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Acoustical noise reduction technique

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Abstract
The noise reduction analysis are studied for different models such as noise reduction for two rooms separated by a brick wall containing single and companied pane of glass , non-distorting wall and infinite flexible wall. The transmitted sound through infinite partition depends on the relative speed and free flexural wave in partition and the incident Plane wave.
This paper presents acoustical noise reduction analysis for the transmission of noise through partitions. The models investigates the reduction in sound pressure level required in two rooms separated by a brick wall containing a single pane of glass and a compound pane of glass also study the noise transmitted and reflected at normal incident through a non-distorting wall simulated as spring and damper mass system and study the analysis of noise transmission through infinite flexible wall and discuss the merits of the various methods that could be used to achieve the reduction.
The analytic model and the analysis in the present work give some insight to the behavior of the structures under noise problem showing the different parameters that related with the transmission of noise, such as power transmitted through the panel, power incident through the panel sound reduction index (transmission loss), octave band center frequency, sound power level, reverberation time, deformation, propagation and non-propagation of noise. A life predication model is presented to control the optimum design and to find a proper combination of noise and life.

Keywords: Noise; Octave band; Sound power; Transmission loss.

1. Introduction
Modifications in the source of sound are usually considered to be the best solution for a noise control problem and may be modified to effect a significant change in noise emission.

1.1 Noise control
Seismographs use for watching earthquakes, Sonar, Ultrasonic disintegration bacteria twice panel partitions are regularly used in sound control manufacturing as soon as comparatively extraordinary insertion loss (IL) takes to be succeeded with light mass assemblies: samples are movable workplace panels and airliners fuselage explosives. Though, the presentation of useful twice panel constructions quickly weakens in the direction of lesser frequencies, at which it can even reduction small of a single panel [1, 2]. The submission of dynamic acoustical control (ANC) approaches be able to suggestion a practicable resolution in these suitcases.

The noise produced by huge pulsating panels can be reduced by applying damping material to the panel surface or by decoupling the panel from the exciting energy, if probable. Manufacture the panel rigid by increasing the panel thickness or decreasing the panel measurements or using stiffening struts may also reduce the peaks of vibration. In maximum cases, reducing the amplitude of vibratory motion of links in a mechanism will decrease the noise produced by the machine element. Replacement of the malfunctioning comportment may resolve the sound problem, in totaling to avoiding further perfunctory destruction to the mechanism. There may be zones, such as panel casings, that pulse exceptionally on a mechanism. These panels are resourceful sound radiators at wavelengths on the order of the measurements of the panel [3].

1.2 Sound and noise

The term noise is resulting from the Latin expression NAUSES which means "seasickness" the unpleasant sounds made by seasick passengers or sailors [4].

- Britannica encyclopedia defines noise as unwanted sound and U. S. Encyclopedia as undesirable sound.
- From the legal viewpoint may be defined as wrong pollution is from the air, causing a material wounding of the right of individuals.
- Acoustic is a formula of dynamism which is radiated by a vibrating frame and transmitted by pressure fluctuation which the human ear can detect and on attainment the ear effects the sense of hearing through nervous tension.
- When one is communication, the exciting of vocal chords create air particles addicted to pulsation and produces pressure waves in the midair, somebody neighboring could then receive the sound of the communication when the pressure waves are observed by the ear.
- Sound can also transportable from end to end other acoustic media, such as water or steel.
- When one is swimming under water, it is probable to hear shouts of the individuals over head the river, and to receive the noise as you blow bubbles in the water.
- Gases other than air can transfer pressure fluctuations that effect sound. For illustration, when one is speaking after inhaling helium from a balloon, the sound of his speech movements through the helium, creation it sound changed from normal.
- Since noise is also a sound, the terms noise and sound are identical
- Acoustics created by all exciting forms are not inaudible. The frequency limits of audibility are from 20 Hz to 20.000 Hz.
- Frequency of sound = Frequency of Sound represent of importance of It's level.
- Sensitivity of ear
- Sound insulation of a wall } all vary with Freq.
- Attenuation of silencer

$< 20\ H_z$	$20\ H_z\ to\ 20.000\ H_z$	$> 20.000\ H_z$
Infrasonic – inaudible	sonic – audible	Ultrasonic– inaudible

1.3 Nonlinear noise reduction

Noise decrease is a vital step in any dimension procedure. Occasionally noise decrease has prepared use of rectilinear procedures such as the Fourier transform which exertion by sorting out the signal from the sound in frequency interplanetary or other rectilinear interplanetary. Many signals, nonetheless safety the same spectrum area as the sound and so need a developed separation arrangement. The algorithm described in this paper involves prediction onto a low dimensional disordered attractor that has been rooted into a higher dimensional space. This nonlinear prognostication method mechanism well for stationary deterministic structures and with care can be used with gradually varying nonstationary information as well. Submissions include vacuuming of noisy speech or ECG signals and insertion of a minor fetal ECG signal that is variegated with a protective Electro Core Grade signal.

Most nonlinear extrapolation or noise decrease approaches consist of examining the time history of the signal for trajectories dissimilar to the portion under concern. Trajectories that were dissimilar in the past will tend to deviate in the prospect due to the optimistic advocates of trajectories that are similar in the future will tend to have divergent histories due to the damaging advocates and these separations are hyperbolic by the quantity noise. Animals that can hear ultrasonic sound are Fish, Dogs, Whales and Snakes and the Animals that can hear infrasonic sound are Bats, Elephants [5].

1.4 Application

As an unassuming, sound transfer through a elastic partition of a rectangular cavity was effectively well-ordered by a vibration control power. Many investigation determinations have been mainly instigated by the defy of noisy turboprop jets and submarine submissions approximately of them with significant success designed at investigating the scheme and presentation of active communication control through cylindrical enclosures by means of vibration control sources The conduction of acoustic energy through any composite partition includes a numeral of fluids – structure connections and coupler occurrences. In opinion, any of these components and / or renovation instruments can be subjective by resources of dynamic procedures. For model, the sound radioactivity from a flexible platter into the free field can be organized effectively by vibration actuators. Other subsidies have allocated with fluid – structure interactions in closed acoustic spaces (voids) [6].

2. Theoretical technique

2.1 Transmission of sound through partitions (Figure 1)

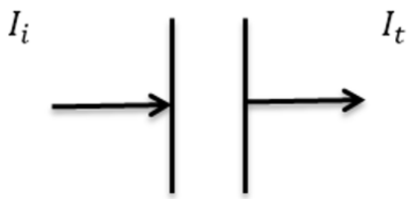

Figure 1. Transmission of sound through partition.

Sound Reduction index (T_L) (Transmission Loss) (Figure 2)

$$T_L = 10\log_{10}\frac{1}{\tau} \quad (1)$$

Relationship between (T_L) and level difference.

where, T_L: Transmission Loss, τ: Transmission of sound through partition, I_t: Intensity of transmitted sound, I_i: Intensity of incident sound , S: surface area of partition.

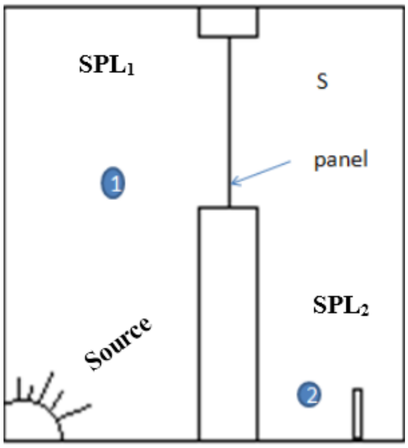

Figure 2. Transmission of sound through single panel portion.

Assume a differ field:

$$T_L = (SPL_1 - SPL_2) + 10\log\frac{S}{a_2} \quad (2)$$

Sound Reduction index (R) $S - \text{Spartion} = S_1 + S_2$

$$\Delta SPL = 20\log P_1 - 20\log P_0 - 20\log P_2 + 20\log P_0 = 20\log\frac{P_1}{P_2} \quad (3)$$

where; a: area of the wall, S: area of panel, P_1: pressure level one, P_2: pressure level two, R: sound reduction S_1: area of panel one, S_2: area of panel Two, P_i: pressure Incident, P_t: pressure transmitted.

2.2 The sound reduction index of compound partitions (Figure 3)

$$TL = (SPL_1 - SPL_2) + 10\log 10\frac{S_1 + S_2}{a} = 10\log\frac{\sum S}{\sum S\tau} \quad (4)$$

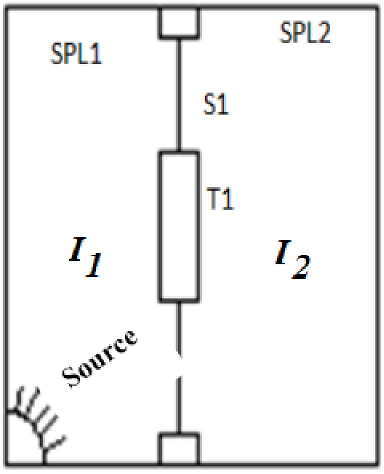

Figure 3. Transmission of sound through compound partition.

2.3 Transmission at normal incidence through a non–distorting wall (Figure 4)

- Equation of motion:

$$M\xi^{\circ\circ} + C\xi^{\circ} + K\xi = \{P_i + P_r - P_t\}\, x = 0 \quad (5)$$

$P_i = A_i\, e^{j(wt-k\varkappa)}$, $P_r = A_r\, e^{j(wt-k\varkappa)}$, $P_t = At\, e^{j(wt-k\varkappa)}$
where: ξ : Displacement for wall , ξ°: Velocity for wall , $\xi^{\circ\circ}$: Acceleration of wall

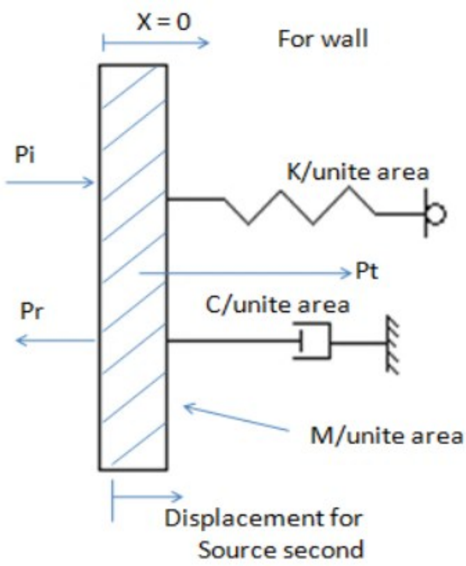

Figure 4. Non-distorting wall.

- For continuity of velocity:

Blocked reflected pressure $P_r = P_i - \rho_o C_o \xi^{\circ}$, $P_t = \rho_o C_o \xi^{\circ}$
Equation of motion may be written as

$$M\xi^{\circ\circ} + (C + 2\rho_o C_o)\xi^{\circ} + K\xi = 2\{P_i\}_x = 0 \tag{6}$$

A system of mass M, Acoustic damping term$(C + 2\rho_o C_o)$, stiffness K
Excited by a pressure twice that of identified.
Accounting for energy radiation away from the surface. Mechanical Impedance,

$$Z_{mech.} = C + j\left(wm - \frac{K}{w}\right) \tag{7}$$

$$\tau = \frac{|A_t|^2}{|A_i|^2} = \frac{4(\rho_o C_o)^2}{(C+2\rho_o C_o)^2 + \left(wM - \frac{K}{w}\right)^2} \tag{8}$$

$$\therefore \frac{|A_t|}{|A_i|} = \frac{Z_{rad}}{Z_{rad} + Z_{mech.}}$$

where: M: mass system, C: damping, K: stiffness, W: natural frequencies.
For Low frequencies

$$w \ll \sqrt{K/m},\ \text{Excitation } f \ll \text{natural frequancy } \tau = \frac{4(\rho_o C_o)^2}{\left(\frac{K}{w}\right)^2},\ \rho_o C_o \ll wM$$

$$T_L = 20\, log_{10}\left(\frac{k}{f}\right) = 74.2\ dB\ , Transmitted\ loss\ (Stiffness\ Law) \tag{9}$$

For High frequencies

$$W \gg \sqrt{\frac{K}{m}}$$

$$\tau = \frac{4(\rho_o C_o)^2}{(wm)^2} \tag{10}$$

$$TL = 20\, log_{10} fM - 42.4\ dB \quad Mass\ controlled\ (Mass\ Law) \tag{11}$$

For Undamped resonance frequency (see Figure 5).

$$W_o = \sqrt{\frac{K}{m}}\quad, \tau \rightarrow \left(\frac{2\rho_o C_o}{C}\right) \Longrightarrow \tau = \frac{1}{1+\frac{C}{2(\rho_o C_o)^2}}$$

If $C \gg 2\rho_o C_o \quad \therefore \tau \cong \left(\frac{2\rho_o C_o}{C}\right)^2$

If $C \ll 2\rho_o C_o \quad \therefore \tau \rightarrow 1$

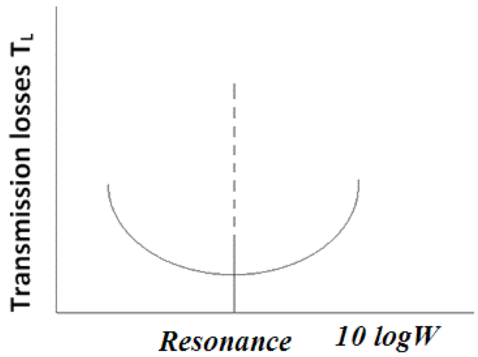

Figure 5. Resource frequency

2.4 Transmission of sound through infinite flexible wall

Insulation of partitions depends on the relative speed of free flexural wave in partition and the incident plane wave (Figure 6).

2.4.1 Free response

- Equation of motion

$$or \quad \underbrace{D}_{\text{Flexural Rigidity}} \frac{d^4\xi}{dz^4} + \underbrace{M}_{\textit{Mass unit/Area of Panel}} \frac{d^2\xi}{dt^2} = 0 \tag{12}$$

Figure 6. Transmission of sound through infinite partition.

Solution (Harmonic) Figure 7

$\xi^\circ = \xi_0^0 e^{j(wt - K_f z)}, K_f = \frac{W}{C_f}$ = flexural wave number , Cf = wave speed of plane

$$D K_f^4 - M W^2 = 0 \tag{13}$$

where $C_f = \sqrt{1.8\, h\, f\, C_L}$ and $C_L = \frac{\text{longtudinal wall}}{\text{speed}} = \sqrt{\frac{E}{\rho_s}}$

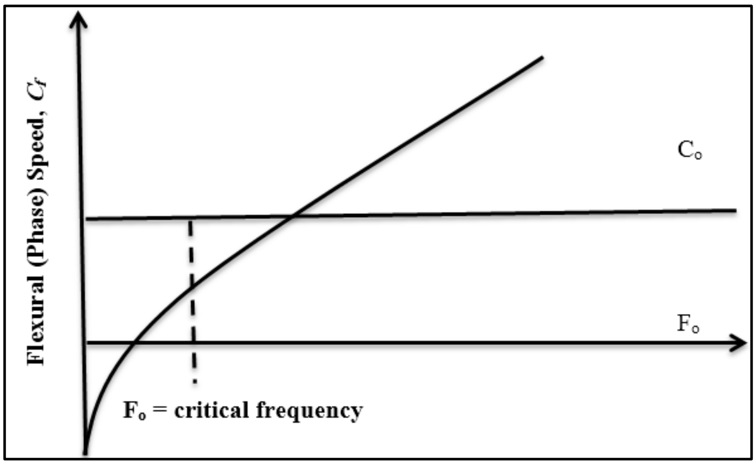

Figure 7. Critical frequency.

2.4.2 Force response

Equation of motion:

$$D = \frac{d^4\xi}{dz^4} + M \frac{d^2\xi}{dt^2} = P_o e^{j(wt - kz)} \tag{14}$$

$\zeta^o = \zeta^o e^{j(wt-kz)}$ and $\frac{\xi^\circ}{jw}[Dk^4 - Mw^2] = P_o$

K: wave number of pressure field and $f_c = \frac{C_0^2}{1.8\, h\, C_L}$

- Low response

Speed of waves in the panel is much slower than the speed of sound.

a- K ≅ K_f

Blows up solution no damping. Where $C_Z = C_f$ matches the solution Blows up since no damping included "Blows up "solution. For Speed of propagation in the z – direction matches the speed of free flexural wave in the plate. We get large motion. Sound transmission is high.

The frequency at which occur is the "Coincidence frequency". Note that the frequency at which occur depends on the incidence of the incident plane wave.

$\frac{C_o}{\sin\phi} = C_f = \sqrt{1.8\, h\, f\, C_L} \quad where\ \phi = 90^o \quad , \quad C_f = C_o$

This is the lowest coincidence frequency Figure 8.

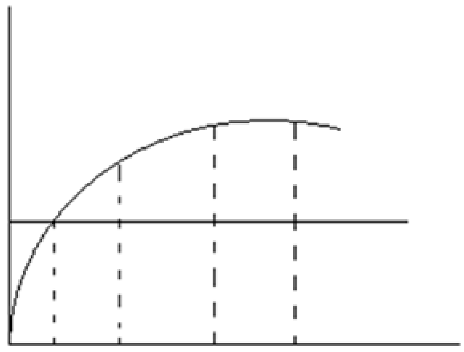

Figure 8. Lowest coincidence frequency.

2.5 The Sound Reduction index of compound partitions

$$\mathrm{SPL} = 10\log_{10}\frac{P^{-2}}{P_{ref}^{-2}} \tag{15}$$

$$T_L = 10\log\left(\frac{S_1 + S_2}{S_1\tau_1 + S_2\tau_2}\right)$$

$$\mathrm{SPL} = 20\log\frac{\sqrt{P^{-2}}}{P_{ref}}\ \text{, where } \sqrt{P^{-2}} = \text{RMS Value and } P_{ref} = 2 * 10^{-5}\ H/m^2 \tag{16}$$

2.6 application of mathematical model (1)

Two sources of sound are radiating uniformly in all direction, since the radiation is uniform and consider no aspheric of radius 3m, 2m RMS 56 sound pressure of the two sources are $2.825*10^{-1}$ N/m^2- $1.124*10^{-1}$ N/m^2 respectively . The SPL for each source ΔSPL , SWL, power for two sources can be determine as follows SPLt.

$S\,P\,L1 = 20\,log_{10}\frac{P_1}{P_0} = 20\,log_{10}\frac{2.825*10^{-1}}{2*10^{-5}} = 83\,dB$

$S\,P\,L2 = 20\,log_{10}\frac{P_2}{P_0} = 20\,log_{10}\frac{1.124*10^{-1}}{2*10^{-5}} = 75\,dB$

$\Delta S\,P\,L = S\,P\,L1 - S\,P\,L2 = 83 - 75 = 8\,dB$

$S\,P\,L1 = SwL1 - 10\,log_{10}\,4\,\pi\,r^2$

$83 = SwL1 - 10\,log_{10}\,4\,\pi\,(3)^2$

$SwL1 = 103.5\,dB = 10\,log_{10}\frac{W}{W_0} = 10\,log_{10}\frac{W_1}{10^{-12}}$

$\frac{W_1}{10^{-12}} = 10log_{10}^{-1}\frac{103.5}{10} \rightarrow W_1 = 0.022\,watts$

$SWL2 = SPL2 + 10\,log_{10}\,4\pi(2)^2 = 75 + 17 = 92\,dB = 10\,log_{10}\frac{W_2}{W_0}$

$W_2 = 10^{-12} * log_{10}^{-1}\left[\frac{92}{10}\right] = 0.0015\,watts$

$SPLt = 10\,log_{10}\left[10^{SPL1/10} + 10^{SPL2/10}\right]$

$$= 10\, log_{10}\left[10^{83/10} + 10^{75/10}\right] = 83.538\ dB$$
$$\frac{W_1}{10^{-12}} = 10 log_{10}^{-1}\frac{103.5}{10}$$
$$W_1 = 0.022\ watts$$

2.7 application of mathematical model (2)

Two room each measuring $3m \times 5m \times 5m$ are separated by a brick wall containing panel of glass the area of brick is 12m^2 and area of glass 3m^2 source of sound in one of the rooms given the data tableted in Table 1 calculated the reduction in SPL required in the other room if 60 db is not to be exceeded.

Table 1. Noise data.

Octave band Centre frequency(Hz)	4000	2000	1000	500	250	125
Machine sound power level (dB 10-^{12})	73	81	95	95	76	72
Sound reduction index of brick (dB)	52	50	43	40	35	32
Sound reduction index of glass (dB)	38	36	30	27	21	18
Reverberation time of machine room (s)	0.5	0.5	1	1	1.5	2
Reverberation time of other room (s)	0.25	0.5	1	1	2	2.5

By: may assume the reverberant mean square pressure P^{-2} in a room related to the source sound power input W by: $P^{-2} = 4\, W\rho_o C_o/S\alpha$. Where Sα is the room absorption, take ρ_o= 1.2Kg/m^3, C_o= 344 m/s. T_1 = 1 sec, T_2 = 1 sec

- The rooms (5*5*3) m^3
- Partition condition 3m^2 at glass – 12 m^2 at brick

$$P_{rev}^{-2} = \frac{4W\rho_o C_o}{S\alpha}$$
$$\tau_{brick} = 5.0118 \times 10^{-5}\ ,\ \tau_{glass} = 1 \times 10^{-3}$$
$$(SRI)_{brick} = 43\ dB \quad \text{and} \quad (SRI)_{glass} = 30\ dB$$
$$T_L = 10 \log \frac{S_1+S_2}{S_1\tau_1+S_2\tau_2} = 36.196\ dB$$
$$\tau = 0.161\ \frac{v}{5}$$
$$\therefore a_1 = 12.075\ m^2 \quad \text{and} \quad a_2 = 12.075\ m^2$$
$$T_L = \Delta SPL + 10 \log \frac{S_{partition}}{a^2}$$
$$S_{partition} = S_{glass} + S_{brick} = 3 + 12 = 15$$
$$\Delta SPL = 35.25\ dB$$

3. Result and discussion

The noise reduction analysis are studied for different models such as noise reduction for two rooms separated by a brick wall containing single and companied pane of glass, nondistorting wall and infinite flexible wall.

The data obtained from the analytical technique can be drawn as shows in figures of this study.

Figure 9 show the noise levels for different partitions which indicated that the higher level for single pane portion.

Figure 10 show the decay and machine sound power for every octave band, the greater wide-ranging influence is in the centre band frequency.

The relation between the sound reduction indexes of brick and sound reduction index of glass is linear and directly proportional is shown in Figure 11.

To compare the reverberation time for the source room and the other room of transmitted noise can be investigated by Figure 12 to predict for the amount and time of transmitted and reflected sound pressure.

The curve obtained from the octave band frequency and sound reverberation index of glass and brick are shown in Figure 13 and Figure 14 where the octave band of brick and glass increased gradually with time.

The octave band frequency in Hz varies in the reverberation time of source index in descending manner and varies at constant for the rest band frequency as in Figure 15.

For the other room the time of reverberation decreased slowly with octave band frequency and the taking a linearized relation as shown in Figure 16.

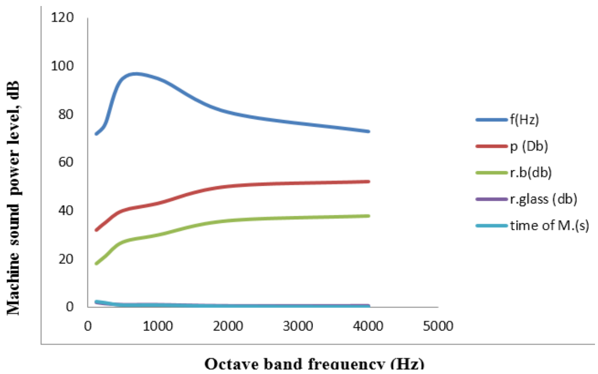

Figure 9. Octave band and machine sound power level.

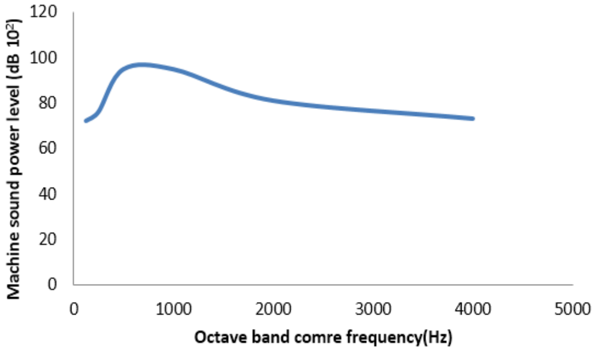

Figure 10. Octave band frequency and machine sound power level.

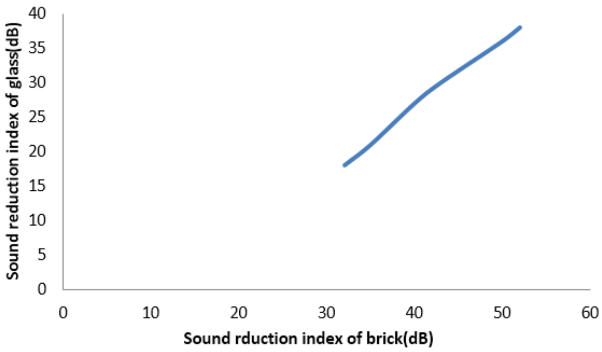

Figure 11. Sound reduction indexes for brick and glass.

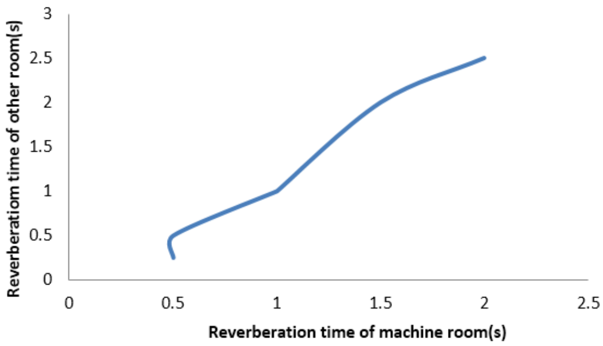

Figure 12. Reverberation time of machine room and other room.

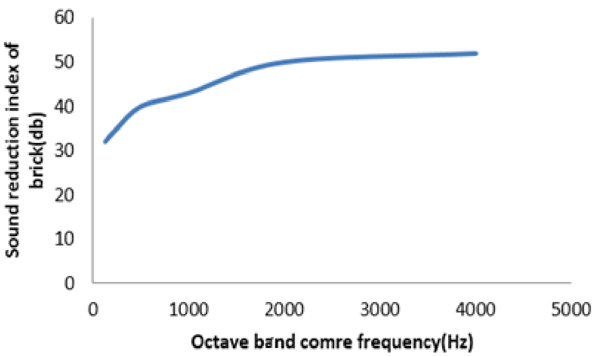

Figure 13. Octave band frequency and sound reduction index of brick.

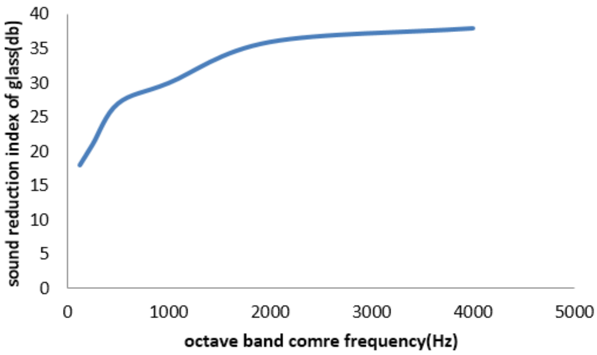

Figure 14. Octave band frequency and sound reduction index of glass.

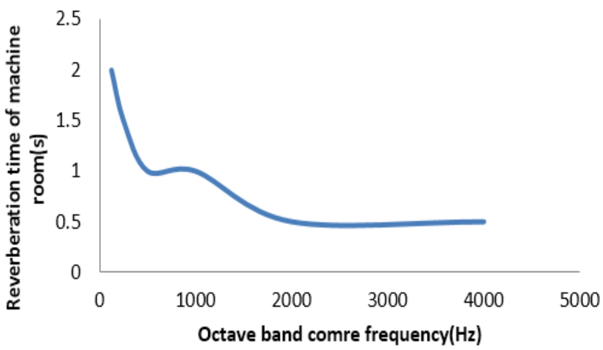

Figure 15. Octave band frequency and reverberation time of source room.

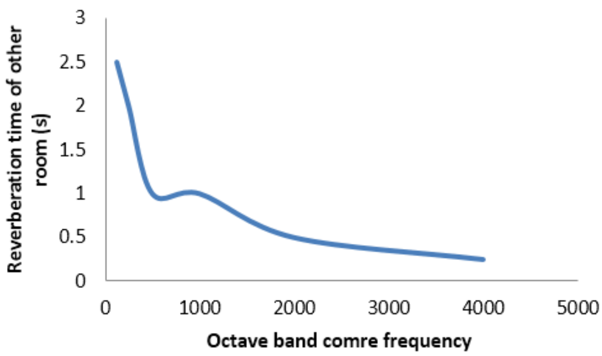

Figure 16. Octave band frequency with reverberation time of other room.

4. Conclusion

The paper state that the noise of the sound can be reduced using multiple pane, where the compound pane can be better than single pane for reduction the noise in rooms.
The standing waves pattern produced by compound pane are set of normal modes where the superposition of two travelling waves of the same amplitude interfering to produce a standing wave
The interior noise level and its dominant frequencies vary with many factors, including the running speed. Even at a fixed running speed, the interior noise frequency distribution will vary from one partition to another and also spatially within the single partition. The partition can be designed more specifically for particular locations in the system, and the present work can provide an orientation for its low noise analysis.
The non-distorting wall is a good model to predict the incident, reflected and transmitted noises were the noise is damped by springs and dampers. The transmitted sound through infinite partition depends on the relative speed and free flexural wave in partition and the incident Plane wave.
Weighted noise has its peak in the mass controlled frequency region, where increasing the thickness of the pane provides the most significant improvement in sound transmission loss. Increasing the air gap and damping also has some advantage because the air can only vibrate in resonance frequencies
The octave band frequency in Hz varies in the reverberation time of source index in descending manner and varies at constant for the rest band frequency. The frequency at which occur is the "Coincidence frequency". Note that the frequency at which occur depends on the incidence of the incident plane wave.
A life predication model is presented to control the optimum design and to find a proper combination of noise and life.

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