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Effects of Sand Bed Anti-Vibration Mount on Transmitted Noise from Portable On-Site Electricity Generator

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Abstract

This study investigated the effect of different particle sizes of sand bed anti-vibration mount on transmitted noise from a portable on-site electricity generator. Ten sand bed anti-vibration mounts, 650mm x 650mm in cross section and 75mm thickness were prepared with particle sizes ranging from 0.09 to 2.30mm. Noise measurements were taken in the four cardinal directions using Extech HD600 digital sound level meter. The results of the study showed that the ability of the sand particles to dampen vibration noise from the portable electricity generator reduces with increase in particle size. The sand bed anti-vibration mounts reduced noise levels by 0.11 to 2.78 dB(A). However, fine sand bed of particle size 0.09mm and 0.15mm exhibited superiority in noise reduction over all other sand beds. In order to achieve appreciable noise reduction, the use of ISO 14688-1:2002 fine sand category is recommended as anti-vibration mount in combination with other damping methods.

Keywords: Electricity generator, noise, sand, particle size and attenuation

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Introduction

Electricity is a basic necessity for sustenance of life though for the ever increasing global population, electricity supply is irregular or unavailable in some parts of the world. According to the International Energy Agency (IEA, 2015), an estimated 1.2 billion people do not have access to electricity and more than 95% of those living without electricity reside in sub-Saharan Africa and developing Asia. In Nigeria, electricity supply has been in short supply as only 40 % of the public is connected to the national grid, of which 60% do not have electricity throughout the day (Julia et al., 2008). Hence households, commercial and government establishments have resulted to the use of onsite electricity generators as their main or complementary source of power. However, the use of onsite electricity generators has several environmental consequences such as air and noise pollution.

In contrast to other environmental problems, noise pollution continues to grow in an unsustainable manner because it involves direct and cumulative adverse health effects (WHO, 1999). Several studies have shown that short or long period of exposure to noise results in auditory effects such as auditory fatigue and hearing loss, and indirect non-auditory effects such as speech interference, annoyance, loss of concentration and absenteeism, and several psychological changes (Bryan and Tempest, 1970; Edworthy, 1997; OSH, 2002; Ambekar, 2006; Duggal, 2007; Juang et al., 2010; WHO, 2011). The cut-off time for safe noise decreases as sound level increases and exposure to noise levels less than 85 dB(A) for

a maximum duration of 8 hours is considered safe (WHO, 2004). Exposure to loud sounds for any length of time causes fatigue of the ear's sensory cells (temporary hearing loss) and when this noise exposure is regular or prolonged, it can result in a more serious condition of permanent hearing loss (WHO, 2015).

Users of on-site electricity generators are usually exposed to mean noise levels of 104 dB(A) from diesel engine electric power generators and 94 dB(A) from petrol engine electric power generators (Ana et al., 2014). These values are above the recommended limit of World Health Organization which stipulates a range of 30 dB(A) to 55 dB(A) for residential areas depending on time of the day and location, and a limit of 70 dB(A) for industrial, commercial and traffic areas (WHO, 1999). Therefore, provision of cost effective method to prevent or reduce noise from on-site electricity generators is required. The noise sources from a power generator are basically from the engine, cooling fan, alternator (cooling air, brush friction and induction), engine exhaust, and vibration of structural parts and components (Aaberg, 2007).

Vibration noise resulting from the operation of an on-site electricity generator can be attenuated using damping materials which wholly or partially prevents transmission of sound from the generator to any other transmitting medium. Vibration damping materials have some viscous properties and tend to bend or distort slightly thereby consuming some of the noise energy in molecular motion (Davis and Cornwell, 2009). The use of granular damping materials has a

wider temperature range than most other types of conventional damping materials and vibratory energy is removed by momentum transfer through losses that occur during collision of granular materials (Saeki, 2009). Test results from a study (Sato *et al.*, 1995) indicated that systems containing granular medium dampen vibration thereby significantly reducing noise in the examined rigid bodies.

Numerical and experimental results also show that multi-unit damper with properly selected single mass of granular materials is an effective vibration absorber (Inouea *et al.*, 2011). Specifically sand bed containing medium size particles was found to be effective in suppressing noise in an on-site electricity generator (Parvathi and Gopalakrishnan, 2003). The purpose of this study is therefore to further assess the effect of using several particle sizes of sand as the bed in anti-vibration mount for a portable electricity generator commonly used for electricity generation in Nigeria.

Materials and Methods.

Data Collection

A free field environment was chosen and experimental study on noise levels due to the operation of a portable power generator on different particle sizes of anti-vibration mounts was undertaken. River bed type of sand with granular structure was obtained from a sand deposit. It was separated into various particles sizes using standard B.S test sieves with pore sizes ranging from 0.09mm to 2.3mm. Ten sand bed anti-vibration mounts, 650mm x 650mm in cross section and 75mm thickness were prepared. The classes of sand used in the study according to ISO 14688-1 classification is presented in Table 1. Two samples were from the fine sand category, six samples fall within the medium sand category while one sample each was from the coarse sand and fine gravel category.

Table 1. Classification of particle sizes of sand used in the study

Size of studied sand particle (mm)	*Size Range (mm)	*Aggregate name
0.09, 0.15	0.063– 0.2	Fine sand
0.212, 0.212, 0.25, 0.3, 0.4, 0.5	0.2 – 0.63	Medium sand
1.0	0.63 – 2.0	Coarse sand
2.3	2.0 – 6.3	Fine gravel

*Source: ISO (2002)

A single phase portable gasoline on-site electricity generator (Tiger T.G 1250) of 650 VA power output and 50Hz output voltage was chosen for the study. It is locally called “I pass

my neighbor”, and it is the cheapest and most popular brand of on-site electricity generators in Nigeria. It is manual start, petrol-run and has dimensions 375mm x 315 mm x 330 mm. The generator uses oil mixed gasoline at a ratio 1:50 and its fuel tank capacity is approximately 4 liters. Noise measurements were taken using a digital data logging sound level meter model HD600 manufactured by Extech® Instruments Corporation, U.S.A. The sound level meter meets Type 2 requirements of ANSI S1.4 and IEC 61672-1, and measures and displays Sound Pressure Level (SPL) from 30dB(A) to 130dB(A) with $\pm 1.4\text{dB(A)}$ accuracy in 3 measurement ranges.

The sound level meter was mounted on its tripod and positioned at a height of 1.5m above the ground. For each sand bed, the background noise was taken when the on-site electricity generator was not in operation. The electricity generator was positioned such that its exhaust faces the North. Noise measurements were then taken using each prepared sand bed sample placed under the on-site electricity generator as anti-vibration mount. The prescribed procedure stipulated in HD600 User's Guide and the WHO document containing strategies for conducting noise surveys (Lester *et al.*, 2001) was followed in taking all the measurements. The sound level meter was set to slow/fast response measurement of A-weighted sound levels at a sampling interval of 1s. Preliminary study showed that noise decay was insignificant at distances greater than 7.5m. Therefore, each sampling point consists one set of readings comprising 120 was taken for 2 minutes, at distances 1m, 2m, 4m and 8m from the on-site electricity generator and in the four cardinal directions (North, South, West and East). A total of 120 readings were taken at each sampling point in each cardinal direction.

Data Analysis

The sound level readings consist of recorded noise within the sampling period. The basic noise descriptors used in the study are:

a) Maximum noise level ($L_{\max}$): Peak measured sound pressure during the measurement period

b) Average noise level (L_p) is given as

$$L_p = 20 \log \frac{1}{n} \sum_{j=1}^n 10^{\left(\frac{L_j}{20}\right)} \quad \text{Equation (1)}$$

where:

n = number of sound pressure level readings taken;

$L_j = j^{\text{th}} \text{SPL}; j = 1, 2, 3, \dots, n$

c) Equivalent Sound Pressure Level (L_{eq}): constant noise level that, over a given time, expends the same amount of energy as the

varying sound level over the same period of time. Mathematically,

$$L_{eq} = 10 \log \sum_{i=1}^n \left(10^{\frac{L_i}{10}} \right) (t_i) \quad \text{Equation (2)}$$

where: n = Total number of Sound pressure level samples taken
 L_i = Sound pressure level in the i^{th} sample; t_i = Fraction of total Sound pressure level sample time

Noise level data was compared with the control experiment which has no anti-vibration mount and also with acceptable noise levels recommended by WHO for different land-use types. Contour maps were constructed using Surfer 8 software package manufactured by Golden Software, Inc, USA. Surfer contains contouring and 3D surface mapping program that creates contour maps from XYZ data.

Results and Discussion

The recorded noise level at a distance of 1m to 8m away from the on-site electricity generator in the four cardinal directions varies from 65.73 to 82.93 dB(A). The resulting noise map from the use of the on-site electricity generator (as control experiment) is shown in Figure 1. As expected the areas close to the generator are more critical and noise level decreased with increase in distance away from the generator. The greatest noise observed at 1m, 2m, 4m, and 8m away from the portable generator is 82.93, 77.66, 72.34 and 68.69 dB(A) respectively. According the WHO (1999), noise levels greater than 45 dB(A) for 6 hours and 55 dB(A) for 16 hours in outdoor living areas may cause sleep disturbance and serious annoyance respectively. Also in industrial, commercial and outdoor residential areas, noise levels greater than 70 dB(A) for 24 hours can cause hearing impairment.

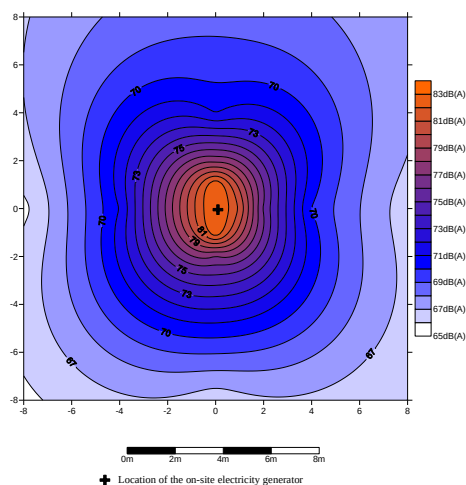


Figure 1 Noise contour map for the on-site electricity generator (Control).

The Equivalent sound pressure level (L_{eq}) for the measured distances away from the on-site electricity generator in the northern, southern,

eastern and western direction is presented in Table 2, 3, 4 and 5 respectively. It was observed that all the noise level readings when sand anti-vibration mount was used were greater than WHO limit of 45 to 55 dB(A) for residential areas while 65% of the readings were greater than the 70 dB(A) recommended limit for industrial, commercial and traffic areas. However, the sand beds decreased noise level by 0.16 to 2.59 dB(A) in the northern direction, 0.14 to 2.78 dB(A) in the southern direction, 0.23 to 1.69 dB(A) in the eastern direction, and 0.11 to 2.33 dB(A) in the western direction.

Table 2. Equivalent noise variation with distance in the northern direction.

Particle size (mm)	Distance (m)			
	1	2	4	8
0.09	80.8	76.2	70.2	68.2
0.15	80.34	76.33	70.21	68.3
0.212	80.81	76.39	70.21	68.24
0.25	80.7	76.4	70.25	68.26
0.3	80.9	76.41	70.26	68.28
0.4	80.95	76.83	70.33	68.27
0.5	80.93	77.09	70.38	68.29
0.85	81.34	77.26	70.4	68.3
1	82.3	77.3	70.77	68.3
2.3	82.5	77.5	70.79	68.34
Control	82.93	77.66	70.96	68.69

Table 3. Equivalent noise variation with distance in the southern direction

Particle size (mm)	Distance (m)			
	1	2	4	8
0.09	80.82	75.91	69.7	66.1
0.15	80.1	75.9	69.82	66.16
0.212	80.0	76.12	69.89	66.19
0.25	80.2	76.33	69.93	66.21
0.3	80.3	76.42	69.99	66.2
0.4	80.35	76.54	70.03	66.18
0.5	80.37	76.67	70.01	66.31
0.85	80.6	76.78	70.21	66.05
1	80.2	76.76	70.25	66.12
2.3	82.13	76.98	70.34	66
Control	82.78	76.92	72.34	66.36

Table 4. Equivalent noise variation with distance in the eastern direction.

Particle size (mm)	Distance (m)			
	1	2	4	8
0.09	79.06	74.82	69.13	65.9
0.15	79.32	74.85	69.14	65.9
0.212	79.23	74.89	69.17	65.91
0.25	79.45	74.9	69.2	65.91
0.3	79.37	74.91	69.21	65.92
0.4	79.58	74.89	69.27	65.93
0.5	79.64	75.01	69.28	66
0.85	80.02	75.12	69.3	65.95
1	79.93	75.31	69.5	66
2.3	80.34	75.5	69.7	66
Control	80.75	75.83	69.93	66.45

Table 5. Equivalent noise variation with distance in the western direction

Particle size (mm)	Distance (m)			
	1	2	4	8
0.09	79.7	76.17	68.7	65.5
0.15	79.7	76.23	70.25	65.5
0.212	79.84	76.34	70.27	65.55
0.25	79.32	76.41	70.35	65.57
0.3	79.48	76.62	70.41	65.58
0.4	79.63	76.73	70.48	65.57
0.5	79.72	76.91	70.52	65.59
0.85	79.98	76.83	70.56	65.58
1	80.06	77.01	70.63	65.6
2.3	80.19	77.03	70.68	65.62
Control	80.56	77.34	71.03	65.73

In all, sand of particle size 0.09mm exhibited superiority in noise reduction over other sand beds with an average noise reduction (L_p) of 1.24 dB(A) followed by 0.15mm [L_p = 1.17dB(A)] and this reduction progressively decreases with increase in particle size up to the 2.3mm particle size sand bed which had the least noise reduction [L_p = 0.43 dB(A)]. It indicates that the ability of the sand particles to dampen vibration noise from the portable electricity generator reduces with increase in particle size. The resulting noise map from the use 0.09mm sand bed anti-vibration mount is shown in Figure 2. In comparison with the control in Figure 1, the 0.09mm particle size sand bed decreased noise by a maximum of 2.13 dB(A) in the northern direction, 2.64 dB(A) in the southern direction, 1.69dB(A) in the eastern direction and 2.33 dB(A) in the western direction. The noise reduction may be due to the ability of the particles' molecular structure to distort slightly and consume some of the vibration noise energy thereby prevent its transmission. It is noteworthy that vibration noise from the structural parts of an electricity generator is just a fraction of the total noise from an electricity generator. However, it is usually difficult to acoustically prevent vibration noise from being transmitted through any physical member connected to electricity generator. More so its effect is normally felt before airborne transmission of noise from other sources within the electricity generator. Therefore, combining sand with particle size falling within the fine sand category as anti-vibration mount with other noise damping methods may lead to appreciable reduction of noise intensity from portable on-site electricity generators.

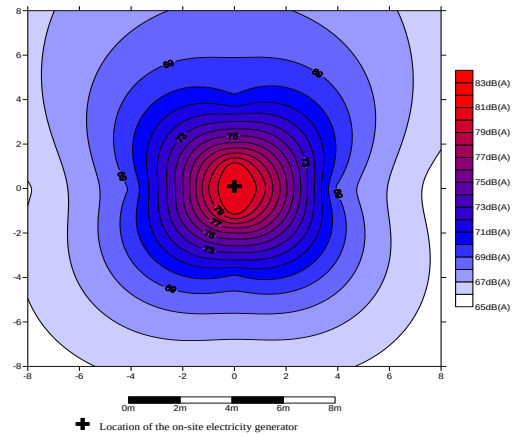


Figure 2. Noise contour for the on-site electricity generator mounted on sand with 0.09mm particle size

Conclusion

This research work was aimed at assessing the effect of different particle sizes of sand bed anti-vibration mount on noise intensity from a portable on-site electricity generator. Distance from the on-site generator plays a dominant role in noise intensity. Results obtained from the study reveal that noise emitted from the portable electricity generator without any anti-vibration mount varies from 65.73 to 82.93 dB(A) at a distance of 1m to 8m away from the on-site electricity generator. These values exceed the acceptable limit recommended by the World Health Organization for residential, commercial and industrial areas. Upon introduction of sand beds with particle size ranging from 0.09mm to 2.3mm, noise intensity from the portable generator was reduced by 0.16 to 2.59 dB(A) in the northern direction, 0.14 to 2.78 dB(A) in the southern direction, 0.23 to 1.69dB(A) in the eastern direction, and 0.11 to 2.33 dB(A) in the western direction. Specifically sand bed anti-vibration mount with 0.09mm particle size has the highest reduction of vibration noise emanating from the on-site electricity generator while the 2.3mm particle size had the least reduction. This is because the 0.09mm sand particles were able to distort slightly and absorb most of the vibration noise energy from the on-site electricity generator unlike the 2.3mm particles which reflected most of the noise energy. Though the noise reduction is not substantial because a greater part is transmitted through air, it is usually difficult to isolate vibration noise acoustically and its effect is normally felt before airborne transmission. Therefore, based on this study, the use of ISO 14688-1:2002 fine sand category is recommended as anti-vibration mount in combination with other damping methods in order to achieve appreciable noise reduction.

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