Reduce Generators Noise with Better Performance of a Diesel Generator Set using Modified Absorption Silencer

Md. Nasir Uddin [α], Md Ahbabur Rahman [σ], M. M. Rashid [ρ], N A Nithe [Ѡ] & JI Rony [¥]

Abstract- Noise pollution is considered to be one of the major environment pollutants which affect human beings both physically and psychologically, as such, a noise-free environment is in great demand worldwide. Diesel engine generators are highly appreciated as power sources of electric equipment in factories, houses and business centers. Loud sounds from diesel generators are a major cause of noise pollution. This paper analyzes the noise source of diesel generators and mitigates this pollution by a modified absorbance silencer or muffler. For automotive engines, the principle source of noise is its intake, radiator, combustion, etc. In our society, all of the industries, the residential sector and business plants use generators. In this research, an absorbance silencer is modified for reduced noise of the generator set. It is constructed from a combination of baffle or perforated duct with sheet metal. This paper aims to study the sound characteristics of generator sets and also aims to reduce the sound by means of a well-modified muffle silencer. This paper focuses on design and tests silencers, particularly absorption silencers for engine exhausts.

Keywords: diesel engine; generator; absorption silencer; noise.

I. Introduction

Sound pollution means unwanted sounds or noise. It is perceived by most people as annoying. Noise pollution harms most people's lives. Additionally, it is a great cause of environmental pollution. It greatly hampers humans not only physically, but mentally also. For these reasons, noise reduction is in great demand in this society, and noise prevention is a rising concern in all markets. In our society, all of the industries, the residential sector and business plants use generators. Diesel engine generators cause loud sounds.

A silencer is essential and an important part for sound attenuation of engine exhausts. There are many theories and designs of acoustic silencers of generator sets, developed in detail by Stewart theory and design of Acoustic and silencer of Generator set developed in detail by Stewart [1, 2] and he apply it to create many types of silencer and also success that explained in [2].

In 2013 Dr. Chazot, Nenning and Perry performed the method of unity finite element of 2D noise field with sound absorbing materials [3]. Now a days on top is a large company who designing, producing and manufacturing prefab modular flue and also distributing. It disposes of a modern product that certified ISO 9001 and also environment friendly as metaloterm lightweight silencer for flue system. In 2012, Mr. Ghosh, Bose and Chakraborty in india modified muffler and get a good performance of a diesel engine by used it [4]. The review of Generator set and silencer should be not complete without it mixed the effects of different absorption elements [5] .The diesel engine is the main noise sources of sound power also the generator exhaust and radiator fan [6], are measured by the method of sound intensity. At first May and Olson expressed an electronic noise absorber by pressure release on back face of resistive sheet [5]. Its introduce the notion of active absorption. Guicking and Lorenz in the year of 1980 fulfilled this theory and done experiment [7]. Various research have sought to complement multiple hybrid absorbance technique, leading to patent application [8]. In 1997 Mr. nail and Furstoss improved a layer of optical wool backed by air cavity closed through an active surface [9] by an active treatment. In the same year Beyene and Burdisso found active boundary condition [10]. They achieved it by impedance adaption means in layer of porous rear face.

But after the century in 2004 cobo et al. explained structure of thinner hybrid active and passive absorbers feasibility. He used micro perforated panels more than the porous materials[11]. The design mufflers and procedures are also in the literature (Munjal, 1987)[12]. Long time ago Stewart used electro acoustic analogies in deriving acoustic filters theory & design.[1]. After that Davis approach systematic studies result of muffler.[13]. Igarashi and M. Toyama calculated transmission characteristics by using electric circuit. [14, 15]. The last year in 2014 Babu, A.R Rao simulated a new muffler for reduce sound level of SI engine.[16]

In this paper, an absorbance silencer is modified for reduced noise of a generator set. It is constructed using a combination of baffle or perforated duct with sheet metal. The maximum generator has a simple silencer for reduction of the exhaust noise only. In this paper, a silencer is modified to reduce the noise

Author α ρ: Mechatronics Engineering, International Islamic University Malaysia. e-mail: nasir.u@live.iium.edu.my
Author σ: Masters of Business Administration; FTMS Global Malaysia. e-mail: muhammadahbab92@gmail.com
AuthorѠ¥: Dhaka & Bhola polytechnic Institute, BTEB. e-mail: engnasirbd@yahoo.com

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level and keep it at a minimum; also generators' noise sources and their characteristics are discussed herein.

a) Method of Noise Measurement

Noise means unwanted sounds that are abnormal or loud- it is a relative term. Singing or hearing a song or musical instruments may be noise for some. Automotive engines create a large portion of the noise in our society. I.C engines are also a great source of sound pollution, as they are a powerful source of noise. The noise sources of both gasoline and diesel engines are the same, but their noise characteristics are different. Noise is highly subjective, and that which is irritating to one can be acceptable for another. To overcome this, noise is measured by a decibel (dB) meter in unit of dBs, withdB(A) representing the human ear's sensitivity of 0 to 180 dB, where 0dB means no sound at all, and 180dB is a loud sound. An alternative explanation for 180 dB is the level of sound an atomic bomb would make upon explosion. The dB scale is a logarithmic meter. If d Bs risein in crements of 10, then the sound level rises 10 decade or 10 fold. If we know the level of noise source and maximum allowed level, then it is easy to calculate the required sound reduction for the silencer. Alternatively, if the level of noise and the necessary noise reduction of silencer are known, then the remaining noise level can be easily calculated. Noise and sound have different frequencies. The unit of frequency is Hertz (Hz). Hertz means period per second, calculated by the equation f=1/t. We can hear from 20Hz to 20 kilohertz (20000Hz), but this depends on age. Machinery like engines, generators, vehicles and ventilators generally produce 50Hz to 3000Hz. The USA standard ASTM E413 describes frequencies of machinery as being in the range of 125 to 4000 Hz [17]. Similarly, The international standard ISO 717 refers to frequencies 100 to 3150 Hz[18]. The SI unit of sound reduction is dB and frequency is Hz[19]. But it is important to know that different frequencies demand different types of silencers

b) Different Types of Generators Noise

Three types of fuels are used in generators: diesel, propane and natural gas. In general, generators are of two types: spark-ignited and diesel. Spark ignites are combined with propane and natural gas engines.

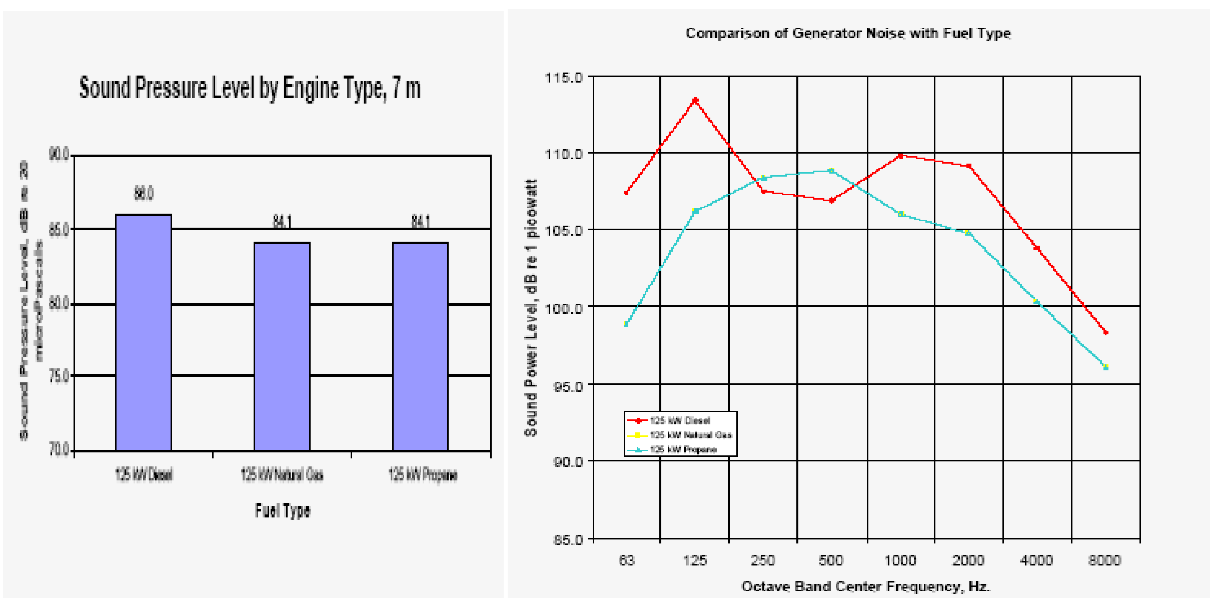


Figure 1 : Noise characteristics of various type of Engine.

The line graph in Figure 1 illustrates the power of noise between two level standards. On this graph, the x-axis shows noise pressure and the y-axis shows the noise power level. The noise power levels of spark-ignited or natural gas and propane generators are the same. The sound power level relates to the generator's total energy and is similar to horsepower. The bar graph in Figure 1 depicts sound variation against fuel type. The diesel engine leads here with 86 dB A, compared to a spark-ignited type generator achieving 84.1dBA for natural gas and propane. It varies with location and distance from the source of noise. The sound pressure level (SPL) of a quiet residential place is 45 dBA during the day, and 35 dB A at night (Ahuja et al., 1997). 70 dBAsis the level of noise of a busy place from 100 foot distance and conversations are around 60 dBAs from 3 feet away. The line graph in Figure 2 shows a comparison of diesel generator noise with size, withvarious lines representing each of the four types of generator: the red line is for a 125 kw diesel generator, the yellow line is for a 500 kw generator, the green line represents a 1 MW generator, and finally the blue line represents a 2 MW diesel generator. The bar graph in Figure 2 illustrates the sound pressure level by engine size: large, 2 MW enginesproduce 99.2dB;1 MW engines achive 94dB; and 91dB and 86dB are generated from 500kw and 125kw engines, respectively [14].

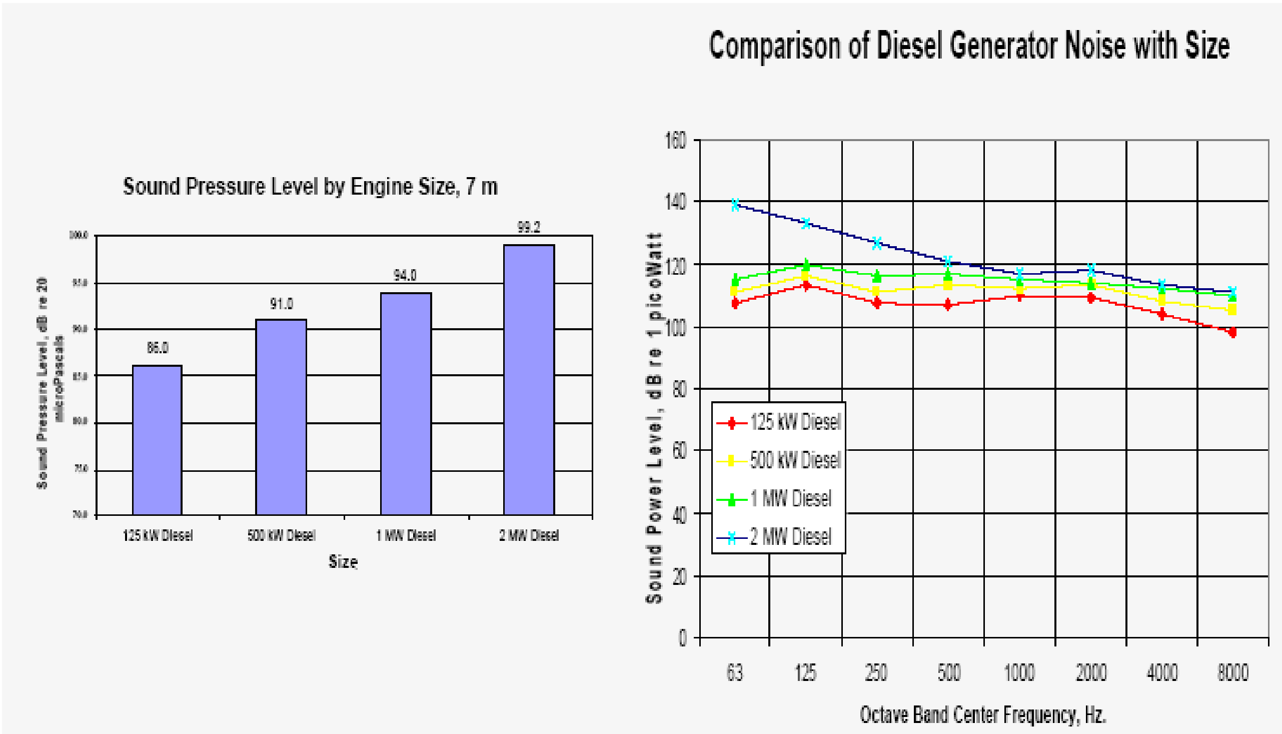


Figure 2 : Noise Characteristics with Engine Size.

c) *Source of Noise Generation in Generator set*

Engines are the cause of much noise pollution today. Engines are of many types, such as I.C. engines, of which there are two types: gasoline and diesel. These two types of I.C. engines have different noise curves, however, the occupational noise source is same for both. For automotive engines, the principle source of noise comes from its intake, radiator and combustion. The dominant source is the engine block of the generator and the air intake. There are also some primary noise sources that are shown below.

(A) (B)

Figure 3 : Source of Noise

Figure 3B shows a radiator fan as the primary noise source. The engine block also combines with the radiator fan to produce noise by discharging radiating air. This noise is produced by the generator, and can dominate part of the frequency spectrum. There are also some parts or units produce noise together, like the exhaust, the turbo charger, the load bank, vibration, the engine, theconnection to ductwork or exhaust pipe, and electrical components. The load bank is very noisy. Often, it is portable and brought in for testing. Maximum noise ordinances will accept noise to the threshold of a code limit. Otherwise, the load bank's place would be a generator room but not outside the room. A significant source of noise is vibration. It is not a normally a source in the case of the generator being placed on the roof or an upper floor. For reduction of the vibration, a spring isolator is used as a supporting structure. Vibration isolation is essential for larger engines of a big generator sets, otherwise supporting structures can become damaged.

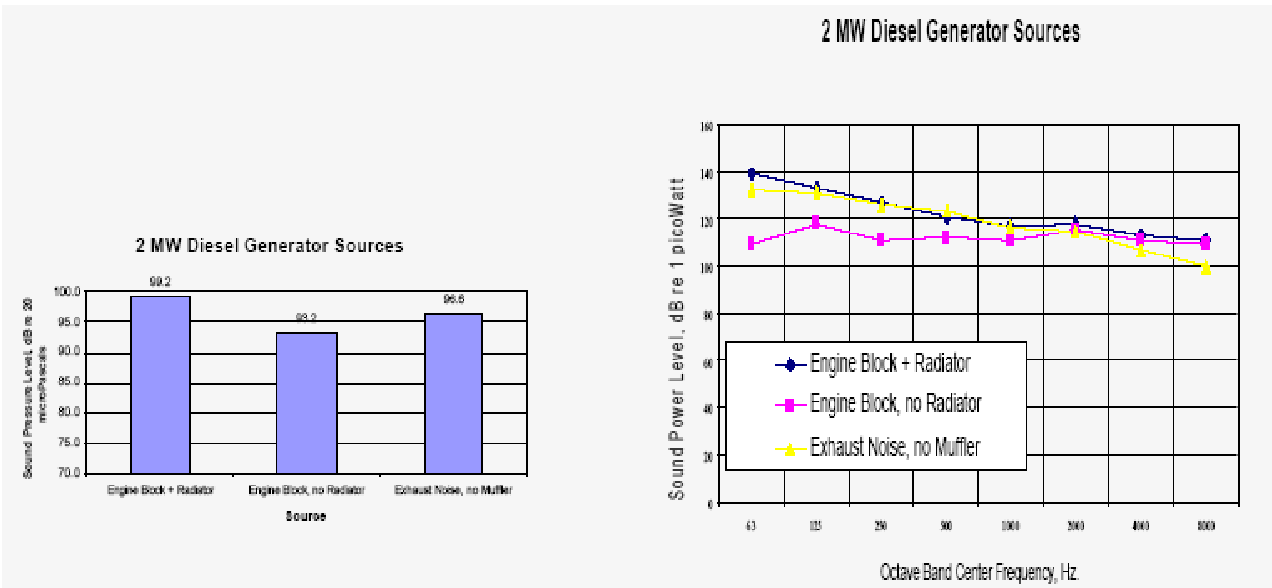


Figure 4 : Noise source of 2MW Diesel Generator.

Figure 4 shows noise characteristics of a 2 MW generator. The line graph in Figure 4 depicts the generator's sound power level. The blue line shows the sound power level of an engine block with a radiator, the pink line shows the sound power level of the engine block without a radiator, while the yellow curve shows sound power levels for the exhaust noise without a muffler. The bar graph in Figure 4 shows the sound pressure levels for each of these same three sources (i.e. engine block with radiator, engine block without radiator, exhaust without muffler). The exhaust system has inherent problems of structure and design, which impose limitations on the procedure for reduction of noise from the engine exhaust. The noise range of the exhaust system is 100-120dBA, which is considered to be very high. Temperatures reaching the range of 950°-1050°F are classed as high temperatures. Similarly, high velocities are those ranging from 5000-15000fpm. Insertion loss is the reduction of noise that happens when an element of silencing is entered into the system. Due to the engines producing a high sound, the muffler insertion loss will vary with variable engines, load and inlet outlet piping configuration. However, a drop of pressure significant. The noise of an engine exhaust varies significantly with its loading. At the full load, the sound level is about 10dB more than the 'no-load' condition. The silenced exhaust noise level is high at low frequencies.

II. Noise Reduction Techniques

The noise reduction techniques are dependent on the generator room, exhaust and its type of structure, borne, noise & vibration. Some techniques are shown in the following sections.

a) *Generator Rooms*

a. Room Enclosure:

i. Roof

ii. Walls

iii. Doors

iv. Internal Lining

b. Intake Air and Discharge Air:

i. Duct Silencers

ii. Acoustic Louvers

iii. Exterior Screens

b) *Exhaust Noise*

a. Resistive Mufflers/ Absorbance Silencer

b. Active Noise Control

c) *Structure Borne Noise & Vibration*

a. Spring isolators on generators larger than 175kW.

b. If a floor joint is present, the weight of concrete beneath the generator should be not less than twice the generator weight.

c. Flexible pipe connectors, duct connectors, electrical connection at the generator.

Active noise cancellation silencers used to be available as amanu factured product, but are not currently available. They were effective in reducing the low frequency tones associated with the cylinder firing. In this research paper, we design and modified resistive mufflers / absorbance silencers for reduction of exhaust noise.

III. Methodology

The methodology involves silencer design and development, and consists of some steps. After this, a modified silencer for use with a generator for a practical experiment is produced. The properly designed muffler for any particular application should satisfy the often – conflicting demands of at least five criteria simultaneously.

a) Criterion and Flowchart of Methodology

The acoustic criterion, which specifies the minimum noise reduction, is required from the muffler as a function of frequency. The operating conditions must be known because large steady-flow velocities or large alternating velocities (high sound pressure levels) may alter its acoustic performance. The aerodynamic criterion specifies the maximum acceptable average pressure drop through the muffler at a given temperature and mass flow. The geometrical criterion specifies the maximum allowable volume and restrictions on shape. The mechanical criterion may specify materials that are durable and require little maintenance. The economical criterion is vital in the marketplace [33]

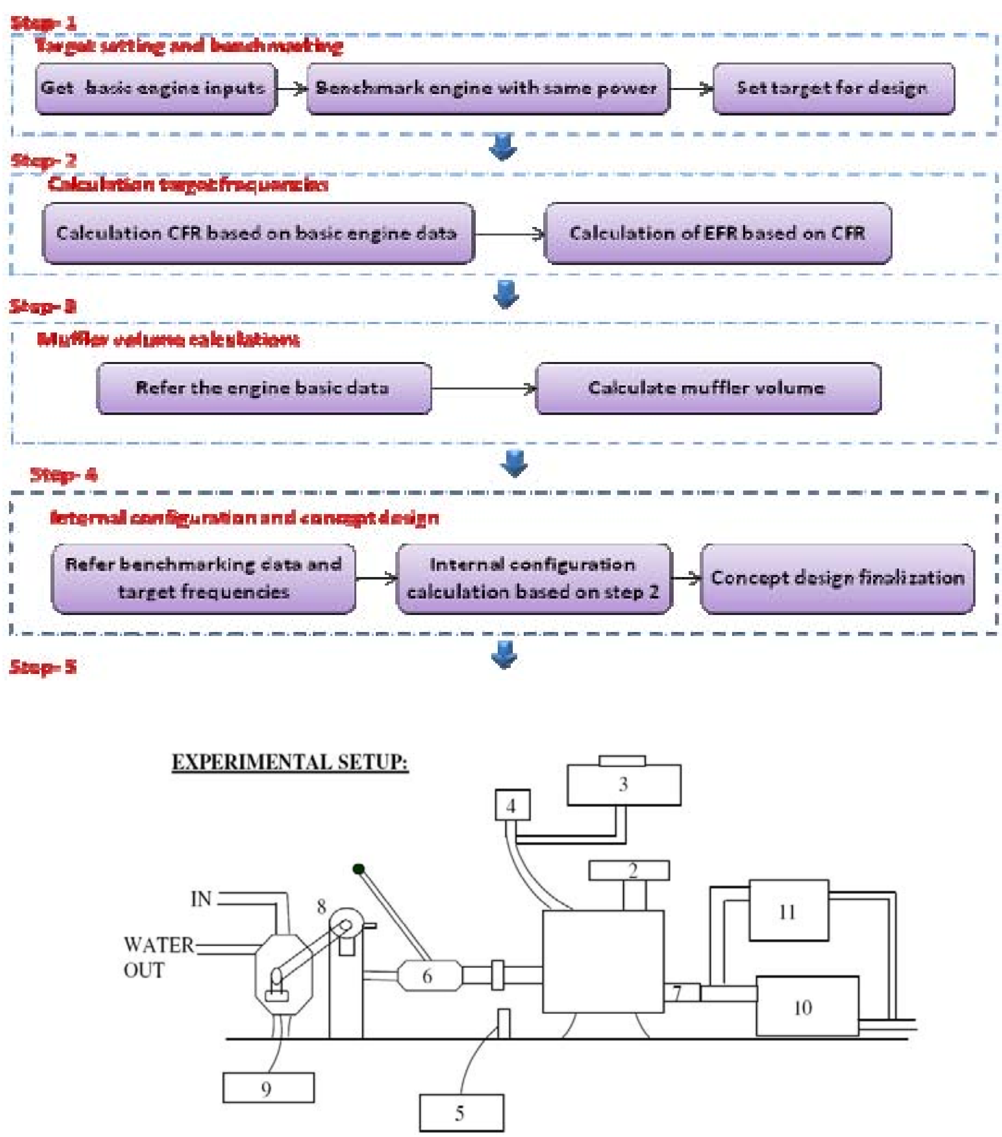


Figure 5 : The steps showing the process of design of the silencer andthe experimental setupof the generator set with a diesel engine.

1. Diesel Engine
2. Filter
3. Tank
4. Burret
5. RPM Indicator
6. Clatch or Shaft
7. Exhaust Outlet
8. Alternator
9. Radiator
10. Silencer
11. Sound Meter

The generator block diagram is replaced by the experimental setup block diagram. The various types of generator sets include 150KW, 350KW, 500KW, 1MW and 2MW diesel engines for use during the experiment and data collection. The experimental silencer was designed for a 500KW diesel engine generator set, and the basic specifications of the generator set are given in Table 1.

Table 1 : Specifications of the generator set

SN	Item	Specification
1	Rating	635KVA
2	Power	508KW
3	Current	850A
4	Rated revolution	1800RPM
5	Pressure	460KPA
6	cylinder	6
7	Cycle/stroke	4
8	Engine Load	75% and Full Load also

Figure 6 : Generator Set

b) *Experimental Evaluation of Unsilenced exhaust Noise in Diesel Generator Set*

The noise of an engine exhaust varies significantly with its loading. At the full load, the sound level is about 10 dB more than the no-load condition. The silenced exhaust noise level is high at low frequencies. Figure 7 shows a 2MW engine with un silenced exhaust noise level load for 16cyl at 1800RPM.

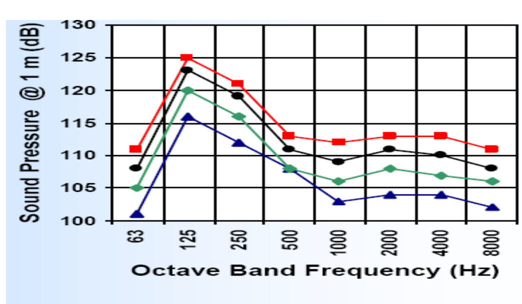


Figure 7 : Sound Pressure at 1m distance for 2MW Engine by load.

The graph shows that the exhaust system starts at 110dBA and varies by 10 dBA, reaching a maximum of 120dBA. It is measured 1m from the outlet exhaust. The exhaust sound is affected by turbochargers of engines and after coolers by cooling fans. Hence, collecting noise data from engines is the optimal method chosen for this experiment. The un silenced engine's exhaust noise level is high at low frequency. Figure 8 shows data comparisons for the various engines including 150KW, 350KW, 500KW and 2 MW diesel engines.

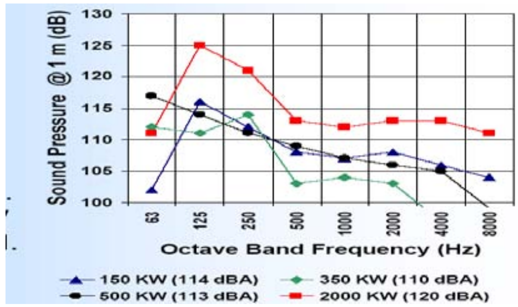


Figure 8 : Sound Pressure of various Engine at 1m distance.

The spectrum of exhaust noise always contains loud sound associated with the cylinder firing rate (CFR). Each cylinder fires once every drive shaft revolution in a 4-cycle engine, and the CFR is calculated with different formulas for 4 cycle engines (Equation (1)), and 2 cycle engines (Equation (2)).

$$CFR = \frac{RPM}{120} \quad (1)$$

$$CFR = \frac{RPM}{60} \quad (2)$$

The engine firing rate is defined as

$$EFR = N * CFR \quad (3)$$

Where, N= number of cylinders.

Figure 9 shows the exhaust noise of a 500 KW diesel engine with 6 cylinders, running at 1800RPM without using any silencers. The narrow band spectrum data was collected at a 3m distance from the outlet of the exhaust without use of a silencer, with the engine running at full load. The engine firing rate (EFR) is 90Hz and the CFR is 15 Hz.[21]

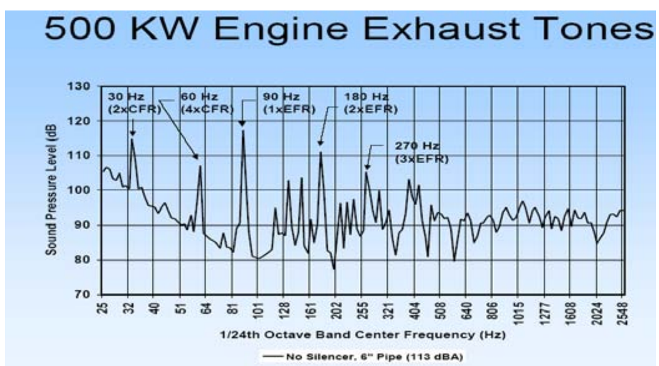


Figure 9 : Sound Pressure Level of CFR & EFR without silencer

IV. Design and Principle of Absorption Silencer

The first step in any design and development activity is to set a target by doing a benchmarking exercise of models, which was carried out in this experiment.

a) Benchmarking

After the benchmarking exercise, one needs to calculate the target frequencies to give more concentration of higher transmission loss. The primary step in silencer design is benchmarking based on engine input data:

$Bore, D = 80mm$
$Stroke, L = 98mm$
$Number\ of\ Cylinder, n = 6$
$Engine\ power, P = 65hp$
$Max.RPM = 1800RPM$
$Allowable\ Back\ Pressure = 10\ in\ H2O$
$Transmission\ Loss\ Noise\ target = 30dB$

b) Calculation of CFR & EFR

The exhaust noise always contains loud sounds associated with the CFR. Each cylinder fires once every drive shaft revolution in a 4-cycle engine, as can be seen in Equation (1) and (2).

$$CFR = \frac{1800}{120} = 15Hz.$$

Engine Firing rate (using Equation (3)): *6*15=90Hz*

c) Volume of the muffler (Vm)

The volume of the muffler isdefined as Vm, with units in litres. The calculation of the volume can be done using Equation (4):

$$Vm = Vf * \frac{\pi}{4}(d^2 * l) * \left(\frac{n}{2}\right) \quad (4)$$

Swept volume per cylinder is calculated as follows:

$$Vs = \frac{\pi}{4}(d^2 * l) = \frac{3.14*80^2*98}{4} = 0.5\ Lit. \quad (5)$$

Total *n*Vs=6*0.5=3 Lit.*

Volume, $Vm=(n)*\frac{Vs}{2}=1.5$ *Lit.*

The silencer volume is considered to be at least 12 to 25 times larger, with a factor of 16

$$Silencer\ Volume\ =\ 16 * 1.5 = 24\ Lit.$$

d) Insertion Loss

Figure 10 shows insertion loss for various mufflers, showing the absorptive muffler performance being optimal in the frequency region of 1000Hz to 2000Hz.

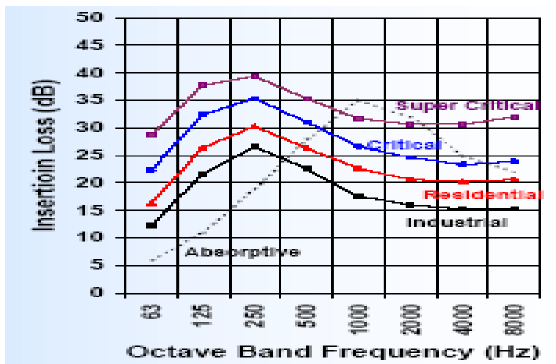


Figure 10 : Insertion Loss of various Muffler

The 500 KW generator engines have an unsilenced exhaust noise level (UNL) of 116 dBA at a 1 m distance. Asafety factor (SF) of 5 dBa is allowed for noise transmission paths. The Exhaust noise criteria (ENC) = Required Noise Criteria (RNC) -5 dBA. This means that if our expected noise level is 60dBA, then we have to design a muffler for 55dBa. The UNL equation from the exact location is shown in Equation (6):

$$Lp(xr)\ =\ Lp(x0)\ -\ 20\ log\ (xr/x0) \quad (6)$$

For example, $Lp(25\ m)\ =\ Lp(1\ m)\ -\ 20\ log\ (25/1)$

$$Lp(25\ m)\ =\ 116\ - 28\ =\ 88\ dBA$$

$$The\ required\ insertion\ loss, IL\ =\ UNL - ENC + SF.$$

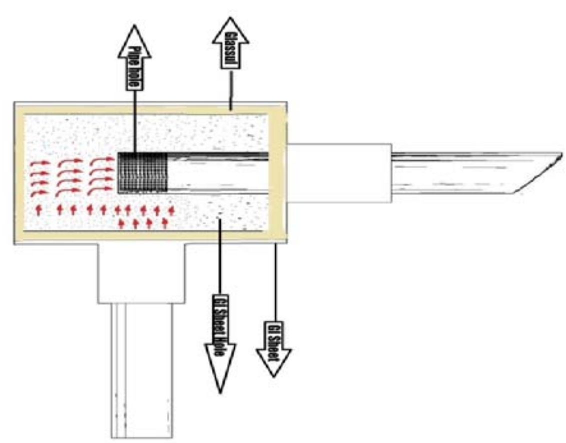
$$IL\ =\ 88\ dBA\ -\ 55\ dBA\ +\ 5\ =\ 38\ dBA.$$

A silencer element'stransfer matrix method (TMM) is a function of state variables [28] , geometry of elements, velocity of mean flow, duct liner properties [29]. The transfer matrix method also influenced by temperature, nonlinear effects, high order mode etc.[30]. The Transmission Loss is shown in Equation (7) below.[24, 31, 32]

$$TL = 20\log\left|\frac{T_{11}+T_{12}/Y_1+Y_{11}T_{21}+T_{22}}{2}\right| \quad (7)$$

e) Internal Configuration and Design of the Proposed Silencer

The silencer contains glass wool shielded from the exhaust stream by perforated metal. Glass silk, fiber optic or steel wool is commonly used. When the absorbance silencer works effectively, the materials suffer from deterioration in service. The combustion products take the form of absorbing materials. Materials melt due to heat generation until they have low thermal conductivity. The absorbance silencer is designed with low pass filter forms in order for it to be able to deal with the low frequency. Effective measures were used to reduce the sound. The noise power has to be applied in the numerical analysis.



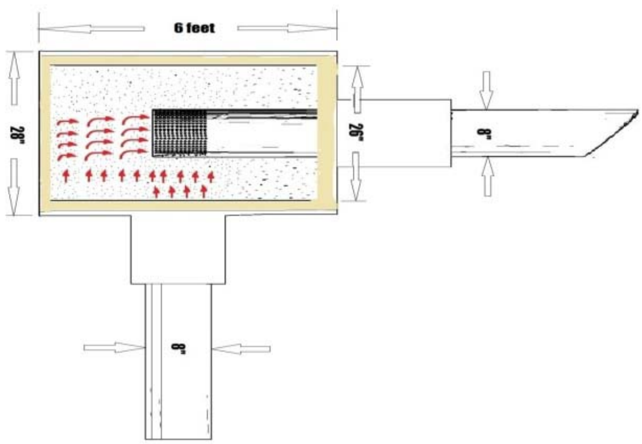


Figure 11 (A,B) : Design of Modified Absorption Silencer

The operation and principle of the new absorption silencer is shown in Figure 11. Exhaust gas enters from the inlet pipe and is directed in multiple directions in the indoor chamber. The indoor space has a U-shape configuration with large spaces. Therefore the gases flowing into the space from the inlet to the outlet are distributed by the inner pipe hole. The inner pipe also has absorption materials like glass fiber, steel wool and sheet hole. The exhaust gases are absorbed automatically by these materials as they move around the inner space. The flow of these gases interfere with the leading gas flow, causing it to have a lower speed [23]. Figure 12 shows the inlet pipe and tail pipes (outlet pipes) with a diameter of 8 inches. The main perforated chamber is 6 feet long with a 28inch diameter. The absorption materials on the coating layer are only 2inches wide. The exhaust outlet pipe has resonance that increases its noise. To remove this, a short tail was used with a length of a quarter wavelengths (λ/4). Equation (8) describes the size of the tail pipe that described by jerry jlilly in AGL acoustic [17].

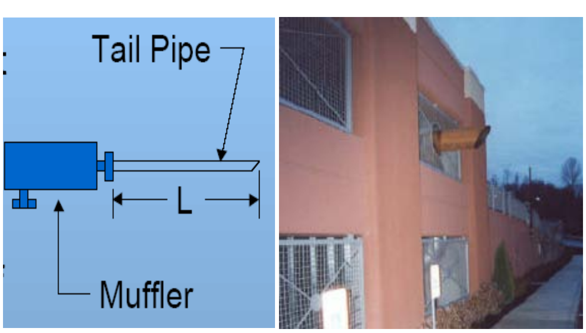


Figure 12 : Tail Pipe.

Here n= positive integer number. when $L = n\lambda/2$, then occurs Resonance and for this reason this size is avoided. Resonance frequency of Tail pipe,

$$fn = nc/(2L) \tag{8}$$

c = sound speed. For a four stroke engine the EFR frequency is 90Hz and its wavelength is 20ft. The best tail pipe is exactly 5 ft. for cancel the EFR frequency of 90 Hz tone at the exhaust of outlet [21]. Here give the calculation for 6 cylinders @ 1800 RPM (950^{0}F)

$$CFR = \frac{1800}{120} = 15Hz$$

$$EFR = 6CFR = 90Hz$$

$$c = 49.03 * \sqrt{(460+950)} = 1841\,ft/\sec$$

$$\lambda_{CFR} = \frac{1841}{15} = 122\,ft.$$

$$\lambda_{EFR} = \frac{1841}{90} = 20\,ft.$$

$$L = \frac{20}{4} = 5\,ft.$$

Where L= tail pipe length. The tail pipe is a metal sheet that lies downstream of the exhaust silencer and has an acoustic resonance that can increase or amplify the final exhaust noise if matched. This resonance can be removed by making the tail half of the wavelength at the tone or sound frequency. However, it is advisable to avoid the tone by creating an accurate size at a quarter of the wavelength. The pipe hole's or perforated holes' number and diameter with measurements are given in Figure13[24].

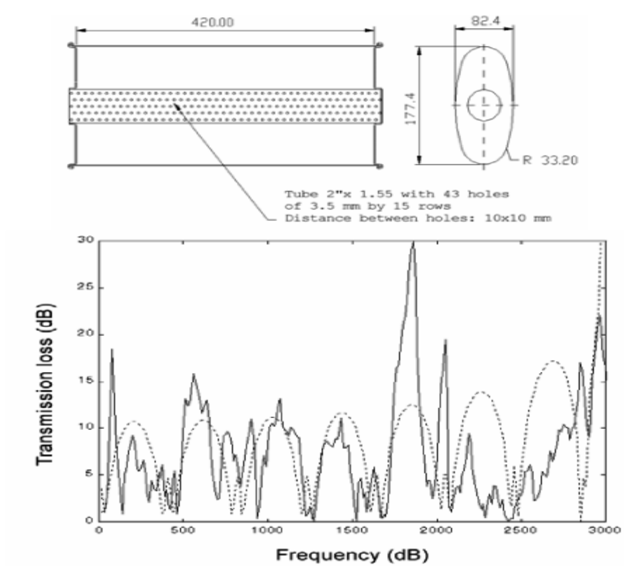


Figure 13 : Transmission Loss of Concentric Perforated Tube.

The pipe hole of expansion chamber of the inner space helps to reduce the sound. The inlet pipe and outlet pipe can be extended to get more attenuation. [25, 26]. The absorption materials also reduce higher frequencies, especially that of mineral wool or glass wool [27].

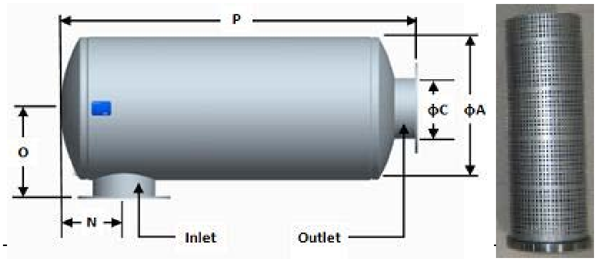


Figure 14 : Side View of Absorption Silencer and Perforated hole

The diameter of inlet and Outlet exhaust pipe is-

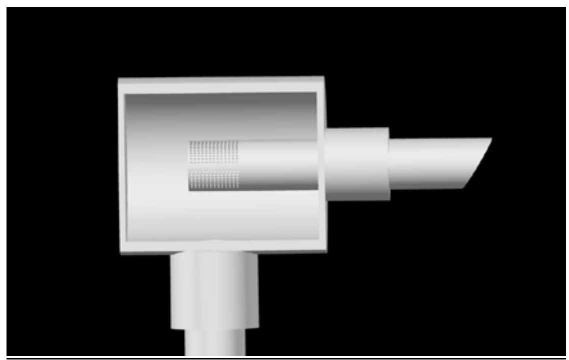
$$Vm = \frac{\pi}{4}(d^2 * l)$$

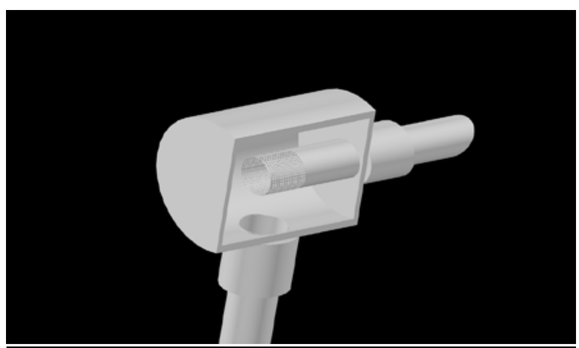
D2=0.04

D=0.2m=200mm

And the perforated hole diameter is, $d_1 = \frac{1.29}{\sqrt{N}}$.[22]

Figure 15 : 3D view of Modified Absorption Silencer





V. Result Analysis with Proposed Silencer

The silencer design is success fulas it reduced the overall noise to the lowest level that can be reached within acceptable limits. It is of good quality and does not have any effect on engine performance. The noise or sound attenuation characteristics of the new absorption silencer was measured and also compared with the old silencer and is presented in Table 2. Shao (2011) measured and tested a new muffler and compared it with traditional muffler. The new muffler was designed with a combination of absorbance materials, a perforated pipe, an expansion chamber, a buffle and inter pole ducting [23]. Figure 16 shows the test result.

Table 2 : Sound attenuation characteristic.

SN	DISTANCE FROM SILENCER	PREVIOUS RECORD dBA	AFTER RECORD dBA	GENERATOR OR LOAD	PREVIOUS TEMP *C	AFTER TEMP *C	PRESURE KPA	RPM
01	1 Meter	120 dBA	85 dBA	75 %	82* C	82* C	460	1800
02	2 Meter	109 dBA	80 dBA	75 %	82* C	82* C	460	1800
03	3 Meter	106 dBA	70 dBA	75 %	82* C	82* C	460	1800

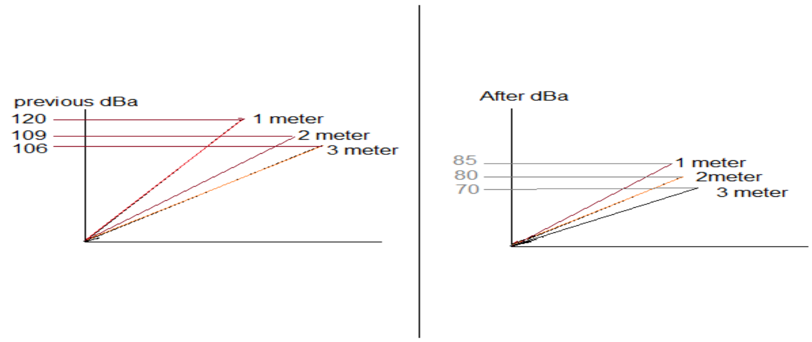


Figure 16 : Sound Test Result.

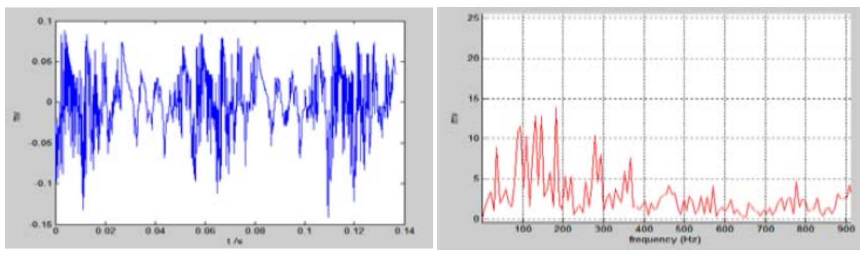


Figure 17 : Time domain chart and spectrum of new absorption silencer

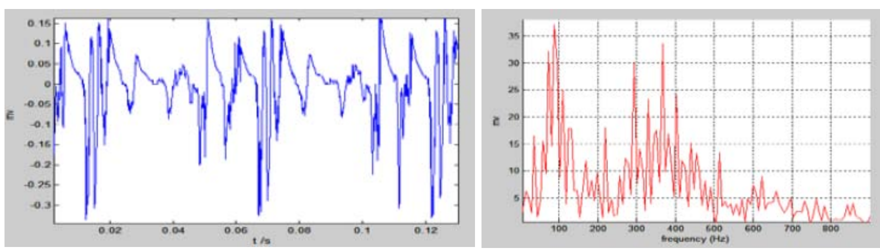


Figure 18 : Time domain chart and spectrum of local or traditional silencer

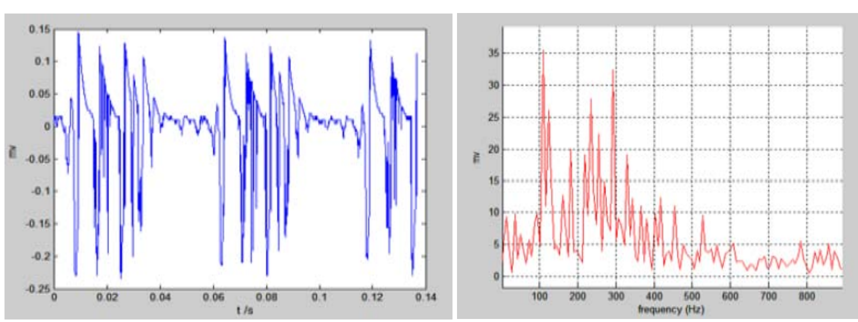


Figure 19 : Time domain chart and spectrum of without silencer

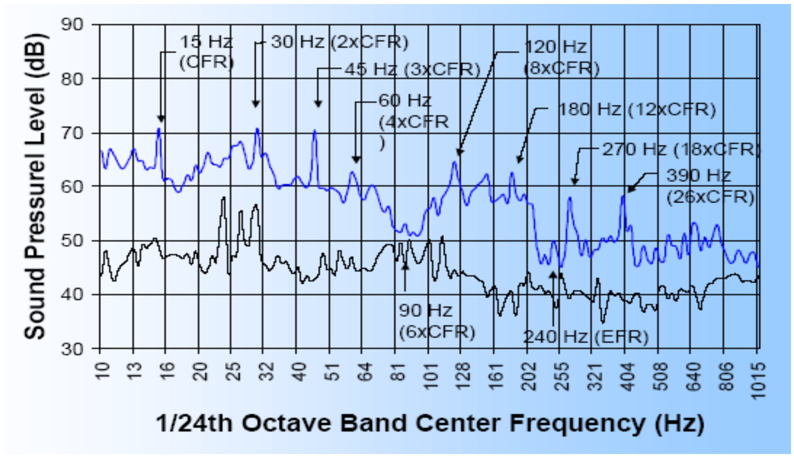


Figure 20 : Sound Pressure Level of CFR & EFR with Proposed silencer

Figure 16 shows that the sound pressure level decreases by approximately 30dB with a modified absorption silencer as compared to a traditional silencer. It also gives a better performance at various distances from the outlet exhaust as compared to other silencers. At 1500 RPM, the modified silencer gives the best result without any change of engine parameters -for example the temperature, pressure and KPA is the same as other traditional silencers. Figures 17 - 19 show the level of sound pressure of an exhaust in three types of silencers.

Table 2 and Figures 17 - 19 illustrate that the modified absorption silencer has better noise reduction properties than other, traditional silencers and mufflers. Figure 20 shows a narrow band spectrum data, collected from a 3m distance from the outlet of an exhaust, used with a proposed silencer. Note the dip in the curve in the vicinity of 80 Hz and 240 Hz. The fact that there is no EFR tone (240 Hz) at all is very impressive.

The main benefit of the modified absorption silencer is the reduction of exhaust noise. However, there are also some other advantages that are highly beneficial, such as: the reduction of noise; possession of a twin wall; the property of being pre-insulated, light and portable; the property of being of a minimal length and weight; possessing an inlet and an outlet that suit modular character; being light weight; having low vibration ability; being easy to build and inexpensive - complex equipment and mounting kits are not needed. In the market, the financial criterion is of crucial importance.[14, 33]. In addition, the modified silencer is easily designed and re-assembled.

Figure 21 : After installation and at running.

VI. Conclusion

The experiment was performed successfully with good conditions. All the spectrums have been observed, in addition to the rules concerning its modification. This paper proposed a practical approach and the importance of a methodology to create a modified exhaust silencer. This design methodology gave a clear basic concept and will help anyone. It saves production time and cost with the easy and simple design. The experiment's conditions and the testing method are correct but the silencer was only tested witha 500KW generator set which ran at 1800RPM. It usually causers duct ion of exhaust gas flow noise.

Further work has to be done to test this absorption silencer with various generator sets such as 1 MW and 2MW engines. Additionally, the inclusion of transmission loss was included by using the TMM. It will developedwith the frequency range in the future in order to give a reliable expected value.

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