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Research Paper

Experimental investigation of noise characteristic of a compression ignition engine

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Abstract

Noise is a very important phenomena for passenger comfort in a vehicle. Engine of the vehicles produce disturbing noises in different frequencies. In the application of acoustic, there are different filters to predict the sound pressure level and disturbing noises. The aim of the present study is to investigate the noise characteristic of a compression ignition engine at different weighting filters. In the experiments, the engine was fuelled with low sulphur diesel and sunflower biodiesel fuels and it run at different engine speeds ranging from 1200 to 2400 rpm, with steps of 300 rpm. The results indicated that noise characteristic of compression engine with engine speed shows different trends at A- weighting filter than C- and Z- weighting filters especially at 1500 rpm. Moreover, in the study, it was cleared that the SPL decrease with the addition of biodiesel fuel regardless of its ratio.

Keywords: Noise, Acoustic filter, Biodiesel, Compression ignition engine

1. INTRODUCTION

Noise generation of internal combustion engine is a highly complex phenomena. In a vehicle, engine, powertrain, tyre road interaction, and aerodynamic are the main sources of the noise generation [1]. Noise of the engines has significant effects on vehicle passengers and urban residents. On the other hand, noise of the engine provide information about its operating condition. Acoustic signal presents useful diagnosis signal at various frequencies. Although noise is generally considered as annoyance at the basic level, it may cause more serious health problems. Therefore, regulations have been developed by governments to bring down the vehicle noise generation. A- weighting filtered sound pressure level (SPL) is generally assessed in terms of road-traffic noise since A- weighting is similar to perceived loudness by human ear at 40 dB. A- weighting filter covers the frequency range of 20 Hz to 20 kHz with resemble shape of human ear sensitivity. However, C- weighting level is more flat and represents human hearing at 100 dB. C- weighting is covers audible frequencies used for the measument of peak SPL [2]. Whereas, Z- weighting level is a flat frequency response. Detailed view of frequency weighting curves were shown in Figure 1.

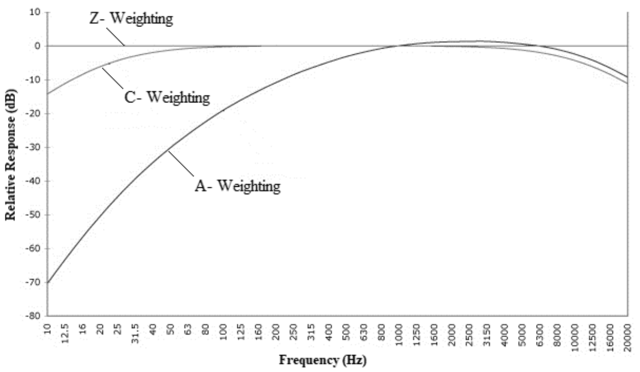

Figure 1: Frequency weighting curves

In previous studies, noise emission of vehicles and engines are generally evaluated with dB(A). In those studies, researchers are mostly compared the noise emission generation of alternative fuels, maintenance and ergonomic issues of an engine or a vehicle. In the study of Patel et al. (2019), a genset engine was used for investigation of noise generation of the engine when it was fuelled with soybean and rapeseed biodiesels [3]. According to their experimental studies, they concluded that there was a strong relationship between the

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heat release rate and combustion noise. Numerical approach on noise generation of an engine was also studied by researchers [4]. Sancho et al. (2017) were analysed the evolution of noise emission of motorcycles, light vehicles, buses, trucks and other type of vehicles in years [5]. Hoffmann and Kroop (2019) were studied for the combine model of tyre/road noise [6]. They achieved that the auralization tool delivers pass by sounds that are perceived in a very similar as recordings except a small range. Different weighting filters were investigated in some studies such as Sinay et al., 2018 [7].

Due to the depletion of fossil fuels and environmental concerns, alternative fuels has gained great attention by the community. Therefore, all effect of alternative fuels should be investigated in details. In this study noise generation of a compression ignition engine was investigated by using various filtering. A-, C-, and Z- weighting filters were used to measure and analyse the noise generation. During the experiments, the engine was operated at different speed while it was fuelled with diesel and sunflower biodiesel fuels.

2. MATERIAL AND METHOD

The engine experiments were conducted on a Mitsubishi Canter 4D34-2A, four stroke, four-cylinder diesel engine. The experimental room and periphery of the dynamometer was covered by special sound absorbers. In the experiments the engine were operated at 1200 rpm, 1500 rpm, 1800 rpm, 2100 rpm, and 2400 rpm with no load condition to avoid the high-level noise generation of dynamometer. The properties of the experimental engine was given in Table 1.

Table 1 Technical specifications of the test engine.

Brand	Mitsubishi Canter
Model	4D34-2A
Configuration	In line 4
Firing order	1-3-4-2
Type	Direct injection diesel with glow plug
Displacement	3907 cc
Bore	104 mm
Stroke	115 mm
Power	89 kW @ 3200 rpm
Torque	295 Nm @ 1800 rpm
Oil cooler	Water cooled
Weight	325 kg

The experimental engine was fuelled with pure low sulphur diesel fuel (D), pure sunflower biodiesel fuel (S100) and their blends in the ratio of 20%, 40%, 60%, and 80% (S20, S40, S60, S80, respectively). The sunflower biodiesel were produced via the transesterification reaction. The properties of test fuels were presented in Table 2.

Acoustic data were recorded via Soundbook™ universal portable measuring system which uses SAMURAI v2.6 software program. Sound level meter of the software is capable to measure according to IEC 60651, IEC 60804, DIN EN 61672-1:2003 standards and it process the data with the frequency weightings A, C, and Z simultaneously.

Table 2 Fuel Properties of the test fuels.

Test Fuels	Density (kg/m^3)	Cetane Number	Kinematic Viscosity at 40°C (mm^2/s)	Gross Heating Value (kJ/kg)
D100	837	59,3	2,7	45857
S20	844	56,5	3,1	44246
S40	854	53,6	3,4	43430
S60	869	51,1	3,7	42998
S80	876	49,0	4,1	41874
S100	886	44,5	4,5	39149
EN590	820–845	Min 51	2.0–4.5	-
EN 14214	860 - 900	Min 51	3,5 – 5,0	-

GRAS 46AF 1/2” LEMO half-inch free-field standard microphone set was used for collecting the noise of the engine. The microphone was placed 1 meter away from the engine blocks. Specifications of the microphone were presented in Table 3.

Table 3 Specifications of microphone

Brand		GRAS
Model		46AF
Frequency range (±1 dB)	Hz	5 to 10 k
Frequency range (±2 dB)	Hz	3.15 to 20 k
Dynamic range lower limit	dB(A)	17
Dynamic range upper limit	dB	142
Set sensitivity @ 250 Hz (±2 dB)	mV/Pa	50
Temperature range, operation	°C	-30 to 70

3. RESULT AND DISCUSSION

The result of noise generation characteristic of the engine was discussed in dB(A), dB(C), and dB(Z) in different engine speed when the engine was fuelled with D, S20, S40, S60, S80, and S100 fuels. The results of the experiments and filters were shown in Figures 2-7.

Based on the measured values, there are significantly different amplitude values in the low engine speed. The results revealed that, for all test fuel, the highest SPL magnitude was obtained at 1500 rpm engine speed with C- and Z- weightings. However, with A- weighting, SPL values were increased with increment of engine speed. Different slope between weightings may related with the gain magnitude of filters. Since, the generated noise at low engine speed, means low frequencies filter by A- weighting. The difference between C- and Z- weighting were decreased with increasing engine speed. This is also due to the filtering bands of C- weighting at low frequencies.

Average SPL found slightly lower than that of low sulphur diesel fuel with the use of biodiesel. The decrement was 0,6 dB(A), 1,0 dB(C), 1,3 dB(Z) for S20; 0,5 dB(A), 0,5 dB(C), 0,2 dB(Z) for S40; 0,7 dB(A), 0,7 dB(C), 0,5 dB(Z) for S60; 0,8 dB(A), 0,8 dB(C), 0,6 dB(Z) for S80; 0,6 dB(A), 0,6 dB(C), 0,4 dB(Z) for S100; Decrement of SPL with biodiesel addition may be related with the decrement of engine vibration and increment of combustion quality due to the extra oxygen content of biodiesel fuel [8,9].

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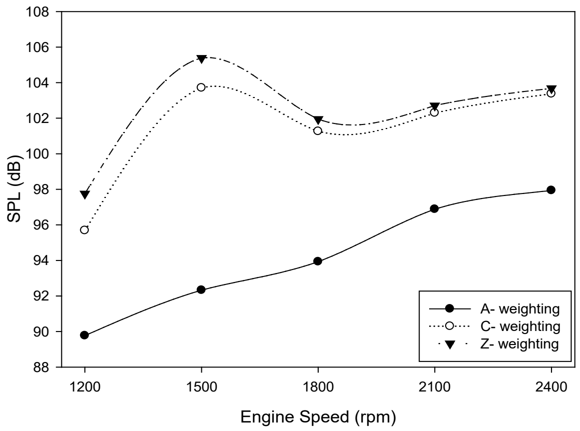

Figure 2: SPL values with D fuel

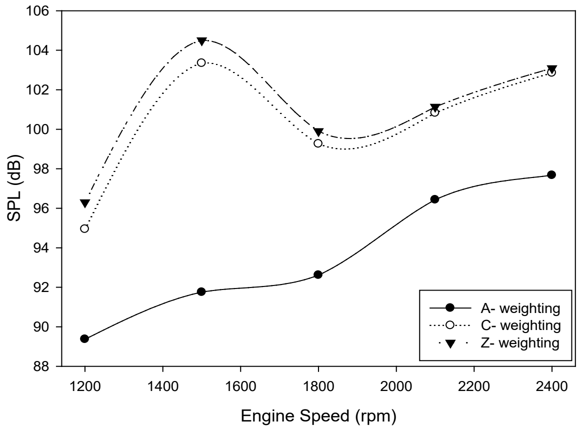

Figure 3: SPL values with S20 fuel

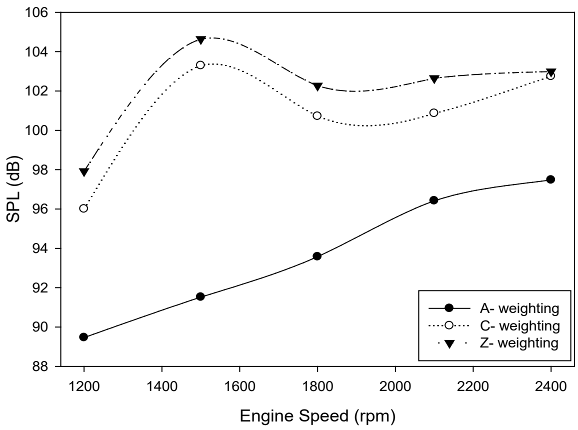

Figure 4: SPL values with S40 fuel

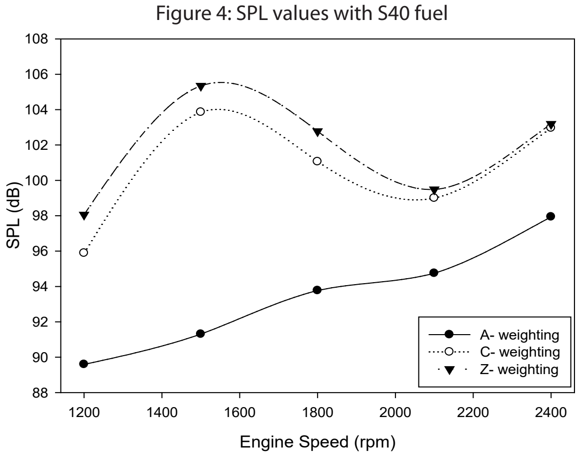

Figure 5: SPL values with S60 fuel

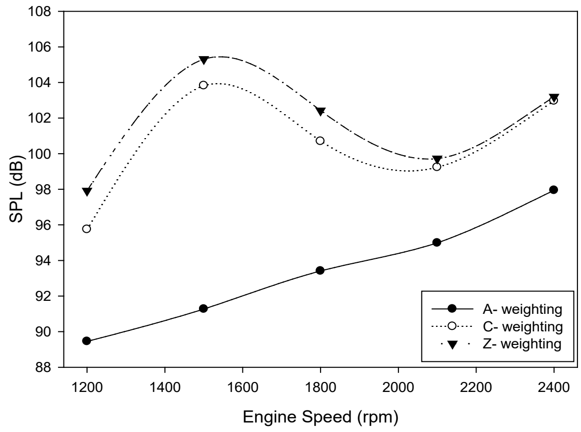

Figure 6: SPL values with S80 fuel

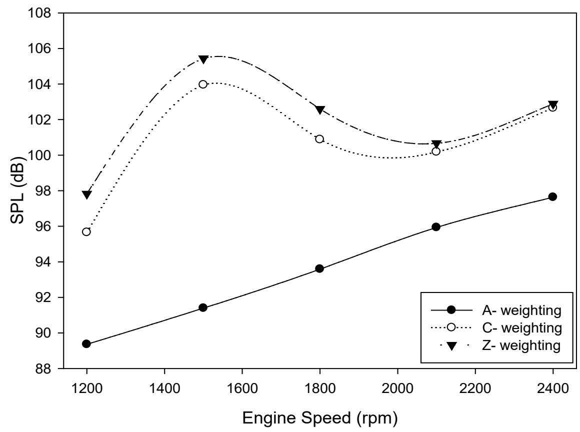

Figure 7: SPL values with S100 fuel

4. CONCLUSION

In the present study, noise generation of a compression ignition engine was investigated by using different filtering. The engine experiments were performed with low sulphur diesel and sunflower biodiesel fuels at 1200 rpm, 1500 rpm, 1800 rpm, 2100 rpm, and 2400 rpm engine speed at no load condition.

- Result of the study showed that main difference between the filters are observed at 1500 rpm engine speed. At this speed, the highest magnitude of C- and Z- weightings filters were measured. Whereas, dB magnitude increased with engine speed at A-weighting filter.
- Compared to pure low sulphur diesel fuel, addition of biodiesel was decreased SPL. However, there was no significant change observed with the ratio of biodiesel.

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