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An experimental study of noise reduction of the portable generator using a locally made acoustic enclosure

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Abstract

Portable generators are now widely used in shops, offices, and homes to provide electrical power during power outages in Iraq. However, these generators produce a lot of noise from rotating mechanical parts and fuel combustion inside the engine chamber. This noise harms the neuroendocrine, cardiovascular, respiratory, and digestive systems. Therefore, the reduction of generator noise still attracts the interest of many researchers. In this work, the removal of generator noise using an acoustic enclosure made from local materials is investigated experimentally. Experimental work uses a 2kW generator and compares the sound intensity for two cases: a generator without enclosure and one with a section. The chamber comprises plywood, galvanized sheet, glass wool, cork, and a compressed sponge. The results include the measurement of sound intensity at day and night, at zero to full load, and at two different distances. The findings showed that generator noise reduction reaches 10.3 dB at night and 9.6 dB during the day. In addition, in the case of using the enclosure, the engine temperature is kept within the allowable range of air-cooled generators, which is 300 °C. Therefore, the maximum temperature at 100% load measured inside the enclosure was 77.86 °C at night and 91.75 °C a day.

Keywords: Domestic generator, canopy, sound transmission, soundproof enclosure.

الخلاصــة: تسـتخدم المولدات المحمولة الآن على نطاق واسـع في المتاجر والمكاتب والمنازل لتوفير الطاقة أثناء انقطاع التيار الكهربائي في العراق. تنتج هذه المولدات الكثير من الضــــوضـــاء نتيجة الاصـــوات المنبعثة من دوران الاجزاء الميكانيكية ومن احتراق الوقود داخل غرفة الاحتراق في المحرك. لهذه الضوضاء تأثير سلبي على الغدد الصم العصبية والقلب والأوعية الدموية والجهاز التنفسي والجهاز الهضمي. نتيجة لذلك لا يزال الحد من ضوضاء المولد يجذب اهتمام العديد من الباحثين. في هذا العمل، تم دراسة تقليل ضوضاء المولد تحت استخدام غلاف صوتي، مصنوع من مواد محلية، بشـكل عملي. حيث تم اسـتخدام مولد بقدرة 2 كيلو واط و تم مقارنة شـدة صـوت المولد لحالتين: مولد بدون حاوية والأخرى مع حاوية. العلبة مصـنوعة من الخشـب متوسـط الكثافة، والحديد المغلون، والصـوف الزجاجي، والفلين، والاسـفنج المضـغوط. تضـمنت النتائج قياس شـدة الصـوت في النهار والليل، ولحالات تحميل مختلفة تراوحت من صــفر إلى حمولة كاملة، وعلى مســافتين مختلفتين. أظهرت النتائج أن الحد من ضــوضـــاء المولد يصل إلى 10.3 ديسيبل في الليل و9.6 ديسيبل أثناء النهار. بالإضافة إلى ذلك، يتم الاحتفاظ بدرجة حرارة المحرك، في حالة استخدام الحاوية، ضمن النطاق المسموح به للمولدات المبردة بالهواء وهو 300 درجة مئوية. كانت درجة الحرارة القصوى عند 100٪ من الحمل المقاسة داخل العلبة 77.86 درجة مئوية أثناء الليل و91.75 درجة مئوية في النهار.

1. INTRODUCTION

Local and international pollution have faced noise risks every day, especially in summer, because of the lack of electricity in many countries, leading to the use of portable generators in their houses, workplaces, hospitals, and public utilities. Undoubtedly, this affects the people near these generators and causes a lot of injuries, for instance, stress, nuisance, lack of sleep, and hearing problems. So, many researchers have tried to solve this problem using various methods. All the generators emitted about 90 dB noise level which is unacceptable according to Iraqi law no.41 to control the noise inside the cities as represented in Table 1.

Table 1 The allowable noise level according to Iraqi law no.41 in 2015 [1]

	Residential areas within the city (dB)	Residential areas outside the city(dB)
Day	60	55
Night	50	45

In the literature, the researchers follow three ways to control the radiant noise active, passive, and hybrid (i.e., a mix of active and passive). In the work presented in Ref.[2], the Hooke and Jeeves, or pattern search, optimization method was employed for the investigation. Depending on the original starting locations and required weighting values, this method solves for the best material attributes in about 30 iterations. The shape of the enclosure was cubic and with dimensions of (660×460×430) mm3. It was made from plywood. About 7 dB of noise reduction was achieved, according to this study. A rectangle enclosure frame of (1000×530×710) mm^3 dimensions and the outsides of the enclosure were steel walls and absorber materials inside the chamber walls inserting three-layer elastomeric plates prevents structural transmission through the engine mounts. Inside the enclosure, special care is taken to air freshening and temperature. Through the air intake, air freshening, and exhaust apertures, low frequency noise escapes from the enclosure. The enclosed generator's spectrum is dominated by exhaust noise[3].

The Centre for Environmental Studies (CES) at Anna University conducted experimental studies on the assessment and control of indoor and near-field noise levels caused by the operation of a portable power generator. Anti-vibration mounts (made of rubber, coir, polyurethane foam, thermocole, wool-felt, and sand bed) and enclosures were used to study noise control (made up of cardboard, thermocole, and a sandwich of cardboard and thermocole) there were numerous enclosures with numerous materials and dimensions, but all those enclosures were rectangles. An air gap of 5 cm between sandwich enclosure walls was found to be the most effective in controlling noise caused by generator operation, with a reduction of 28 dB. (A). The indoor noise levels in the library, all classrooms, and entrance I of the auditorium conformed to the noise level ranges specified in IS: 4954 (1968), with an air gap of 5 cm between the sandwich enclosure walls. With an air gap of 2.5 cm between the enclosure walls, the indoor noise levels in classroom I was within the 35-40 dB(A) range specified for classrooms[4]. This study looked at the noise side only without considering the thermal behaviour.

The researchers of the work presented in [5] have investigated the ability of poroelastic materials to control the low-frequency noise radiated outside a parallelepiped cavity containing a point source. The enclosure comprises five rigid walls and one flexible plate, which can all be treated with a porous slab. The porous medium is modelled using the Biot-Allard theory, three equivalent fluid approaches, and a locally reacting assumption. The system response is calculated using a finite element model for all components. A box shape enclosure with (600×780×850) mm3. This research provides insight into the ability of porous materials to reduce sound transmission outside the section and experimental noise reduction treatments. Particularly advanced are modelling alternatives and propositions concerning the various mounting conditions, locations, and distribution of the absorbing material. These two aspects are the primary contributions of the current work to the recent research effort for modelling porous materials in complex systems. This study didn’t consider the thermal behaviour.

Another study was conducted by Pandey et al as in [6] for investigating the controlling of the noise level of 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. This paper discusses in detail that constructing a double wall enclosure, and if the air gap is filled with mineral wool, can give a further 10 dB reduction. Where designed with dimensions (4000×2150×2300) mm3.

A rectangular enclosure made from steel and rock wool attenuates the generator noise, as shown in [7]. The section has helped in the reduction of noise by 15 dB. In addition, a soundproof device for noise attenuation for 950Watt portable generators has been evaluated in [8]. As a result, the emitted generator noise has decreased by 7.64, 6.24, 6.82, 8.72, and 8.68 dB at sound measuring distances of 0.70, 1.40, 2.10, 2.80, and 3.50m from the generator, respectively.

In 2016, an ANN regression model of Field Data Based Multivariate (FDBM) regression model was presented in [9] to predict the noise level outside the canopy/acoustic enclosure. This model predicts the noise of a canopy-equipped DG set based on several independent parameters, such as engine load, canopy thickness, foam thickness, and foam density of the system. But here (Ghorbani et al., 2016) studied two contrasting types of enclosures; one was made from a steel frame with plywood, and the dimensions were (930×750×670) mm3 and were also a rectangle. The other type was modified inner walls lined with absorbing material and steel plates, and the measurements were (930×750×670) mm3 [10]. Duncan's multiple range tests revealed that covering the generator with various types of enclosures reduced the generator sound level (93.2 dB(A)) significantly ($P<0.01$) to 88.4 dB(A) for SE, 87.2 dB(A) for SME and 86.1 dB(A) for FME. They also discovered that increasing the generator's electric load significantly increased its sound ($P<0.01$).

In this paper presented in the reference[11] , a rectangle sheet metal enclosure with a volume of 18.7m^3 was used, with two doors, one of which was made of glass and inner walls lined with rock wool. The section resulted in a reduction of transmitted noise by 3 dB. Plywood, polyurethane foam, ground glass, and composite sawdust made an enclosure wall. The enclosure dimensions were (735×495×605) mm^3. In the work presented in reference[13], an enclosure with (4.5×1.75×2) m^3 dimensions. The enclosure walls comprise steel plates, stiffeners, rock wool supported by steel sheets, and glass windows. A noise reduction of 7 dB was achieved. A study has presented an enclosure design with a box shape with dimensions of (535×520×520) mm^3. One of the walls was used as the enclosure door. The walls and the entrance are composed of plywood, damper rubber, and acoustic foam. The total noise reduction was 4.7-7 dB [14]. Al Bugharbee & Jubear investigated an enclosure with dimensions (100×83×62) cm3 made of plywood, foam, sponge, and galvanized iron sheet. The generator sound transmission loss under using of the section was estimated at 50% compared to the none enclosure case[15].

The present work aims to experimentally investigate the noise reduction in a 2kW domestic generator, commonly used in Iraq, using simple acoustic enclosures at various loads. The study also includes monitoring the generator temperature due to the use of the section. This work can be classified as a passive technique since the enclosure was used without changing the generator parts.

2. MATHEMATICAL FORMULATION

In this work, the generator enclosure performance is investigated in terms of reducing noise and preventing accumulation of engine heat. These can be estimated using the following equations described in the following sections.

2.1.The acoustic performance of the enclosure

The sound intensity (i.e., here is the noise) is measured in decibels, which can be described in equation 1. And which can be defined as a relative logarithmic unit used to measure the noise level using the sound level meter. The intensity in decibels = 10 * log10 (intensity/ intensity of zero decibels)

$$S = 10\, log \frac{I}{I_0} \tag{1}$$

S: is the intensity in decibels.

I: is the sound intensity.

I_0: is the sound intensity of zero decibels= 10^{-12} W/m^{-2}

2.2.The thermal performance of the generator

For thermal performance, Nusselt number and heat transfer coefficients are calculated using the equations (2& 3). These parameters are commonly used in the analysis the thermal performance of the generator.

$$h = \frac{q}{A\Delta T} \tag{2}$$

$$Nu = \frac{hl}{K_f} \tag{3}$$

Where $\frac{q}{A}$: is the energy lost to the enclosure from the generator per area of the heat transfer.

l: is the characteristic length.

K_f : is the fluid thermal conductivity ($\frac{W}{m.K}$) at ΔT

3. EXPERIMENTAL TEST RIG

The present enclosure was made from different materials with different thickness, and these materials were chosen to be low-cost, available, and recyclable. The enclosure walls included two sides with dimension $(94 \times 100)cm^2$ and the other with dimensions $(84 \times 100)cm^2$. The wall section contains, from inside to outside, 2 mm galvanized iron, 10 mm glass wool, 25 mm cork, 30 mm air gap, 30 mm compressed sponge, and 16 mm MDF (medium density fibres) panels as shown in Figure (1) these thicknesses of the materials choose because it is the common in the local market. And the materials choose according to the noise reduction number (NRC) which is a rating of the average quantity of sound a soundproof product c an absorb as shown in table (2).

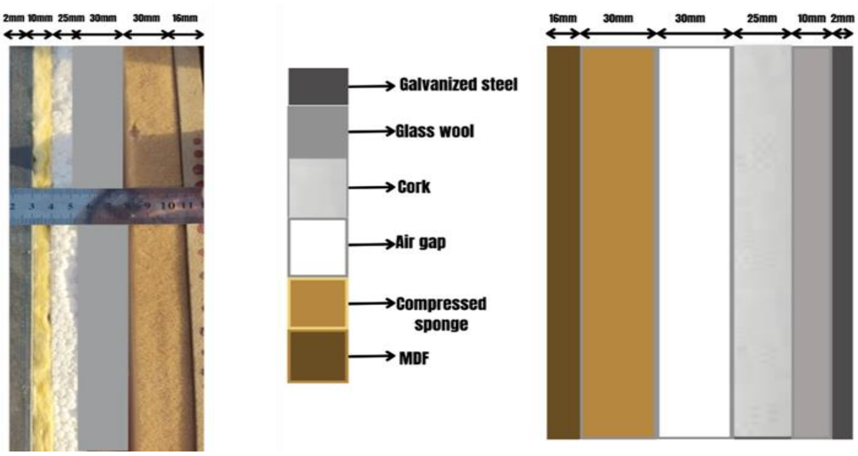


Figure 1 Components of enclosure wall section

Table 2 The NRC of the chosen materials

Materials	Noise reduction coefficient
Galvanized iron	1
Mineral wool	0.78
cork	0.7
Compressed sponge	0.47
Medium density fiber	0.7

The upper and lower were made from three layers (16 mm MDF, 25 mm cork, and 16 mm MDF) respectively. Two electrical fans, each of 110 m^3/h were used as intake and outtake fans. Figure (2) shows the enclosure used in the experimental work.

G

Figure 2 The present enclosure

Figures (3) shows the 2 kW generator inside the enclosure. It also shows the intake and outtake fans which used to keep continuous air movement inside the enclosure to improve the heat dissipation. The schematic diagram is shown in Figure (4). It represents the arrangement of the devices to take the measurements of the sound and the heat.

Figure 3 the generator inside the enclosure

The measurement devices and necessary wiring is shown in Figure (4).

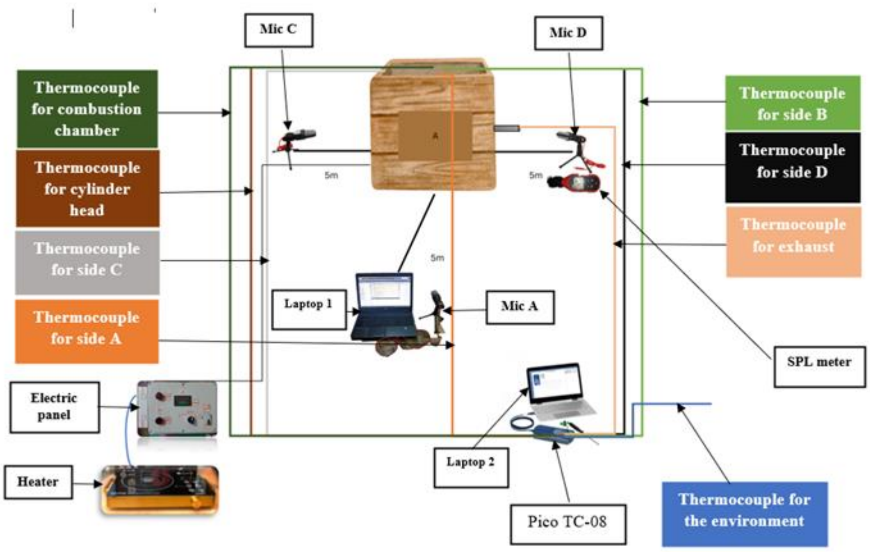


Figure 4 the schematic diagram of the experimental work

Four condensers' microphones SF 920, as shown in Figure (5) rounded (A, B, C, D) at distance 5 m from the generator in non-enclosure and the same distance from the enclosure in the second case the measurements taken at every 10 minutes for each side. Microphones were used for acquiring generator sound signals from the four sides. The signal was recorded at 44.1K sample per second. In addition, a UT 353 sound meter as shown in Figure (6) was utilised to record the sound intensity in dB. Generator cylinder temperature, exhaust temperature, and surrounding air temperatures were recorded using eight types K [Ni-10% (+) Cr versus Ni-5% (-) aluminium silicon] thermocouples. These thermocouples were connected to the Pico data logger through a USB port. All the sound and temperature recordings were conducted at various generator loads (i.e., 0, 25, 50, 75 and 100%) loads and at two distances 3 and 5 meter. To change the applied load on the generator was used power source (heater) and electric panel.

Several parameters were considered when designing the soundproof container, including the location of the exhaust pipe outside the container, the appropriate air flow rate from the fans, as well as the fast design, and low maintenance requirements.

Figure 5 The condensing microphones SF920

Figure 6 The sound level meter (SPL)

4. RESULTS AND DISCUSSION

The results were obtained for both generator conditions: inside and outside the enclosure. The section presents the significant results obtained from this work, including comparing average temperature difference with generator load percentage.

4.1.Temperature variation

The thermal performance of the generator with and without enclosure is depicted in Figure (7) at daytime (which starts from 3 p.m.), and in Figure (8) at nighttime. The X-axis represented the load change (0%, 25%, 50%, 75%, and 100%), and Y-axis represented the temperature difference between the cylinder head temperature and the surrounding temperature (Th-Ts) in centigrade. From the Figure, it can be easily noticed that the generator temperature increases with the increase in load. It is valid for both cases of generators with and without enclosure. In addition, the same behavior is observed during the day and nighttime. It can be attributed to the fact that more applied load resulted in more fuel combustion, and consequently, more heat is radiated.

But at day time the temperature difference when the generator out of the enclosure is more than the temperature difference when the generator inside the chamber because Ts inside the enclosure is more than Ts out the enclosure, which leads to being the difference in case non-enclosure is greater than the difference in the enclosure also the cylinder head temperature, is also more than the case when the generator out the enclosure[15]. The cylinder head temperature does not exceed the allowable cylinder head temperature which is (300) ˚C[16].

However, at nighttime in Figure (8), the temperature difference of the generator outside is lower than the case inside the enclosure because the heat for the same reason Th and Ts are more in this case. In addition, the accumulation of heat inside the chamber was increased during the work process at each load, and then take the difference between the cylinder head temperature and the surrounding temperature, which was huge inside the enclosure, lead to be the case inside the chamber being lower.

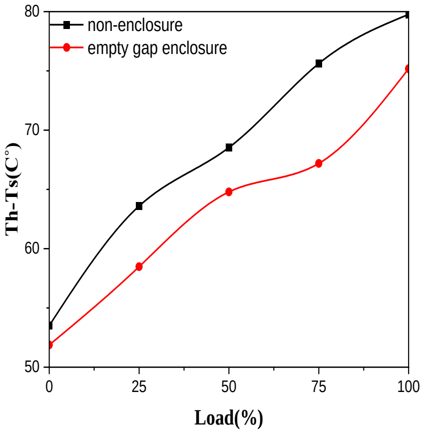


Figure 7 Temperature difference versus generator load at daytime

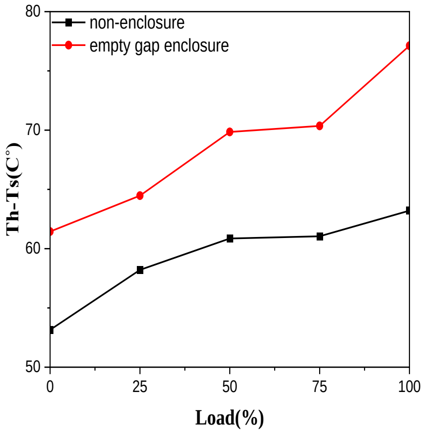


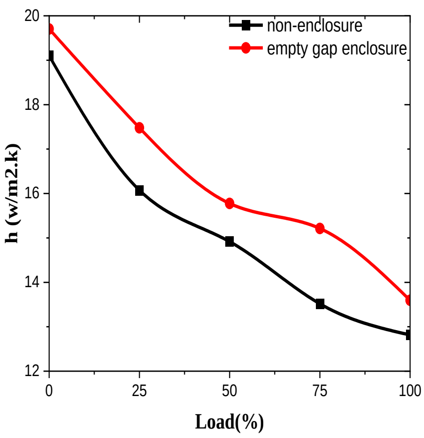
Figure 8 Temperature difference versus generator load at nighttime

4.2.Heat transfer coefficient and Nusselt number

Table 3 Temperature difference, Nusselt number and heat transfer coefficients

The case	Load %	ΔT_{noon} °C	h_{noon} W/m^2K	K_f $\frac{W}{m.K}$	Nu at noon	ΔT_{night} °C	h_{night} W/m^2K	K_f $\frac{W}{m.K}$	Nu at night
The generator without enclosure	0	53.51	19.10241	0.027	311.2985	53.15	19.2318	0.028	302.2139
	25	63.6	16.07186	0.02817	251.0336	58.21	17.56004	0.02805	275.4516
	50	68.53	14.91566	0.029	226.3065	60.86	16.79543	0.02808	263.1763
	75	75.62	13.51719	0.02917	203.8932	61.04	16.7459	0.02815	261.7477
	100	79.76	12.81557	0.02927	192.6495	63.21	16.17102	0.02817	252.5824
The generator inside the enclosure	0	51.88	19.70258	0.02802	309.391	61.44	16.63688	0.02815	260.0436
	25	58.48	17.47897	0.02805	274.1799	64.47	15.85497	0.02817	247.646
	50	64.79	15.77666	0.02817	246.4229	69.85	14.63379	0.029	222.0299
	75	67.19	15.21313	0.029	230.8199	70.36	14.52771	0.02881	221.8742
	100	75.18	13.5963	0.02917	205.0865	77.12	13.25428	0.02921	199.6536

Then, the behavior of heat transfer coefficient (h), at daytime for case with empty gap enclosure is lower than outside the enclosure case because heat transfer coefficient dependent on (Th-Ts) as illustrate at Figure (9) and Figure (10).



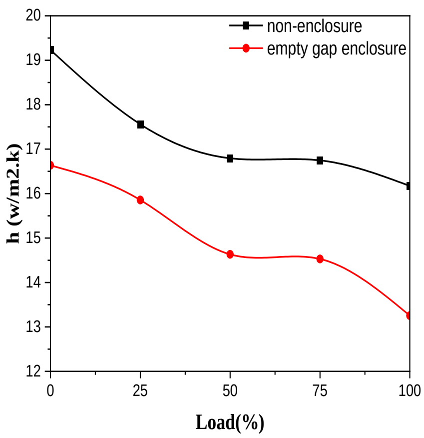


Figure 9 the comparison of the heat transfer coefficient behaviors of cases (non-enclosure and empty gap enclosure) at daytime

Figure 10 the comparison of the heat transfer coefficient behaviors of cases (non-enclosure and empty gap enclosure) at nighttime

While Nusselt number at daytime and nighttime follow the same behavior of heat transfer coefficient because it depends on heat transfer coefficient behavior as shown in Figure (11) and Figure (12).

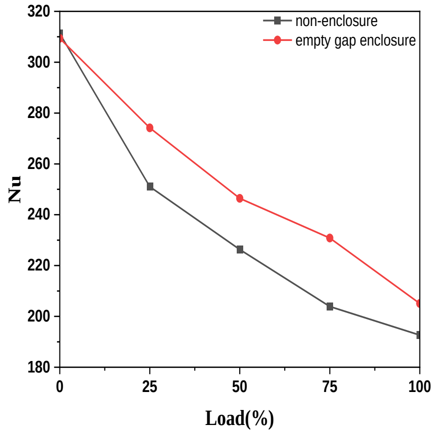


Figure 11 The comparison of Nusselt number behaviors of cases (non-enclosure and empty gap enclosure) at daytime

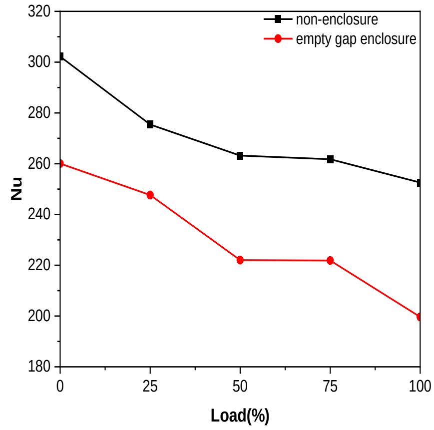


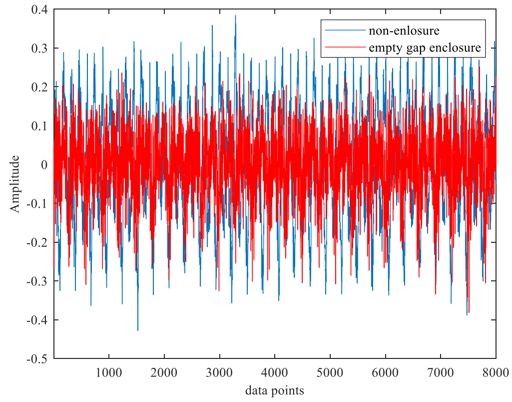
Figure 6 The comparison of Nusselt number behaviors of cases (non-enclosure and empty gap enclosure) at nighttime

4.3.Sound pressure level

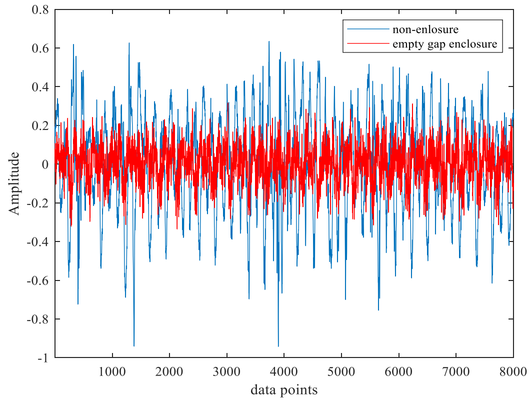
Figure (13) represents the microphone readings for both cases of the generator when the microphone is at a 5 m distance. The readings were recorded for (10) minutes and at an (8000) sampling rate. For all generator load percentages, it is clearly seen that the amplitude of the microphone reading decreases when the generator is put inside the enclosure. This is because the chamber insolates the sound and fragmentation the sound wave by the enclosure walls.

The sound pressure levels measured by using a sound level meter UT 353 at a 5m distance away from the generator in case the generator was without an enclosure and the same for case with an empty gap enclosure. The readings are acquired after 20 minutes of generator working. Table (3) the generator's sound level in decibels for both cases of the generator (inside and outside the enclosure), and for both day and night-time.

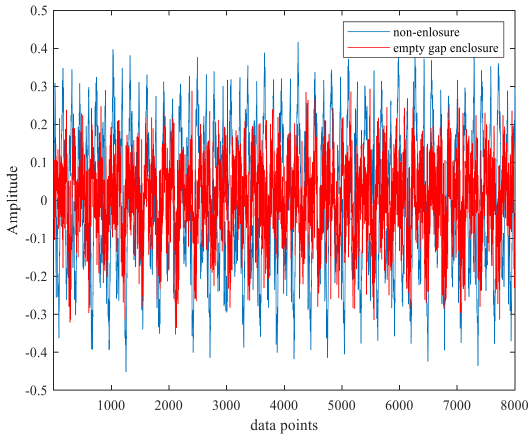
The bar charts in Figures (14) &(15) show the generator sound level recorded at the exhaust side at a 5m distance. It can be deduced that for all the cases, the generator sound level for the point where the generator is inside the enclosure is lower than in the case where the generator is inside the chamber. In addition, the sound level at night-time is generally greater than those recorded at daytime. Based on the experimental results of this work, the noise reduction percentage is estimated as (13.3%, 9.59%, 10.32%, 8.28%, and 9.36%) at night and (12.81%, 8.83%, 8.62%, 11.89%, and 9.56%) at day in each load (0%, 25%, 50%, 75%, and 100%). The sound intensity was also reduced when the generator was placed inside the enclosure because the energy of the sound wave was lost during transmission and some of this energy was absorbed by the walls. However, the maximum sound level was recorded at 5 m distance when the load was (100%) is (69.7 dB) at nigh time while at daytime at load (100%) was (69.9 dB).



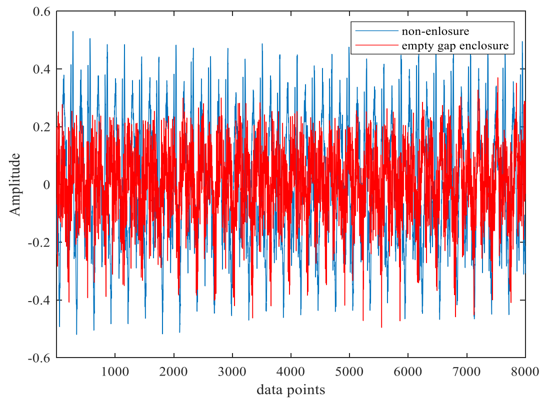
a. 0% load



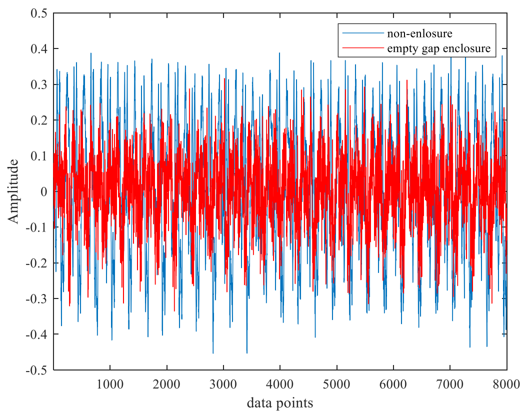
b. 25% load



c. 50% load



d. 75% load



f. Full load

Figure 13 The time domain of the sound at various load

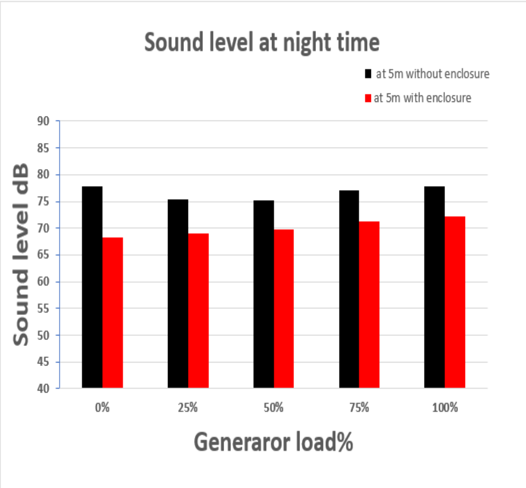


Figure 7 the sound level comparison for the exhaust side (D) at each load of cases (non-enclosure and empty gap enclosure) at night-time

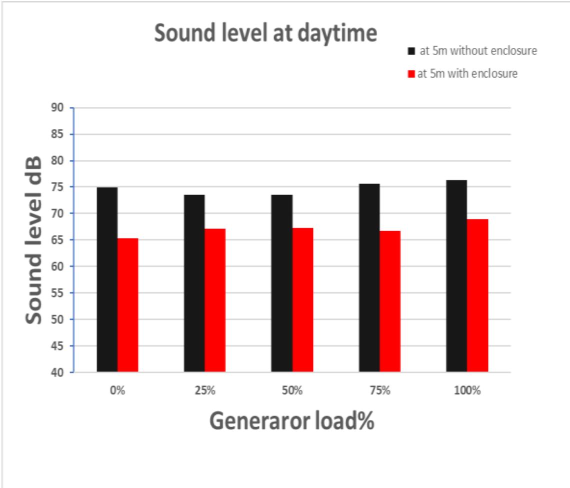


Figure 8 the sound level comparison for the exhaust side (D) at each load of cases (non-enclosure and empty gap enclosure) at daytime

The reduction percentage (R.P.) is between the two cases at night-time and daytime, as shown in Figure (16) at 0%, 25%, 50%, 75%, and 100% loads. It is clearly seen that the reduction at night-time is more than that observed at daytime because the noise level in residential regions at daytime is more than night-time. With (13.36, 9.59, 10.35, 8.28, and 9.36) % at night time for the five loads respectively, and (12.81, 8.83, 8.62, 11.89, and 9.57)% at day time.

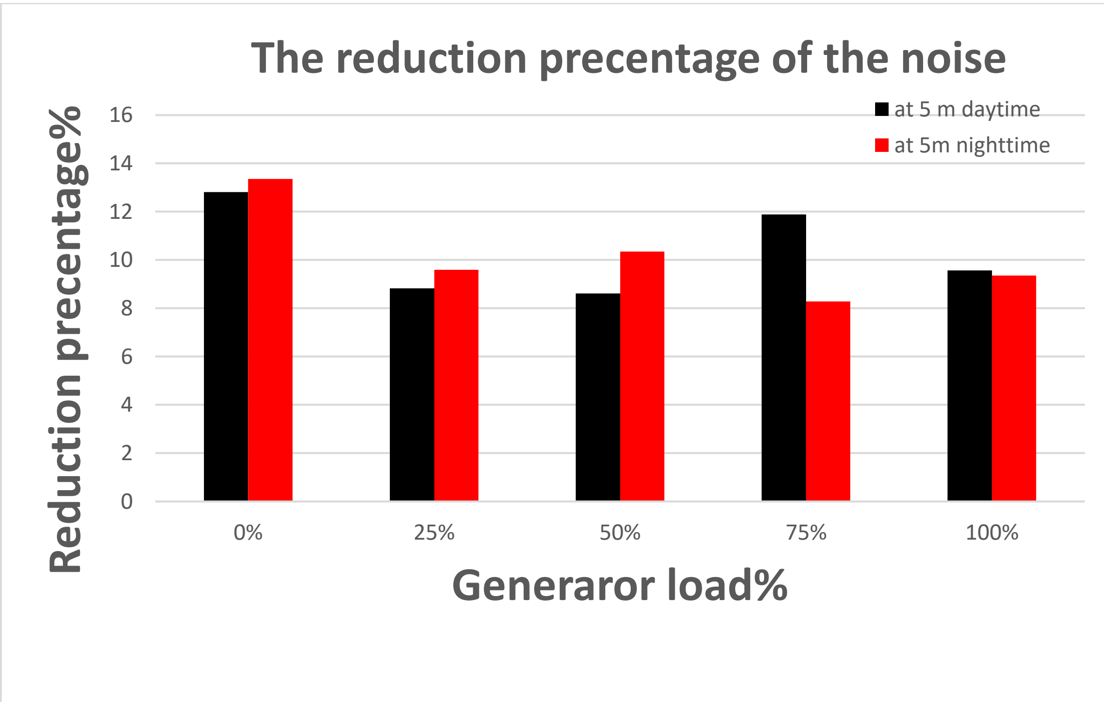


Figure 9 the reduction percentage of the fourth microphones rounded for daytime and night-time.

5. CONCLUSION

In this research, an experimental investigation conducts to evaluate the acoustic and thermal performance of generator enclosures made from relatively low-cost materials. The work includes measuring generator cylinder head temperature and emitted sound level for a generator with and without enclosure at different load percentages. Furthermore, the enclosure performance is compared for the two generator conditions in terms of noise reduction, Nusselt number, temperature difference, and heat transfer coefficient. The results showed that the maximum generator temperature stays within the designed range when using the enclosure. In addition, it was found that the maximum noise reduction was about (10.3 dB) at night while (9.6 dB) at daytime.

References

[1] Al-Auoin Al-Sahera.(15-12-2016), http://alsahroon.gov.iq

[2] Blanks, J., Saunders, W., Robertshaw, H., Nelson, D., & Chairman, C.(1997). *Optimal Design of an Enclosure for a Portable Generator*. MSC Thesis, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

[3] Cuesta, M., & Cobo, P.(2000). Active control of the exhaust noise radiated by an enclosed generator. *Elsevier*, 61(2000), 83-94.

[4] Parvathi, K., & Gopalakrishnan, A.(2003). Studies On Control Of Noise From Portable Power Generator. *In Proceedings of the Third International Conference on Environment and Health*, 2003, pp. 15–17. http://citeseerx.ist.psu.edu

[5] Bécot, F., & Sgard, F.(2006). On the use of poroelastic materials for the control of the sound radiated by a cavity backed plate. *J. Acoust. Soc. Am.*, vol. 120, no. 4, pp. 2055–2066.

[6] Pandey, K., Deb, K., & Kumar, U.(2009). Experimental studies on effect of noise level control for 7 . 5 kva diesel generator set with an enclosure. *J. Environ. Res. Dev.*, vol. 4, no. 2, pp. 506–516.

[7] Hammad, U., Aizaz, A., Khan, A., & Qurehi, T.(2013). Design and development of noise suppression system for domestic generators. *Eur. Sci. J.*, vol. 4, no. December, pp. 526–533.2013.

[8] Akhaze, M., & John, E.(2016). Development of a soundproof device for 950 Watt rated portable generators. *J. Appl. Sci. Environ. Manag.*, vol. 20, no. 1, p. 83.

[9] Askhedkar, R., Modak, J., & Vanalkar, V.(2016). Formulation of a field data based model to estimate the noise level in a diesel generator set with acoustic enclosure. *Int. J. Mech. Eng. Technol.*, vol. 7, no. 3, pp. 368–386.

[10] Ghorbani, Reza Hassan, S., & Ghobadian, B.(2016). Noise reduction of a portable generator set driven by small natural gas engine using an acoustic enclosure. *Agric. Eng. Int. CIGR J.*, vol. 18, no. 3, pp. 159–170.

[11] Prasad, K., Bankar, H.(2017). Acoustic enclosure optimization for a higher capacity diesel generator set using statistical energy analysis (sea) based approach. *SAE Tech. Pap*, 10.4271/2001-01-1525.

[12] Mushiri, T., Madziro, N., & Mbohwa, C.(2017). Design of an optimum acoustic enclosure for an open frame diesel generator. *Procedia Manuf.*, vol. 8, pp. 424–431.

[13] Arslan, E., Çalışkan, M., &Uyulan, Ç.(2018). Sound field calculations of a diesel generator with enclosure by finite element analysis. *INTER-NOISE 2018 - 47th Int. Congr. Expo. Noise Control Eng. Impact Noise Control Eng.*

[14] Adeboye, B., Oyelami, S., & Ayoola, P.(2019). Fabrication of an acoustic enclosure for a portable generator. *Int. J. Sci. Eng. Investig.*, vol. 8, no. 88, pp. 16–18.

[15] Al-Bugharbee, H., & Jubear, A.(2020). An experimental investigation of enclosure's effect on noise reduction in portable generators. *Int. J. Eng. Trans. B Appl.*, vol. 33, no. 2, pp. 350–356.

[16] Tandon, N., Nakra, B., Ubhe, D., & Killa, N.(1998). Noise control of engine driven portable generator set. *Appl. Acoust.*, vol. 55, no. 4, pp. 307–328.

[17] Cuesta, M., Cobo, P.(2001). Optimisation of an active control system to reduce the exhaust noise radiated by a small generator. *elsevier,* S0 00 3-6 8 2 X (9 8) 00 00 4-8.

[18] Fuller, C., Papenfuss, C., & Saux, T.(2012). Active-passive control of portable generator set radiated noise. in *Australian Acoustical Society Conference 2012, Acoustics 2012: Acoustics, Development, and the Environment*, pp. 105–111.

[19] Zhang, N., Yang, W., & Fei, R.(2008). Noise control technology for generator sets in enclosures. *Front. Mech. Eng. China*, vol. 3, no. 4, pp. 377–384.

[20] Tengku, T., Deraman, L., Ibrahim, W., & Lutpi, N.(2015). Investigation of noise reduction coefficient of organic material as indoor noise reduction panel. *Mater. Sci. Forum*, vol. 803, pp. 317–324.

Nomenclature:

The symbol	The definition	The unit
q	Is the energy lost from the generator by the area	$W/_{m^2}$
h	Heat transfer coefficient	$W/_{m^2K}$
K_f	The fluid thermal conductivity	$\frac{W}{m.K}$
l	Is the characteristic length	m
Nu	Nusselt number	-
S	Sound intensity in decibel	dB
I	is the sound intensity	
I_0	is the sound intensity of zero decibels	W/m^{-2}