

Research Article

Performance Testing for Sound Absorption Coefficient by Using Impedance Tube

J. Niresh, S. Neelakrishnan, S. Subharani and R. Prabhakaran
PSG College of Technology, Coimbatore, India

Abstract: The sound absorption characteristics of the single and multi layered porous materials are studied with the help of impedance tube. In Impedance tube standing wave and transfer function methods are used more for its accuracy and reliability. The standing wave method is simple and transfer function method is accurate. The materials are tested for its sound absorption co-efficient. The standing wave method is used in this study. The results are compared with the existing tube. The two different samples are compared with existing tube. The results are analyzed.

Keywords: Coefficient, standing wave, transfer function

INTRODUCTION

One of the major problems faced by the people using automotives is noise pollution. The difficult task for the industry is to reduce the noise without increasing the vehicle weight. The controlling of noise in the automotives is done by active and passive methods. The active method is expensive and complex when compared to passive method. In Passive method porous materials like foams, fibres, glass wool either alone or with natural fibres as composites are used. These materials are used in head and trunk liners, door liners and carpets and under roof in the automobile applications. These materials should be considered for not to affect the overall weight of the car. Overall 2.2% weight of a car is textile materials. For noise control the proper material should be considered based on the acoustic characteristics of the material. The Impedance tube is used for measuring characteristic impedance, absorption co efficient, propagation constant and transmission loss for the materials.

The sound propagation in a duct is assumed as stationary plane waves. The pressure $p(x, t)$ and particle velocity $v(x, t)$ of the medium are:

$$p(x,t) = Ae^{j(\omega t - kx)} + Be^{(\omega t + kx)} \quad (1)$$

$$v(x,t) = \frac{1}{z_0} [Ae^{j(\omega t - kx)} + Be^{(\omega t + kx)}] \quad (2)$$

where,

A and B = Amplitudes of incidences and reflected waves, respectively

ω = The angular frequency

k = The wave number

z_0 = The characteristic impedance of the air at 20°C and ρ and c are the density and speed of sound in air (Scott, 1945).

The absorption of sound results from the dissipation of acoustic energy into heat. The sound energy is converted into heat through frictional losses, momentum losses and temperature fluctuations. The sound waves, generally longitudinal wave are carries by air molecules. This air molecules when vibrate inside the material with the frequency of sound causes frictional losses, the change in flow of direction of sound waves through irregular pores in the material causes momentum losses, periodic compression and relaxation of air molecules causes temperature fluctuation.

CONTROL OF NOISE IN AUTOMOTIVES

Zwicker and Kosten (1949) says Nowadays materials with selective acoustic properties for different frequency of interest are used. These materials mainly absorb noise produced by engine, tire, rotating mechanical components and the outside environment. Each element produces different noise in different frequency ranges with different decibel values. In order to implement regulations constraining the level of noise to certain range of dB values, it is necessary to use noise control mechanism in vehicles.

Noise control is very essential for passenger vehicles as they are in same closed environment for travelling more distances. Automotive industries employ various noise controlling materials in the vehicle. In general, materials like polyester, nylon, composites of carbon and fibres are used in the car. These materials are placed in interior fitments, safety facilities, tire reinforcement and carpets. They are used for both sound and thermal insulation.

Introduction to impedance tube: The tube is made by rigid, transparent or opaque materials to confine the

sound within the tube along one direction towards the direction of propagation. Thus it simplifies the three dimensional wave equations to one dimensional wave equation. The samples required are small compared to reverberation method.

The design specifications of the tube are given by ASTM Standard E1050-98 (1998). The impedance tube have loud speaker at one end and sample holder with rigid determination. The microphones are placed between the loud speaker and the sample. For materials with low flow resistivity four microphone method is more suitable says (Muehleisen and Beamer, 2002). The loud speaker is driven by signal source and one dimensional wave carries the sound energy towards the sample. The standing waves are produced inside the tube due to its cylindrical construction. Based on the absorption co efficient of the material the material placed at the other end absorbs sound energy. The remaining reflected back sound energy forms the standing wave pattern.

MEASUREMENT METHODS

The measurement of sound absorption co efficient in impedance tube is done using two methods namely:

- Standing wave method
- Transfer function method

Standing wave ratio method: The standing wave ratio method is the oldest and the simplest method compared to transfer function method. In this method, the microphone car in moved in and out for measuring absorption co efficient. Figure 1 explains standing wave ratio method.

In standing wave ratio method the complex acoustical properties are measured directly. In a cylindrical tube when an incident wave encounters a boundary between hard and soft, part of incident wave

is reflected and others absorbed which is shown in Fig. 1.

In standing wave method the sample is measured for its sound absorption co efficient by measuring the standing wave ratio. It is the ratio between pressure maxima and pressure minima obtained in the oscilloscope:

$$\frac{B}{A} = \frac{S-1}{S+1} \tag{3}$$

where A and B are the amplitudes of incident and reflected waves and S is the standing wave ratio. The phase angle can also be calculated using:

$$\theta = 2k(L-x_1)-\pi \tag{4}$$

where L is the length of the tube and x_1 is the distance of first node from end. The absorption co efficient can be calculated from the standing wave ratio.

Transfer function method for absorption Co efficient: One of the most widely used method for measuring normal incidence absorption co efficient of noise control material is transfer function method which is shown in Fig. 2. This method is comparatively faster than the standing wave method. Chu (1986) describes about the implementation of transfer function method. In this method the normal incidence absorption of the materials is determined by measuring the transfer function between the microphones.

Figure 2 explains the two microphone transfer function method is implemented using (ASTM Standard E1050-98, 1998). The power spectral densities S_{11} , S_{12} and cross spectral density S_{12} at the two microphone locations. Seybert and Ross (1977) says The signal source should be able to produce noise signal with uniform spectral density. The microphones should be phase matched for accurate results.

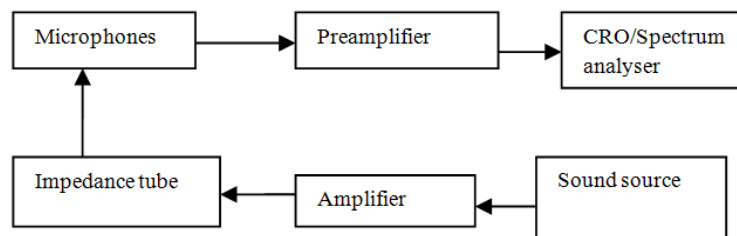


Fig. 1: Impedance tube setup for standing wave ratio method

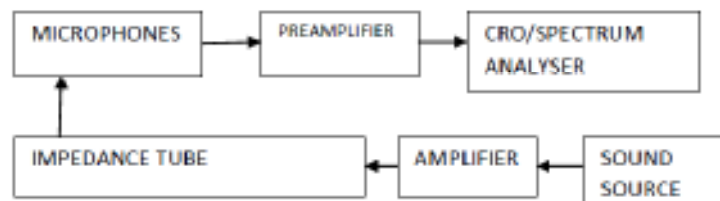


Fig. 2: Transfer function method setup

The transfer function (H) is calculated from the auto and cross spectral densities measured:

$$H = \frac{S_{12}}{S_{11}} \quad (5)$$

The complex reflection coefficient (R) can be measured as:

$$R = \frac{H - e^{-jks}}{e^{-jks} - H} e^{j2k(l+s)} \quad (6)$$

where,

L = The distance from the sample face to the first microphone

s = The distance between the microphones

$$k = 2\pi f/c$$

f = The frequency

c = The speed of sound

The normal incidence absorption coefficient can be calculated from the reflection coefficient as follows:

$$\alpha = 1 - |R|^2 \quad (7)$$

The normal specific acoustic impedance ratio can be calculated as:

$$z/\rho c = \frac{(1+R)}{(1-R)} \quad (8)$$

The transfer function method can be used for both high and low frequencies. Other acoustical parameters can also be measured from transfer function method (Delany and Bazley, 1970).

ELECTRONIC CIRCUIT DESIGN

Preamplifier circuit: The output of condenser microphone is fed to a two stage amplifier shown in

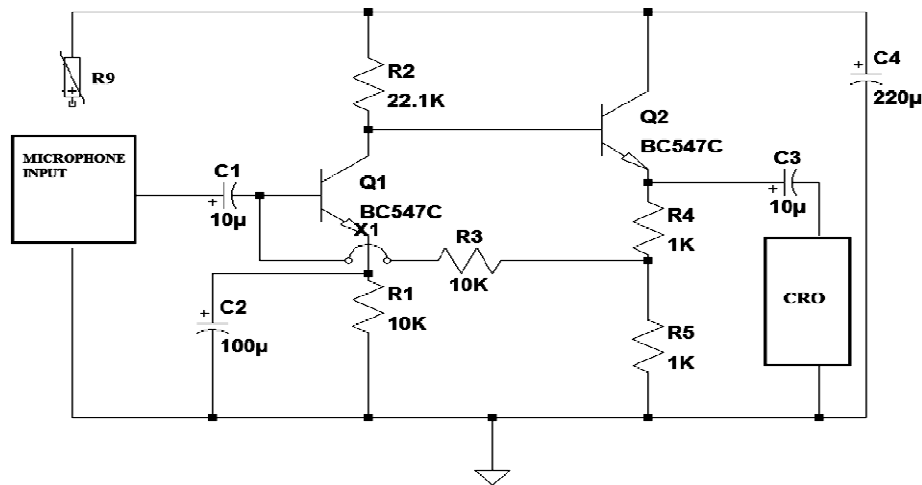


Fig. 3: Pre amplifier circuit design

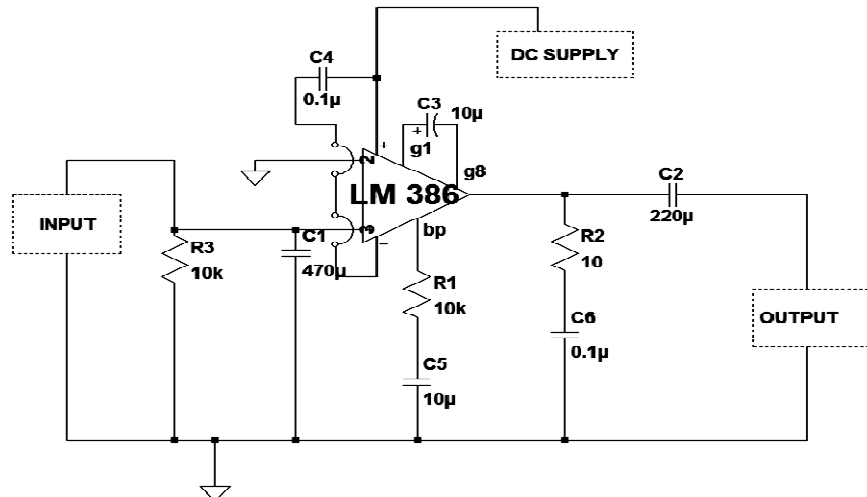


Fig. 4: Pre amplifier circuit design

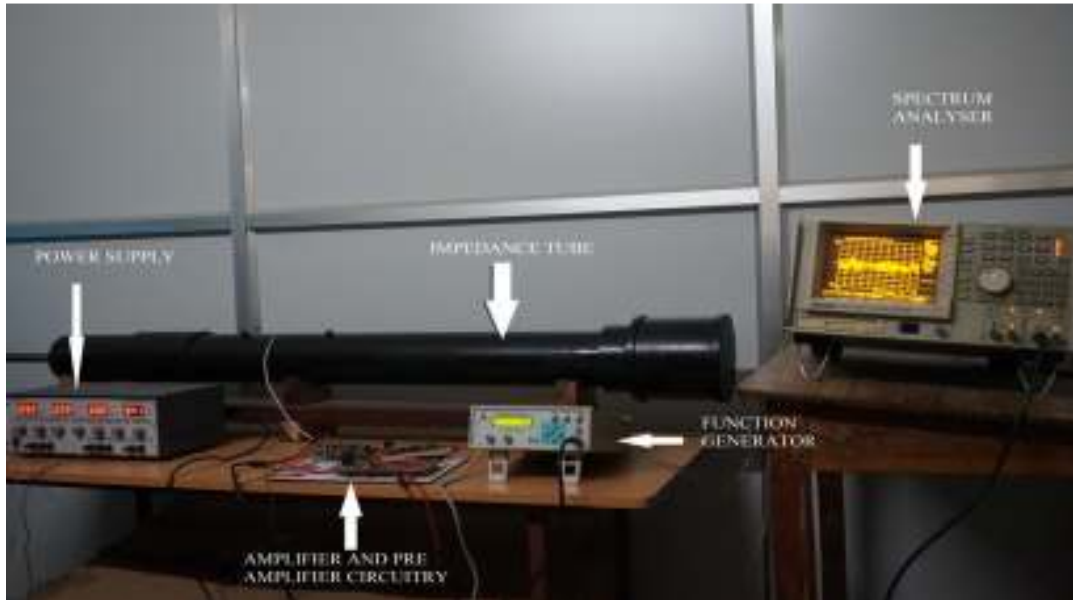


Fig. 5: Experimental setup

Fig. 3 for amplification of sound received by the microphones. Transistor Q1 forms the first stage and second stage comprising transistor Q2 is connected in the voltage shunt feedback configuration. These two stages provide sufficient gain to pick up even the slightest whisper. The circuit requires a 4.2 volt supply for operation. The value of this resistor may be altered to suit different supply voltages.

Output of the microphone amplifier can be made variable by connecting a variable resistor. Circuit's gain can be increased by reducing the value of R6, depending on the input sensitivity of the main amplifier system. Increase in gain was also observed by using 3V supply and eliminating R9 altogether. The microphone should be housed in a small round enclosure.

Audio amplifier circuit: The audio amplifier circuit shown in Fig. 4 is using lm 386 amplifier IC, it is used to amplify the sound source given to the impedance tube. Maximum gain of the circuit can be set between 20 to 200. The 10 uF capacitor from pin 1 to 8 is used to set the gain of 200. If you want gain of 20 then remove the 10 uF capacitor from pin 1 to 8. This lm 386 circuit will work on 9 volt or 12 volt from any source like adaptor or battery.

Experimental setup: The experimental setup in Fig. 5 shows how the testing is done to obtain sound absorption coefficient. The output can be obtained either from spectrum analyser or CRO.

Testing of samples: The sample taken for testing is Flame Retardant Polyurethane Foam (FR PUF) with the combination of Non Woven Fabric (NWF) of 80 kg/m³ density/25 mm and 120 kg/m³ density/25mm.

RESULTS AND DISCUSSION

The properties of the materials tested are tabulated in Table 1. Two samples with different densities are taken for calculating the absorption coefficient.

The readings obtained by the tube is compared with the existing Impedance tube for accuracy. The data from Table 2 describes the deviation between the readings of both the tubes for density 80 kg/m³/25 mm.

The data from Table 3 describes the deviation between the readings of both the tubes for density 120 kg/m³/25 mm.

Figure 6 shows the Comparison of FR PUF with varying density of both 80 kg/m³ density/25 mm and 120 kg/m³ density/25 mm.

Table 1: Sample properties

Sample name	Density (kg/m ³)	Thickness (mm)	Type
FR PUF	80	25	Nonwovenfabric + Foam
FR PUF	120	25	Nonwovenfabric + Foam

Table 2: Absorption coefficient readings for 80 kg/m³ density/25mm

Frequency	B&K tube	Obtained reading
80	0.026	0.031
100	0.042	0.048
125	0.046	0.052
160	0.061	0.067
200	0.082	0.091
250	0.108	0.115
315	0.140	0.148
400	0.166	0.172
500	0.270	0.276
630	0.431	0.438
800	0.664	0.671
1000	0.876	0.882
1250	0.944	0.951
1600	0.805	0.812

Table 3: Absorption coefficient readings for 120 density kg/m³/25mm

Frequency	B&K tube	Obtained reading
80	0.029	0.034
100	0.040	0.045
125	0.054	0.060
160	0.064	0.068
200	0.085	0.093
250	0.097	0.104
315	0.127	0.132
400	0.195	0.201
500	0.273	0.278
630	0.380	0.386
800	0.516	0.523
1000	0.671	0.677
1250	0.879	0.885
1600	0.985	0.989

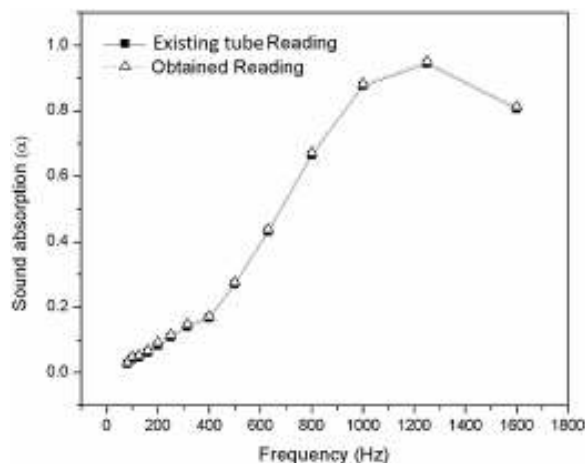


Fig. 6: Comparison of FR PUF with density 80 kg/m³/25mm

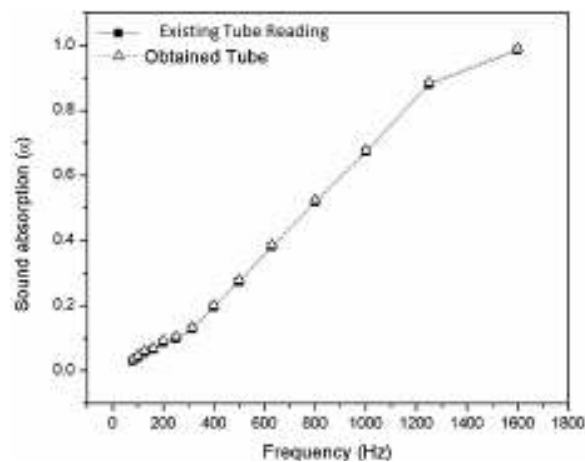


Fig. 7: Comparison of FR PUF with density 120 kg/m³/25mm

Figure 6, we infer that the sound absorption coefficient of NR PUF is low at lower frequencies and increases with increase in frequency. Both the tubes existing and modified tube shows similar results over the mid frequency range. The material with density

80/25 mm shows drop in sound absorption coefficient above the frequency range of 1200 Hz.

From the Fig. 7, we infer that the sound absorption coefficient of NR PUF is low at lower frequencies and increases with increase in frequency. Both the tubes existing and modified tube shows similar results over the mid frequency range. The material with density 80/25 mm shows drop in sound absorption coefficient above the frequency range of 1200Hz.

CONCLUSION

This study discuss about the measurement of absorption characteristics of NR PUF material with two different densities. The experimental results shows that the values obtained by the modified tube and existing tube are similar, but the modified tube is cost effective for obtaining sound absorption coefficient of the materials. The results was analyzed and it have variations with 5% and it is obtained by regressive analysis. So the modified tube can be used for measuring sound absorption coefficient of different materials.

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