International Scholars Journals

African Journal of Physics Vol. 3 (3), pp. 049-058, March, 2016. Available online at www.internationalscholarsjournals.org © International Scholars Journals

Full Length Research Paper

Exhaust system performance optimization of the domestic electric generating plant

***Ohwovoriole C. Henry, Walter O. I and Okpara H. M**

Department of Mechanical Engineering, School of Engineering and Engineering Technology, Federal University of Technology Akure, Ondo State, Nigeria.

Accepted 22 April, 2015

Sound is a common part of everyday life, but when a sound is unwanted, it is considered noise. When noise in a room is at unacceptable levels, it can be an annoyance, distracting the occupants and in industry, it results in higher stress levels and decreased productivity. In this study, an exhaust/silencer system, that is capable of reducing exhaust noise, was fabricated for use in a domestic generator. Experiment was carried out with the factory fitted silencer and the fabricated silencer. The fabricated exhaust system was able to reduce noise of 8.06% compared to 4.16% obtained with the factory fitted silencer. Also, the fuel consumption rate of the generator is lower when the fabricated exhaust system is used. This showed that (in the long-run) the new exhaust system would efficiently serve as alternative to the old system.

Key words: Noise, generator, exhaust systems, fuel consumption, efficiency.

INTRODUCTION

Noise is an unwanted sound at amplitude which causes annoyance or interferes with communication. Noise has been known as menace that can cause a several serious health effect (Abraham, 2003). Noise can cause physical problem such as permanent hearing loss and also psychological problem like stress. Environmental noise is unpleasant or unwanted outdoor sound that disrupts the human life activity and it is mostly generated by traffic, industry and generators. It has also been recognized that, despite significant reduction in the noise produced by individual source, total exposure to environmental noise has not changed significantly. Most people are affected by noise exposure more than any other environmental stimulus. The most widespread problem created by noise is nuisance.

Portable generators are commonly used in industry, shops, offices and homes today in order to supply and maintain power during power shutdowns or in an emergency power outage. This has however, made generator a major contributor of environmental noise. These generators emitted very high levels of noise, in addition to noxious air emissions. The noise maybe generated by aerodynamic effects or due to forces that result from combustion process or may result from mechanical excitation of rotating or reciprocating engine components (Hultgren, 2011). Environmental noise which results from the use of generator has affected mankind in many ways like hearing loss, cardiovascular effect, annoyance and quality of life, and sleep disturbance (Abraham, 2003).

It is obviously most desirable to reduce the noise produced by the generator. If the source is given, the options for noise control, in an application such as under consideration here, can be broadly divided into two categories, namely passive absorbing and attenuating

*Corresponding author. E-mail: ohwo.henry12@hotmail.com

enclosures to reduce the noise radiated into the environment.

Passive control

This can include a range of measures taken to reduce the transmission and radiation of noise. These include, passive mufflers for the intake and exhaust, vibration-isolating mounts for the engine, dampening of surfaces subject to vibration such as oil pan covers and finally enclosures that cover the engine generator set partially or completely.

Mufflers and silencers for reducing the inlet and exhaust noise have been practical for a long time. Typically over 20 decibel reductions in the sound pressure levels can be achieved with well designed silencers. A drawback in their use is the additional pressure drop that occurs and attempts to reduce this are constantly being made. Alternative design given by a respondent to the market survey is described below and the use of an active noise control system is another approach. Challen (1999) indicates some of the methods used to reduce the noise radiated by the vibration of various covers in the engine. Tree and Thien (2000) indicated some of the steps involved in the design and construction of enclosures. They also stress the importance of sealing of even small holes such as are needed to connect services to the engine and of preventing the enclosure from reverberating. The publication of Tandon et al. (2001) is an excellent documentation of the detailed approach to noise reduction of a portable gasoline engine generator set of 800 watts capacity. The noise sources in the engine were identified and the passive control measures taken, including a partial enclosure, helped to achieve a maximum noise reduction of about 8.5%.

Active control

The prospect of active control and cancellation of noise has interested scientists and engineers since its original conception and patenting by Lueg (1998). His basic idea was to superimpose a secondary acoustic wave to interact destructively with the primary noise and lead to lower sound pressure levels. This idea had to wait another fifty years for the advent of fast digital signal processing before becoming practical. This is because even the simple active control consisting of a microphone, the electronics and a loudspeaker requires adaptive control to compensate for slowly changing conditions. Adaptive control offers self-optimizing and tracking capabilities. Today, active noise cancellation technology can be categorized as either active noise control or as active vibration control. The former category describes a system that uses a secondary sound source to interfere destructively with unwanted sound from the primary source. The latter category describes a control system that uses secondary (control) vibrations to interfere destructively with the unwanted vibrations that are the sources of the noise. From a practical point of view, the generation of a stable destructive interference pattern is possible only at low frequencies of 500 Hertz or less and with slowly changing conditions. This restriction necessitates the combining of active control measures with passive control for broad band noise control. Application of active control can reduce the noise levels in the far field, which is typically beyond ten or more wavelengths from the source.

A diesel engine produces a fairly wide bandwidth noise and would make a case for over an active control. A variable speed engine compound this problem by fast changes in this radiated noise in amplitude and spectral distribution and would make it even more difficult.

The magnitude of the exhaust scavenging effect is a direct function of the velocity of the high and medium pressure components of the exhaust pulse. Performance headers work to increase the exhaust velocity as much as possible. One technique is tuned-length primary tubes (Kristna, 1999). This technique attempts to time the occurrence of each exhaust pulse, to occur one after the other in succession while still in the exhaust system. The lower pressure tail of an exhaust pulse then serves to create a greater pressure difference between the high pressure head of the next exhaust pulse, thus increasing the velocity of that exhaust pulse. In V6 and V8 engines where there is more than one exhaust bank, 'Y-pipes' and 'X- pipes' work on the same principle of using the low pressure component of an exhaust pulse to increase the velocity of the next exhaust pulse. Great care must be used when selecting the length and diameter of the primary tubes (Wegrzyn, 2003). Tubes that are too large will cause the exhaust gas to expand and slow down, decreasing the scavenging effect. Tubes that are too small will create exhaust flow resistance which the engine must work to expel the exhaust gas from the chamber, reducing power and leaving exhaust in the chamber to dilute the incoming intake charge. Since engines produce more exhaust gas at higher speeds, the headers are tuned to a particular engine speed range according to the intended application. Typically, wide primary tubes offer the best gains at lower speeds.

Many strategies have been adopted for reducing generator set noise. Some of these are summarised as thus;

Acoustic barriers

Rigid materials with significant mass and stiffness was used to reduce the transmission of sound from generator. Examples include sheet steel typical of enclosures and concrete- or sand-filled block walls or solid concrete walls typical of indoor generator room installations (Crocker, 1994).

Acoustic insulation

Sound-absorbing materials were used for lining air ducts and covering walls and ceilings. Directing noise at a wall covered in sound absorbing material was also very effective materials that are resistant to oil and other engine contaminants were selected. Fibreglass or foam was also suitable based on factors such as cost, availability, density, flame retardance, resistance to abrasion, aesthetics and clean-ability (Fahy, 1989).

Isolation mounts

Vibrating equipment creates sound pressure waves (noise) in the surrounding air. Anything that is physically connected to a generator set can cause vibrations to be transmitted to the building structure. In view of this, connection points include skid anchors, radiator discharge air ducts, exhaust piping, coolant piping, fuel lines and wiring conduit and fitting these connections with flexible joints effectively were used to reduce noise transmission. Mounting a generator set on spring type vibration isolators effectively also reduces the vibration and noise that were transmitted through the floor (Jacobi, 1999).

Cooling air attenuation

Inlet and outlet air attenuation baffles were used to reduce the noise produced by the cooling air as it moves across the engine and through the radiator. Noise from the movement of cooling air is significant because of the volume required – about 20 m^3/s for a generator set with a 50 L diesel engine. Alternatively, the radiator was remotely located to a roof, for example, to eliminate this noise source or direct it up and away from people or the property line. Also, air was made to travel through a 90° bend in a duct to reduced high-frequency noise (Mamod, 1986).

Maximizing distance

When there are no reflecting walls to magnify the noise produced by the generator set, the noise level will decrease by approximately 6 dBA every time the distance is doubled. If the property line is within the near field of a generator set, however, the noise level may not be predictable. A near-field environment is any location within twice the largest dimension of the noise source (generator set manual).

Isolating internal sources

The reason for excess noise can be due to specific parts of the generator. To reduce the sound it makes, major sources were isolated, such as the fuel tank and exhaust outlet, from the enclosure. Instead, fuel tank was mounted remotely in a shady location with good ventilation. It was mounted and reduced higher than the engine and reconnected (Fishly, 2000).

Muffling the sounds with water

A simple and effective way to lessen the sound in a hurry was used by connecting the generator exhaust pipe to a tank filled with water. This muffled the noise it made – much like air radiators in an aquarium. The water itself was discoloured quickly, but lasted a number of days before it evaporated. The heat the generator produced was responsible for this and the process was repeated (Ayum, 2001).

Levelling the generator

If the generator is not on a level surface, it will be creating a lot more noise and vibrating sounds. To combat this, the generator was kept on a flat level surface. Using the levelling feet, the portable generator was stabilized to the desired position and the noise level was reduced considerably by keeping the generator raised (Moses et al., 2002).

Oke and Kareem (2012) evaluated the effects of leaked exhaust system on the noise and fuel consumption of the automobile engines. Effort at developing a silencer which will serve as alternative to factory fitted silencers in terms of noise reduction and fuel economy is pertinent in reducing environmental pollution. In this study a silencer was developed, tested and evaluated for noise level and fuel consumption economy.

MATERIALS AND METHODS

Manufacturer's specifications of the factory fitted silence were initially investigated to determine how best an alternative silence of high performance can be fabricated. Procedures of enhancing noise free industrial environment were also studied. These include fitting the engines with a suitable muffler (silencer) in good condition in order to: sustain effective silencer on the air exhaust port; install less noisy movement/reversing warning systems for equipment and vehicles that will operate for extended periods, during sensitive times; sustain occupational health and safety requirements; and maintain vibration-isolating mounts for the engine.

Previous muffler designs for engines (Oke and Kareem,

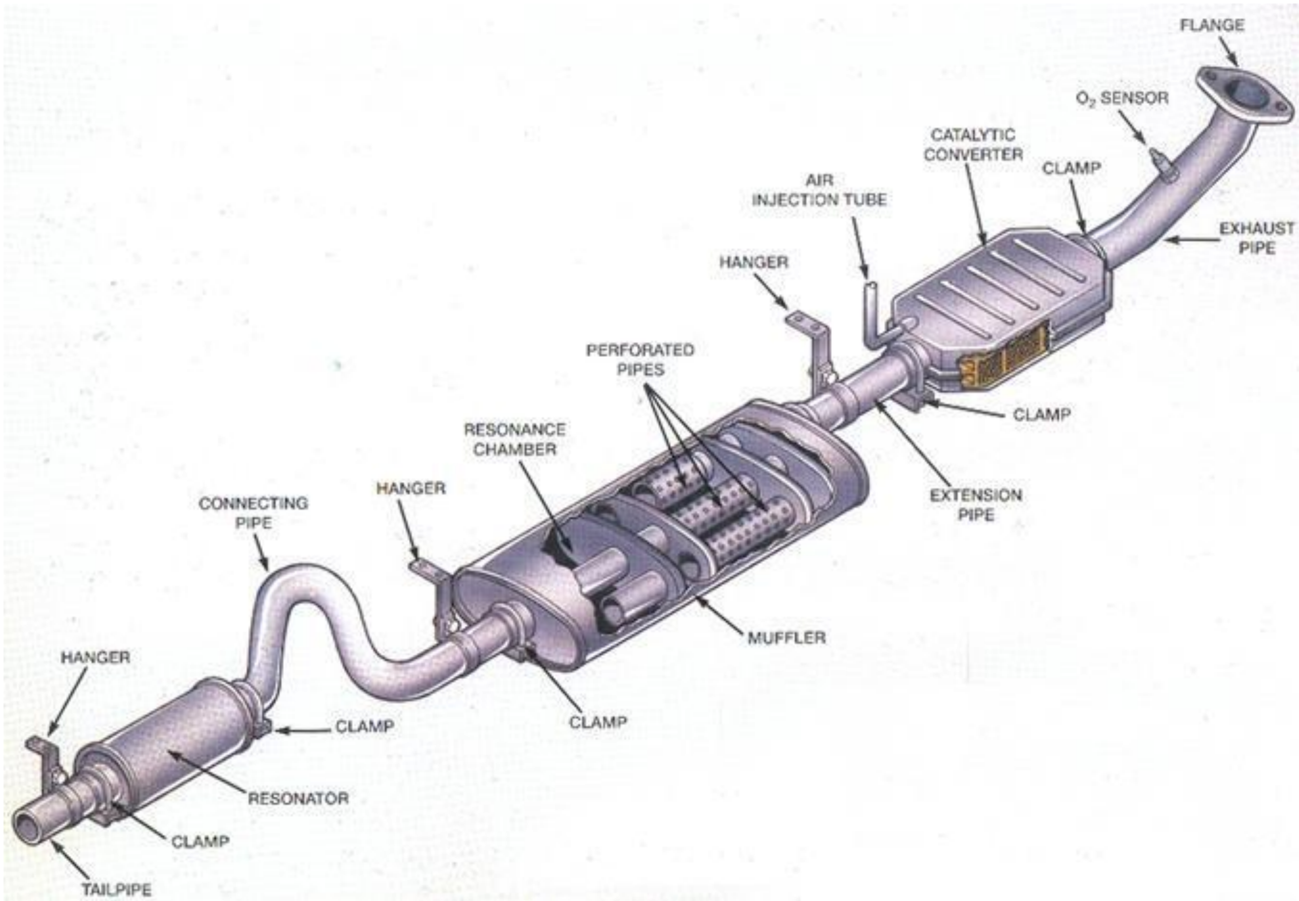

Figure 1. Major components of the factory fitted exhaust system.

2012) are capable of achieving over 20 decibel reductions in the sound pressure levels if well redesigned to overcome the problem of additional pressure drop that occurs in them while on active service. The major components of the existing factory fitted silencers are assessed. They are described as follows (Oke and Kareem, 2012):

- Exhaust muffler; mufflers are installed to increase airflow out the engine by dissipating exhaust gases. They are also used to suppress the exhaust noise by decreasing sound levels emitted by the engine. A straight muffler increases maximum airflow of exhaust by allowing gases to pass through the muffler and out the tail pipe quickly. A muffler that is curved restricts exhaust airflow, but it can produce a sportier "roaring" sound.

- Exhaust manifold; the exhaust manifold is bolted to the engine's cylinder head. It can be of a one piece or two pieces construction, in performance type vehicles, the exhaust manifold is often replaced with extractors and it helps to move spent combustion gases from the engines exhaust ports to a central collection point, from there the gases go through the cars emissions system, mufflers and out the tails pipe.

- Tail pipe; the tail pipe takes the exhaust gases away from the vehicle. It exit point must not allow any of the exhaust gases to enter the vehicle.

- Resonator; the resonator is located between the muffler and the exhaust outlets. Its function is to reduce any resonance levels that the muffler could not adequately suppress.

- Catalytic converter; the catalytic converter is attached to the engine pipe, between the engine and the muffler. It helps to convert the harmful by- product of combustion to relatively harmless gases.

- Exhaust bracket; the exhaust bracket are supported along the length of the vehicle by brackets suspended from the under-body. These are usually rubber- mounted supports that helps isolate the vibrations of the exhaust from the main body of the vehicle; rubber is preferred because of its natural dampening effect.

- Engine pipe; the engine pipe is attached to the exhaust manifold, it takes the gases away through the catalytic converter, then through the muffler system to the outside environment. Figure 1 shows a factory fitted silencer (exhaust system) commonly used in engines/automotives and plants including electric generating plants.

In order to solve the problem of occasional pressure drop in the previous factory fitted silencer that leads to high noise, alternative silencer was fabricated with a careful choice of relevant and available materials based on resulted design parameters.

Materials

The fabricated exhaust system needs a material that has good mechanical abilities for high durability, must not be too expensive and must be repairable and serviceable. The materials suitable are mild steel and aluminium but aluminium has a lower volume weight ratio, it is cheaper and it has high anti-corroding ability but mild steel was still considered a better choice for this project because of the ability to withstand heat and they are stronger than aluminium. Sanitary problems can arise with the use of aluminium due to improper handling during fabrication. Aluminium has a relatively low surface hardness, and therefore is susceptible to scratching.

Design

After an exhaustive study and analysis of the generator's factory fitted silencer, it was observed that, although the generator's internal combustion engine accounts for some of the noise, most of which comes from pressure waves generated by the rapid opening and closing of the engine's valves. The silencer's backbox is internally designed to receive the pressure waves and bounce them around inside carefully designed chambers and cylinders. The shape and length of these baffles creates pressure waves of a roughly equal nature moving in opposite directions. When they collide with one another, the waves of equal but opposite amplitude cancel each other out. One drawback of this design is that it causes backpressure, which reduces performance (Tong and Cheung, 2005).

In compensating for this backpressure, in the design of the fabricated silencer, the nominal diameter of the exhaust tubing and piping were made little higher than that of the engine exhaust outlet. Another modification is that the exhaust tubing and piping were made reasonably longer than the factory fitted silencer. Also, an exhaust net is incorporated to help filter the emitted gases before it is passed out through the tail pipe.

The fabricated exhaust has different chambers, one is the catalytic converter, which will be attached to the engine pipe, between the engine and the muffler, its function is to convert any harmful by-products of combustion to relatively harmless gases, which helps to reduce the emission of carbon mono-oxide to the atmosphere. Another chamber is the exhaust port, which comprises the muffler, resonator and the exhaust net. The muffler reduces noise that comes out of the engine. In order to determine the correct size of exhaust system, there is need for data collection on the host- generator's engine (Figure 2b). These data are presented as in the following section:

Design calculations

Specifications of the generator engine:

Indicated Power, I_p = 950 W
Engine Speed, N = 1500 rpm
Engine Type, two stroke engine
Number of cylinders, k = 1
Diameter of Exhaust, d = 14 mm = 0.014 m
Frequency of the engine = 50Hz
Engine Configurations;
Cylinder Bore, D = 38 mm = 0.038 m
Piston Stroke, L = 68 mm = 0.068 m

Calculations of design parameters

Working Volume, V $= \frac{\ \ ^2}{4} = 7.71 \times 10^{-5}\ m^3$

Since the nominal diameters of the exhaust tubing and piping were to be made a little higher than that of the engine exhaust outlet (as stated above), then it necessary to calculate the area of the exhaust exit in order to determine the appropriate area of the exhaust tubing and piping of the fabricated silencer.

Area of the exhaust exit = $\frac{\ \ ^2}{4}$ (where d is the exhaust diameter) $= 1.54 \times 10^{-4}\ m^3$

Also, in order to determine the length of the fabricated silencer (which is reasonably longer than that of the factory fitted silencer), the length of the exhaust pipe, before the connection of the muffler, is required. This was determined from the relation (Prasad, 1980): Length of the fabricated silencer = 2.52 × length of the exhaust before connecting muffler. The fabricated exhaust system is shown in Figure 2a.

Testing the system

Testing conditions include:

- The experiment was conducted in an open, quiet and isolated environment. The ambient noise level of the environment was taken (and recorded) with the aid of the sound meter before the start of the experiment.
- Experiments were carried out with the two silencers

Figure 2a. Fabricated exhaust system.

Figure 2b. Testing of the fabricated exhausts system attached to a generator set.

(the factory fitted and the fabricated) consecutively using the same generation and environment.

• The fuel tank of the generator was disassembled. Fuel is supplied to the generator by a mean of hose and burette connection (Figure 3), while the generator is run under no-load condition.

• The generator was test run three times for 5 min and it was ensured that fuel in the burette is completely drained. For the main experiment, fuel is poured into a beaker to a certain volume (which is noted). The fuel is supplied from

Figure 3. The hose and burette connection.

Table 1. Experimental results using the factory fitted silencer.

Test No	Fuel Consumption [redacted], x1	Max. Noise level (dBA)	Min Noise level (dBA)	Av. Noise level [redacted], n1	% Noise level reduction
1	73	105.9	101.2	103.55	4.44
2	71	104.8	100.9	102.85	3.72
3	68	105.6	101.8	103.70	3.60
4	71	105.8	102.0	103.90	3.59
5	72	106.9	101.1	104.00	5.43
				Mean	4.16

the beaker to the burette and from the burette to the generator. With this, the volume of fuel consumed at each run of experiment was determined.

- Five runs of experiment (with each silencer) were carried out and data on noise level and fuel consumption were recorded at 5 min interval.
- Before the commencement of each run of experiment, the generator was test-run until it went off so as to ensure that the fuel in the engine carburetor has been completely drained. This was done to obtain the actual fuel consumption during the experiment.
- During each run of experiment, noise meter is used to measure both the minimum and the maximum noise levels, out of the five noise levels obtained from each run of the experiments.

RESULTS

The results presented in Table 1 were obtained for noise level and fuel consumption during the experiments using the factory fitted silencer.

Percentage of sound/noise reduction by the generators exhaust for each of the readings is calculated as:

$$\frac{\max - \min}{\max} \times \frac{100}{1}$$

The average noise reduction ratio of the generator when the factory fitted silencer is used is estimated as mean of % noise level reduction.

The results obtained for the five tests carried out when

Table 2. Experimental results using the fabricated silencer.

Test No	Fuel Consumption [redacted], x2	Max. Noise level (dBA)	Min Noise level (dBA)	Av. Noise level [redacted], n2	% Noise level reduction
1	55	87.9	76.7	82.3	12.74
2	54	89.6	83.7	86.65	6.58
3	56	92.7	85.6	89.15	7.66
4	56	91.3	88.6	89.95	2.96
5	55	97.4	87.3	92.35	10.37
				Mean	8.06

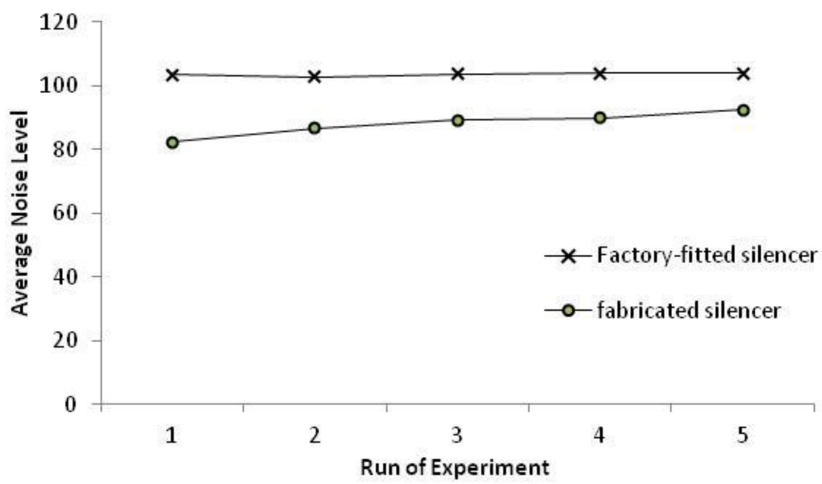

Figure 4. Noise level performance of the silencers.

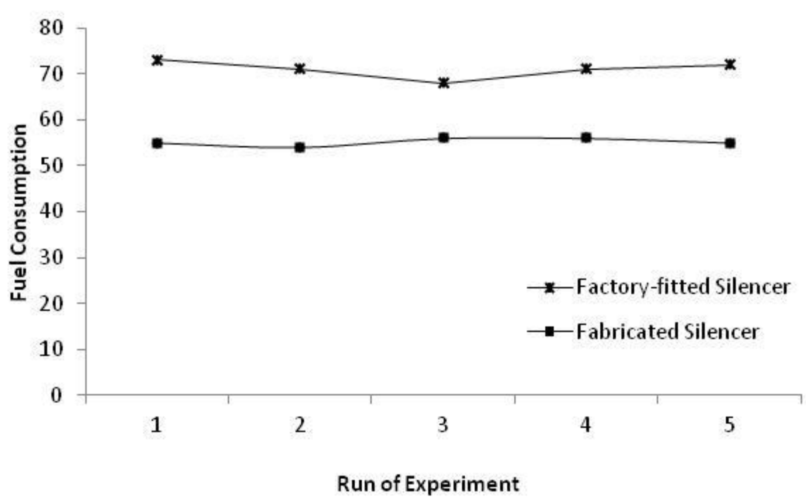

Figure 5. Fuel consumption performance of the silencers.

the fabricated silencer was used are given in Table 2. Percentage of sound reduction ratio by the fabricated exhaust and the mean percentage noise level were obtained using similar methods.

The performances (based on noise level and fuel consumption) between the two experiments using factory fitted and fabricated silencers are shown by Figures 4 and 5, respectively.

DISCUSSION

From the results presented in Tables 1 and 2, respectively for the factory fitted silencer and the locally fabricated system it can be observed that quantities of fuel consumption using the latter (ranging from 55 - 56 cm^3) was lower than the former (ranging from 68 - 73 cm^3). This was similar to the results of range of noise obtained from both systems (that is, 82.3 - 92.35 dBA against 102.85 - 104.00 dBA). Mean noise levels indicated clearly the superiority of fabricated (new) exhaust system (with mean maximum noise level, 92.35 dBA) to the factory fitted system (104.00 dBA). This outcome was further buttressed by the percentage performance index from which the fabricated exhaust system was able to reduce noise by 8.06% compared to the 4.16% obtained with the factory fitted silencer. This is about 50% increase in performance over the factory fitted system. However, Paired T-Test statistical results indicated that (at 95% confidence interval of the difference) there is no significant difference between the outputs of the factory fitted and fabricated silencers (Appendix 1 and 2). The implication of these statistical results showed that the differences reflected in Figures 4 and 5 in noise level and fuel consumption between the two silencers- factory fitted and fabricated, are minor within the span of the experiments. Therefore, the trend of the performance under long-run of the experiments may require further investigation.

CONCLUSION

Most people are affected by noise exposure more than any other environmental stimulus. The most widespread problem created by noise is nuisance. Portable generators are commonly used in industry, shops, offices and homes today in order to supply and maintain power during power shutdowns or in an emergency power outage. This has however, made generator a major contributor of environmental noise. These generators emitted very high levels of noise, in addition to noxious air emissions. The noise maybe generated by aerodynamic effects or due to forces that result from combustion process or may result from mechanical excitation of rotating or reciprocating engine components. Environmental noise which results from the use of generator has affected mankind in many ways like hearing loss, cardiovascular effect, annoyance and quality of life, and sleep disturbance. To reduce this unpleasant noise from these electric generators this study has developed a silencer system which will be more efficient than those available locally. The exhaust/silencer system was designed with different chambers, including the catalytic converter, and the exhaust port. The silencer was fabricated from locally available materials (mostly mild steel and aluminium) of good mechanical properties. Experiments, using domestic electric generator, were carried out with the factory fitted silencer and then with the fabricated silencer. The fabricated exhaust system was able to reduce noise and fuel consumption of the generator better than the factory fitted silencer. The reductions in noise and fuel consumption at short-run are found to be statistically insignificant. The reduction in noise level and fuel consumption rate of the fabricated system over the factory fitted exhaust system could be significant at long-run. Further investigation may be required to confirm this. However, it can be concluded from the experimental outcomes that the new exhaust system would efficiently serve as alternative to the old system.

ACKNOWLEDGEMENT

The authors thank the management of the Federal University of Technology, Akure, Nigeria, for making the facilities available for the fabrication and experimental analyses of the exhaust system.

REFERENCES

Abraham JA (2003). Fundamentals of Materials Science and Engineering: An Integrated Fundamentals of Materials Science and Engineering, 3rd edition, John Wiley & Sons, Inc., 111 River Street, Hoboken, New Jersey.

Ayum MA (2001). Guidelines for an Urban Noise Ordinance. North Emerson Street, Cambridge, USA, pp. 44

Challen (1999). General layout, structural design and a practical guide to Muffler Design. National Science

Crocker AD (1994). Noise Control Economics of diesel power plant: Diesel Engine Engineering works 4th edition, McGraw Hill Book Company, New York USA. pp. 26

Fahy DD (1989). Gasoline Engine Installation Sound Emissions. Peace Publishers, Moscow, Russia, pp. 26, 45.

Fishly NM (2000). Proposed Criteria for Low Frequency Noise from Combustion diesel Power Plant, Peace Publishers, Moscow, Russia, pp. 2 – 4.

Hultgren LS (2011). NASA Glenn Research Center. “Full-Scale Turbofan-Engine Turbine Transfer Function Determination Using Three Internal Sensors,” 17th AIAA/CEAS Aeroacoustic Conference, June 6-8, 2011, Portland

Jacobi AB (1999). Controlling Noise Impact in the Community from Power Plant Operations, Noise Control Eng. J., 52: 4.

Kristna CK (1999). Non-Acoustic Design Parameters for Industrial Mufflers. Burleson, Texas, USA, pp. 13 – 18.

Mamod OK (1986). The Reduction of Low Frequency

Combustion Generator Exhaust Noise, Birmingham, England, p. 10.

Moses M (2002). The Noise Perception Index for assessing Noise Impact from Major Household Generator in the U.S, Noise Control Eng. J., 56:5

Oke PK, Kareem B (2012). Effects of leaked exhaust system on fuel consumption rate of an automobile, Electrical Engineering and Intelligent Systems, Lecture Notes in Electrical Engineering, Sio-long Ao, Len Gelman eds., Vol. 130 , Chap. 25, pp. 301-311.

Prasad M (1980). Acoustical modeling of automotive exhaust systems. PhD thesis, Purdue University.

Tandon N, Nakra B, Ubhe D, Kills N (2001). Noise Control of Engine, Driven Portable Generator Set, Applied Acoustics, 55:4, 307-328.

Tong HY, Cheung CS (2005). A Modal Approach to Vehicular Emissions and Fuel Consumption Model Development. J. Air Waste Management Association. 55: 1431-1440.

Tree, Thien (2000). Handbook for Noise Reduction. Elsevier Science Publishing Co., Inc. Manufacturers Association, pp. 4 – 58.

Wegrzyn JT (2003) Down with Noise; Practical Control System for Combating Audible Noise. Focal Press. pp. 26. ISBN 0-240-80755-3.

Appendix 1. Paired Samples Test (n1 and n2) - Noise level: Factory fitted and fabricated exhaust system.

	Paired differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Mean	Std. Deviation	Std. Error Mean
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Pair 1n1 - n2	15.52000	3.59437	1.60745	11.05700	19.98300	9.655	4	.001

Appendix 2. Paired Samples Test (x1 and x2) – Fuel consumption: Factory fitted and fabricated exhaust system.

	Paired Differences					t	df	Sig. (2-tailed)
	Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference		Mean	Std. Deviation	Std. Error Mean
	Lower	Upper	Lower	Upper	Lower	Upper	Lower	Upper
Pair 1 x1 - x2	15.80000	2.38747	1.06771	12.83557	18.76443	14.798	4	.000