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An Initial Study of Finite Element Analysis on Sound Pressure and Pressure Drop on a Diesel Generator Sets

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Abstract: This study is concern about the behavior of a diesel generator sets in terms of sound pressure level and pressure drop. Numerical study had been carried out by using simulation from the ANSYS software to obtain the sound pressure level and pressure drop across a duct silencer of a diesel generator sets. ANSYS Fluent and ANSYS Harmonic Responses was used to perform the simulation on the sound pressure level and pressure drop of the duct silencer. The design of the 3-dimensional model consists of splitter and rockwool as its porous medium. Observation was focused along the simulation process and detailed investigation has been carried out on the duct silencer. From the results obtained, there is noise reduction and pressure drop occur across the duct silencer and contour were observed clearly.

Keywords: Duct silencer, pressure drop, sound pressure level, diesel generator sets, finite element analysis

1. Introduction

Electricity is one of the crucial elements that we need in our life. Without it, eventually, many bad things can happen. As we know many buildings, houses, military bases, and communication towers are powered up by electricity. When these premises experience power outages, it may contribute to bad things. Blackout can cause catastrophe for businesses and create inconveniences for individuals [1]. Hence, a backup emergency power, or we can call diesel generator sets (gen-sets) is used to prevent from this thing happen. In 2013, Sellapan states that generators are important for usage in a construction site where electricity cannot reach [2]. It can provide enough power to cover a range of places where the power grid cannot reach. Although it benefits us with the electricity produced, yet still has some disadvantages when using it. The lean-burning design of diesel generators and the high pressure and temperature of the combustion process give rise to a considerable emission of NOx (gaseous oxides of nitrogen), an air pollutant which is a unique challenge in reducing them. In the generator, the magnetic field generates the circumferential forces needed for the transfer of electricity [2].The forces generated during the transfer of electricity might produce vibration and noise produced. Hence, users and passer-by will expose to the noise and could experience damage to the hearing system. Furthermore, one of the worst occupational risks that ever recorded is exposure to noise, experience by the worker's bot from the US and worldwide. Recent studies show that 22 million U.S. workers are exposed to high noise levels while working and 25% of U.S. workers have a history of noise exposure during their career. Excessive noise exposure is the cause of hearing loss that can still be prevent [3]. In Malaysia, the highest cases of occupational disease ever been recorded which is 2478 cases compared to other diseases were occupational noise-induced hearing

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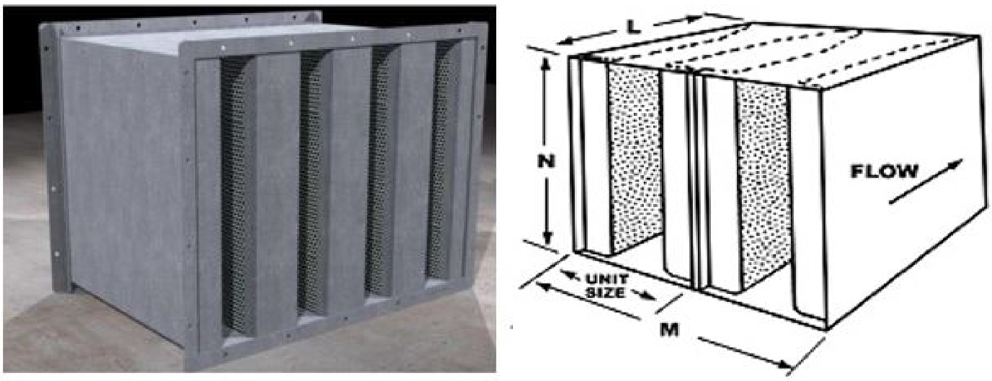
disorder[4]. The Malaysia Factories and Machinery (Noise Exposure) Regulation 1989 was introduced to protect the workers from excessive exposure to noise and may be prescribed shall be taken as will eliminate the risk[5]

This study focuses on the simulation of sound pressure level and pressure drop on a duct silencer of a diesel generator sets. The perimeters and other related information are retrieved from a local consultant, Modulus Acoustic Plt Company. ANSYS is used to simulate and study the behavior of the diesel generator sets.

2. Methods

2.1 Materials

Duct silencer are commonly used to reduce noise from the engine, blower, and exhaust (discharge) [6]. An acoustic air vent is a soundproofed option for allowing ventilation into music rooms, studios, and band rooms without jeopardizing other soundproofing measures. It provides two types of work which are providing air into an enclosure and prevent unwanted noise from entering or out from an enclosure, it depends on what the system is used for.



(a) **(b)**

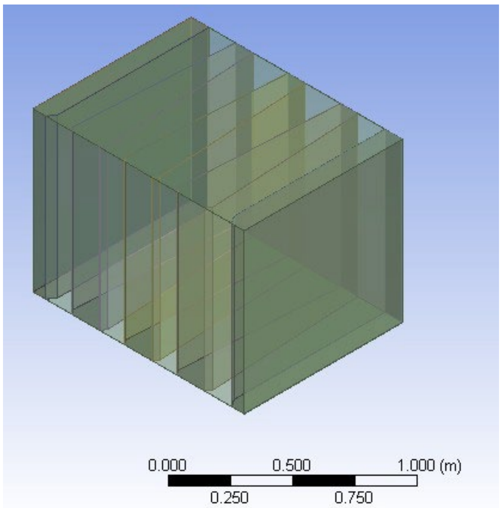
Fig. 1 - (a) Splitter duct silencer; (b) schematic dimension of silencer [7]

	Metric
Density	40 kg/m^3)
Mechanical Properties	
Fluid resistivity	10000 Ns/mm^4

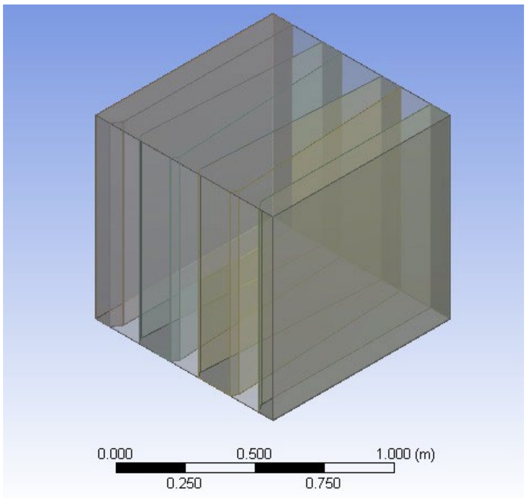
2.2 Ansys Process

The initial geometry model of duct silencers is created using SolidWorks software. The duct silencer consists of two type which is discharge silencer and intake silencer. The dimension for discharge silencer is 900mm x 900mm x 900mm and for intake silencer is 900mm x 900mm x 1200mm and both geometry models are exported to ANSYS as shown in Figure 2.

Ansys workbench is used to make the simulation of sound pressure level and pressure drop on both model of silencer. To ensure that the simulation work effectively, the data, CFD and harmonic responses is used to make the simulation. Computational Fluid Dynamic (CFD) is a technique used to study the fluid dynamic characteristic of a fluid. While harmonic responses are a technique used to determining the steady-state sinusoidal response to sinusoidal varying loads all acting at a specified frequency. The velocity input for discharge and intake silencer is 2.47 m/s and 1.94 m/s respectively. While the frequency defined by user for harmonic responses range from 63 Hz to 8000 Hz.



(a) **Intake silencer**



(b) Discharge silencer

Fig. 2 - Geometry model of discharge silencer and intake silencer

3. Results and Discussions

3.1 Pressure Drop Theoretical

Pressure drop throughout the silencer need to be take great care of as to prevent any harm towards the diesel generator sets. Thus, based on the catalogue, it had stated the allowable pressure drop towards the silencer. The formula to calculate the pressure drop at the silencer has been given as follows;

$$Pressure\ drop = kv^2 \qquad (1)$$

where k is a constant value of the silencer model and v is the face velocity of the silencer.

Silencer model used for this diesel generator sets is MO-DS2S-33 with length 900mm. From the catalogue, the k (silence loss coefficient factor) is 1.9. The dimension for discharge silencer is 900 mm x 900 mm x 900 mm (Length × Width × Height).

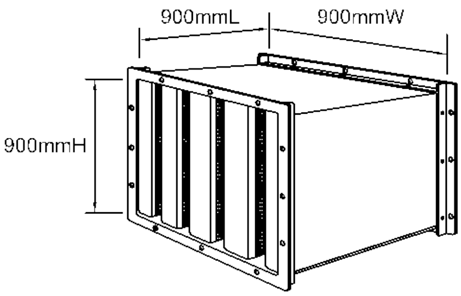


Fig. 3 - Discharge silencer

The value of radiator airflow is needed to calculate face velocity. Hence, from catalogue, it had stated that the value of airflow during cooling performance at high temperature when it is in its prime power is 2 m3/s.
Hence, with this equation,

The value of radiator airflow is needed to calculate face velocity. Hence, from catalogue, it had stated that the value of airflow during cooling performance at high temperature when it is in its prime power is 2 m^3/s. Hence, with this Equation (2), the face velocity is 2.47 m/s

$$Face\ velocity(v) = \frac{\text{radiator airflow } (m^3/s)}{\text{cross section area of the silence } (m^2)} \quad (2)$$

Sub the face velocity value from Equation (2) into equation (1), the pressure drop is:

$$\text{Pressure drop} = 1.9 \text{ x } 2.47^2 = 11.59 \text{ Pa.}$$

As for the intake silencer, with the dimension of 900 x 1200 x 900 (length x width x height)

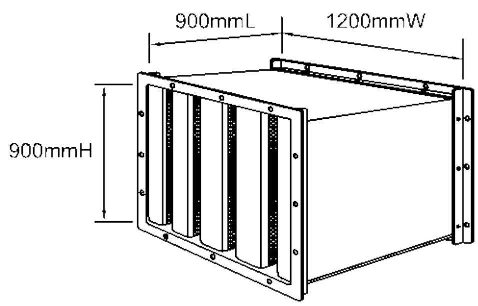


Fig. 4 - Intake Silencer

$$Face\ velocity(v) = \frac{\text{radiator airflow + combustion airflow } (m^3/s)}{\text{cross section area of the silence } (m^2)} \quad (3)$$

From catalogue, the value that been provided for the intake silencer is the combustion airflow where it had been taken from intake and exhaust system air consumption during its prime work which is 5.7 m^3/min and it needed to convert its unit to m^3/s.

$$\frac{5.7\ m^3/min}{60s} = 0.1m^3/\text{s}$$

Hence, the value of radiator airflow and combustion airflow is 2 + 0.1 = 2.1 m^3/s. Substitute the value into Equation (3) the face velocity is 1.94 m/s and the pressure drop is:

$$\text{Pressure drop} = kv^2 = 1.9 \text{ x } 1.94^2 = 7.15 \text{ Pa.}$$

3.2 Sound Pressure Level Theoretical Calculation

Noise need to be calculated in order to fulfilled the Department of Environment requirement. As the diesel generator sets produce loud noise and can contribute to noise pollution, the installation of silencer at the enclosure is needed. Hence, sound pressure level will be calculated for the discharge and intake silencer. Figure 5 below is the calculation for intake and discharge silencer.

Frequency	63	125	250	500	1k	2k	4k	8k	overall noise
Genset Sound Power Level	80	86	90	92	89	89	82	77	
Correction factor	-11	-11	-11	-11	-11	-11	-11	-11	
Genset sound pressure level	69	75	79	81	78	78	71	66	
reverberation factor	**2**	**2**	**2**	**2**	**2**	**2**	**2**	**2**	
genset sound pressure level	**71**	**77**	**81**	**83**	**80**	**80**	**73**	**68**	**88 dB(A)**
silence model insertion loss (model: MO-DS2S-33/900 mm)	3	8	15	29	39	41	31	21	
expected noise spectrum at 1m	**68**	**69**	**66**	**54**	**41**	**39**	**42**	**47**	
overall noise level after treatment				**73**					**73 dB(A)**
Noise level@boundary 13 m (20 log 13 m) = 22 dBA				73 dB(A) - 22 dB(A)					51 dB(A)
Attenuation (after treatment)				**88 dB(A) - 73 dB(A)**					**15 dB(A)**

Fig. 5 - Calculation for intake and discharge silencer

From Fig. 5 above, it has stated several parameters that were needed in the calculation. Correction factor is needed to change from sound power level to sound pressure level.
Equation that are to be used was;

$$L_p = L_w + \left(10_{log}\frac{Q}{4\pi r^2}\right) \qquad (4)$$

Where L_p is the sound power level, L_w is the sound pressure level, Q stands for directivity index and r is the distance from the sound source. By assuming Q=1 (sound propagation in full spherical) and r =1 m.
Hence, the equation used is;

$$L_p = L_w + (-11) \qquad (5)$$

Referring to Fig.5 for the frequency of 63 Hz, the sound pressure level for generator is 80 dB(A) and the correction factor is -11. Thus, the sound pressure level of the generator sets is as in Equation (5).

$$L_p = 80 - 11 = 69dB(A)$$

By assuming the reverberation factor of 2 dB(A) at the machine and the enclosure, therefore;

$$69dB(A) + 2dB(A) = 71dB(A) \text{ at the frequency of 63 Hz}$$

Total sound pressure level can be calculated using the Equation 6,

$$\text{Total sound pressure level}=10\log\left(10^{\frac{L1}{10}} + 10^{\frac{L2}{10}} + 10^{\frac{L3}{10}} + \cdots\right) \qquad (6)$$

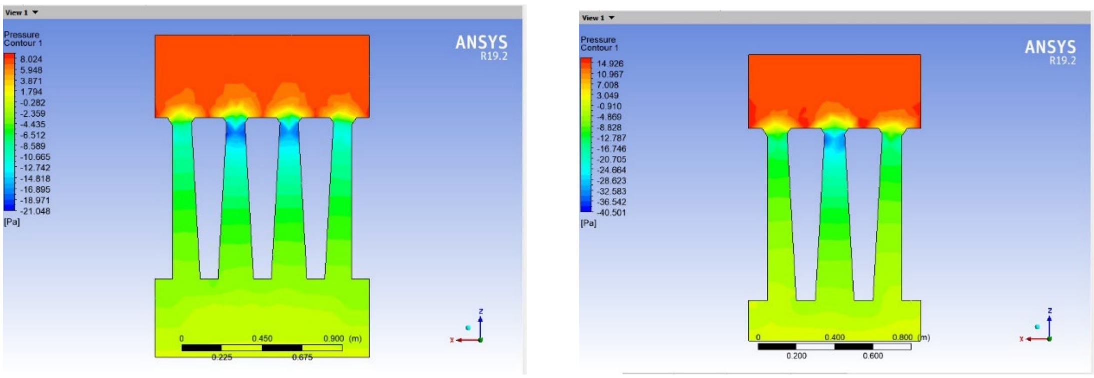
$$=10\log\left(10^{\frac{71}{10}} + 10^{\frac{77}{10}} + \cdots + 10^{\frac{68}{10}}\right)$$

$$=88dB(A)$$

The reduction of noise from generator can be achieved with the usage of silencer model MO-DS2S-33. Noise reduction at the frequency of 63 Hz is 68 dB(A) and the total sound pressure level after the installation of silencer is 73 dB(A) at the distance of r = 1m.

3.3 Pressure Drop Simulation

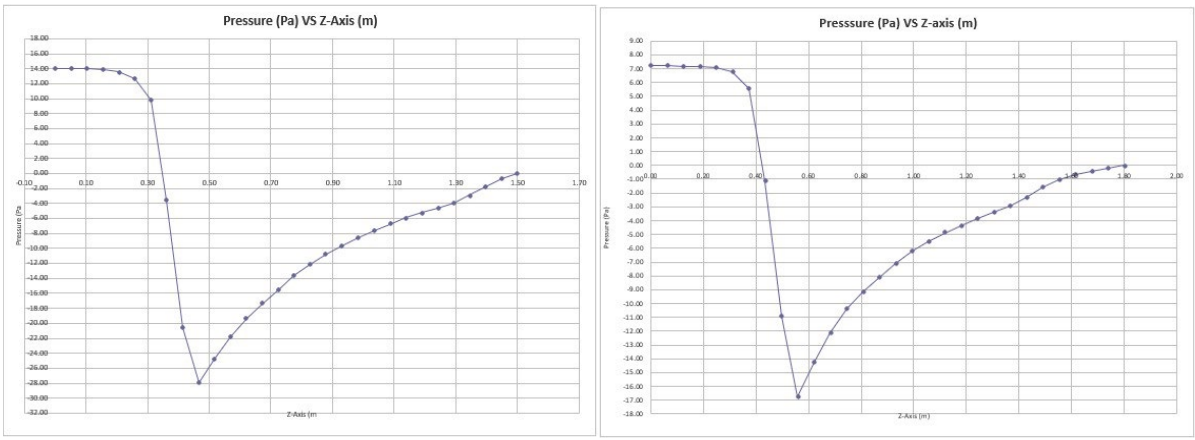
Fig. 6 shows the pressure contour throughout the silencer from inlet to outlet. The upper part of the figure is the inlet region while the lower part is the outlet region. Thus, the pressure at the inlet is higher to be compared to the outlet. Thus, we can deduce that there is the occurrence of pressure drop throughout the silencer. Moreover, the pressure at the outlet is lower than the inlet. Hence, there is no backflow at the vent. Back pressure is a serious matter that we do not take it lightly. It can disrupt the efficiency of a system and also can contribute to the malfunction of a system.



(a) Intake silencer **(b) Discharge silencer**

Fig. 6 - Pressure contour for discharge silencer and intake silencer

Fig. 7 shows the data collected from 30 locations along the z-axis of the silencer model from inlet to outlet. These data were exported from ANSYS as it can show the exact value of pressure at a certain point or several points at one time. The result of the graph started to plummet and constantly increasing after a certain point. Fig. 7(a) is for discharge silencer and Fig. 7(b) is for intake silencer. From the graph, we can extract the value of the inlet pressure and the outlet pressure. Thus, we have obtained the pressure drop across the silencer. For discharge silencer, the pressure inlet is 14.1 Pa and the pressure outlet is 0 Pa. Hence, the pressure drop across the discharge silencer is 14.1 Pa. As for intake silencer, the pressure inlet is 7.21 Pa and the pressure outlet is 0 Pa, so the pressure drop across intake silencer is 7.21 Pa.



(a) Discharge silencer **(b) intake silence**

Fig. 7 - Pressure Vs Z-axis graph for silencer

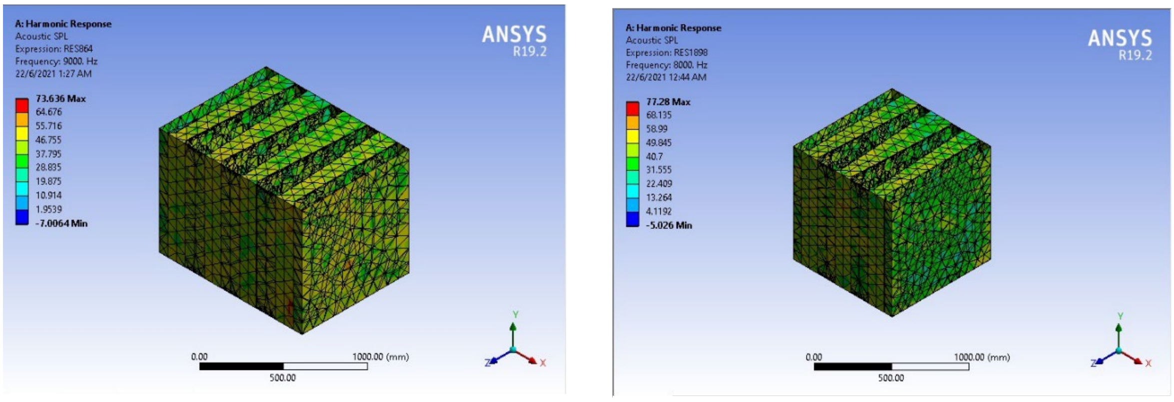
Table 2 below shows the result obtain from simulation compared to theoretical. The value obtained from theoretical for intake and discharge silencer is different may because of the dimension and the different in number of splitter. As for the value obtained from simulation, it is slightly different compared to the theoretical. It may happen because of the solver input or the geometry itself. To conclude, the simulation able to simulate and obtain a good result as the result is not significantly different compared to theoretical

Table 1 - Theoretical vs CFD result

Model	Face velocity (m/s)	Pressure drop (Pa)	
		Theoretical	CFD
Discharge silencer	2.47	11.59	14.1
Intake silencer	1.94	7.15	7.21

3.4 Sound Pressure Level

Fig. 8 shows the contour of sound pressure level across the silencer from inlet to outlet. In general, the reduction of sound pressure level is happening as it goes through the silencer. Thus, we can deduce that there is attenuation of sound pressure level throughout the silencer. The value obtained is the value after the installation of silencer. The noise reduction occurs because of the present of rockwool and the splitter. The rockwool absorb the noise produced and convert acoustic energy to heat energy. Furthermore, the thickness of the porous-medium also affect the performance of the silencer[8]



(a) Intake silencer **(b) Discharge silencer**

Fig. 8 - SPL contour for discharge silencer and intake silencer

From Fig. 8 the comparison between theoretical and simulation result slightly different. Value for simulation might be differ because of solver input or geometry. Between discharge silencer and intake silencer, there is quite a big difference for discharge silencer as the difference between theoretical and simulation is about 4 dB(A). As for intake, the difference between theoretical and simulation is only about 0.6 dB(A). Despite of the difference, we still able to simulate the sound pressure level for these silencer. To be conclude, the simulation able to obtain satisfactory result as the result is not significantly different compared to theoretical. Table 3 shows the result obtain and being compared with theoretical.

Table 3 below shows the value obtained from theoretical compared to simulation. The difference in value between the simulation and theoretical is might because of solver input and geometry. This is because, as in geometry, the placement of rockwool during assembly in SolidWorks is in the centre of splitter and did not filled the entire space of it. Hence, there might be a present of air space between the splitter case and the rockwool that might interrupt the simulation process in ANSYS. Finally, the theoretical results and the simulation results is still in permissible noise level allowed by Department of Environment which is 80 dB(A)[9].

Table 2 - Theoretical vs harmonic responses result

Model	**Sound pressure level (dB(A))**	
	Theoretical	Harmonic responses
Discharge silencer	73	77.28
Intake silencer	73	73.6

4. Conclusion

Sound pressure level and pressure drop of a duct silencer on s diesel generator-sets has been studied numerically where the simulation was carried out by using ANSYS. The result obtained from the test simulation was compared with the theoretical results, which creates a significant agreement between the pressure drop and the sound pressure level. However, the simulation had its limitation as the software demanded a very high specification of computer. Besides, based on the study which has been implemented, it is shown that the pressure contour and sound pressure contour has tremendously influenced by the presence of splitter and rockwool. Moreover, it leads to the pressure drop and the reduction of noise across the silencer. To be conclude, the simulation able to obtain satisfactory result as the result is still in range of tolerance.

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