Noise, Vibrations and Combustion Investigations of Preheated Jatropha Oil in a Single Cylinder Genset Engine

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Abstract

High viscosity of vegetable oil causes ignition problems when used in compression ignition engines. There is a need to reduce the viscosity before using it as engine fuel. Preheating and pre-treating of vegetable oils using waste heat of exhaust gases is one of the techniques, which reduces the viscosity and makes it possible to use it as alternate fuel for some niche applications, without requiring major modifications in the engine hardware. Several applications such as decentralized power generation, agricultural engines, and water pumping engines, can use vegetable oils as an alternative fuel. In present investigation, performance, combustion, and emission characteristics of an engine using preheated 20% blend of Jatropha oil with mineral diesel (J20) has been evaluated at a constant speed (1500 rpm) in a single cylinder four stroke direct injection diesel engine. Analysis of cylinder pressure, rate of pressure rise, heat release rate and cumulative heat release was done in addition to engine performance parameters such as brake thermal efficiency, brake specific fuel consumption and brake specific energy consumption. Regulated emissions such as CO, CO_2, THC, NO and smoke were also measured in this comparative study. Since noise regulations are becoming stringent, therefore noise levels were measured (dBA) and combustion noise was calculated from cylinder pressure data from combustion analysis of the engine. Vibrations were measured using accelerometers at vertical, lateral and longitudinal directions. Noise and vibration analysis of the engine has also been carried out to assess vegetable oil's performance on these parameters vis-a-vis baseline mineral diesel.

Introduction

Energy demand in India has increased rapidly in last decade due to improvement in living standards, high growth rate, increased usage of automotive vehicles and stationary gen-sets for power production. India consumes large amount of oil in Asia-Pacific region and it depends on imports for major part of its total oil requirement. These imports are a heavy burden on the economy of the country, and it affects India's development. Thus there is an urgent need to look for the renewable alternative fuels which decrease the dependency on fossil fuel. Oil extracted from Karanja and Jatropha seeds is a promising non-edible renewable alternative fuel in India. This oil has a higher viscosity than conventional fuels like diesel. Thus, there is a need to reduce the viscosity of these oils before using them in an engine. There are various ways to use these fuels in engines e.g. by direct usage and blending with mineral diesel, micro-emulsion, pyrolysis, transesterification, and preheating [1, 2]. In remote areas, these oils can be utilized by blending and pre-heating because other processes require significant additional supporting facilities.

Giakoumis et. al. [3] have conducted experiments on a turbocharged diesel engine of a truck to investigate the mechanism of combustion noise. Combustion noise peak was observed at 30-40% load in steady state condition for all speeds [3]. Rakopoulos et. al. [4] have investigated 30% biodiesel blend with diesel and reported that biodiesel blends have no significant effect on overall combustion noise. Redel-Macías et. al. [5] have carried out experiments on olive pomace oil methyl ester (OPME) blended with diesel and found that cetane number has a significant effect on noise reduction. Liaquat et. al. [6] have conducted experiment on four test fuel samples (JB5, JB10), 5% Jatropha biodiesel and 5% waste cooking oil (J5W5) and diesel. They reported that noise levels for all blended fuels had reduced, as Higher oxygen content of biodiesel blends helped in reducing noise. Sanjid et. al. [7] have conducted experiments on a single cylinder diesel engine at speeds ranging from 1400 - 2200 rpm using 5% and 10% blends of palm and Jatropha biodiesel (PBJB5, PBJB10) and reported 2.5% and 5% reduction of noise compared to diesel. Bao and He [8] have carried out experiments on a 8.8 kW single cylinder diesel engine using 30% rapeseed oil blended with diesel and observed that fuel delivery angle and exhaust valve angle were the main factors influencing noise. It was also reported that noise reduction of 2 - 4 dB was achieved by optimal adjustment of these two factors. Alisaraei et. al. [9] measured vibrations in vertical, lateral and longitudinal directions by conducting experiments on a four stroke six-cylinder tractor engine and found that vibrations of pure biodiesel (B100) were lower than diesel. They observed lowest vibrations with B20 and B40 blends, while B15, B30 and B50 showed the highest vibrations. How et. al. [10] reported a reduction of 13.7% in root mean square value of acceleration with B50 at engine load of 0.86 MPa vis-à-vis baseline diesel.

Agarwal and Dhar [11] reported that Karanja oil blends showed significantly lower peak cylinder pressure with increase in engine load compared to mineral diesel. They observed higher combustion duration for Karanja oil and its blends. Higher heat release rate was observed during mixing controlled combustion phase. Agarwal and Dhar [12] investigated preheated and unheated Jatropha oil and reported higher peak in-cylinder pressure at low engine loads while lower peak in-cylinder pressure at high engine loads. They reported higher CHR for preheated Jatropha oil.

Slightly higher brake specific fuel consumption (BSFC) was observed for vegetable oils compared to diesel [13, 14, 15]. Some researchers have carried out experiments using 5-20% blends of vegetable oils and reported lower brake specific energy consumption (BSEC) at 20% load [16]. Exhaust gas temperature (EGT) was reported to be higher for Karanja and Jatropha vegetable oils and blends [11, 17].

Canakci et. al. [13] have conducted experiments using preheated crude sunflower oil and found slightly higher CO emissions due to preheating to 75°C. Yilmaz and Morton [18] used preheated vegetable oils and showed rise in CO emissions. 10-20% blends of vegetable oil with diesel have also showed higher CO emissions when they were used in six cylinders turbocharged heavy duty direct injection engine [19] whereas other studies reported 39% reduction in CO emissions with 10-90% blends of vegetable oil with diesel [20]. There was CO_2 reduction of 2.05% upon using preheated vegetable oil [13], while some researchers reported 3 to 7% higher CO_2 emissions [14, 20]. Reduction in HC emissions from preheated vegetable oils were observed and however higher HC emissions were found at no load condition [13,18], while 10-90% blends of vegetable oil with diesel produced higher HC emissions [19,20]. Many researchers have reported increased NO emissions due to preheating of blended vegetable oil [14, 16, 19]. Smoke opacity was found to be lower for Karanja oil blends [11].

However, there have been limited research efforts reported in open literature, involving noise and vibrations using straight vegetable oils. For addressing this gap, experiments have been performed for noise and vibrations, combustion, performance and emission measurement on a single cylinder compression ignition diesel engine fuelled with 20% Jatropha vegetable oil blended with diesel at heated (J20H) and unheated(J20) fuel conditions and these results have been compared with mineral diesel.

Experimental Setup

A single cylinder, naturally aspirated, constant speed, four stroke, water-cooled engine (Kirloskar, DM-10) (Figure 1) was used to compare the combustion, performance, emission, noise and vibration characteristics for different fuels. Specifications of the engine are given in Table 1. Test fuel properties are given in Table 2.

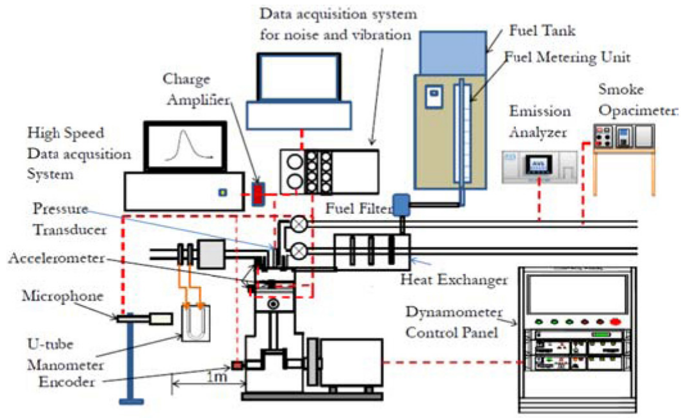

Figure1. Engine Experimental setup

A piezoelectric pressure transducer (Kistler; 6613CQ09-01) was installed in the cylinder head to acquire the in-cylinder pressure. These signals were amplified using a charge amplifier (Kistler; 5015). A high precision shaft encoder (Encoder India; ENC58/6-720ABZ/5-24V) was installed on the engine crank shaft. It delivers signals with a resolution of 0.5° crank angle degree, including a TDC signal. The signals from the pressure transducer and shaft encoder were acquired by a high-speed combustion data acquisition system (Hi-Techniques; meDAQ).

Table 1. Detailed specifications of the engine

Parameters	Specifications
Manufacturer	Kirloskar Oil Engines Ltd., India
Engine Type	Vertical, four-stroke, single cylinder, constant speed, direct injection, CI engine
Rated Power	7.4 kW at 1500r/min
Bore/ Stroke	102mm/116mm
Displacement Volume	0.948 litre
Compression ratio	17.5
Start of fuel injection timing	26°BTDC
Nozzle opening pressure	200 bar
Cooling Type	Water Cooling
Length/width/height	685/532/850 mm
BMEP at 1500 r/min	6.34 kg/cm^2

Table 2. Test fuel properties

Test fuel	**Calorific value (MJ/kg)**	**Density (g/cm^3)**	**Kinematic Viscosity @ 40c (cSt)**
Mineral Diesel	43.06	0.819	2.71
J20	42.75	0.8362	4.48

A portable five gas emission analyzer (AVL; Digas 4000) was used for measurement of CO, CO_2, HC and NO emissions. Smoke opacity was measured by using smoke opacimeter (AVL; 437). Noise and vibration data were acquired with the help of a software (NI; Labview signal express 2012) with the help of a data acquisition chassis (NI; cDAQ-9178) and a module (NI; 9232) at a sampling rate of 102.4 kS/s. Miniature piezoelectric charge amplifier accelerometers (B & K; 4374) were used to measure the vibrations of the engine in vertical and longitudinal directions. Vibration in lateral direction was measured by a miniature tear drop CCLD accelerometer (B & K; 4517). Noise data of the engine was acquired using a microphone (B & K; 4192) which was kept 1 m away from the engine, as per the standard test protocols. Combustion noise was analyzed by a data acquisition system (NI Drivven; µDCAT) [21] by acquiring pressure and crank angle data from the engine. Combustion noise was calculated by converting the crank angle based cylinder pressure to time based cylinder pressure and converting this time domain pressure signal to frequency domain. These results were converted into a third octave spectrum by summing all harmonics between the third octave frequency and by filtering it for human ear and engine structure attenuation. Engine tests were conducted at constant engine speed of 1500 rpm at 200 bar fuel injection pressure for mineral diesel, J20 and J20H. J20 was preheated using heat exchanger which utilized exhaust heat. Combustion data were acquired at six engine loads (0%, 20%, 40%, 60%, 80%, and 100%). Cylinder pressure data were acquired for 250 consecutive engine cycles and then averaged in order to eliminate the effect of cycle-to- cycle variations. All tests were carried out after thermal stabilization of the engine.

Results and Discussion

Noise Analysis

Noise signals were acquired with the help of Labview Signal Express 2012 software. Acquired signals were analyzed with the help of a Matlab code. Time domain signals were converted into frequency domain. One-third octave analysis was carried out by applying A-weighting filter for 20-20000 Hz bandwidth. Figure 2a, b, c, d, e, f represent noise from the engine in 1/3 octave bands for 0- 100% load condition for diesel, J20 and J20H fuels. Almost similar trend was found for all these loads with slight variation among different test fuels. Noise was found in the range of 20-50 dBA at center frequencies of 20, 25 and 31.5 Hz and it does not contribute much to overall engine noise. Noise of 50-70 dBA was produced by the engine at center frequencies of 40, 50, 63, 100, 125 and 160 Hz. 70-80dBA noise was produced in the range of frequencies 80, 200, 250, 315, 400, 500, 5000, 6300, 8000, 10000, 12500, 16000 and 20000 Hz. Maximum noise was found in the range of 80-85 dBA at center frequencies of 630, 800, 1000, 1250, 1600, 2000, 2500, 3150, and 4000 Hz.

Relatively higher noise was produced by J20H at center frequencies of 63, 80, 100, 125, 160, 315, 8000, 10000, 16000 and 20000 Hz at 0 - 100% engine load compared to J20 and diesel. It will not affect overall engine noise because noise produced in this range is lower than 70 dBA. Diesel noise was higher in frequency range of 630 - 4000 Hz for almost all loads. Higher or equal noise was observed at frequency 200Hz and 400Hz for J20 as compare to diesel. J20 showed nearly same or lower noise as that of mineral diesel for all loads for other frequency range.

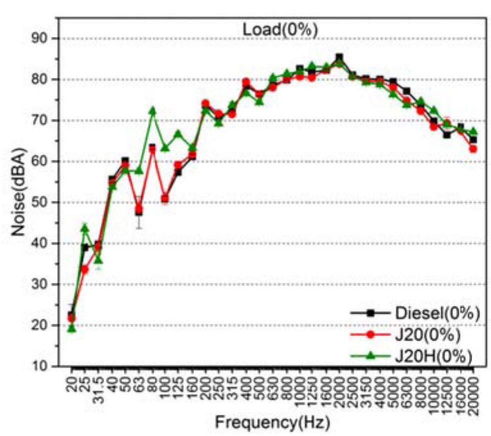

Figure 2 (a). 1/3 octave frequency spectrum (0%) load

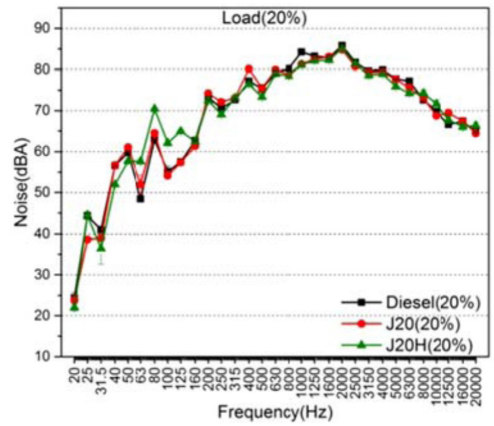

Figure 2 (b). 1/3 octave frequency spectrum (20%) load

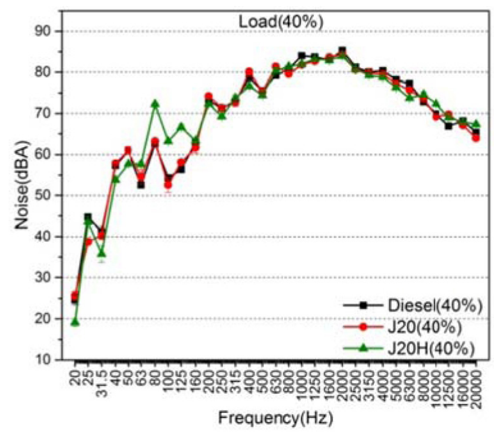

Figure 2 (c). 1/3 octave frequency spectrum (40%) load

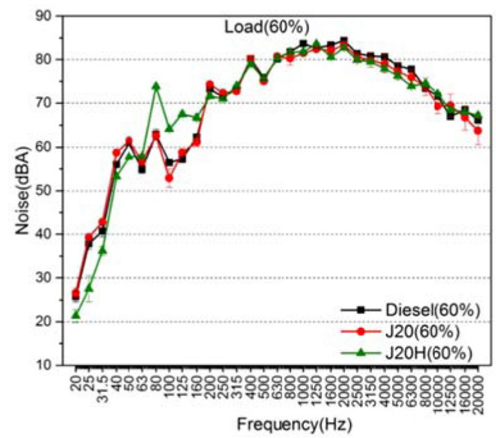

Figure 2 (d). 1/3 octave frequency spectrum (60%) load

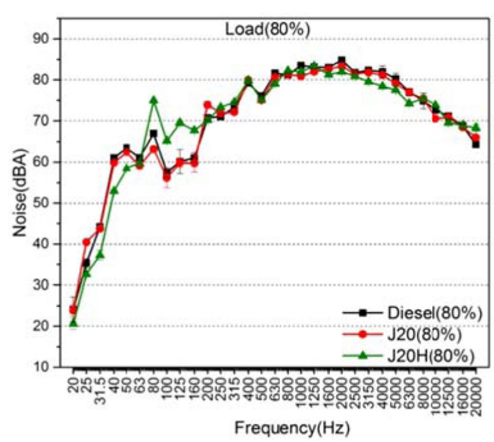

Figure 2 (e). 1/3 octave frequency spectrum (80%) load

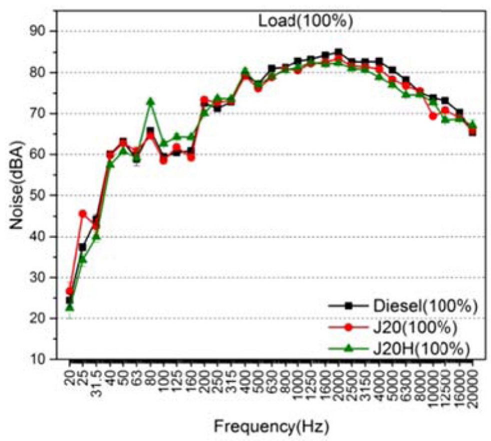

Figure 2 (f). 1/3 octave frequency spectrum (100%) load

Figure 3 shows the RMS value of noise, measured by microphone. It was observed that Noise measured by microphone was higher than combustion noise and it was in the range of 91-93 dBA for all three fuels. Higher noise from diesel was seen at almost all loads, while J20H showed lowest noise level among these test fuels.

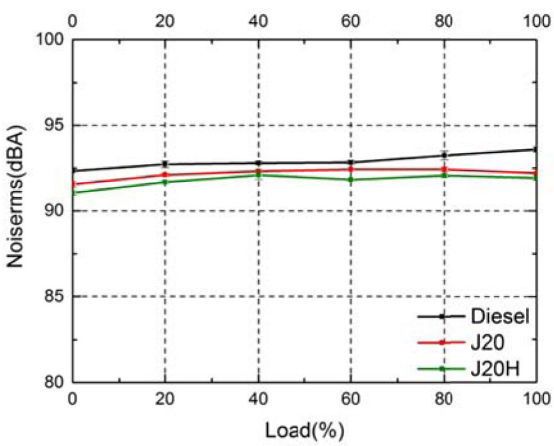

Figure 3. RMS value of noise

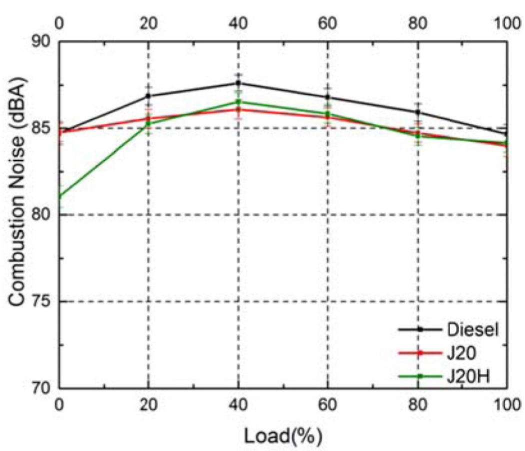

Figure 4. Combustion noise

Figure 4 shows the combustion noise for diesel, J20 and J20H. Combustion noise level of 80-87 dBA was observed for all three test fuels at all loads. Combustion noise is maximum at 40% load for all test fuels. This is similar to trends reported by other researchers [3]. Higher combustion noise was observed for mineral diesel which shows relatively more knocking combustion at all loads. J20 and J20H show noise reduction of 1-2 dBA for all loads except no load. Combustion noise reduction of 4 dBA was observed for J20H compared to diesel at no load conditions.

Vibration Analysis

Figure 5 shows the acceleration produced in genset engine in vertical, longitudinal and lateral directions corresponding to all three test fuels Vibrations in vertical direction were approximately 22-32 g for all test fuels. Diesel and J20 showed similar vibration levels at low load (0%). J20 showed slightly lower vibration level at all loads except at no load, when compared to J20H and diesel. Vibrations for diesel and J20H were almost similar at 20, 40, 60% loads. Diesel showed higher vibrations at 100% load in vertical direction. Combustion forces due to higher HRR are primarily responsible for higher vibrations in vertical direction.

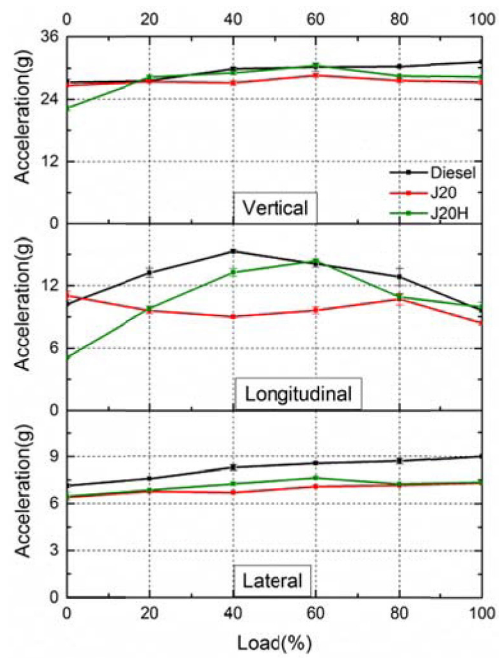

Figure 5. Vibrations in vertical, longitudinal and lateral direction

Vibrations were observed to be in the range of 5-15g in the longitudinal direction. It was observed that diesel produced 10g vibrations at no load, which increased to approximately 15g at 40% engine load. Vibrations decreased after further increase in load and reached 10g again at higher engine load. Vibrations for J20 were observed to be 10g for all loads.

Vibrations were observed to be 6-8.7g in lateral direction. Vibrations were higher for diesel amongst all test fuels at all engine loads. Diesel showed 7g vibrations at no load condition, which increased with increasing engine load and reached a maxima of 8.7g at 100% load. Vibrations of 6g were observed at no load, which reached to 7g at 100% load for J20 and J20H.

There is no study showing vibration from vegetable oil fuelled engine however similar results are reported by few researchers for biodiesel. Alisaraei et. al. have reported lowest vibrations for B20 [9]. How et. al. [10] observed largest reduction of 13.7% in RMS of acceleration for B50 at BMEP of 0.86 MPa w.r.t. baseline diesel.

Combustion Analysis

Figure 6a, b, c, d, e, f show the Pressure history, Heat Release Rate (HRR) and Cumulative Heat Release (CHR) from no load to rated engine load. Peak cylinder pressure was observed to be in range of 50-70 bar from no load to full load for all test fuels. Diesel and J20 showed similar peak pressures while slightly lower pressure (~ 2 bar) was observed for J20H at all engine loads. Peak pressure location was observed to be shifting away (by 2-7.3 CAD) from TDC at no load to full load conditions. Negative heat release rate was observed due to accumulation and evaporation of fuel in beginning of the ignition delay phase. HRR becomes positive only after the start of combustion (SOC). Similar ignition delay period was observed for all three test fuels. In premixed combustion phase, fuel-air mixture of all test fuels burns rapidly and rising HRR is seen. Relatively higher HRR was observed for J20 during premixed combustion phase for 0, 20 and 40% loads, followed by J20H. Preheating and blending of the Jatropha oil results in superior fuel atomization. Fuel bound oxygen in the vegetable oil helps in combustion and results in higher HRR for biofuels.

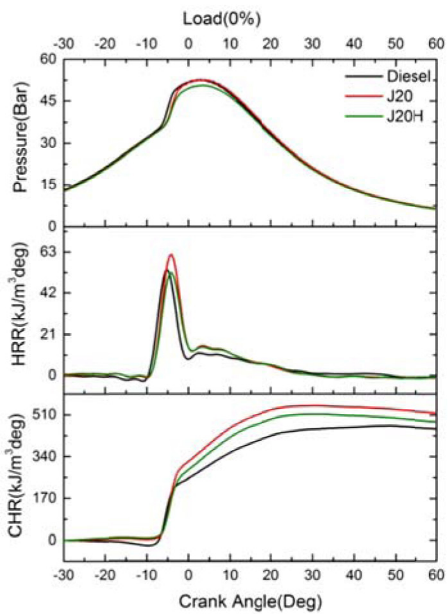

Figure 6a. Pressure, HRR and CHRR at 0% load

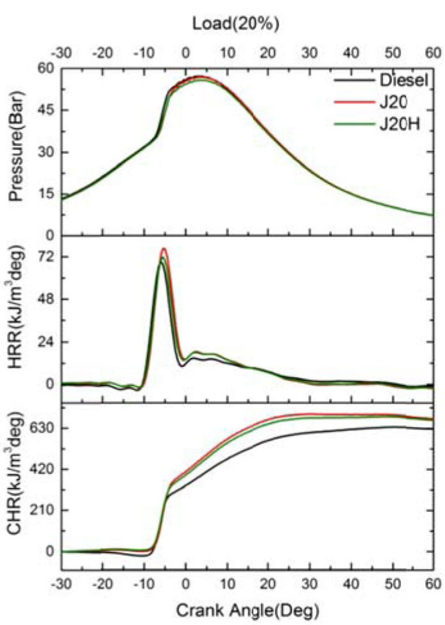

Figure 6b. Pressure. HRR and CHRR at 20% load

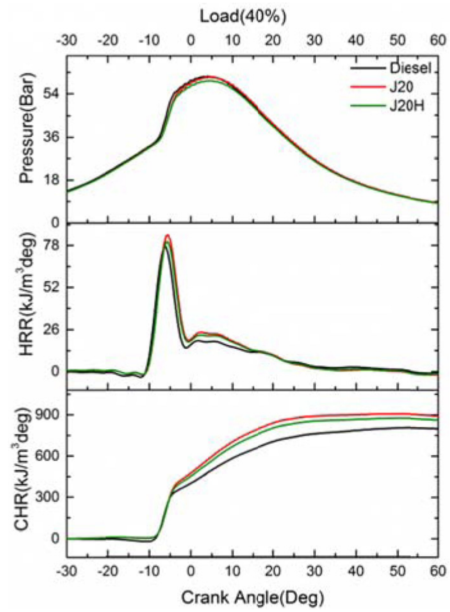

Figure 6c. Pressure, HRR and CHRR at 40% load

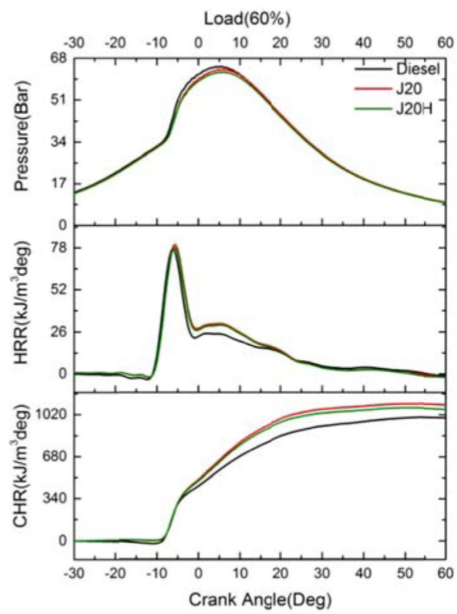

Figure 6d. Pressure. HRR and CHRR at 60% load

There was a slightly higher HRR in premixed combustion phase for mineral diesel at 80% and 100% load. Premixed combustion phase was followed by mixing controlled combustion phase, where the HRR for all test fuels decreased. CHRR was higher for J20 & J20H in comparison to diesel up to 60% load. It was because of higher HRR in premixed combustion and mixing controlled combustion phases of J20 and J20H. At higher loads, CHRR was almost equal for all three test fuels.

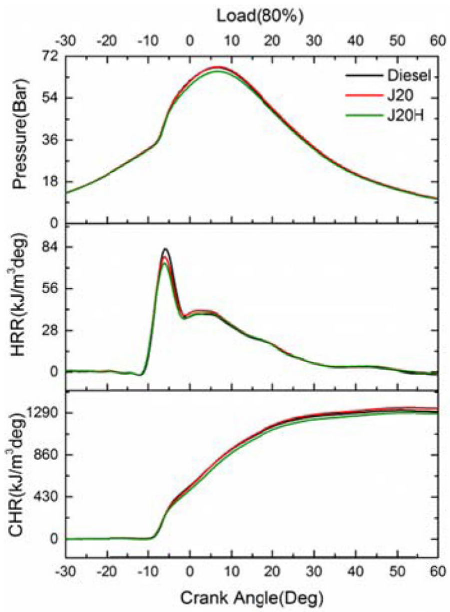

Figure 6e. Pressure, HRR and CHRR at 80% load

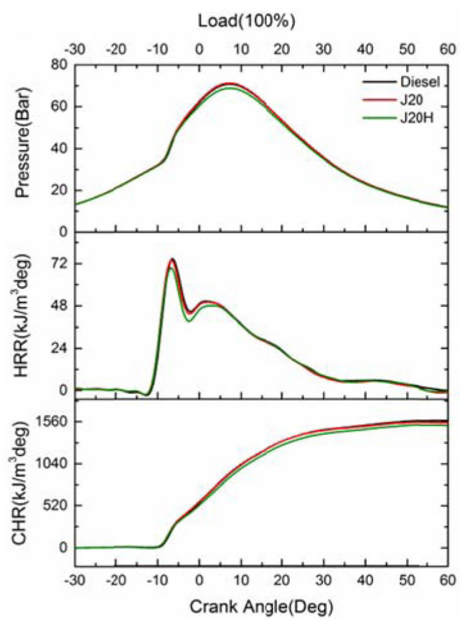

Figure 6f. Pressure, HRR and CHRR at 100% load

Figure 7 shows the mass burn fraction (MBF) (10% and 90%) and combustion duration for diesel, J20 and J20H. There was no significant difference in MBF10 of these three fuels. MBF10 was observed to be 6-8° BTDC at almost all loads. J20 and J20H blends took lesser time in burning 90% fuel. Both these fuels took nearly equal time. J20 and J20H blend take approximately 14 to 26 CAD for no load to full load condition. Diesel took approx. 19-26 CAD for 0100% load. Combustion duration for diesel was also higher by approx. 5° CA compared to J20 and J20H at no load to 60% load. Both J20 and J20H had combustion duration ranging between 20-34° CA while for diesel; it was 25-34° CA. Therefore, it is evident that additional fuel oxygen in molecular structure of J20 and J20H helps in combustion at lower and medium load.

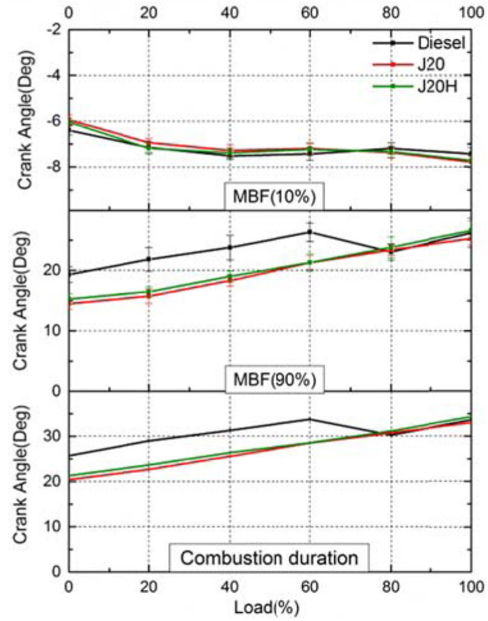

Figure 7. Mass burn Fraction (10%-90%) and combustion duration

Performance and Emissions

Experiments were conducted on J20 and J20H and were compared with the results of mineral diesel. Entire load range was represented in terms of brake mean effective pressure (BMEP) for evaluating engine performance and emissions. Figure 8 shows the Brake Thermal efficiency (BTE), Brake Specific Fuel Consumption (BSFC), Brake specific Energy Consumption (BSEC) and Exhaust Gas Temperature (EGT) at all engine loads for all test fuels.

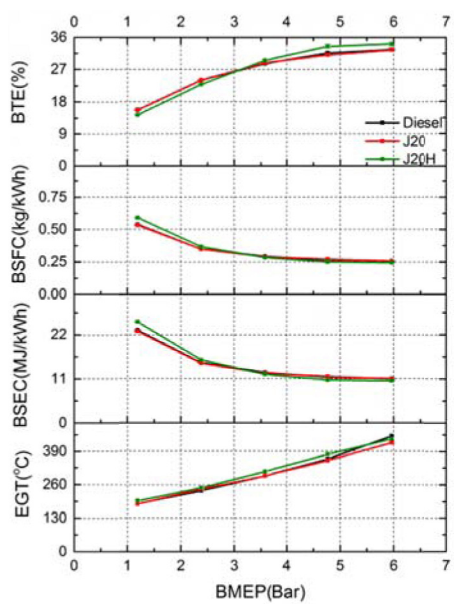

Figure 8. Engine performance

BTE of the three test fuels was observed to be lower at low engine loads and it increased with increasing load. Diesel and J20 showed nearly equal BTE at all loads. Slightly lower BTE was observed for J20H at lower engine loads however it became slightly higher at high engine loads vis-à-vis mineral diesel. Rakopoulos et. al. [19] reported similar results and suggested that BTE of the engine was almost similar for vegetable oil blends and diesel. Yilmaz and Morton [18] reported that preheating the vegetable oil increases the engine efficiency. BSFC and BSEC were relatively higher for low loads and with increasing engine load, they decreased for these three test fuels. Diesel and J20 showed almost similar BSFC and BSEC at all engine operating conditions. J20H showed higher BSFC and BSEC at low engine loads and with increasing load, it became almost similar to diesel and J20. There was roughly 5% increase in BSFC, primarily due to difference in the calorific value of the test fuels [13]. Approx. 3% higher BSFC was observed on volume basis and similar BTE was observed for vegetable oil [14]. EGT increased with increasing engine load. Almost similar EGT was observed for diesel and J20 except at 100% load. Higher EGT was observed for J20H compared to other test fuels at all engine loads except 100% load. Preheating of the fuel was responsible for higher EGT. At 100% load, EGT was observed to be highest for diesel.

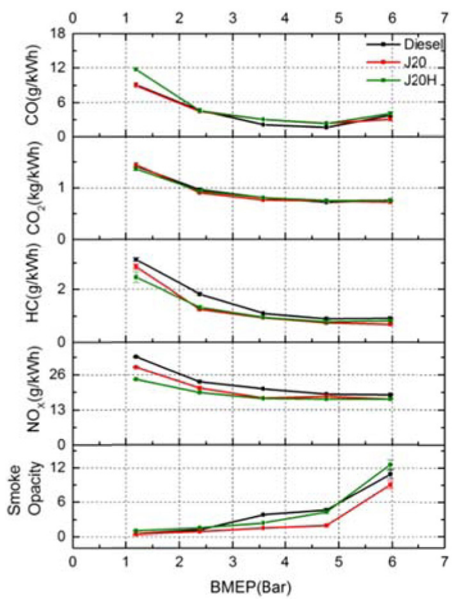

Figure 9. Engine exhaust emissions

Figure 9 shows the exhaust emissions of CO, CO_2, HC, NO_X and smoke opacity for J20, J20H and diesel. CO emission was higher at low engine loads for all fuels. At lower engine loads, presence of fuel rich zones in the combustion chamber results in higher CO emissions. Slightly higher CO emissions were observed due to few fuel-rich pockets, which remained unburnt. Diesel and J20 shows almost similar trend for CO emission while J20H produced slightly higher CO emissions at all engine loads. Canakci et. al. [13] reported 1.77% rise of CO emissions by preheating the sunflower oil up to 75°C. Higher CO emissions were also observed by other researcher for vegetable oils [18, 19, 20]. No significant difference was seen among CO_2 emissions for three test fuels. There was no significant difference in CO_2 emissions by blending and preheating vegetable oil [13-14, 20]. It shows that CO_2 emissions are largely unaffected for 20% blend of vegetable oil with mineral diesel. HC emissions were observed to be higher at low engine loads, which decreased with increasing engine load. Combustion improved with increase in engine loads due to superior air-fuel mixing, which resulted in lower HC emissions at higher engine loads. HC emissions were observed to be relatively lower for J20 and J20H compared to diesel at all engine loads. Yilmaz and Morton [18] and other researchers [19-20] also reported similar results of reduced HC emissions for vegetable oils. Fuel's molecular oxygen present in the vegetable oils leads to superior combustion and lowers HC emissions for vegetable oil blends (J20 and J20H).

Higher NO_X mass emissions were observed at low engine loads which decreased with increasing engine load. NO_X emissions were observed to be highest for diesel and minimum for J20H at all engine operating conditions. At higher engine loads, emissions from J20 were nearly equivalent to J20H. However, some researchers found increasing trend of NO emissions upon preheating or blending of vegetable oil compared to baseline diesel [14, 18-19].

Smoke opacity was found to be lower at lower engine loads and it increased with increasing engine loads for all test fuels. At medium loads, smoke opacity was higher for mineral diesel and lower for J20. At higher loads, J20H showed highest smoke opacity in comparison of diesel and J20. Similar results were reported by Canakci et. al. [13], who observed that smoke opacity reduced by preheating the vegetable oils.

Conclusions

In the present study, effect of engine load variation on engine performance, emissions and combustion characteristics including noise and vibration analysis fuelled with SVO blends (J20 and J20H) vis-à-vis baseline mineral diesel has been investigated for a single cylinder genset diesel engine. From this study following conclusions can be drawn:

- Maximum noise at 80-85 dBA in the frequency range of 630 - 4000 Hz levels is generated for diesel. Noise produced in this bandwidth is reflected in the overall noise trends from the engine.
- Higher or equal noise was observed at 200Hz and 400Hz for J20 as compared to diesel. J20 showed nearly same or lesser noise as that of mineral diesel for all loads for other frequency range.
- Higher noise was produced by J20H in the 63-125Hz frequency range.
- J20 and J20H produced relatively lower combustion noise (by 1-3 dBA) compared to diesel. RMS value of noise has similar trend as that of combustion noise, however this value is higher by 8-10 dBA at all engine loads. J20 and J20H have RMS value lower than diesel.
- Vibrations were found to be highest in the vertical direction (22-32g). Combustion forces are responsible for higher vibrations in vertical direction compared to lateral and longitudinal direction. Vibrations observed in longitudinal direction are in the range of 5-15g and for lateral direction, they are in the range of 6-8.7g. Diesel produces higher vibrations amongst all test fuels in longitudinal and lateral direction. J20 has lowest vibrations in all three directions amongst all test fuels.
- Peak cylinder pressure was almost similar for diesel and J20; however J20H showed slightly lower peak cylinder pressure at all engine loads. Higher heat release rate was observed at lower loads (0%, 20%, and 40%). It was similar at 60% load. Diesel showed slightly higher HRR at higher load (80% and 100%). CHRR was higher for J20, J20H at lower engine loads. It was almost similar at higher loads (80%, 100%).

- All three fuels (Diesel, J20, and J20H) took almost same crank angle duration for the MBF10. SVO blends took lesser time for MBF90 up to 60% load. At higher loads, all three test fuels showed almost equal combustion duration. Combustion duration for burning of diesel was relatively higher up to 60% load compared to J20 and J20H. It was almost similar at higher loads (80% and100%).
- Diesel and J20 showed almost similar CO emission while J20H showed slightly higher CO emission. No significant difference was observed among three test fuels for CO_2 emission. HC and NO_X emissions for diesel were observed to be higher compared to J20 and J20H. Diesel showed higher smoke opacity at medium loads. J20H showed higher smoke opacity at higher loads.
- Diesel and J20 showed almost equal BTE, BSFC and BSEC for all loads. J20H showed relatively lower BTE at low loads and higher at high loads. It also showed slightly higher BSFC and BSEC at low loads. It was observed to be almost similar for increasing load. EGT was higher for J20H compared to diesel and J20

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Abbreviations

OPME - Olive pomace oil methyl ester

J20 - 20% blend of Jatropha oil with mineral diesel

J20H - 20% blend of Jatropha oil with mineral diesel preheated at 100°C

J5W5 PBJB5 - 5% Jatropha biodiesel,5% waste cooking oil blended with diesel

PBJB10 - 5% and 10% palm and Jatropha biodiesel

B50 - 50% biodiesel

TDC - Top dead centre

CAD - Crank angle degree

BTE - Brake thermal efficiency

BSFC - Brake specific fuel consumption

BSEC - Brake specific energy consumption

EGT: - Exhaust gas temperature

CO - Carbon monoxide

CO_2 - Carbon dioxide

HC - Hydrocarbon

NO_x - Nitrogen oxide

HRR - Heat release rate

CHRR - Cumulative heat release rate

dBA - A weighting decibel value of noise

THC - Total Hydro Carbon

g - Acceleration in m/s^2

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