Combustion, Noise and Vibrational Analysis of Linseed Biodiesel Fuelled Engine

A. Venkata Swami, Ravi Kumar Naradasu, and A. Swarna Kumari

Abstract With the rising population day-to-day there is surge in number of automobiles in the world. The huge increase in quantity of vehicles on track more demand for fuel. The widespread use of petrol and diesel leads to unadorned environmental problems like global warming, emissions of greenhouse gases, and reduction in their levels. Due to more demand and usage of fuels, stringent emission norms there is a need for development of renewable fuel. Engine vibration is higher in diesel engines, resulting in a shorter engine life cycle. Using a single cylinder compression ignition engine, an experimental study was conducted to measure combustion, noise, and vibration properties, as well as their similarities. The tests were conducted without maximum charge, using Linseed biodiesel, 10% and 20% (v/v) Linseed mix and baseline-mineral diesel. Samples of engine combustion noise were used with a microphone. In 3 direction measurements of motor acceleration, a triaxial accelerometer is utilized: vertical, lateral, and longitudinal. NI LabVIEW is used to collect data and perform research. Within the range of 0–100 Hz and three ways, higher peak amplitudes are observed for both diesel and linseed biodiesel at the frequency of 25 Hz. The highest level of combustion noise was observed with a 20% biodiesel mix, related to a longer delay in ignition and an increased rate of heat release. These findings were supported by other observations concerning combustion noise, ignition delay, and heat release rates.

Keywords Linseed biodiesel · Combustion · Noise · Engine · Vibration

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Nomenclature

B0	100% Diesel fuel
B10	10% Linseed oil and 90% of diesel
B20	20% Linseed oil and 80% of diesel
B100	100% Of linseed oil
BP	Brake Power
Bsfc	Brake specific fuel consumption
BTE	Brake Thermal Efficiency
CO	Carbon monoxide
HC	Hydrocarbon
NOx	Oxides of Nitrogen

1 Introduction

Because of their high efficiency, diesel engines have long been a popular option for heavy-duty applications, such as trucks. However, they have disadvantages such as excessive noise, weight, and vibrations. The world is heading toward a more sustainable energy age with an emphasis on renewable energy and energy conservation. Concerns over diesel's long-term availability and environmental impact have prompted a hunt for a clean diesel replacement. Alternative fuels have grown in popularity in recent decades as a result of environmental issues and country-specific pollution laws. One of the most appealing features of biodiesel is that it can be used in existing generators, cars, and facilities with little or no modification. The pumping, storage, and burning of biodiesel can be done in the same way as the diesel petrol fuel and can be used either alone or to a certain extent with petrol diesel.

Oleic acid, linoleic acid, and linoleic acid are the principal composition of linseed oils. Oils of linseed are of 26–30 mm^2/s at 40 °C kinematic viscosity. They have a high viscosity due to their greater molecular weight and chemical composition. The molecular weights of vegetable oils are 600–900, three to four times that of petrol. Linseed oil has a very high flash point (around 222 °C). The temperature of auto-ignition is around 343°C. It is 931 kg/m^3 in density and 0.93 in particular. The heat value is about 40 MJ/kg, lower than diesel fuels (approximately 45 MJ/kg).

Balamurugan et al. [1] An experimental test of a CI engine showed how alcohol mixing affects heat breaking performance, CO, HC, and NOx emissions, and that alcohol mixed biodiesel increases the thermal braking efficiency while CO, HC, and NOx emissions are decreased. Ashok Kumar et al. [2] Explained that the performance and emission characters of the VCR-tested esterified pinnai oil were found to be marginally higher than that of standard part load diesel for all compression ratios the frequency strength of the biodiesel. Ramkumar et al. [3] Diesel engine output and emission characteristics were investigated. Fueled by neem oil, the brake heat efficiency decreased when blends increased with an increase, and increased with an increase in compression ratio, as the compression ratio increased from 15 to 18 Ravi Kumar et al. [4]. The experiment was performed on a VCR diesel engine with soybean meat ester (SOME) in combustion and vibration analysis as a fuel in a compressive variable engine, at different loads, and compression ratios. Combustion and vibration analysis of diesel engine was investigated under different engine loads and compression ratios. The emission characteristics at compression ratio 15, 16, 17, and 18 were plotted and the variations observed. Vibration data was measured using Lab view vibration tool kit. During combustion, the performance parameters are investigated such as individual fuel consumption, thermal brake efficiency, and burn characteristics, including heat release rates, burned mass fractions, and cylinder pressure. The particular fuel consumption at CR 15 and maximum at CR 16 was also observed and remained identical to the higher compression ratio of 17. Parikh et al. [5] Analyzes of effectiveness and emission of 4-stroke, ethanol-based biodiesel engines combined with diesel fuel, and it was found that using ethanol/diesel mixtures raises the ignition lag time due to ethanol's low cetane amount.

Knothe et al. [2010] find Methanol is an alcoholic-based fuel additive with about 30% more oxygen in basis than mineral gasoline, allowing diesel engines to reach higher full combustion. Because of the extra oxygen in the liquid, complete combustion is possible. Furthermore, the use of alcohol additives reduces PM, HC, and CO levels in exhaust greatly. Rakopoulos et al. [6] A turbocharged diesel engine's transient output and emissions were investigated. Biodiesel blends have the greatest impact on combustion activity and reliability, while the n-butanol blend had the least. Low speed proved to have the greatest effect on the production of combustion noise and its absolute values. Sanjid et al. [7] analyzed the experimental findings of a study that looked at the brake-specific fuel intake, Characteristics of a palm–jatropha blend's exhaust and noise emissions because of their lubricity and damping characteristics, the sound level emitted by biofuel blends was lower as compared to diesel fuel.

2 Methodology

Before being used in IC Engines, raw vegetable oils must undergo some changes to their properties such as viscosity and density. Transesterification is a method of lowering the viscosity and density of crude. An alcoholic-reacting triglyceride responds to a mixture of fatty acid alkyl ester and glycerol in the presence of either an acid or a base catalytic in vegetable oils. Linseed oil in the presence of a basic catalyst is generated to react with methanol (NaOH). Table 1 shows the chemical properties of linseed oil biodiesel.

Experimental Setup

The experimental design consists of an oil checked vertical four-stroke, one-cylinder, water-cooled, direct injection engine; Table 2 lists the specifications for the engine. The figure of the experimental arrangement is shown in Fig. 1. The air flow was

Table 1 Properties of linseed biodiesel and its blends

Properties	Diesel	Linseed oil	B10	B20
Density (kg/m^3)	846	899	885.2	868.4
Kinematic viscosity (centistokes)	4.75	4	5.41	5.07
Flash point (˚C)	62	64	66	78
Fire point (˚C)	76	72	76	98
Calorific value(kJ/kg)	42,500	38,000	42,050	41,600

Table 2 Engine specifications

Features	Specifications
Make	Kirloskar oil engine
Type	Four stroke, water cooled diesel
No of cylinders	One
Combustion principle	Compression ignition
Max speed	1500 rpm
Connecting rod length	234 mm
Cylinder diameter	87.5 mm
Stroke length	110 mm
Compression ratio	Variable
Capacity	661 cc

determined by the technique of the air box, which involved the pressure drop by a manometer through the sharp edge opening of the air surge chamber. The amount of diesel flow was calculated by recording the time it took to consume 5 cc of fuel. A digital tachometer was used to determine the engine's speed. For loading the turbine, an electric current dynamometer is used. The HC, CO, CO_2, NOx, and O_2 exhaust gas constituents are tested using an AVL DiGas 444 gas analyzer, and an AVL 437C smoke meter was used to assess smoke opacity. Engine vibration and noise were measured using NI Labview coding and sensors.

3 Results and Discussion

This section compares the power, combustion, emission, friction, and noise characteristics of a high-speed diesel engine running on linseed biodiesel at various loads, from no load to full load.

The difference of brake thermal efficiency with engine load is visualized in Fig. 2. The BTE increases significantly with load irrespective of the fuel type. The maximum BTE was observed for pure linseed oil and next to it was B20 (20% linseed oil and

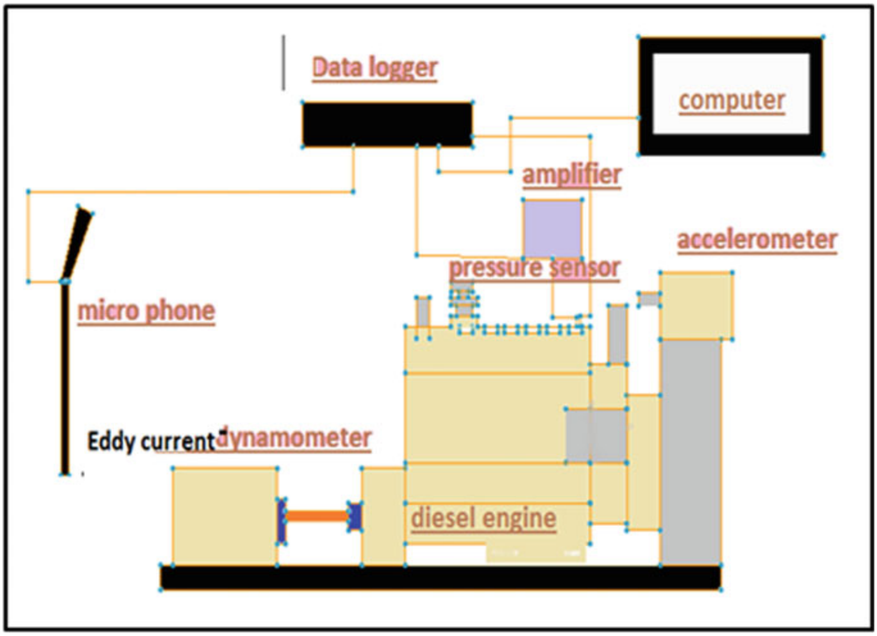


Fig. 1 Experimental setup of computerized diesel engine with exhaust gas analyzer, smoke meter, vibration, and noise sensors

80% diesel). At maximum load the BTE of pure linseed oil was 6.865% greater than pure diesel and BTE of B20 was 4.26% greater than pure diesel.

Figure 3 illustrates how bsfc changes with engine load; for all fuel blends, bsfc decreases as load increases. When the engine's load or power output is increased, the turbulence and in-cylinder temperature increases which results better combustion efficiency of the fuel and decrease in fuel consumption.

Figures 4 and 5 demonstrate the change in cylinder pressures at no load, maximum load at constant speeds of 1500 RPM for different test blends. The peak pressure was obtained for B-10 blend with a value of 43.856 bar at no-load and at full load it is 62.26 bar for Diesel. It was discovered that as the load within the cylinder increased, the peak pressure inside the cylinder increased for all fuel blends.

The change in NOx and HC emissions for Diesel engines operating on Diesel and Linseed biodiesel blends as seen in Figs. 6 and 7. Since linseed biofuel blends have lower calorific values than pure diesel, the pressure and temperature inside the combustion chamber are lower, resulting in lower NOx pollution. The peak NOx concentration for diesel is 128 PPM which is 25.78, 26.56, and 41.41% greater than the peak NOx concentrations for B-10, B-20, and pure linseed oil. However, from the graph it can be inferred that the peak NOx value is obtained at slightly lean mixture for all blends. Since the flame temperature is already very high and oxygen can be excessive and react to various oxides by nitrogen, the situation has been dangerous.

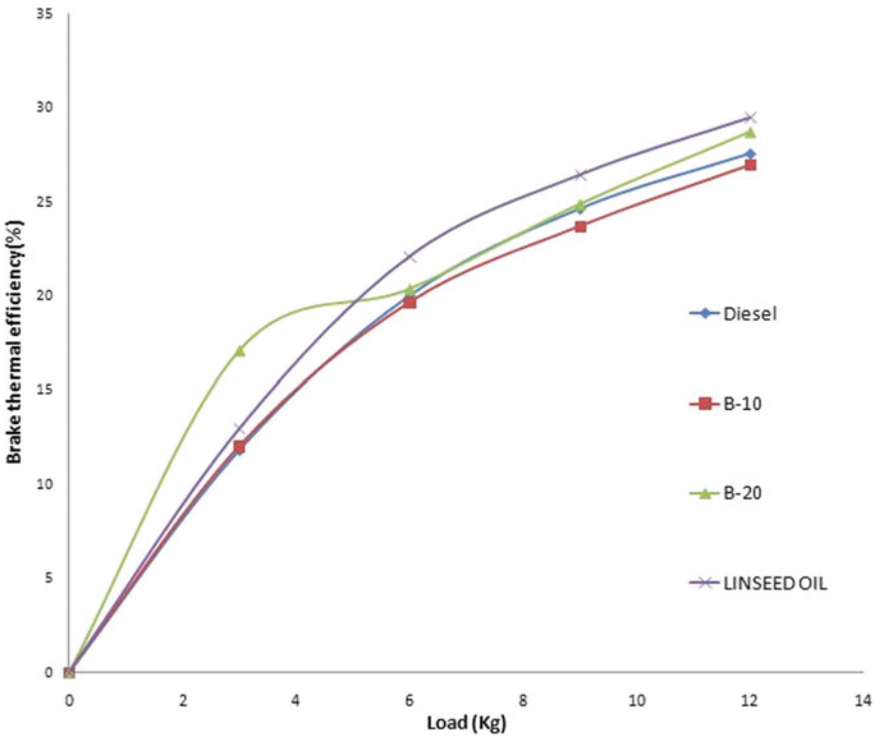


Fig. 2 Variation of brake thermal efficiency with load

Similarly, the biodiesels are oxygenated fuels and contain excess oxygen. This allows proper combustion in the engine cylinder to minimize HC emissions in biodiesel mixtures as opposed to gasoline.

The majority of the smoke is made up of elemental carbon from incomplete fuel combustion and traces of engine lubricant. The smoke concentration from the test engine is depicted in Fig. 8 represented as a bar graph with various blends. The bar graph shows that as more linseed oil was substituted for diesel fuel, the smoke concentration increased. Highest smoke concentration was observed at peak loads, due to the abundance of fuel and non-availability of enough oxygen. The reasons for increasing emissions at higher fractions of linseed oil may be the strong fuel viscosity resulting in reduced Reynolds, higher mean fuel drop sizes and lower fuel air mixture.

The changes in the speed and vibration amplitude of the diesel motor with diesels and various biodiesel blends at full load conditions are presented in Figs. 9 and 10. The time domain vibration signals were calculated using an accelerometer at no load and a sampling frequency of 25.6 kHz for all fuel blends. Out of all fuel blends B-10 is showing the highest vibration amplitude at no load whose values range from 259.04 to 302.944 m/s^2, which is 4.74% greater than that of pure diesel. The peak

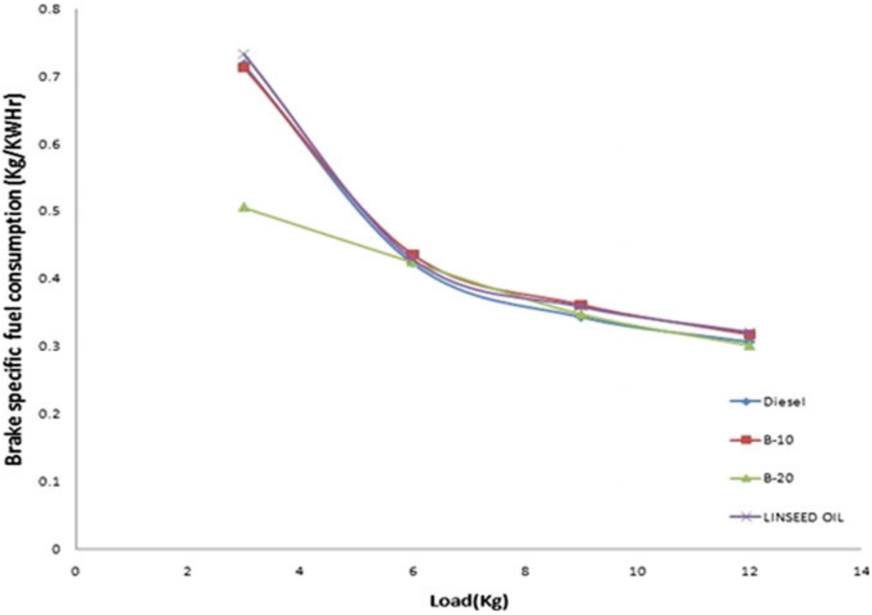


Fig. 3 Variations of bsfc with load

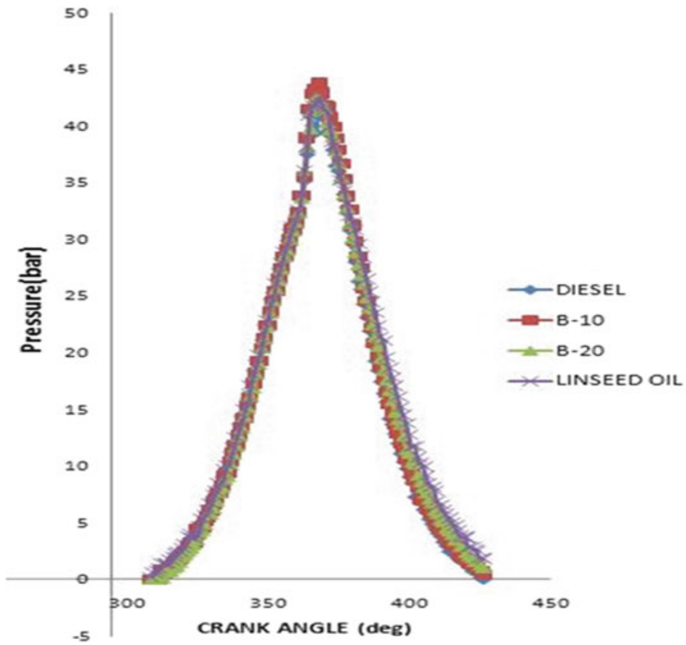


Fig. 4 P-θ diagram for diesel engine running with different fuel blends at no load

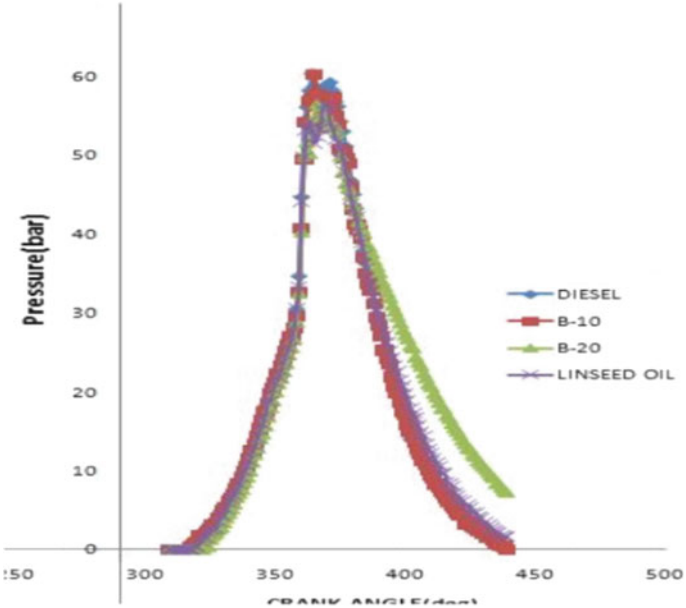


Fig. 5 P-θ diagram for diesel engine running with different fuel blends at full load

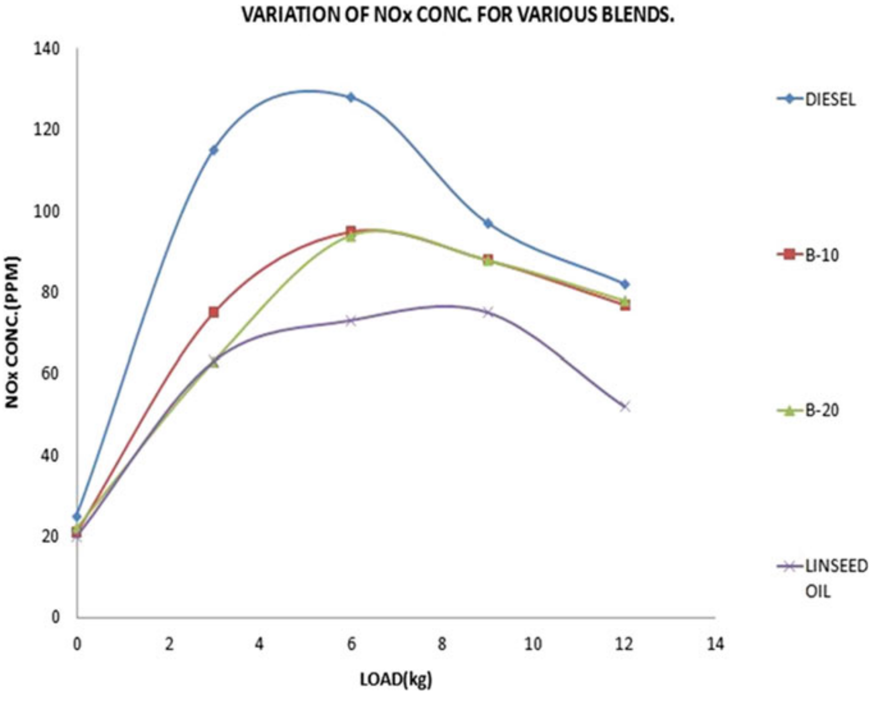


Fig. 6 Variation of NOx with load for different fuel blends

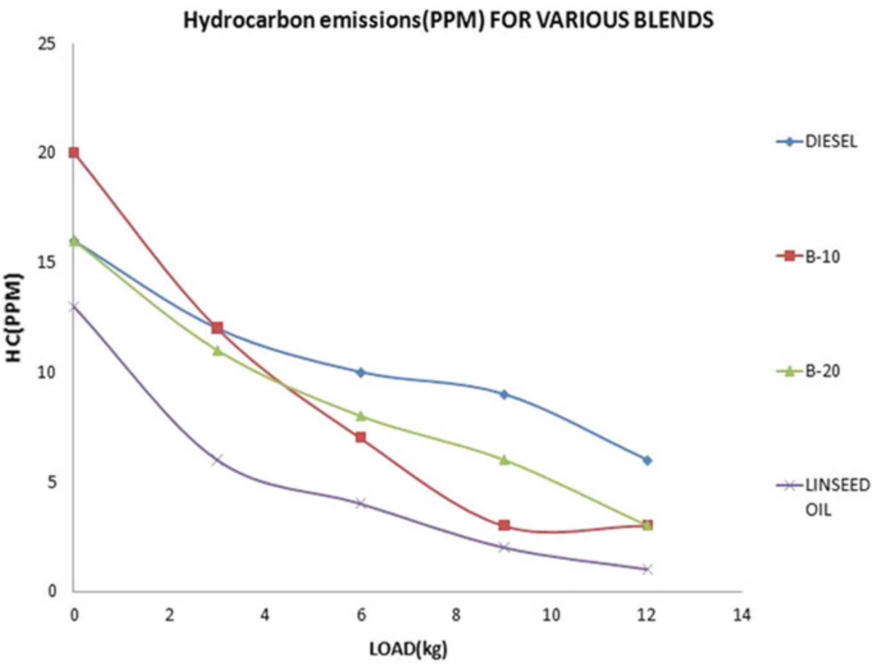


Fig. 7 Variation of HC emissions with load

amplitude (RMS) values for diesel, B-10, B-20, and linseed oil are 4.71, 4.586, 4.437, 4.43 m/s^2 respectively at full load condition.

The above Fig. 11 represents the change in noise level of Diesel engine running with linseed oil at no load condition. The running speed and the cylinder pressure produced within the cylinder have a significant impact on combustion noise. The rate at which cylinder pressure rises during the engine cycle determines combustion noise. At no load as the ignition delay is maximum it leads to lower combustion temperatures and lower peak pressure values as it can be observed from the P-Θ diagram. At no load the noise level for biodiesel blends is significantly identical but higher than pure diesel. For pure linseed oil the noise levels vary with time with amplitudes ranging from 89 to 96 db. At peak loads as the combustion process is steady and efficient therefore the combustion noise is stable and doesn't vary much from the part loads.

4 Conclusions

In order to investigate various engine characteristics, the biodiesel linseed and its diesel blends were produced and tested on a diesel engine.

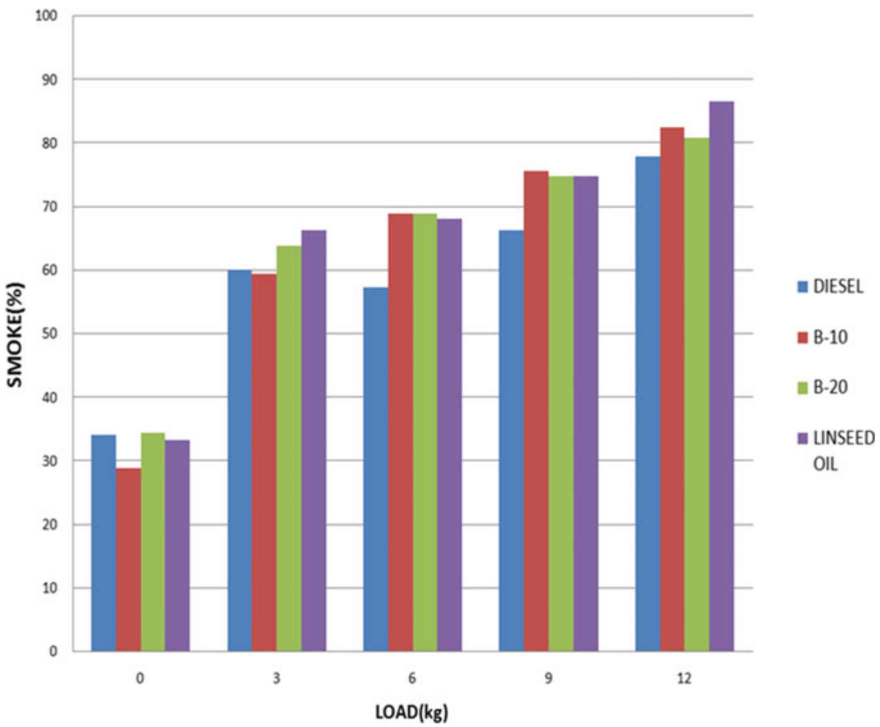


Fig. 8 Variation of smoke with load for different fuel blends

The maximum BTE was observed for pure linseed oil and B20. At maximum load the BTE of pure linseed oil was 6.865% greater than pure diesel and BTE of B20 was 4.26% greater than pure diesel.

Higher combustion and flame temperature influence the formation of NO_X. For biofuels, the emissions of NOx are relatively lower. The peak NOx concentration for Diesel is 128 PPM which is 25.78, 26.56, and 41.41% greater than the peak NOx concentrations for B-10, B-20l and pure linseed oil.

The peak amplitudes for Diesel, B-10, B-20, and linseed oil are 1.8148, 1.7162, 1.4731, and 1.510 m/s2 respectively. The peak amplitudes of biofuel blends are clearly smaller than those of pure Diesel. The engine noise levels of diesel and biodiesel mixtures vary between 85 and 96db.

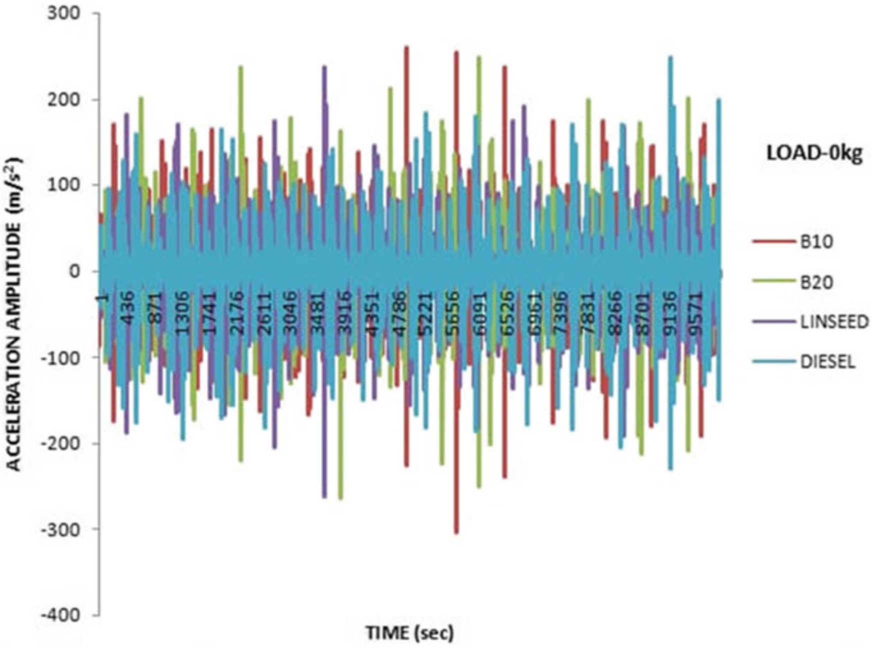


Fig. 9 Change in acceleration of engine at no load

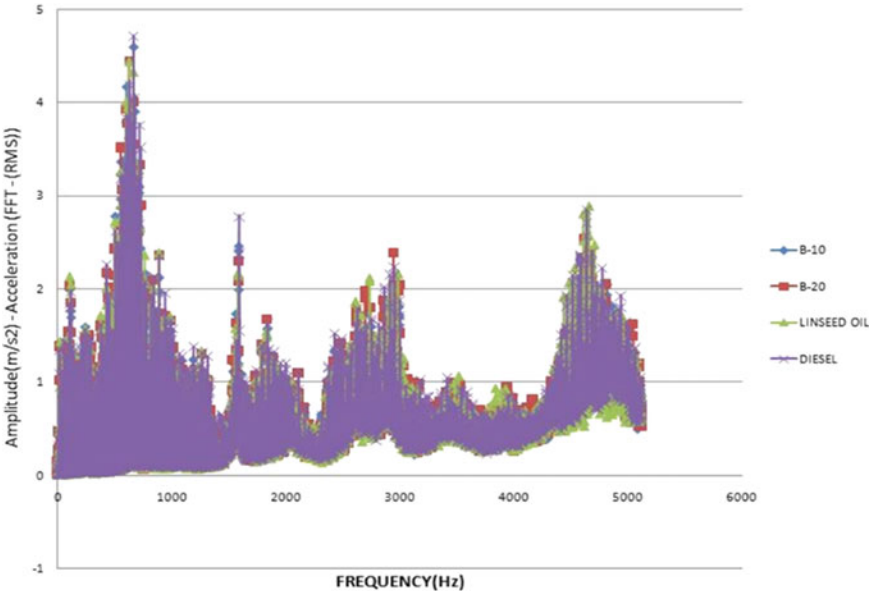
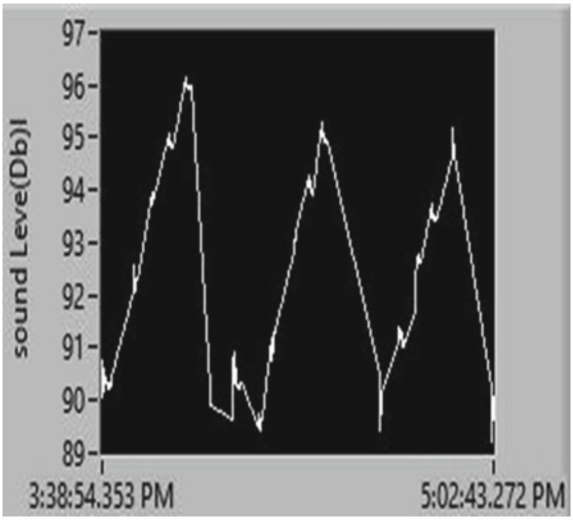


Fig. 10 Change in Vibration amplitude (RMS) for all full blends at full load

Fig. 11 Variation of noise level in Diesel engine at no load running with linseed biodiesel



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