DEVELOPMENT OF A SOUNDPROOF ENCLOSURE FOR A 3KVA GENERATOR

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ABSTRACT

Soundproofing is any means of reducing the sound pressure with respect to a specified sound source and receptor. The use of generators in Nigeria has become rampant, having consequences of excessive noise into the environment, which is unpleasant and hazardous to nearby commercial tenants and residents. This research aims to develop a soundproof enclosure for 3KVA generator system. The enclosure was constructed using mild steel sheet mineral wool, angle iron, plywood and rubber damper. Using attenuation principle, to bring the sound level of the generator to a tolerate limit, sound pressure level of the generator was determined without the enclosure and with the enclosure at various distances ranging from 1 to 7 metres using digital sound pressure level meter. The optimum results were obtained at a distance of 2 metres with 63.2 and 55.8dB sound pressure level without enclosure and when enclosure was used respectively giving a difference of 7.4dB. The use of mineral wool and plywood as insulation absorbers has been proofed to be very effective as they can reduce sound coming from a 3kVA generator.

Keywords: Soundproof, Insulation, Attenuation

1 INTRODUCTION

A well-designed soundproof enclosure is one of the cheapest ways of increasing engine efficiency, quality, effective damping treatment and noise reduction for a generator. The soundproof enclosure of generator is the easiest way of boosting its performance [1]. The purpose of a soundproof enclosure is to obtain both acoustical and thermal insulation to a generator, all materials whether man made, or natural, have a natural mode of vibration known as resonance frequency. Excessive source of noise into the environment can be potentially hazardous, as well as unpleasant to nearby commercial tenant and residents [2]. Generator with proper vibration isolators becomes very critical in dampening the forcing frequency of the engine and isolating it from the rest of the structure. Generator noise comes from cooling fan, exhaust and frame vibration [2]. A well and accurate designed soundproof enclosure can make a generator effective to attenuate the generator noise to sound level at the human being comfortable hearing frequency range. As well as to create well ventilation through channels for air circulation enhance engine performance [3]. The 3000 watt (3KVA) portable petrol generator is featured with four-stroke single cylinder engine with capacity of 15 liters fuel tank with air cooled as the cooling system with a total weight of 48kg. The generator rated frequency is 50Hz also rated voltage of 230V with rotational speed of 3600 (rpm) [3]. The high level of noise that radiates from domestic generators in most part of the neighborhood in Nigeria is becoming very much uncomfortable and constitutes nuisance to public serenity thereby creating noise pollution. The 3KVA-SV5500 generator also have no enclosure for waterproof and weatherproof, thereby only work at limited season. This research is aimed at the development soundproof enclosure and observing its performance. This could be achieved through reducing the sound pressure level (SPL) of the generator to a comfortable noise level. The scope of the study is limited to only 3KVA-SV5500 generator engine, with dimensions of length, width and height (0.715x0.46x0.46 meter) excluding the exhaust manifold, turbocharger /supercharger and exhaust gas recirculation (EGR) devices [4]. The overall design significance is to produce soundproof enclosure construction that will offer good sound reduction of the outcome engine exhaust gases (nitrogen oxide, carbon monoxide etc.) in other to produce outflow of air and increase critical performance as well as considering the weight, cost, materials and temperature. Sound is produced when an object vibrates in open air and the process emits pressure waves into the air. The decibel (dB) scale defines the level of sound and these scales are from 80 to 100 (very loud), 100 to 125 dB (uncomfortable) and 140 dB (threshold of pain). According to [4], noise is an unwanted sound. Absorbing sound spontaneously converts part of the sound energy to a very small amount of heat in the intervening object (the absorbing material), rather than the sound being transmitted or reflected. The Maximum permitted overall noise levels range from 45 dB to 72 dB, depending on location and zoning. Since untreated generator set noise levels can approach 100 dB or more, both the location of the generator set and noise mitigation takes on great importance. Soundproofing is any means of reducing the sound pressure with respect to a specified sound source and receptor. There are several basic approaches to reducing sound which includes: increasing the distance between source and receiver, using noise barriers to reflect or absorb the energy of the sound waves; using damping structures such as sound baffles, or using active anti-noise sound generators [5]. Soundproofing can suppress unwanted indirect sound waves such as reflections that cause echoes and resonances that cause reverberation [6]. According to [7], acoustic quieting, noise mitigation and noise control can be used to limit unwanted noise. Generators produce high level of noise and vibration whether they run continuously in power applications or only occasionally in standby mode. Sources of generator noise include engine noise, Cooling fan noise, alternator noise and induction noise. Others are engine exhaust and structural/mechanical noise [6]. Sound can become painful, uncomfortable or a nuisance when the amplitude of the pressure wave exceeds the threshold level. Ideally, the noise should not exceed 60dB at 3 meters. Ambient sound levels exceeding 60-70 dB can be regarded as noise pollution, which leads to significant health problems such as depression and most commonly, loss of hearing [8]. [9], presented a model for computing coupling loss factor in the prediction of sound transmission through lightweight double walls, in which Sound attenuation was needed to meet local noise ordinances or reduce impact on employees or neighbors. From the review so far, the use of mineral wool, plywood and rubber for insulating 3KVA generator enclosure has not been fully explored.

2 METHODOLOGY

The materials used are: Mineral wool, Rubber damper, Mild steel sheet, Plywood, 1 1/2 Square pipe, Consumable electrode, Gauge 12 Arc welding electrode, Filler metal, Angle iron 1 1/2*2mm, Hinchey, Aluminum paint, Cutting and filling files. The equipment used for the construction are: Consumable arc welding machine, Sprayer machine air-Ga F75, Angle grander, Hand saw, Hammer, Chisel, and G-clam. According to [1], the enclosure diameter is calculated as using the relation.

$$C = 1\text{-}10\left(\frac{-dB}{20}\right)\left(\frac{-dB}{20}\right) \tag{1}$$

$$Qc = \dot{m}\,\dot{m} \text{ x } C = pv \text{ x } Cv \tag{2}$$

Where dB = Decibel, C = Coefficient of sound reduction (dB), QC= Heat released from combustion (W), m = Mass flow rate of fuel (Kg/m^3), ρ = Density of fuel (Kg/m^3), Cv = Calorific value of fuel (KJ/Kg), QL = Heat loss to exhaust (W), QA = Energy available in generator (W), Qe = the heat generated in the soundproof enclosure (W), Vf = Volumetric flow rate of air (m^3/s), ρa = Density of air, Cp

= Specific heat capacity of air at constant pressure. ΔT = Temperature difference between ambient air and air in the enclosure.

$$VF = \frac{\dot{m}}{\rho a} = \frac{Qe}{Cp\Delta T\rho a} \quad (3)$$

Noise control at its transmission path is accomplished through the installation of acoustic barriers and the use of insulation the inside of the enclosure was lined with a 15 mm thick mineral wool (sound absorber) and padded with 5 mm thick plywood. A flexible pipe is connected to the generator exhaust pipe to dissipate the exhaust gas into the atmosphere. Figure 1 shows the cost of materials purchased. The fabrication of the soundproof enclosure measuring 0.9 m x 0.78 m x 0.72 m was done using mild steel sheet of 2 mm thickness and this was carried out at the Faculty of engineering workshop university of Maiduguri Borno state. The inside of the enclosure was lined with a 15 mm thick mineral wool (sound absorber) and padded with 5 mm thick plywood. Selection of all the materials is based on some parameters which include weight, property and cost. A flexible pipe was connected to the generator exhaust pipe to dissipate the exhaust gas into the atmosphere. An induction fan was installed to extract heat from the enclosure and dispel to the surrounding. The transportation cost is 10% of the total material cost.

Table 1. Bill of Engineering Measurement and Evaluation

S/N	Materials	Description	Prices (₦)
1	Square pipe	1½ fine black	3,500
2	Angle iron	1½ x 2mm	3,500
3	Plywood	½	10,000
4	Mild steel Sheet metal		12,000
5	Rubber damper		2,000
6	Hinges		400
7	Aluminum paint		3,000
8	Consumable Electrode	Gauge 12	2,000
9	Mineral wool		2,000
10	Cutting and filling disc		2,500
	Total		40,900

2.2 Analysis of Sound Frequency

Sound wave frequencies can be measured with a frequency counter or with a spectrum analyzer. These devices work by using a microphone to convert the sound wave into an electrical signal. The peaks and valleys of wave are counted to find the frequency. There are inexpensive smartphone apps designed for measuring sound frequencies. There are three types of audio analyzers: analog, digital, and converter-based. The difference between the analog and digital audio analyzers is the hardware they use. (a) Microphones, (b) Sound level meters, (c) Frequency analyzers, (d) Noise dosimeters, € Recorders. Figure 1 present the isometric drawing of the enclosure in 3D form.

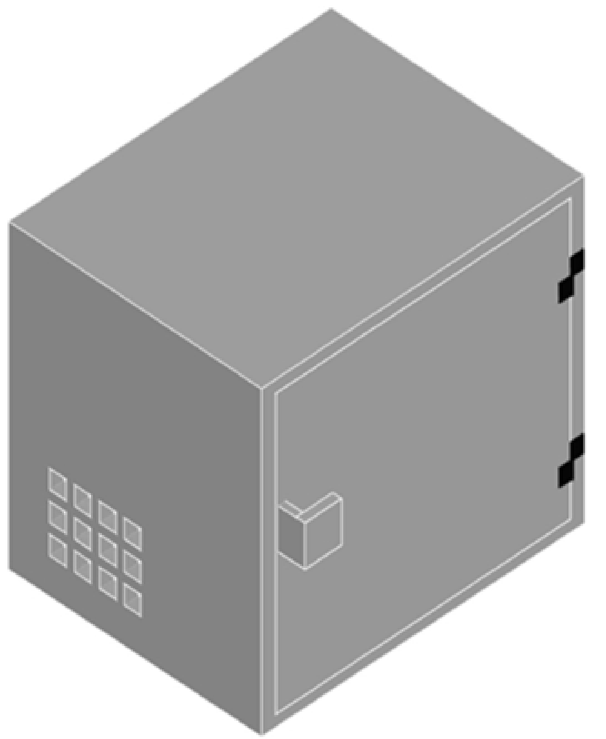

Figure 1. 3D Isometric Generator Enclosure

2.3 Test Procedure

A 3 kVA Elepaq generator was operated and placed inside the sound proof enclosure and allowed to run for 25 minutes in order to assess the performance of the enclosure. A sound level meter with a measurement range of 30 to 130 dB was used to measure the sound pressure level at various distances which were recorded in Table 2. Using the constructed sound proof enclosure and the digital sound level meter, however when the generator was placed inside the sound proof enclosure, the following result were obtained. At ambient temperature of 37°C and air temperature inside the enclosure was 65° C.

3 RESULTS AND DISCUSSION

The variation of sound pressure level of the generator run in an open environment and in the soundproof device with the distance of measurement from the generator is shown in Table 2. It can be seen from figure 1, that the sound pressure level decreases as the distance from the generator increases for both running the generator in an open environment and in the soundproof device. The values of the sound level pressure of the generator range between 65.0 and 56.7dB as the measured distances range between 1.0 and 7.0m, when it was run in open environment. Exposure to this range of sound pressure level could be classified as high risk as defined by [10]. There are reductions in sound pressure level measured for the generator run in the soundproof device at distances of 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, and 7.0m by 7.9, 7.4, 8.9, 9.0, 9.3, 9.4 and 9.7dB respectively. This trend of reduction of sound pressure level is similar to the trend observed by [11]. Where the reduction in sound increases with increase in distance. It was observed that the noise level from the generator was very high when placed in an open environment reading as high as 65.0dB at a distance of 1.0 m. which in most cases are the distances generator sets are placed from residential buildings. This result agrees with some of the findings reported by some acoustic researchers such as [12].

Table 2. Measurement of Sound Pressure Level

S/N	Distance (m)	without enclosure (dB)	With enclosure (dB)	Reduction in sound (dB)
1	1.0	65.0	57.1	7.9
2	2.0	63.2	55.8	7.4
3	3.0	61.9	53.0	8.9
4	4.0	60.2	51.2	9.0
5	5.0	59.3	50.0	9.3
6	6.0	57.8	48.4	9.4
7	7.0	56.7	47.0	9.8

The variation of sound pressure level after computing is presented in the Figure 2.

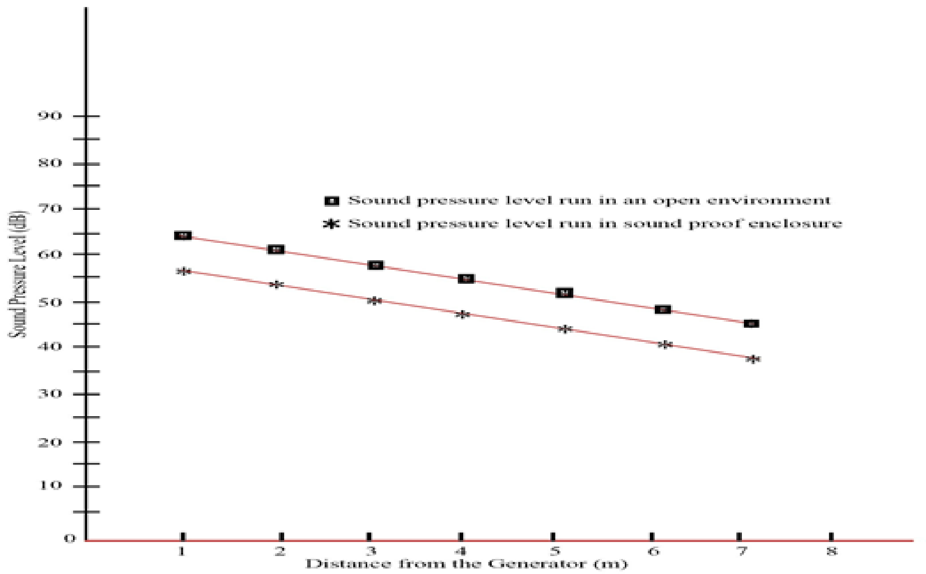

Figure 2. The variation of sound pressure level

4 CONCLUSIONS

The use of portable generator is unavoidable as it is the readily available, affordable and alternative energy source for developing economies like Nigeria. However, the noise pollution from these generators, which are detrimental to our health, can be mitigated to a reasonable extent by the use of the developed soundproof device, which is simple in production. The soundproof device showed reduction in sound pressure level of the 3kva generator by 7.9, 7.4, 8.9, 9.0, 9.3, 9.4 and 9.7dB at distances of 1.0, 2.0, 3.0, 4.0, 5.0, 6.0, and 7.0m from the generator respectively. The use of mineral wool and plywood as insulation absorbers has been proofed to be very effective as they can reduce sound coming from a 3kVA generator. Which moderate noise level at that distance. Hence reducing the noise pollution generated in many neighborhoods and eliminating earing health hazard.

REFERENCES

1. Amos, A.E., Olisa, Y.P. and Kotingo, K. (2018). Design and Performance Evaluation of a Sound Proof Enclosure for a 2.5Kva generator. *Journal of Applied Science and Environmental Management*, vol. 22, no.12, pp. 1975-1978.

2. Onawumi, A.S., Okoli, S., Mfon, U. and Raheem, W. (2018). Noise level investigation and control of household electric power generator, *Covenant Journal of Engineering Technology*, vol. 2, no. 1, pp. 69-78.

3. Pandey, K., Deb, K. and Kumar, U. (2009). Experimental studies on effect of noise level control for 7.5 kva diesel generator set with an enclosure. *Journal of Environmental Research and Development*, vol. 4, no. 2, pp. 506-516.

4. Chandrashekara, K., Yogish, H., Srinidhi, R., Harsha, B.P. and Sharma, P.R. (2014). A Comparative Study of Sound Pressure Level (SPL) Generated in CI DI Diesel Engine Run on Petro diesel and Biodiesel Blends. *International Journal of Thermal Technologies*, vol. 4, no. 3, pp. 208-213.

5. Fahy, F. (2001). Foundations of Engineering Acoustics. Text Book of Engineering Acoustic. *Institute of Sound and Vibration Research, University of Southampton, Southampton UK. Printed and bound in Great Britain, Cornwall, UK. Academic Press, London*, pp. 250-270.

6. Zahra, G., Hassan-Beygi, S.R. and Barat, G. (2016). Noise reduction of a portable gas generator set using an acoustic enclosure. *AgricEngInt: CIGR Journal Open access*, vol. 18, no. 3, pp. 159-170.

7. Xiaoning, T. and Xiong, Y. (2020). Airflow Resistance of Acoustical Fibrous Materials: Measurements, Calculations and Applications. *Journal of Industrial Textiles*, vol. 49, no. 8, pp. 981-1010.

8. Angaw, Y., Kumie, A., Tefera, Y., Wakuma, S., Nega, A., Degefa, H.D., Mehari, M., Alemseged, E.A., Hailay, A., Gebremeskel, F., Mamo, H., Belay, H., Berwo, M.M. and Teame, H. (2021). Temporary Hearing Loss and Associated Factors among Ayka Addis Textile Factory Workers in Oromia Region, Ethiopia: A Cross-Sectional Study. *Open Access Peer Reviewed Scientific and Medical Journals*, vol. 14, pp. 719-728.

9. Gupta, P. and Anand, P. (2022). Prediction of Sound Transmission Loss of Cylindrical Acoustic Enclosure using Statistical Energy Analysis and Its Experimental Validation. *Journal of the Acoustic Society of America*, vol. 151, no. 1, pp. 544-560.

10. Yesuf, A.L., Ana, G.R., Yawei, Z. and Umar, O.Z. (2013). Work on environment noise levels and risk locations in two selected commercial areas in Ibadan, Nigeria. *Global Journal of Medical Research Interdisciplinary*. vol. 13, no. 6, pp. 25-34.

11. Hammad, U., Aizaz, A. and Khan, A. (2013). Design and Development of Noise Suppression System for Domestic Generators. *European Scientific Journal, National University of Science and Technology, Islamabad, Pakistan, Special Edition*, vol. 4, pp. 526-533.

12. Kuku, R.O., Raji, N.A. and Bello, T. (2012). Development and Performance Evaluation of Sound proof Enclosure for Portable Generators. *Research Journal of Applied Sciences, Engineering and Technology*, vol. 16, no. 4, pp. 2600-2603.