EXPERIMENTAL STUDIES ON EFFECT OF NOISE LEVEL CONTROL FOR 7.5 KVA DIESEL GENERATOR SET WITH AN ENCLOSURE

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ABSTRACT

In this paper the effects of noise level control for 7.5 KVA diesel generator set with and without enclosure is discussed. It has been found that the noise level at zero distance with enclosure is 78.6 dB and with the recorded data graphs have been plotted, it shows a noise of 27.4 dB(A) reduction. It is discussed in detail in this paper that constructing a double wall enclosure and if the air-gap is filled with mineral wool, it can give a further 10 dB reduction.

Key Words: Noise control, Decibel meter, Enclosure, Diesel generator, Air gap, Noise pollution.

NOTATION

<table>
<thead>
<tr>
<th>Term</th>
<th>Symbol</th>
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<tbody>
<tr>
<td>Correction factor</td>
<td>$R^2$</td>
</tr>
<tr>
<td>Decibel</td>
<td>Db</td>
</tr>
<tr>
<td>Distance</td>
<td>d</td>
</tr>
<tr>
<td>Speed of sound</td>
<td>c</td>
</tr>
<tr>
<td>Weighted</td>
<td>(A)</td>
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INTRODUCTION

Over the past several years, there has been a significant improvement in the range and variety of materials available to meet acoustic, thermal and other generator–set enclosure design requirements. Many of these new material composites provide significantly more integrated, cost-effective solutions to meet or exceed market requirements for acoustic, thermal, water resistance and durability, among other design factors. Industrialization, together with the needs of our modern society for various machines foe human comfort. The harmful effects of noise are well known. Exposure to high noise levels can cause hearing loss. Noise can also result in other ill effects such as general annoyance, loss of sleep, headache, stress, constriction of blood vessels and deterioration in work performance. Thus it is important to reduce noise levels as much as possible. An enclosure has been designed to control the noise of diesel generator set which can be adopted by the designer at the design stage are described in this article. In many

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situations the methods described can also be adopted at the development stage or even later to control noise levels. Enclosure is a commonly used form of noise control at the work place. It is also possible to incorporate enclosures into the design for machines or their parts. In an enclosure, any pipes from the machine and exhaust fan should not be rigidly attached to the enclosure, but should be supported by vibration isolating hangers. Air gaps need not be minimized. Ducts for fresh air and exhaust gases should be adequately silenced. The insides of the panels of the enclosures are lined with absorbent materials to avoid build up of noise due to reflections. While designing the enclosure, two types of enclosure resonance are taken into account. The first is the mechanical resonance of the enclosure panels and other is the acoustic resonance of the air-space between the enclosed machine and the enclosure walls. The first few panel resonance frequencies of the enclosure should not be in the frequency range in which sound attenuation is desired. If the sound source radiates predominately high frequency noise, then an enclosure with low frequency panel is recommended, implying a massive enclosure.

**Literature Review**

There is huge literature available for noise control related to internal combustion engines. Some of them which are closely related are described here. If the sound radiation is predominantly low frequency in nature, then an enclosure with a high resonance frequency is desirable implying a stiff but not massive enclosure. Inside the enclosure a reverberant sound field is produced in addition to the noise from the source. Also acoustic resonances occur at the standing wave frequency given by:

\[ f = \frac{c}{2d}, \]

where ‘c’ is the speed of sound and ‘d’ is the distance between source and panel. To suppress acoustic resonance, absorbent materials can be used on the inside of the enclosure. Absorbent material reduces the amplitude of the standing waves, and the layer of such material should be about half the thickness of the air space to damp out the resonance considerably. During the course of part six decades, the internal combustion engine has been under ever tighter security, regarding its role as a major source of noise pollution. Noise from internal combustion engine is of special concern to scientist, engineers, and technicians. Industrialization, together with needs of our modern society for various machines and for fast travel internal combustion engine had led to an increase in the levels of noise pollution almost everywhere. The harmful effect of noise are well known. Exposure to high noise levels can cause hearing loss. Noise can also result in other ill effects, such as general annoyance, loss of sleep, headache, stress, constriction of blood vessels and deterioration of work performance. Traffic noise is also the most important environmental noise source in Europe and in rest of the world. 40% of the population in Europe is exposed to transportation noise with an equivalent sound level over 65dB(A). At this sound level sleep is seriously disturbed and most people become annoyed. (Rao ,et al, 1987). In all the transport systems utilizing internal combustion engines, exhaust and intake noise are major contributors to the overall noise pollution and need to be significantly reduced. The Noise from Internal Combustion Engine is produced primarily
from engine intake and exhaust, vibration transmitted to the chassis from the internal combustion engine transmission and differential gears, tire treads, tires thumping against road irregularities and wind turbulence about body protrusions. Intake and exhaust noise are primarily pulsating pressure phenomena associated with the engine rotational speed. At the normal operating speeds of I.C. Engines, effective reactive mufflers can be designed to reduce by substantial amounts of the pulsating pressures causing intake and exhaust noise. (Arcadio, 1996). The paper reports about the different sources of Noise Pollution and its control in Internal Combustion Engine by different noise reducing techniques. Special Emphasis given to I.C. Engine parts and their control of Noise Pollution. Apart from this it has also been discussed about Brake Noise, Engine Accessories Noise, Bearing Noise, Vibration Control, Road Noise, Exhaust Noise and their techniques for control; so that, Environment remain free from Noise Pollution caused by I.C. Engine. Thus it is important to reduce noise levels as much as possible. Various techniques for noise control for I.C. Engine are described in this report, and it is advisable to consider noise control methods at the design stage itself or even later to control noise level.

At present much studies are being conducted in the area of noise pollution control from internal combustion engines as it pollutes the environment much like A.H. Amundsen, R. Klaeboe and A. Fyhri2 studied on Annoyance from vehicular air pollution: Exposure–response relationships for Norway. Gwo-Hshiung Tzeng, Cheng-Wei Lin and Serafim Opricovic3 worked on Multi-criteria analysis of alternative-fuel buses for public transportation. Ronald D. Joslin, Russell H. Thomas and Meelan M. Choudhari4 worked on Synergism of flow and noise control technologies. Giorgio Zamboni, Massimo Capobianco and Enrico Daminelli5 worked on Estimation of road vehicle exhaust emissions from 1992 to 2010 and comparison with air quality measurements in Genoa, Italy. Thilo Bein et al.6 studied on Smart interfaces and semi-active vibration absorber for noise reduction in vehicle structures. It can be seen from the above reviews that many case studies are being conducted in the area of noise pollution control from internal combustion engines in many countries.

A scheme is proposed by Ayoub Kazim7 whereby the United Arab Emirates government can achieve greater economic and environmental benefits associated with the introduction of proton-exchange membrane fuel-cell (PEMFC) vehicles in the transportation sector. he clearly demonstrate the economic and environmental advantages of introducing PEMFC vehicles in the UAE’s transportation sector. The total environmental savings are expected to be around 1.44_109 kg in the 20-year period while, the total economical savings associated with PEMFC vehicles introduction would be approximately $23_108 during the same period. Antonio Borghese and Simona S. Meroli8 worked on detection of extremely fine carbonaceous particles in the exhausts of diesel and spark-ignited internal combustion engines, by means of broad-band extinction and scattering spectroscopy in the ultraviolet band 190–400 nm. This work reports on the detection of organic extremely fine particles in the exhausts of both diesel and spark-ignited engines, by means of broad-band extinction and scattering spectroscopy in the ultraviolet band 190–400 nm. Extinction and
scattering spectral data have led to characterize the scatters in terms of: (1) their complex index of refraction in the ultraviolet band 190–450 nm; (2) their average size, in the order of few nanometers and (3) their volume fraction $f_V$ (hundreds of ppm) in the water-trapped exhausts. Resulting optical gaps are very low ($E_g \approx 0.2$ eV) for air-diluted diesel exhausts, involving the presence of soot, as expected, whereas, in all the other cases explored, $E_g$ spans over values greater than 3 eV, associated with carbon-containing nanoparticles. M.M. Ettefagh proposed method is based on the modeling of the cylinder block vibration signal by auto regressive moving average (ARMA) parametric model. It is observed that one of the estimated moving average parameters is highly sensitive to the knock, so by monitoring this parameter, it is possible to detect the knock in SI engines even in very initial stages. The results also demonstrate that the proposed method is capable of detecting knock by simple hardware with low sampling frequency, leads to reduction the computation time as well as hardware complexity and cost. Moreover, a new method of utilizing the tachometer signal in parallel to the accelerometer one to estimate the knock-sensitive window (KSW) is introduced. M.A. Beeck and Werner Hentschel worked on applications for analyzing the vibration and noise behaviour of brake systems, engines and the whole car body by means of holography, ESPI and scanning vibrometry. These techniques have the advantages of making visible vibrations and structure-born noise of complicated components and coupled systems with highest spatial resolution. Measuring nonintrusively with imaging measurement techniques inside the combustion chamber of modern IC engines has become a requirement in order to understand the complex in-cylinder processes. Time-resolved visualizing of the flow formation and of the spray penetration and evaporation by using PIV, LIF and high-speed "lming helps to optimise the combustion and thus to further reduce fuel consumption and pollution of modern direct-injection gasoline and diesel engines. The principle of using DFWM for quantitative measurement of NO concentrations in a firing engine has been demonstrated by P. Ewart. The variation of combustion generated NO was measured using DFWM as a function of equivalence ratio and ignition timing. Data obtained using DFWM were found to agree with measurements using optical absorption and a conventional exhaust gas analyzer. Crucial to the successful application of DFWM in the harsh environment of an engine test cell was the use of a robust and reliable optical system to produce the correct alignment of the input pump and probe beams. Yu-Jia Zhai and Ding-Li Yu worked on the model predictive control strategy is applied to engine air/fuel ratio control using neural network model. The neural network model uses information from multivariables and considers engine dynamics to do multi-step ahead prediction. an adaptive RBF model-based MPC is applied to AFR control of automotive engines. The simulation results validated that the developed method can control the AFR to track the set-point value under disturbance of changing throttle angle. Ronald D. Joslina and Russell H. Thomsab studied on the synergism of flow and noise control technologies relevant to both air and undersea vehicles. Because many review publications specifically focus on either flow control or noise control, this presentation will not provide an exhaustive literature survey. The interactions between flow and noise control objectives and technologies and their implementation by examining direct and
indirect linkages, counterproductive linkages, and no linkages between noise and flow control technologies. Automobile engine tribology—design considerations for efficiency and durability was studied by C.M. Taylor\textsuperscript{14}. He concluded that the total scope of tribological considerations with regard to the above prospective research themes is immense and the present paper focuses upon the major frictional components of the automobile engine, that is, the bearings, the valve train and the piston assembly. In particular, the current position surrounding the modelling of these components is reviewed and future possibilities identified. The importance of the tribological design of the major frictional components of the automotive internal combustion engine has been emphasised from the point of view of efficiency, durability and emissions. H. Trad, et. al.\textsuperscript{15} worked on a first step for the implementation and the development of a rapid and quantitative measurement technique using the UV broadband-lamp absorption spectroscopy. This technique is applied to detect nitric oxide molecules inside the combustion chamber of a methane-fueled spark-ignition engine. Under certain engine operating conditions, this technique is proved to be able to detect NO molecules in harsh temperature and pressure environment. The continuous and skip-firing operating modes were experimented to investigate the limits of this technique. Fredrik Ostman and Hannu T.Toivonen\textsuperscript{16} worked on a method for reducing the torsional vibration of the crankshaft. This technique balances the cylinder-wise torque contributions by utilizing the measured angular speeds of the crankshaft system. The method relates the lower torque orders to the cylinder-wise torque contribution by means of phase-angle diagrams.

It can be seen from the above literature that still there is a need to carry further research in the direction of air pollution from Internal Combustion Engines. The present work is an attempt to fill the gap.

**Power Generator Noise Sources**

The Noise spectra for power generators varies widely, but the noise sources are typically the same. Those noise sources are engine noise, engine exhaust, turbulent airflow and blade passage associated with cooling fans and alternator noise. The Noise spectrum of each components is dependent on geometry, output power and load conditions.

**Enclosure Design**

There are numerous considerations in enclosure design beyond noise levels, such as air-flow requirements, exhaust requirements, site requirements and weather protection requirements. This discussion will focus on noise control and other design criteria, such as thermal management, that contribute to the relative success of various noise control solutions. When developing a new enclosure design, careful consideration should be given to where the noise will radiate from the enclosure. Typically, it is best to minimize enclosure openings and to incorporate torturous paths where openings can not be avoided. Thus, the typical enclosure design is an optimization of noise control and thermal management. Ideally, it is best to design additional space for noise control materials to be incorporated into the enclosure to preclude any interference with functionality of the power generator. This assists in optimizing the openings in the enclosure to maximize air-flow for thermal management while at the same time minimizing openings for better noise control.
MATERIAL AND METHODS

The first step in developing and effective noise control solution for existing enclosure designs is to identify the dominant noise sources and quantify noise levels and noise spectra by collecting baseline data for the particular power generator. From this information, the noise control solution can be tailored to treat the dominant noise sources and address the significant noise transmission path. Typical test involve sound pressure measurement at eight locations, seven meters from the power generator under full load. Test data is critical for identifying which of the components contribute most to the overall sound level. And overall noise level can be calculated bases on the eight position average of the sound pressure levels measured. Differences in noise measurements gathered at eight test position are also examined to identify and rank problem noise sources. A well-developed test plan and iterative testing is used to quantify the noise attenuation gained by current treatments, if they exist, or to optimize noise solutions. By recognizing the problem noise sources and corresponding spectra, design changes and noise control materials are selected to further optimize the noise control solution. Sound level is measured by Decibel meter and data are analyzed with help of standard methods of curve fitting.

RESULTS AND DISCUSSION

In the heart of the Silchar town, there is a four stroke Diesel Generator Set whose noise in dB (without enclosure) are mentioned in Table 1 recorded as given below, along with graphs. (Fig. 1 and Fig. 2).

Table 1 : Recorded Data (without enclosure)

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Noise in (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>106</td>
</tr>
<tr>
<td>1</td>
<td>95.5</td>
</tr>
<tr>
<td>2</td>
<td>89.1</td>
</tr>
<tr>
<td>3</td>
<td>83.5</td>
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<tr>
<td>4</td>
<td>80.2</td>
</tr>
<tr>
<td>5</td>
<td>75.5</td>
</tr>
<tr>
<td>6</td>
<td>78.7</td>
</tr>
<tr>
<td>7</td>
<td>71.1</td>
</tr>
<tr>
<td>8</td>
<td>68.4</td>
</tr>
</tbody>
</table>

The recorded data shows that noise level at zero distance 106 dB, which is more in tolerable and due to this, the people of that locality lodged a complain to Pollution Control Board Silchar against noise generated by 7.5 KVA Diesel Generator set and afterwords, the Pollution Control Board constructed a single wall enclosure made of plywood with dimensions (2.1 x 1.5 x 1.78) m³ and calculated reverberance time comes out as 0.24 Secs. And the recorded noise level for the same with enclosure are as given below (Table 2) alongwith graph (Fig 3 and Fig. 4).
Table 2: Recorded Data (with enclosure)

<table>
<thead>
<tr>
<th>Distance (m)</th>
<th>Noise in (dB)</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>78.6</td>
</tr>
<tr>
<td>1</td>
<td>75.6</td>
</tr>
<tr>
<td>2</td>
<td>72.8</td>
</tr>
<tr>
<td>3</td>
<td>69.5</td>
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<tr>
<td>4</td>
<td>66.1</td>
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<tr>
<td>5</td>
<td>64.0</td>
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<tr>
<td>6</td>
<td>62.8</td>
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<tr>
<td>7</td>
<td>61.5</td>
</tr>
<tr>
<td>8</td>
<td>59.2</td>
</tr>
</tbody>
</table>

Fig. 1: 7.5 KVA diesel generator set (without enclosure).
Fig. 2: 7.5 KVA diesel generator set (without enclosure).

\[ y = 0.004x^2 - 0.934x + 52.60 \]
\[ R^2 = 0.959 \]

Fig. 3: 7.5 KVA diesel generator set (with enclosure).

\[ y = -0.402x + 31.27 \]
\[ R^2 = 0.975 \]
It has been found that the noise level at zero distance with enclosure is 78.6 dB and with the recorded data graphs have been plotted, it shows a noise of 27.4 dB(A) reduction.

So this reduction keep in mind, if we construct a double wall enclosure (design already given in this paper below and also a 3-D view of the enclosure for 200 KVA Diesel Generator set are also given below) and the air-gap is filled with mineral wool, it clearly shows the superior reduction result, a 10 dB (A) further reduction.

\[ y = 0.010x^2 - 1.818x + 79.62 \]
\[ R^2 = 0.991 \]

**Fig. 4**: 7.5 KVA diesel generator set (with enclosure).

**Fig 5**: Three dimensional view of an enclosure for a diesel generator set of 200 KVA capacity.
CONCLUSION

Proper engineering and design of generator set enclosures and proper application of a variety of well-selected materials is critical to optimizing sound attenuation properties in power generator equipment. New materials can often achieve superior results yet be more cost-effective by decreasing the number of components needed to comply with industry standards and meet market demands for more powerful units with smaller profiles. A polynomial and linearized equations are also discussed to analyze the noise reduction theoretically and it differs only a little from experimental results. The recorded data shows that noise level at zero distance is 106 dB, which is more intolerable and with enclosure the sound level reduces to 78.6.

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