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Research Article

A Comparative Study of Sound Pressure Level (SPL) Generated in CI DI Diesel Engine Run on Petrodiesel and Biodiesel Blends

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Abstract

Engine Noise Studies are being focused to check the possibility of reducing the noise at source as a means of control. In the present study, the focus is on SPL analysis, experimental investigations on performance and emission characteristics of a CI DI engine run on petrodiesel and petrodiesel-biodiesel blends. Composite Oil Methyl Ester (COME) of Jatropha and Pongamia, Graded Coconut Oil Methyl Ester (GCOME) and Waste Cooking Oil Methyl Ester (WCOME) are blended with petrodiesel in various proportions and used as fuel in the engine. SPL analysis is carried out using Brule & Kjaer (B&K) - Type 2231 Modular Precision Sound Level Meter (SLM) along with Type 1625 Octave Filter Set which measures noise pressure level differences between use of these fuels in decibels (dB).Injection pressures (IPs), 160 bars, 180 bars and 200 bars are used. The entire 1/1 and 1/3rd octaves of the sound pressure levels (SPL) generated during the combustion process are recorded and analyzed to identify critical frequencies in Hz. Comparison of SPL between petrodiesel and petrodiesel-biodiesel blends is done at the IPs chosen and at various electrical loading conditions of the engine. Experimental results show use of bio-diesel blends generated lower SPL than neat petrodiesel at various IPs and loads. Comparisons between SPL, Brake Thermal Efficiency (BTE), NO_x emissions for all the blends considered have been made. By the spectrum analysis, the dominant frequencies occurred at 1250Hz and either 1000Hz or 1250Hz for 1/1 and 1/3rd octaves respectively. Generally, the occurrence of these frequencies was dominant for the optimized blends of the Methyl Esters considered.

Keywords: *SPL, COME, Octaves and Dominant Frequencies.*

1. Introduction

Automobile engines, mainly used in transportation sector like trucks, buses, vans, SUVs, tractors, earthmovers, and so on use diesel engines as prime movers. Many of them do not fulfill the acoustic comfort criteria because, either the system is not functioning at the specified sound level parameters or they have got degraded due to ageing.

Noise is an unwanted sound; but it is a form of energy. This energy when produced and propagated within the permissible levels then, it is environmentally friendly. However, noise levels when exceeds beyond the standard acceptable limits, then it becomes one of the source of pollution called Environmental Noise pollution. Sound generated by Diesel Engine is normally produced as a result of power generation process and eventually in the process of pressure reduction in the expansion process in a silencer.

In a machine, noise level around it is due to vibration arising in various combinations of processes and rotating components. When it exceeds threshold levels and for durations beyond the permissible values, becomes a cause for environmental pollution which negates acoustic comfort of human beings. Excessive unwanted noise causes stress and affects human wellbeing, impairs productivity in workplaces, affects patients' recovery in hospitals and care facilities for aged people. On one hand, evaluation parameters of the acoustic comfort are based on both subjective criteria like, noise sensitivity [Job RFS, 1999; Van Kamp I et al, 2004], noise annoyance reaction [Ryu J K et al, 2011].On the other hand, they are also based on objective criteria like standardized sound pressure, sound intensity or sound power levels.

The study of engine noise has been carried out since the early stages of engine development. Ricardo found a descriptive relationship between the combustion pressure rise and sound generated [T. Priede, 1980]. Later, a number of parameters in determining the noise developments were investigated which include the first and second derivatives of cylinder pressure. These methods are elective in revealing the relationship between engine combustion and noise. They play an important role in identifying the sources of engine noise [P. W. Schaberg et al, 1990]. Although there are a number of engine noise sources, the most important one is the combustion-induced noise [T. Priede, 1979]. It occurs towards the end of the compression stroke and during subsequent expansion stroke. Rapid pressure change due to the combustion appears as sound energy and propagates through engine

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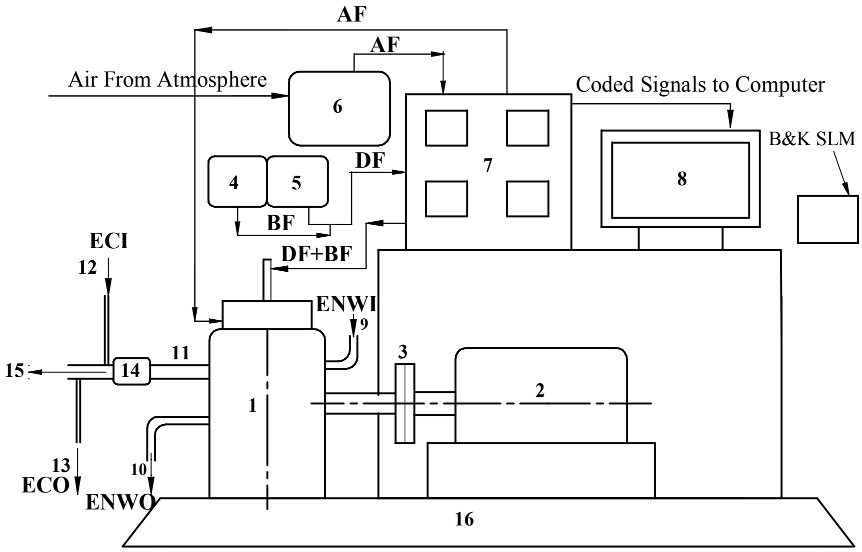


1. Engine 2. Dyanmometer 3. Coupling 4. Biodiesel Tank 5. Petrodiesel tank
6. Air Box 7. Decoder/Display Unit 8. Computer Display 9. Water Inlet
10. Water Outlet 11. Exhaust Manifold 12. Exhaust Coolant Inlet
13. Exhaust Coolant Outlet 14. Eco Gas- 4 Analyser 15. Exhaust to atmosphere 16. Test Setup Platform

AF - Air Flow DF - Diesel Flow BF - Biodiesel Flow ENWI - Engine Water Inlet
ENWO - Engine Water Outlet ECI - Engine Coolant Inlet ECO - Exhaust Coolant Outlet

Figure 1 Experimental Setup

Structures and forms a part of the airborne noise. This pressure change also causes the vibration of the engine components such as the cylinder head, pistons and connecting rods. Vibrations of these components provide another part of the overall engine noise. Together these noise sources account for over 80% of total engine noise. Combustion-induced noise is however the dominant source. It occurs near the Top Dead Centre (TDC). Other noise sources are due to engine functions such as the injection of fuel and the operation of inlet and exhaust valves. These sources usually produce low level noise and make up a fraction of the overall noise. Yet, all have designated times of occurrence in terms of crank angles. For instance, fuel injection is usually performed around 8^0 to10^0bTDC during the compression stroke. The exact instances of these events occurring depend on the design of engines. [Shu G. Et al, 2007]

Several researchers have concluded that complex engine noises using coherent power spectrum analysis, the noise of low-frequency belt is mainly machinery noise, while the noise of high-frequency belt is mainly combustion noise. Most of the engine noise sources are produced by the combustion process. Another airborne engine noise is the machinery noise generated by mechanisms, travelling through several transmission paths. Beside the airborne noise, the structure noise refers to the noise generated by vibration induced in the structure. This also contributes to the total level of the engine noise. Additional noise due to operation of fuel pump, IP, passage of burnt gases in the exhaust manifold at higher pressures, inlet and exhaust valves operation add up to a fraction of the overall noise. [Li, 2001]

In the combustion process, the in-cylinder pressure is varied during the compression and expansion strokes. Change of in-cylinder pressure causes the vibration of the engine components such as the cylinder head, pistons, connecting rods and engine body [Li, 2001]. This results in noise radiation from the engine surface. Consequently, the combustion process should be diagnosed and monitored through analyzing the vibration or combustion noise of the engine. Generally, the higher noise signature in diesel engines is due to the rapid self-ignition of the fuel [Pruvost L. Et al, 2009].This leads to changes of the combustion parameters such as in-cylinder pressure, Rate of Heat Release (RoHR) and ignition delay. Obviously, performance of the fuels has to be monitored by analyzing the combustion induced noise and relate the noise level to combustion characteristics.

Sound and vibration are often linked, where the generation of sound or noise is usually attributed to the vibration of solid objects and can be explained as vibration of the air and considered as airborne noise [D Zhen et al, 2012].

Works of other researchers on sound pressure level for a high thermal capacity burner, indicate that, out the different noise levels during the entire combustion cycle, the critical frequencies have negative impact on the acoustical comfort of the persons nearby [Vlad Lordache et al, 2013].

Investigations and analyses in the present study has led to significant reduction in PM, HC, CO, CO_2 and NO_x emissions (43.25%) and increase in BTE (53.49%) in comparison with other research works. These observations are due to the synergetic effect of mixing of two non-edible oils and then deriving biodiesel by transesterification process [H.Yogish et al, 2012; H.Yogish et al, 2012; H .Yogish et al, 2012; H .Yogish et al, 2013; H .Yogish et al; under review].Waste cooking oil and second grade coconut oil as feed stocks can be important sources of biodiesel as they are available in large quantity.

2. Methods and Materials

2.1 Methods

Engine testing setup consisted of a stationary, four stroke single cylinder, 3.75kW, Kirloskar-AV1 computerized CI DI engine coupled with a DC alternator. Loading was done using an electrical load. Engine cooling was done by means of water. Figure 1 shows the schematic of experimental test rig whose technical specifications are given [H.Yogish et al, 2012; H .Yogish et al, 2012]. This set up is used for investigating performance, emission and SPL. SPL analysis is carried out using Bruel & Kjaer (B&K) Type 2231 Modular Precision Sound Level Meter (SLM) which was used as a measurement system along with B&K Type 1725 Octave Filter Set. This combination of SLM with Filer set was used to measure SPL under various operating conditions of the engine when run on various blends of diesel fuels. These measurement are recorded in decibels (dB) details of specifications are given in table 1. Investigations on emissions were carried out using ECOGAS-4 Gas analyzer.

Figure2 Sound Level Meter and accessories

Table 1 Specifications of SLM

FSD	Measurement Range		
	Lower limit for S/N ration > 5 dB (A-weighting)	Max. peak level	Upper limit for signals of crest factor 10 (= 20 dB)
60	24	73	53
70	24	83	63
80	24	93	73
90	30	103	83
100	40	113	93
110	50	123	103
120	60	133	113
130	70	143	123
140	80	153	133

Engine was not modified in any manner except for changes of injectors, to change IPs, to suit the use of biodiesel blends. Test rig was provided with necessary instruments and probes to sense the signals pertaining to airflow, fuel flow, speed, temperatures and load. Critical positions around the engine test rig were chosen for measuring SPL. Critical position is that position, where SPL values are more as compared to any other position around it. Measurements were performed at 1m distance from the engine by placing SLM on the same horizontal plane of the engine. It was ensured that low background noise was recorded during experiments.

2.2 Mixing of Oils

Jatropha and Pongamia oils were mixed in various proportions and used as feed stock to derive biodiesel. Waste cooking oils collected from different restaurants were mixed. This mixed oil was subjected to transesterification process and biodiesel was derived. Second grade coconut oil (non-edible) was also used but it was not mixed with any other oil. Biodiesels thus derived were tested for various physico-chemical properties like viscosity, density, calorific value, flash point, fire point, Cloud point, Pour point and pH value and they were found to be within the limits suggested by BIS/ASME standards. These properties were found to be very similar to that of petrodiesel.

2.3 Transesterification Process

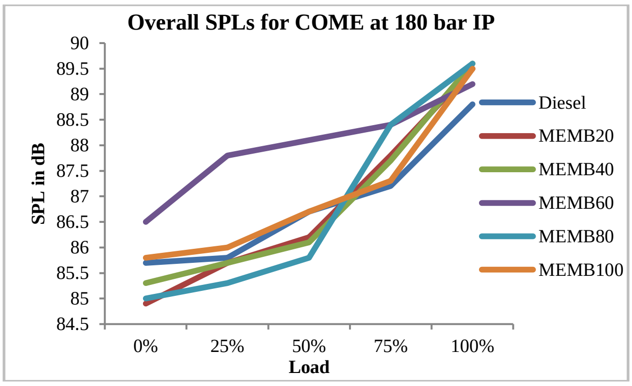
A Laboratory Scale biodiesel reactor of two liters capacity was innovatively designed and fabricated to optimize methanol quantity, catalyst requirement, reaction time and reaction temperature for the three different oils considered. Mixing of NaOH with Methanol after dissolving it completely and then mixing of oils followed by adding H_2SO_4 were done in a single stage. By this, the time required for the production of biodiesels from the feed stocks reduced from 150 min. to 90 min. (about 40% reduction). This is in comparison with present day transesterification processes used. CH_3OH was chosen as alcohol for transesterification of oils because of its low cost. Alkaline catalyst NaOH was chosen for the same reason. They react much faster than acid catalysts.

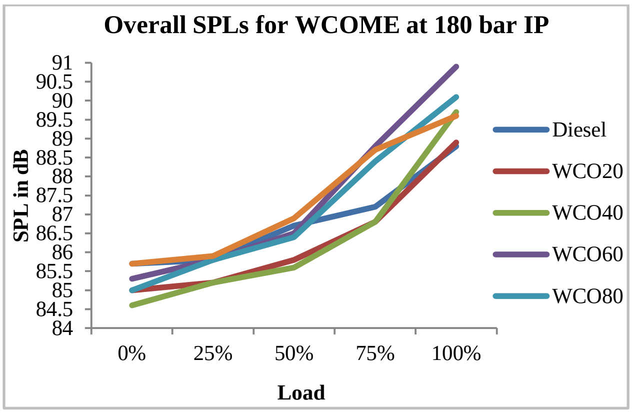
Petrodiesel and biodiesel derived from Composite oil of Jatropha and Pongamia blends were coded as MEMB20, MEMB40, MEMB60, MEMB80 and MEMB100. In the code, B20 means 20% of biodiesel and 80% of petrodiesel. Similarly methyl Esters of mix of waste cooking oils and second grade coconut oil were blended with petrodiesel and coded as WCOB20, WCOB40, WCOB60 and CCOB20, CCOB40 respectively.

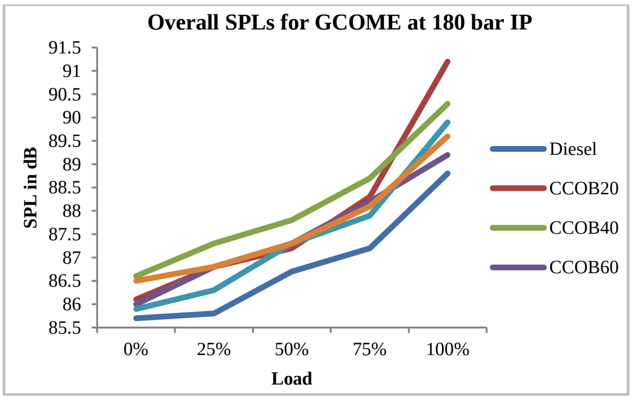
3. Results and Discussions

3.1 SPL and Frequency Analysis

Figure 3 shows the variations of SPLs for blends of WCOME, COME and GCOME with Load. They show the variation of SPLs with respect to load at 180 bar designed IP. The variations at other IPs such as 160 bars and 200 bars are not presented. The general observation is that, for all Methyl Esters and blends considered, SPL increased







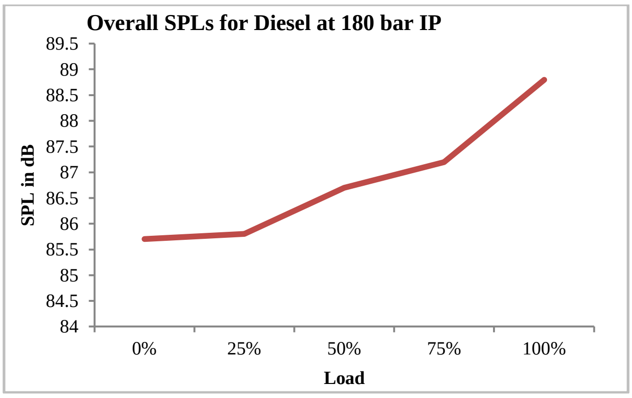


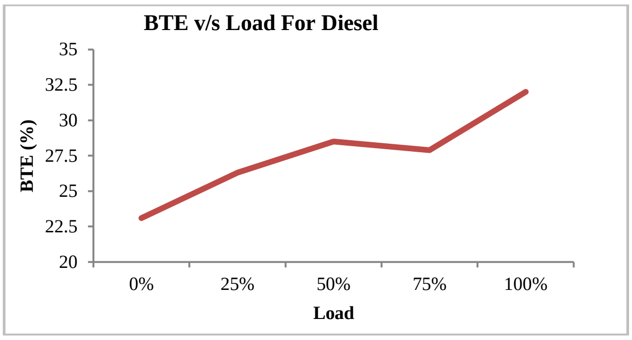
Figure 3 Overall SPLs for Diesel and Methyl Esters at 180 bar IP

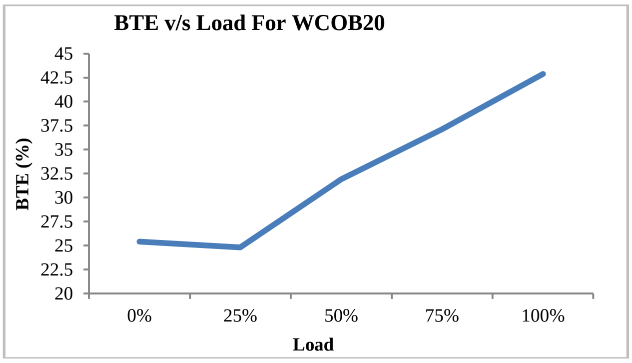
with increase in load irrespective of biodiesels in blends. For WCO20 and WCO40, increase in SPL from 0% to 100% load is 4.3% and 6.03% respectively. For petrodiesel, in the range of the loads considered this value is 3.62%. For MEMB20, MEMB40 and diesel these values are 5.42%, 5.04% and 3.62%. Similarly, for CCOB20, CCOB40 and diesel the values are 5.92%, 4.27% and 3.62%. At 100% load, the differences between SPLs of petrodiesel, WCO20 and WCO40 are 0.62% and 2.41% respectively.

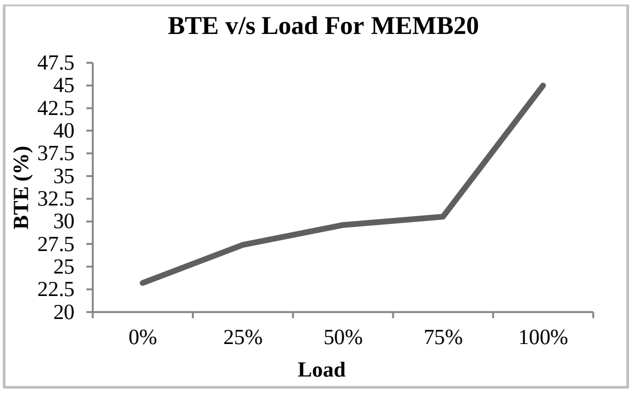
This clearly indicates that use of WCO20 is preferred over WCO40 if WCOME is used as fuel. These values for COME are 1.8% and 1.42%. For GCOME, these values are 2.3% and 0.65%. For all Methyl Esters considered, 20% of Methyl Ester and 80% of diesel gives minimum increase in SPLs. At other IPs such as 160 bar and 200 bar the same trend was observed though there was slight increase in SPL levels as the IP increased. From frequency analysis, for all the Methyl Esters considered, the dominant frequencies at 1/1 octave and 1/3rd octave are 1250Hz and 1000Hz respectively. It suggests that the operation of the engine considered should be avoided at these frequencies since this can cause more noise annoyance.

3.2 Performance

3.3 Emission







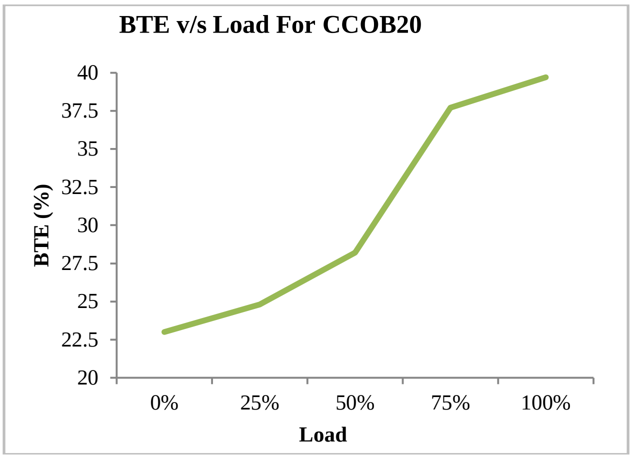
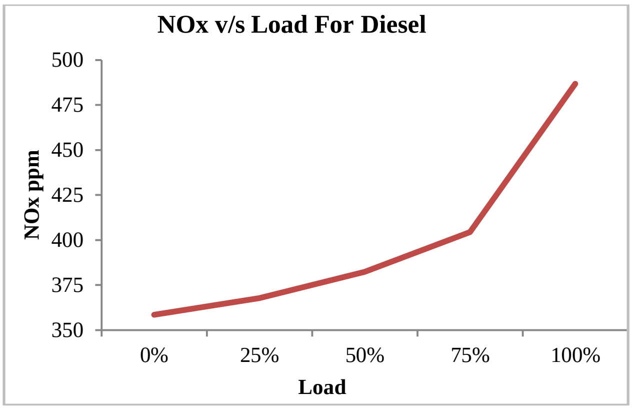
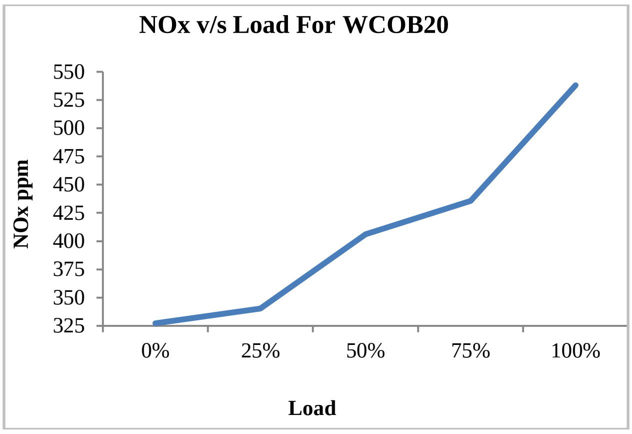
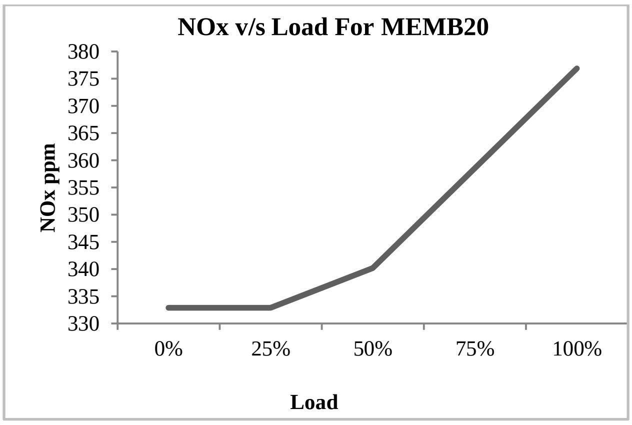


Figure 4 BTE v/s Load for Diesel and Methyl Esters at 180 bar IP







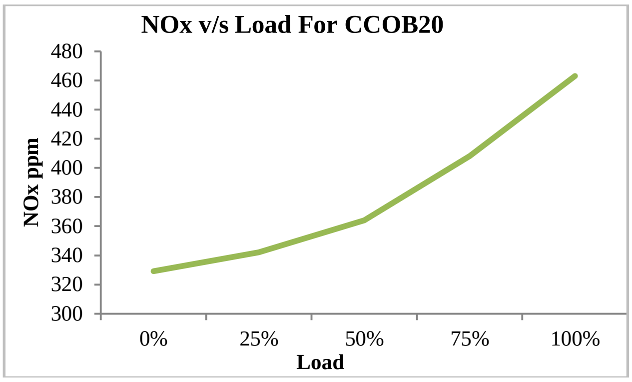


Figure 5 NO_x v/s Load for Diesel and Methyl Esters at 180 bar IP

Conclusions

Experimental results focused on the measurement of SPL produced for running the stationary diesel engine could lead to the following conclusions results of which are presented in detail in earlier sections. Sound Levels measured under various conditions using both Diesel and Bio-Diesel blends has shown that SPL has not increased when the engine is run on Bio-Diesel. Although there are small changes in the values of SPL for various blends, there is no significant change showing increase in the value of SPL for various experiments conducted using prepared blends. Thus diesel engines, even stationary ones, can be run on Bio-Diesel blends as the SPL as a means of a measure of environmental noise has not shown any significant change.

Amongst the blends used, B20 and B40 have shown the minimum SPL under no load conditions for all the operating pressures. Another significant observation is that SPL has not increased for all the varieties of considered Bio-Diesel blends. A significant and noticeable observation is that SPL has decreased for the blends B20 and B40 irrespective of injection pressures. Hence the use of bio-fuels in the blends of B20 and B40 are recommended in stationary and dynamic engines. The dominant frequency is within 1000Hz to 1250Hz, which is the operating frequency for most of the rotating components.

At operating pressure of 180 bars, for a full load (100%), SPL decreased during the implementation of Petro diesel in comparison with other blends. But when injection pressure is changed, Petrodiesel recorded maximum SPL with B60 blend.

This study, in continuation with earlier works, has emphatically proved that, the performance of the engine is the best and emissions are the lowest for B20 and B40 blends. The dominant frequencies are also the lowest for these blends. More investigative research work has to be carried out with the objective of using optimal blends (such as B60, B80 and B100) for a qualitative and quantitative study on the possibility of reducing the engine noise levels under most preferred operating conditions.

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