International Journal of Trend in Scientific Research and Development (IJTSRD)
International Open Access Journal
ISSN No: 2456 - 6470 | www.ijtsrd.com | Volume - 2 | Issue – 4

Acoustic-The Way of Utilizing the Resource for Research and Technology Implementation to Domestic Equipments, An Introductory Overview

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ABSTRACT
Acoustics is the study of small pressure waves or sound waves in air which can be detected by the human beings. The scope of acoustics is not limited and extended to lower and higher frequencies: ultrasound and infrasound. Acoustics now includes Structural vibrations and perception/travelling of sound is an area of acoustical research, for research purposes acoustics are considered, the propagation fluids like air and water. In such a case acoustics is a part of fluid dynamics. The outmost problem of fluid dynamics is that, the equations of motions are non-linear and this implies that an exact general solution of these equations is not available and need to be developed. Acoustics is a first order approximation in which non-linear effects are neglected. In classical acoustics the generation of sound is considered to be a boundary condition problem. The sound generated by a loudspeaker or any unsteady movement of a solid boundary are examples of the sound generation mechanism in classical acoustics. Turbulence is a chaotic motion dominated by non-linear convective forces but an accurate deterministic description of turbulent flows is not available, The famous Lighthill theory of sound generation by turbulence is used as an integral equation which is more suitable to produce approximations than that of a differential equation Next to Lighthill's approach which leads to order of magnitude estimate of sound production by complex flows. In this paper we produced the application of Acoustics, experiments, research done to utilize the benefits of the acoustics are reviewed much more in a better way to conceptually understand the concept and to deduce the equations of motion to build practical acoustics system and also concentration gone through the Acoustic refrigeration system.

Keywords: *Sound waves, ASTM E1050-08, NRC, apparent sound absorption coefficient, Thermo acoustic refrigeration*

I. INTRODUCTION
Acoustic properties such as sound absorption coefficient, sound transformation are required to deduce the acoustic behavior of material and to do required design computations for various multiple applications such as theaters, cinema halls, open field performance, auditoriums etc. While there is a plenty of information on foam based absorption, there is a lack of data related to acoustic properties of wood and wood based panel products.

The results obtained by the experimentation will be very useful to the engineers for developing designs to build recording rooms, television studios, theatres, hospitals, auditoriums, hotels, homes, classrooms, lecture halls etc. It is sometimes useful to employ a single figure called the noise reduction coefficient (NRC) of the material which is the average of the absorption coefficients at 200, 450, 980-990, 1500 and 2100 Hz frequencies. The characteristics of one material will be different from other at different frequencies and also at same frequencies both can have same NRC values at some conditions. When sound waves strike over the surface, the energy may be divided into three portions: the incident, reflected, and absorbed energy. For acoustical designing in architecture it is convenient to use an average absorption coefficient which is assumed to depend only on the physical characteristics of the material and not on the sound field. The sound absorption coefficient of any material depends on the angle at which the sound wave imposes upon the material and the sound frequency. The absorption coefficient is generally reported in the literature at frequencies of 125, 250, 500, 1000 and 2000 Hertz. There are three basic methods of measuring sound absorption. The first method comprises the use of a reverberation room giving results valid for random incidence in a diffuse sound field and is suitable for large objects, furniture, panels, etc. The second method comprises the use of an impedance tube, giving results valid for normal incidence in a plane wave sound field, which is suitable for testing small samples. This method is designed for measurements of absorption coefficient and specific acoustic impedance of small samples of circular-cut sound absorbing materials normally in the frequency range 50 Hz to 6.4 kHz. A. Nandanwar et al. [1].

Some of the widely used panel products for acoustic applications are wood wool building slab and low density particle board, however fiber boards may also be used for particular investigation, Delany presented of an investigation into the acoustical properties of a range of fibrous absorbent materials. Measured values of characteristic impedance and propagation coefficient are shown to normalize as a function of frequency divided by flow-resistance and can be represented by simple power-law functions. Garai developed a new empirical model has to predict the flow resistivity, acoustic impedance and sound absorption coefficient of polyester fibre materials. The parameters of the model were adjusted to best fit the values of airflow resistivity and sound absorption coefficient measured over a set of 38 samples. Garai presented a series of experiments designed to put in evidence the differences between Reflection Index measurements performed in the mentioned critical conditions, according to the QUIESST guidelines, done using MLS (Maximum Length Sequence) or ESS (Exponential Swept-Sine) signals [1].

1.1 Method of Experimentation

The samples from wood based Fiber boards were drawn from different sources/ manufactures having different densities. The samples were tested for sound absorption coefficient as per ASTM E1050-08 and IS 10420-1982[1] [4] [8]

S.W. Rienstra & A. Hirschberg selected Acoustic pulse tester of Bruel and Kjaer (B&K) and a two microphone impendence measurement tube was used to measure sound absorption coefficient of small test samples in the frequency ranging from 50 Hz to 6.4 kHz as per ASTM E1050-08

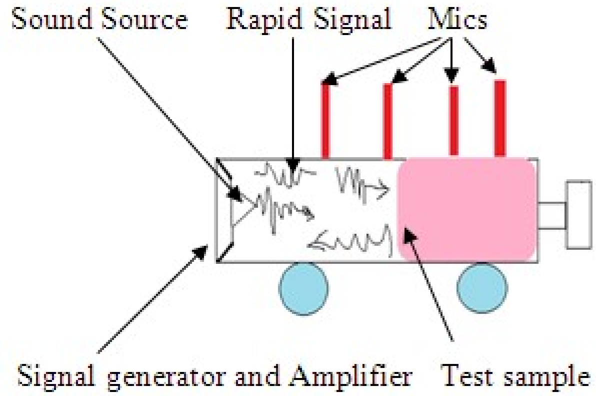

Fig. 1: Conceptual drawing of two-microphone impedance method for sound absorption [1]

$$\alpha' = E_a / E_i$$

whereas the apparent sound absorption coefficient is defined as the ratio of all energy not reflected to incident energy, i.e.

$$\alpha' = \frac{E_a}{E_i} = \left(\frac{E_a}{E_i}\right) / E_i$$

By law of Conservation of Energy principle we have

$$E_i = E_r + E_a + E_t$$

where, E_i = Incident Energy E_r = Reflected energy E_a = Absorbed Energy E_t = Transmitted Energy In general α is a function of the incident angle θ_i. The normal incidence value is denoted α_n[1].
In this investigation, a 1/12 octave real-time analyzer was used, connected with a B&K type 4206 tube. The absorption coefficient based on standing wave method is determined. The sound pressure at two or more locations is measured and the complex transfer function calculated. It is then possible to determine the complex reflection coefficient, the sound absorption coefficient and the normal acoustic impedance of the material [1].

II. SOUND PRESSURE LEVEL MEASUREMENT

Sound pressure level (SPL) uses the decibel logarithmic unit of sound pressure (dB) named after Alexander Graham Bell, to express the wide range of sound pressures perceptible to humans in two or three digits

$$p_{rms} = (p_{ref}) * 10^{spl/20}$$

SPL in decibels is 20 times (log10) of the rms (square root of the mean square pressure acoustic pressure) relative to a reference pressure, The commonly used "zero" reference acoustic pressure in air is 20 µPa rms, which is usually considered the threshold of human hearing (at 1 kHz)which is a pressure of 0 dB[3]

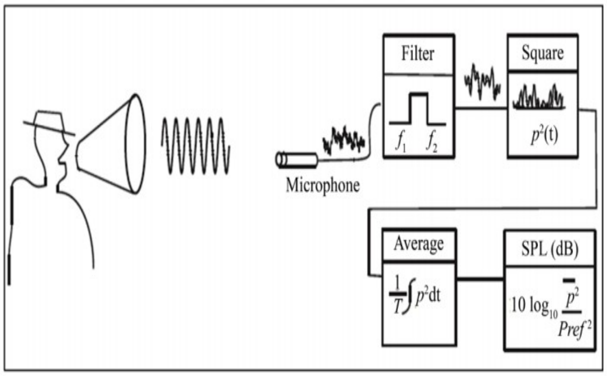

Fig. 2: Determining Sound Pressure Level [3]

SPL can be calculated due to a given source (L_s) from measurements taken in the presence of background noise (L_{bg}), in which L_{comb} is the combined SPL from source and background, is given by the following equation

$$L_s = 10\log\left(10^{\frac{L_{comb}}{10}} - 10^{\frac{L_{lbg}}{10}}\right)$$

The sound pressure level can be calculated using the following equation

$$L_p = \text{Log}\,(p/p_r)$$

in dB, and, Pr = 20 micro-Pascals where: L_s: The source sound pressure level in dB. L_{comb}: The combined source sound pressure level in dB. L_{bg}: The background sound pressure level in dB. The main objective from this experiment is to measure the sound pressure levels of various sources (stationary and non-stationary), in an anechoic chamber and in a noisy environment, then to extract sound pressure level for different sources and compare the results between ideal and actual environments [3].

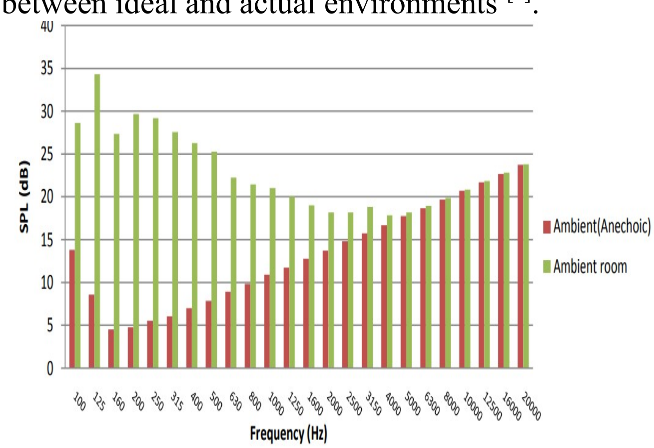

Fig. 3: SPL as function of frequency (Anechoic and room)

The other comparison was made between Harp music inside anechoic chamber; this was done by extracting harp music from:

1. Combined (Harp & ambient), background (ambient).
2. Combined (Harp & white,), background (white)
3. Combined (harp & synthesized), background (synthesized)

The excel files exported from the software have two readings, the frequency, and the SPL for the measured sound. The charts showed the SPL versus distance for each direction and for the frequency band from (100 Hz- 20 kHz).

It can be seen that the data converge as the frequency increases; this may be due to the fact that after the cut off frequency of the room (2000 Hz), the data becomes more accurate.

III. NUMERICAL SIMULATION

The simulation functions are used in k-Wave which requires four input structures. These structures define the properties of the computational grid, the material properties of the medium, the properties and locations of any acoustic sources, and the properties and locations of the sensor points used to record the evolution of the pressure field over time. Ultrasonic absorption in water, at a given temperature and frequency, was calculated using a 7th order polynomial fitted to the data given by Pinkerton. Simulations were performed in two-dimensions. To simulate free-field conditions, a perfectly matched layer (PML) is also applied as to absorb the waves at the edge of the computational domain. By default, this layer occupies a strip of 20 grid points around the edge of the domain. Without this boundary layer, the computation of the spatial derivates via the FFT causes waves leaving one side of the domain to reappear at the opposite side. The use of PML thus facilitates infinite domain simulations without the need of an increase in the size of the computational grid [5].

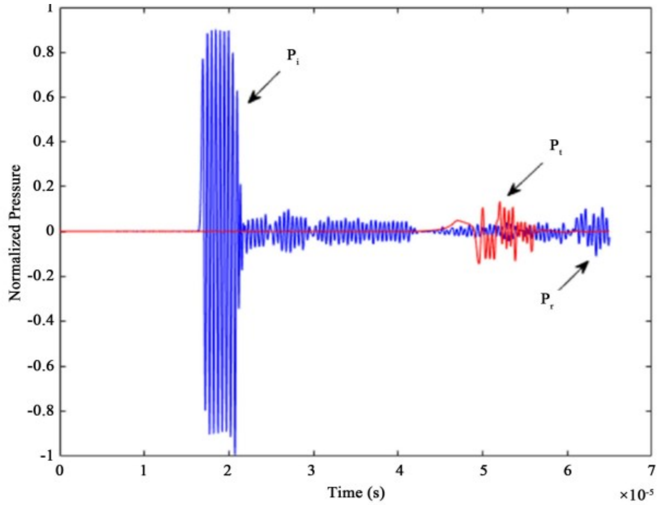

Fig. 4: Simulated temporal signal of reflection and transmission for PSA with single homogeneous layer. P_i: Acoustic pressure incident upon the sample; P_t: Acoustic pressure transmitted through the sample; P_r: Acoustic pressure reflected from the sample [5].

Using both the simulated acoustic reflection and transmission pressure measurements shown in Figure 4, insertion loss (IL) was calculated as

$$IL = -20\, Log_{10}\,(\frac{p_t}{p_i})$$

where P_t is the acoustic pressure transmitted through the sample and P_i is the acoustic pressure incident upon the sample. The fractional power dissipation (FPD) is a parameter of an absorber material that quantifies its inherent dissipation of acoustic energy and is usually specified in commercial absorbers to compare the performance of different acoustic materials. The FPD has been derived from the ER and IL measurements and is defined by Precision Acoustics Ltd and Acoustic Polymers Ltd as

$$FPD = 1 - \sqrt{\frac{P_r}{P_i}} - \sqrt{\frac{P_t}{P_i}}$$

Where, P_r is the acoustic pressure reflected from the sample, P_t is the acoustic pressure transmitted through the sample and P_i is the acoustic pressure incident upon the sample. The FPD has been derived from the ER and IL measurements.

IV. THERMOACOUSTIC REFRIGERATION SYSTEM

A thermoacoustic refrigerator (TAR) is a refrigerator that uses sound waves in order to provide the cooling. In a TAR, the working fluid is a helium-argon mixture, and the compressor is replaced by a loudspeaker. The advantages of this kind of refrigeration cycle are two-fold. The helium and argon are inert, environmentally friendly gases, unlike many of the common refrigerants. The loudspeaker is a simple device that is more durable than a compressor and is the TAR's only moving part.

The downside of the TAR is that as of yet these types of refrigerators have failed to achieve efficiencies as high as those as standard refrigeration units. Some researchers contend that the set-up of the TAR is such that it never will be able to attain efficiencies as high as standard refrigeration units.

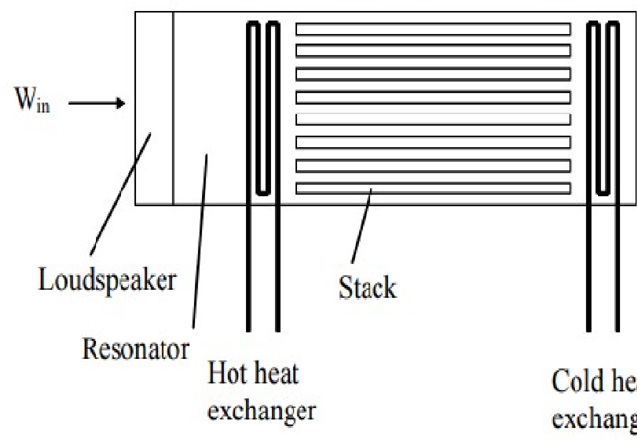

Fig. 6: Sound wave Thermoacoustic

Thermoacoustic refrigeration systems operate by using sound waves and a non-flammable mixture of inert gas (helium, argon, air) or a mixture of gases in a resonator to produce cooling. Thermoacoustic devices are typically characterised as either 'standing-wave' or 'travelling-wave'. A schematic diagram of a standing wave device is shown in figure 6. The main components are a closed cylinder, an acoustic driver, a porous component called a "stack, and two heatexchanger systems. Application of acoustic waves through a driver such as a loud speaker, makes the gas resonant. As the gas oscillates back and forth, it creates a temperature difference along the length of the stack. This temperature change comes from compression and expansion of the gas by the sound pressure and the rest is a consequence of heat transfer between the gas and the stack. The temperature difference is used to remove heat from the cold side and reject it at the hot side of the system. As the gas oscillates back and forth because of the standing sound wave, it changes in temperature.

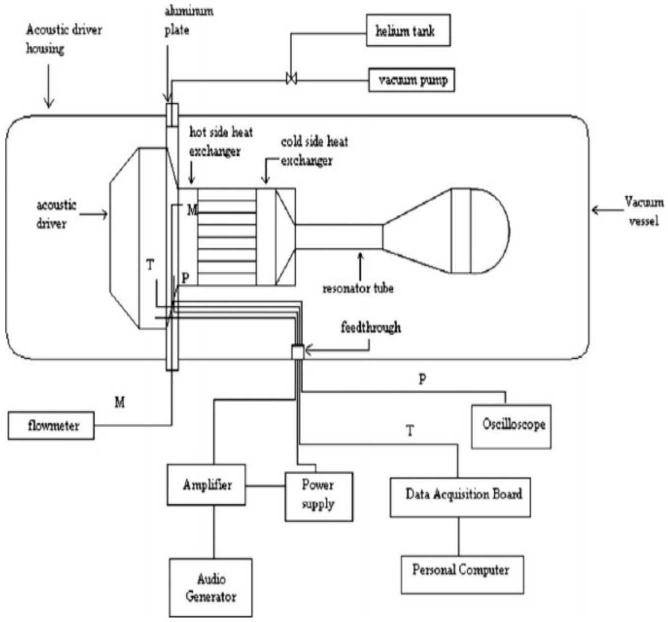

Fig. 7: Acoustic experimental setup [9]

Experimental Testing Setup Experimental setup consists of a Thermoacoustic Refrigeration System, Test Section, and Data Acquisition system 1) Thermoacoustic Refrigeration System The Thermoacoustic Refrigeration System includes resonator tube, stack, acoustic driver and heat exchanger. 2) Test Section Test section involves measurement of temperatures at the inlet and outlet of the heat exchanger, at the middle of resonator, at the surface of acoustic heater and near the electric heater with the help of thermocouples. 3) Data Acquisition System The Data Acquisition System consists of thermocouples, transducer, oscilloscope, flow meter, data acquisition board and personal computer for the data display

V. CONCLUSION

It was shown how to extract any noise source from a combination of sources if the background is known and to utilize these sound waves for useful research and prototype development for sustainable world. An important conclusion is that if the source type is either stationary or non-stationary, it will not affect the results. A small introduction to Mathematical/ Numerical simulation is provided for better understanding of the concept and designing of the models. Acoustic refrigeration system is also concentrated to explain how the sound waves play an important role for developing and producing daily household domestic equipments.

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