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A Finite Element Analysis on Sound Pressure and Pressure Drop on Diesel Generator Sets

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Abstract: Diesel generator sets are extensively utilized to produce energy and may also double as a backup power supply in the event of a power outage. However, it produces a noise that affects the peace and health of the environment. The aim of this study is to determine the sound pressure level and pressure drop of the diesel generator sets' duct silencer by performing a CFD and Harmonic Response simulation by a finite element analysis software. The study is executed by simulating several parameters of the splitters of the silencers and comparing the results of the experiment to the theoretical results. The pressure drop over the discharge silencer and intake silencer, according to data received from ANSYS, is 14.2 Pa and 7.21 Pa, respectively whilst the sound pressure levels for the discharge silencer and intake silencer, according to the data in ANSYS, are 77.28 dB(A) and 73.6 dB(A), respectively. Other results for the comparison of silencers based on splitter dimension is also included. The results were found to be similar and the study is deemed successful, nonetheless, the design geometry must be improved to help reduce noise emissions and an advanced specifications of computers should be used for an effortless simulation analysis.

Keywords: Finite Element Analysis, Diesel Generators, ANSYS Simulation, Silencers

1. Introduction

Diesel generator sets, commonly known as gen-sets, are widely used in the industry, according to Malaysia, our country. In the event that an industry loses electricity, these generator sets can be employed as a power source or as a backup power supply. Diesel generator sets (gen-sets), either within or outside of a facility, are frequently situated close to populated areas. Industries that are situated in locations without access to the electrical grid must also install diesel generators in these locations. These suggests that as Malaysia's industrialization develops, this group of diesel generators (generators) will become increasingly important to the nation's industry.

Inevitably, gen-sets generally produce a lot of noise, which adds to noise pollution. A nation's industries will eventually grow in number as they continue to develop. Because diesel generators are utilised so often, noise pollution is becoming a bigger problem. This is a major problem, especially in populated areas like homes, hospitals, and shopping malls [1]. This problem may also result in a variety

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of occupational diseases. Hearing issues are a frequent occurrence in a range of illnesses that can affect workers in a variety of jobs as a result of exposure to loud noise. There are various types of hearing issues, including conductive hearing loss, sensory hearing loss, and mixed hearing loss, which combines the two conditions previously discussed. A growing body of epidemiological research has significantly supported the impacts of noise pollution on physical health [2][3]. Diesel generators are typically used to provide energy because the PLUS highway is frequently located far from the power grid, and hearing issues have been noted as a result of the reported excessive noise exposure. The highest acceptable sound level near commercial business zones, which we are adhering to, is only 65 dbA, despite the fact that for electric power between 2kva and 240kva, the maximum sound power level legally authorised is 100 dB(A)/1Pw [4].

Hence, in this study, a finite element analysis is done on sound pressure and pressure drop specifically on the duct silencers within the gen-set on the PLUS highway to fulfil the standards of the environmental department. Once the experimental results were received, a comparison is made with the theoretical results to see if it corresponds to one another. It is assumed that if the values are similar, then the theoretical calculation is correct and could be used to improve the generator's noise emission.

All in all, this study was performed in aspiration to reduce the noise emission by the generators and to aid in the medical issues related to noise pollution. It is to make the generators more environmentally friendly while staying efficient.

2. **Materials and Methods**

2.1 Materials

The duct silencer's design is based on a catalogue that is employed by the diesel generator sets enclosure. SolidWorks software was used to create the geometry. The system's geometry is made up of various elements. The dimensions of the discharge silencer are 900 mm x 900 mm x 900 mm (Length x Width x Height). The length, width, and height of the intake silencer are 900 mm, 1200 mm, and 900 mm, respectively. The width of the splitters in the silencer are a constant 200 mm and 100 mm. To further analyse the design in order to compare efficiency, two other designs of the discharge and intake silencers with the exact same length, width, and height of the intake silencer which are 900 mm, 1200 mm, and 900 mm, only with the splitters' width being 100 mm and 100mm, and 250 mm and 100mm, respectively.

2.2 Methods

Once the parameters have been identified, the geometry model is then brought to ANSYS software where we will perform Computational Fluid Dynamics (CFD) and Harmonic Response simulations on both the intake and discharge silencers. CFD's capability of analysing complicated fluid-fluid, fluid-solid, or fluid-gas interactions and it analyses mimic a true physical solution while the steady state dynamic response of a structure subjected to sinusoidally fluctuating loads is predicted using harmonic analysis.

Prior to the simulations, parameters and boundary conditions must be set. As commonly known, meshing is done to the geometry as a step to simulate the silencers on sound pressure level and pressure drop. Soon after, the simulation is executed and results were obtained, it was observed, compared and documented in hopes to ultimately improve efficiency. In spite of that, there were certain limitations to the experiment using the ANSYS software. For example, a high specification computer is needed to run the simulation smoothly, if failure to achieve, a normal specification computer will lag or break down during simulation.

3. Results and Discussion

In this subject, theoretical estimates for the duct silencer's pressure drop and sound pressure level were made. The results of ANSYS Fluent will be shown and discussed. The pressure drop surrounding the silencer was investigated. Once analysed, the results of the simulation and the theory will also be compared.

3.1 Results & Discussion

By using the formula below to calculate the theoretical results, we obtained that the pressure drop is 7.15 Pa and 11.59 Pa for intake and discharge silencer, respectively. The sound pressure level is measured at 73 dBA.

Pressure drop equation:

$$\text{Pressure drop} = \text{kv}^2 \qquad (1.0)$$
$$= k\left(\frac{Q}{A}\right)^2$$
$$= k\left(\frac{Q}{w \times h}\right)^2$$

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 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)**

Figure 1: Calculation for Intake and Discharge Silencer

As for the simulation results, we have obtained the pressure, vector velocity and the sound pressure level to be compared and observed.

We have estimated the pressure drop over the silencer as a consequence. The discharge silencer's pressure intake is 14.1 Pa, and its pressure exit is 0 Pa. As a result, there is a 14.1 Pa pressure decrease over the discharge silencer. Since the pressure at the inlet is 7.21 Pa and the pressure at the outlet is 0 Pa, there is a 7.21 Pa pressure drop across the intake silencer. Table 1 displays the theoretical and CFD results. The simulation value is slightly different from the theoretical value. The geometry or the solver's input might be to blame. The theoretical value for intake and discharge silencers varies according to the various dimensions and the various numbers of splitters. As a result, the number of paths varies according to the usage of splitters. In conclusion, even though the simulation produces similar findings to those achieved theoretically, it might still produce favourable results.

Table 1: Theoretical versus CFD Result

Model	Face velocity (m/s)	Pressure drop (Pa)	
		Theoretical	CFD
Discharge silencer (200mm)	2.47	11.59	14.1
Discharge silencer (100mm)	2.47	11.59	18.22
Discharge silencer (250)	2.47	11.59	37.75
Intake silencer(200mm)	1.94	7.15	7.21
Intake silencer(100mm)	1.94	7.15	13.18
Intake silencer (250mm)	1.94	7.15	39.97

As can be seen in Table 2, the evaluation of theoretical and simulation leads in wildly different findings. The simulation value could vary as a result of solver input or geometry. This appears to be a result of the Rockwool being positioned in the splitter's centre during assembly in SolidWorks rather than covering the whole gap. On account of this, there could be air space between the splitter case and the Rockwool, which might potentially result in a problem with the ANSYS simulation. Between theoretical and simulation results for the discharge silencer (A) of a 200 mm splitter, there seems to be a variance of around 4 dB between the intake and discharge silencers. Only around 0.6 dB separate the theoretical and simulated intake for 200 mm (A). Despite the variances, we were nevertheless able to duplicate the sound pressure level for these silencers. There is a noticeable difference of roughly 6 decibels (A) for the discharge silencer with a splitter length of 250 mm, while there is only a change of around 2 dB (A) for the intake silencer with a splitter length of 250 mm. Last but not least, the noise levels for the splitter's intake and discharge silencers are 76.67 dB(A) and 74.22 dB(A), respectively. Overall, there isn't much of a difference between the theoretical and simulated results; however, when the results of the silencers of different dimensions are compared with one another, we can say that the 250 mm silencers with the longest splitter have the best design, making them more effective at lowering sound pressure level. This is thus caused by the splitter's length being longer than the silencer's 200 mm theoretical length. The splitter may absorb sound more effectively and there is less space between it and the silencer when it is longer.

Table 2: Theoretical versus Harmonic Responses Result

Model	Sound pressure level (dB(A))	
	Theoretical	Harmonic Acoustics
Discharge silencer 200mm	73	77.28
Discharge silencer 250mm	73	67.23
Discharge silencer 100mm	73	74.22
Intake silencer 200mm	73	73.6
Intake silencer 250mm	73	71.86
Intake silencer 100mm	73	76.67

Given that, companies could simply make silencers with a wider splitter to give the same efficiency, if not better, as expensive silencer models with more splitters. In conclusion, the simulation was successful in producing outstanding findings because they did not significantly deviate from the expected outcomes.

4. Conclusion

Finally, the data from each simulation run was collected and compared to the predicted outcomes. Given that the results were not drastically different and were nonetheless bearable, they were satisfying and instructive for future references. The permitted pressure drop limit for the system is 100 Pa, and the pressure drop via the silencer is still below that. The results also show that there is no backflow or even backpressure via the silencer. The study's findings regarding sound pressure level show that the presence of a splitter and rockwool significantly affects the pressure and sound pressure contours. As a result, there has been a decrease in pressure and noise across the silencer. To make the generator sets truly effective, better designs or geometries are advised, and a better equipment with extremely high specifications is needed to execute the analysis smoothly.

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