWR = \frac{P_{max}}{P_{min}} \tag{1}$$

Where P_{max} is the maximum sound pressure, and P_{min} is the minimum sound pressure.

The absorption coefficient of the material can be calculated by using the formulae given by

$$\alpha = 1 - \left(\frac{SWR-1}{SWR+1}\right)^2 \tag{2}$$

The position of the maximum and minimum amplitude can be determined by moving the microphone car until a pressure maxima or minima is found on the oscilloscope. The position of the car can be read from the graduated track.

2.2. Absorption coefficient measurement by impedance gun

An In-situ absorption system is used to characterize the felt material. A procedure given in [5] has been followed. Noise is generated towards the material using a sound source at 23 cm from the probe.

The impedance gun is equipped with a system designed to decouple the sensors from structure born vibration generated by the spherical loudspeaker. The sound pressure and acoustic particle velocity are measured directly on the surface of the material. The absorption and reflection coefficient can be obtained directly from the measured impedance as the complex ratio of sound pressure to particle velocity. Measurement set-up for the impedance gun is shown in Figure 2.

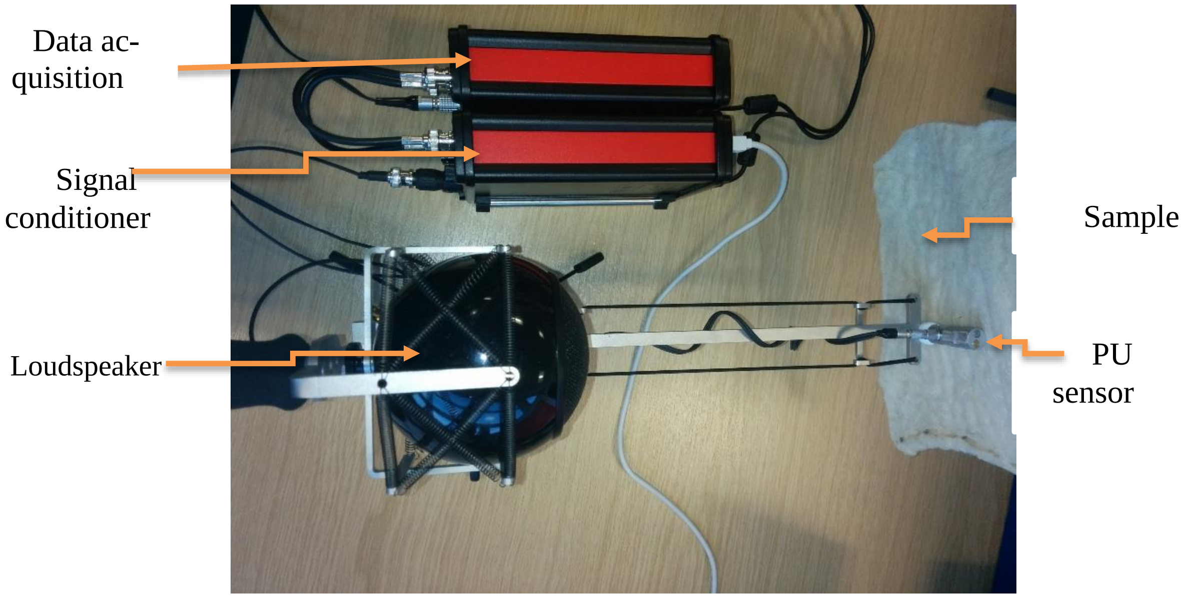

Figure 2: Measurement set-up for impedance gun.

2.3. Porosity measurement by water saturation method:

Water saturation method is used to determine the porosity of the compressed wool. First the liquid saturation where the medium is completely dried, weighed, is measured, and then filled with liquid and weighed again.

Porosity is the ratio of the air volume, V_a to the total volume of porous material, V_T.

$$\emptyset = \frac{V_a}{V_T} \tag{3}$$

where $V_T = V_a + V_b$, and V_b is the volume occupied by the frame of the material.

The weighed mass of the dry wool sample is 13.2 grams, and the weighed mass of the wet sample is 86.4 grams. Porosity is the difference between the wetted mass and the dried mass divided by wetted mass as given below:

$$\emptyset = \frac{86.4 - 13.2}{86.4} = \frac{73.2}{86.4} = 0.847$$

So the porosity of the compressed wool is 0.847 and is a highly porous material.

3. Results

Measurements have been carried out in an impedance tube (SWR) to determine the absorption coefficient of a 10 mm thick material. The material density is calculated to be equal to 161.9 kg/m^3. Measurements are carried out on the material in a small tube and in a big tube with and without an air gap. The absorption coefficient values below 1000 Hz are determined using big tube which has an internal diameter of 10 cm, while the results above 1000 Hz are determined using small tube of 3 cm diameter. Absorption coefficient of the material with and without air gap versus frequency are given in Figure 3. Using an air gap of 10 mm behind the material increases the mid and higher frequency performance of the material, while it decrease the lower frequency performance slightly.

The absorption coefficient obtained using impedance tube method are different than the one obtained using impedance tube, especially at frequencies below 1000Hz as shown in Figure 4. A sharp drop in absorption coefficient is observed between 500 Hz and 1000 Hz. This might be due to the limitation of lower cut-off frequency of the impedance gun method. Another reason may be low flow resistivity causing a low absorption performance at lower frequency.

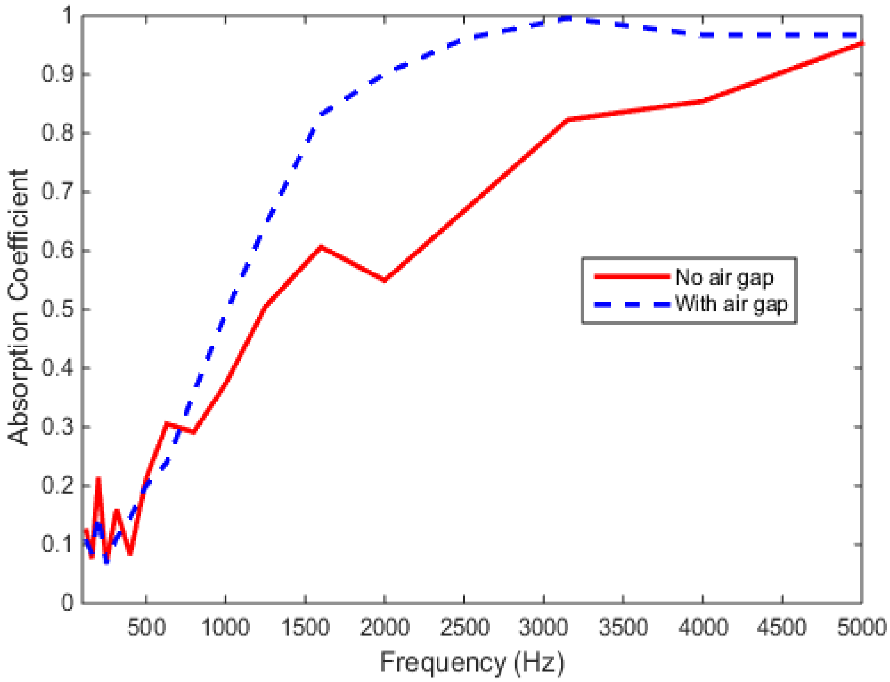

Figure 3: Absorption coefficient of the material with and without air gap versus frequency.

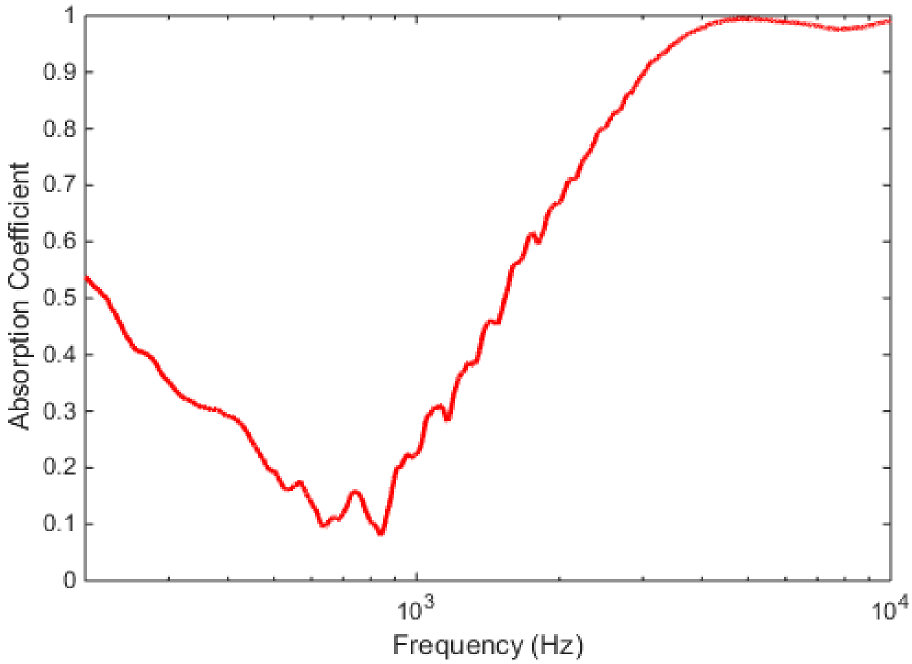

Figure 4: Absorption coefficient of the material determined using impedance tube.

Impedance of the material is measured as the complex ratio of sound pressure to particle velocity. The magnitude of the impedance of the material determined using impedance gun is given in Figure 5.

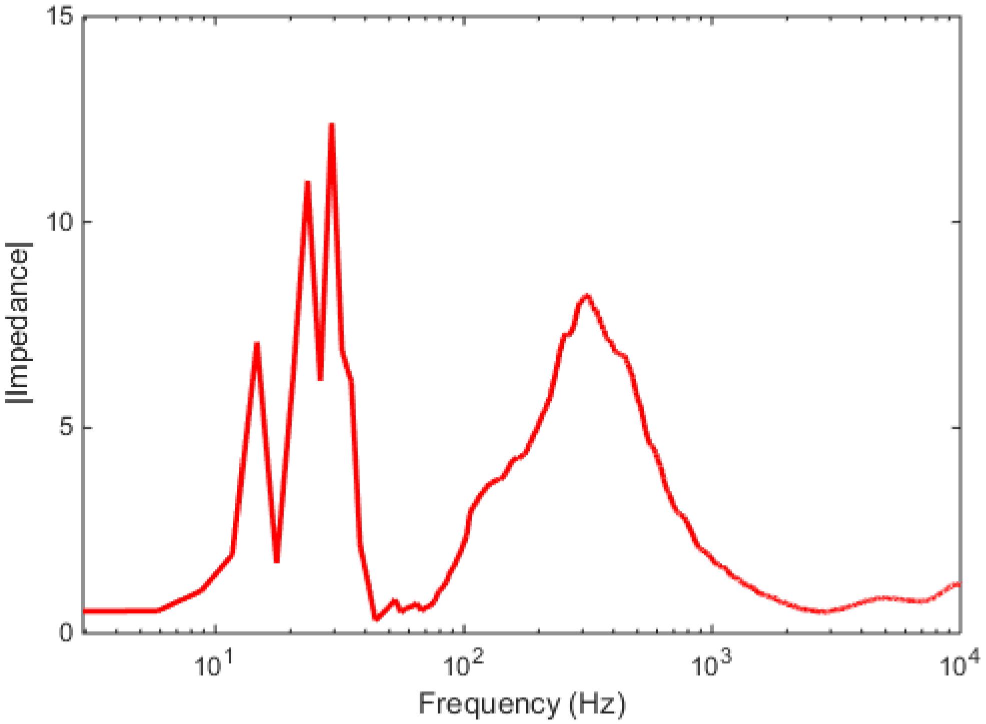

Figure 5: The magnitude of the impedance of the material versus frequency.

4. Conclusions

A non-woven material called felt used for heat insulation and sound absorption is characterised. Acoustical performance of the material is investigated. The porosity of the material is measured using water saturation method and it is found to be equal to 0.847. Its absorption performance is very similar to the other type of material made of wool. It has a lower absorption coefficient at lower frequency and higher absorption coefficient at mid and higher frequencies.

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