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Vibration Analysis of Single Cylinder Diesel Engine Using Various Fuel Blends

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Abstract*: Biodiesel as an environmentally friendly fuel which has the potential to provide comparable engine performance results. Biodiesel is a renewable fuel produced with the help of vegetable and seed oils. Sound and vibration caused by the combustion process in the engine have direct effects on users. Most important characteristics of diesel fuels is high noise and vibration. The present study were carried out to examine the vibration acceleration of different diesel-biodiesel fuel blends in single cylinder CI engine. The main goal was to present fuels with the minimum vibration for full load. The experiments indicated that the magnitude of vibration in the single cylinder CI engine depends on the axis of measurement, engine load and the fuel blends. The results of the experiments showed that vibration acceleration is significantly affected by the axis of measurement. The magnitude of vibration acceleration in linear axis was more than that in the lateral axis. •Fuel blends significantly influenced the vibration. It demonstrated that S0 and S20 have the lowest vibration, and S10 and S30 have the highest vibrations. Vibration acceleration amplitudes also depends upon load on engine. As load on engine increases vibration acceleration amplitude also increases in linear direction.

Keywords— Simarouba Biodiesel, compression ratio, injection pressure, advanced injection timing, % of blends etc

I. INTRODUCTION

The increased number of automobiles in recent years were resulted in great demand for diesel and petrol. This has led to the development of renewable energy. Biofuel, which is used as an alternative diesel fuel, is made up of renewable biological sources like vegetable oil and animal fats. It is bio degradable, non-toxic and possesses low emission profiles. In addition the uses of bio-fuels are environmentally beneficial. In the vegetable oils have comparable energy density, cetane number, heat of vaporization, and stoichiometric air/fuel ratio with mineral diesel. Vegetable oils and their derivatives in diesel engines caused to substantial reductions in emissions of sulfur oxides, carbon monoxide (CO), poly aromatic hydrocarbons (PAH), smoke, particulate matter (PM) and noise. Using biodiesel exhaust gas temperature and Smoke are reduced. Additive mixing further reduced the HC emission and CO emission to larger extent. The biodiesel blend produces less black smoke compared to the conventional diesel because of the oxygen content. A complete combustions were obtained with higher biodiesel blend. Hence, the biodiesel blend is much more environmentally friendly compared to the conventional diesel. Vibration acceleration was significantly affected by engine speeds and the increase in forward speed due to the increase in vibration acceleration amplitude. The vibration acceleration value in linear directions was more than that in the other two axes and in the longitudinal axis was more than that in lateral axis. Fuel blends significantly influenced the vibration. It demonstrated that S100, S10 and S20 have the lowest vibration, and S20 and S30 have the highest vibrations.

Vibration is the movement or mechanical oscillation about an equilibrium position of a machine or component.Vibration can be expressed in metric units (m/s2) or units of gravitational constant "g", where 1 g = 9.81 m/s2. An object can vibrates in two ways which are- first one is free vibration and second is forced vibration.

A. The Principle Characteristics of the Vibration Signal that We Measure are

1) Amplitude
2) Frequency
3) Phase

Vibrations play a pivotal role in our day-to-day lives like in the human anatomy; for voice to be generated the vocal cords need to vibrate, for legitimate walking the leg muscles must vibrate etc. A periodic oscillation can be known as vibration . Sometimes vibrations can produces result of faults, like in the case of machines like pumps or generators. Sometimes, vibrations are generated due to external forces, for eg. powerful winds shaking an improperly built suspension bridge. If the frequency of these external

sources of vibration matches with any of the natural frequencies of the system, then the system undergoes large oscillations. This condition is called as resonance in the system. Effect of resonbance causes breaking of bridges, turbines and wings of airplanes are a few cases of structure failure. Therfore , it is important to analyze a given structure for vibration. Vibration signals can be analyzed in frequency domain and time domain.

B. Why Biodiesel?

1) Biodiesel is an oxygenated fuel, emissions of carbon monoxide and soot results to be reduced compared to conventional diesel fuel.
2) Biodiesel is obtained from vegetable sources, which does not contain any sulfur, aromatic hydrocarbons, metals or crude oil residues.
3) Biodiesel can be used in existing engines without any modifications in the engine which is economical.
4) Unlike fossil fuels, the use of biodiesel does not impact to global warming as CO2 emitted is once again absorbed by the plants grown for vegetable oil/biodiesel production which is beneficial. Thus CO2 balance is maintained.
5) The Occupational Safety and Health Administration classify biodiesel as an non-flammable liquid.
6) The use of biodiesel can increased the life of diesel engines because of it is more lubricating than petroleum diesel fuel.

C. Advantages of Biodiesel

1) It is Non- toxin
2) Mixture of biodiesel and gasoline will increase the engine efficiency up to large extent.
3) Because of its higher flash point it's more suitable and safety for storage obtained from biodiesel.
4) It‘s a renewable source of energy obtained from vegetable.
5) The danger of cancer would be reducing up to 92%.
6) It doesn't have any greenhouse effects because the CO2 pollutant that its produce is equal to CO2 that is absorbate by the vegetable oil plant which causes less pollution.

D. Disadvantages of Biodiesel

1) A little decrease in fuel economy (near 10% for pure biodiesel) because of biodiesel.
2) The density of biodiesel is higher than oher fuel.
3) Than gasoline and in subfreezing condition we need to mix it with gasoline in biodiesel.

E. Simarouba Biodiesel

Simarouba glauca belongs to family simarubaceae, commonly known as “The Paradise Tree” or “King Oil Seed Tree”, is a versatile multipurpose evergreen tree having a height of 7-15 m with tap root system. It is mainly found in coastal hammocks of South Florida. In India, they are found in small regions of Andhra Pradesh, Karnataka and Tamil Nadu etc. It can adapt a wide range of temperature, has the potentiality to produce 2000- 2500 kg seed/ha/year; can grow well in marginal lands/wastelands with degraded soils and therefore considered as a major forest tree. However, in the present context the seeds are economically very important because of they contain 60-75% oil. Dry seeds of S. glauca contain 32-42% protein, with 60-65% unsaturated fatty acids which improves its nutritional profile. The Simarouba kernels shown in figure1 (Seeds of different size and shape is considered).

F. Benefits of Simarouba

Because of ever diminishing sources of fats and oils, there is the growing need for the search of new sources of oil as well as exploiting sources that are currently unexploited in order to supplement the existing ones. Simarouba is a growing tree was found growing in a various range of climatic condition is a promising tree and which has the potential to become a new source of oil. Some of the tropical regions with the fertile soils, receiving good rainfall, which have rich rainforests with a large treasure of flora and fauna. Agriculture is advantageous in these regions and here the farmers are generally happy and love farming.

Though there was less privileged geographical regions in the tropics, which was received low and erratic rainfall that cannot support good vegetation even though they were blessed with plenty of sun light. Cultivation of traditional crops adopting recommended packages is very much uneconomical and often disastrous to agriculturists in these regions Several measures are suggested for mitigating this problem. Among them, recommending a low cost input technology for cultivating hardy perennial crops that can

grow well even with erratic and low rainfall, still giving assured returns is of great significance.

II. EXPERIMENTAL

A. *Physical-Chemical Characterization of Simarouba Biodiesel*

Table 1 Properties of Simarouba Biodiesel

Properties	Diesel	Simarouba Biodiesel
Density(kg/m³)	827	865
Kinematic viscosity at 40˚C (cSt)	3.57	4.68
Flash point (˚C)	54	165
Calorific value (MJ/kg)	42	38.6
Cloud point (˚C)	-12	19
Pour point (˚C)	-16	14.2
Carbon residue (% w/w)	0.15	0.10
Acid value (mg KOH/gm)	-	5.34
Iodine number (gm/100gm)	-	83.4
Ash content (% w/w)	0.01	0.005

B. *Engine Testing Method*

The experimental tests were carried on a single cylinder CI engine, four strokes and water cooled, Kirlosker TV 1 diesel engine Fig 2. The Specifications of the Test Engine which is used are listed in table 1. It is coupled with an Eddy current dynamometer. The dynamometer was interfaced to a control panel. Experimental tests have been carried out to evaluate the performance, vibration characteristics of a diesel engine when fueled with biodiesel (Simarouba oil) and its blends of 0%, 10%, 20% and 30% of biodiesel with diesel fuel separately. Based on the performance the work is carried out to measure the vibration acceleration amplitude fuelled in diesel and biodiesel at different load (0kg, 4 kg, 8kg and 12kg) %) with recommended diesel engine setting at constant input parameters like CR, IP, FF and IT. Vibrometer Model- VB-8201HA is used to measure the vibration acceleration in head of the engine cylinder.

The engine vibrations are measured using accelerometers with the help of vibrometer which is used to measure the engine vibration acceleration amplitudes in the form of its root mean square (rms) value of vibration acceleration. We measured the vibration in both direction that is linear (x direction) and lateral (y direction) putting accelerometer at positions as shown in figure 8 and figure 9. Then, the rms values of vibration acceleration are statistically analyzed using the three factors completely randomized design in software, to study the effects of the compression ratio, fuel type, injection pressure and various load on the rms values of vibration acceleration

Table 2: Specifications of Engine

Product	VCR Engine test setup 1 cylinder, 4 stroke, Diesel with EGR (Comp.)
Product code	234
Engine	Make Kirloskar, Type 1 cyl., 4 stroke Diesel, water cooled, power 3.5kW at 1500rpm, stroke 110mm, bore 87.5mm. 661cc, CR17.5, Modified to VCR engine CR 12 to 18. With electric start arrangement, battery and charger
Dynamometer	Type eddy current, water cooled
Fuel tank	Capacity 15 lit with glass fuel metering column
Calorimeter	Type Pipe in pipe
EGR	Water cooled, SS, Range 0-15%
Piezo sensor	Range 5000 PSI, with low noise cable
Crank angle sensor	Resolution 1 Deg, Speed 5500 RPM with TDC pulse.
Temperature sensor	Type RTD, PT100 and Thermocouple, Type K

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Figure 1 Engine Setup

C. Design of Experiments

Taguchi method was used to optimize the engine operating parameters. Orthogonal L_{16} array was used to design the experiment. The factors for which the engine is optimized are: compression ratio, injection pressure of fuel, advanced injection timing, biodiesel fuel fraction. Four levels of each factor are considered hence L_{16} array was the suggested and most suitable array. Levels of each factor and design of experiment (DOE) are shown in Table VI and VII.

Table 3 Level of Input Parameters

Level of I/P / Parameters	1	2	3	4
% BLEND	0	10	20	30
COMPRESSION RATIO	15	16	17	18
INJECTION PRESSURE	210	230	250	270
INJECTION TIMING	22	23	24	25

Table 4 Design of experiment for experimental testing

SR. NO.	% BLEND	COMPRESSION RATIO	INJECTION PRESSURE	INJECTION TIMING
1	0	15	210	22
2	0	16	230	23
3	0	17	250	24
4	0	18	270	25
5	10	15	230	24
6	10	16	210	25
7	10	17	270	22
8	10	18	250	23
9	20	15	250	25
10	20	16	270	24
11	20	17	210	23
12	20	18	230	22
13	30	15	270	23
14	30	16	250	22
15	30	17	230	25
16	30	18	210	24

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D. Fuel Fraction used for the test

Fuels used for the test include Simarouba oil and its blends. Biodiesel and diesel blends were prepared on the basis of percentage volume basis of diesel and biodiesel for net unit volume. The combination of S10, S20, S30 were selected for the optimization. As the additive is used to improve the combustion properties of fuel, high percentage of biodiesel were selected for the experiment

E. Location of Vibration Measurement


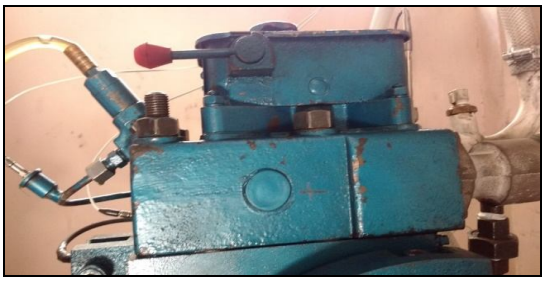

Figure 2 Location of vibration measurements in linear(x) and Lateral (y) directions

Above figures show that the actual location of vibration measured in linear and lateral directions.

III. RESULTS AND DISSCUSSION

Results obtained from the experiment at full load (12 kg load) are

SET NO.	VIBRATION OF ENGIN			
	X		Y	
	MAX.	MIN.	MAX.	MIN.
1	137.4	134.2	36.2	35.1
2	119.3	116.3	32.4	31.6
3	120.6	109	33.4	32.1
4	147.1	145.4	21.9	20.9
5	142.4	141	32.7	26.6
6	136.6	134.1	26.1	26
7	129.6	128.8	26.5	25.2
8	135.1	131.9	25.4	22.9
9	139	136	24.3	21.1
10	139.7	135.4	27.2	25.5
11	134.3	129.9	25.2	22.4
12	134.7	132.1	25.7	22.6
13	134.9	133.5	23.2	20.7
14	138.8	136.6	22.4	19.1
15	127.8	125.6	18.1	17.4
16	131.9	128.8	23.4	21.8

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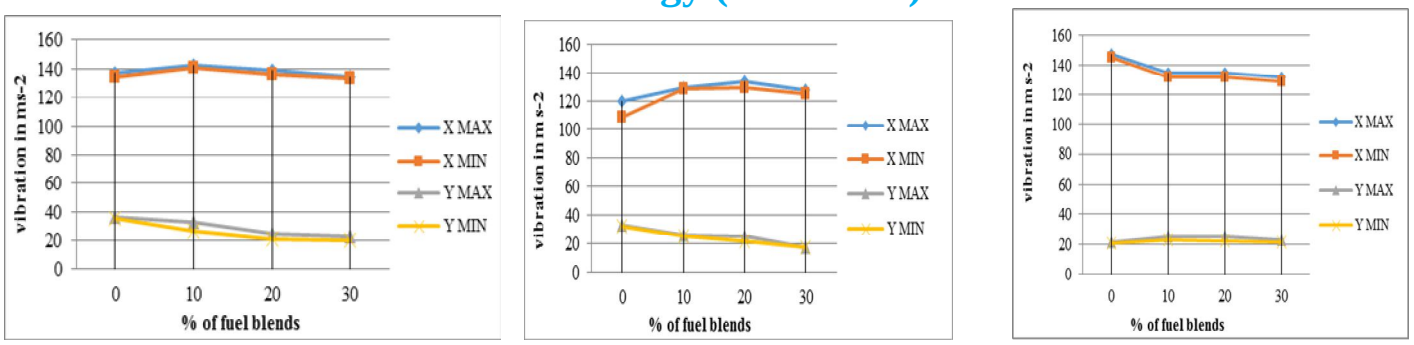

Figure 3 Effect of % of fuel blends on vibration acceleration at different compression ratios

Above figure shows that the effect of fuel blends on engine vibration in both linear (x direction) and lateral direction (Y direction) at various compression ratios(15, 16, 17 and 18) at 12 kg load. From figures it is observed that magnitude of vibration acceleration in linear direction is more than lateral direction. It is observed that in linear direction as increased in % of fuel blends the amplitude of vibration acceleration decreases at full load (12 kg load). Also in lateral direction amplitude of vibration acceleration decreases as increased in % of fuel blends.

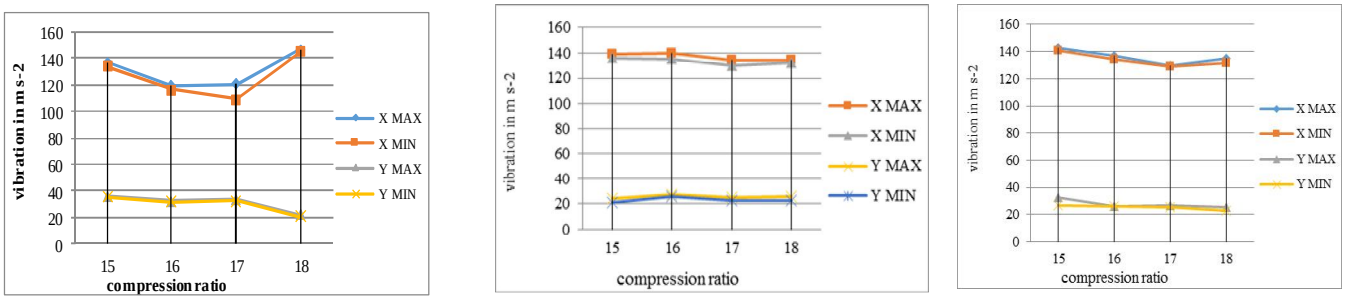

Figure 4 Effect of compression ratio on vibration acceleration at different % of fuel blends

Above figure shows that the effect of compression ratio on engine vibration in both linear (x direction) and lateral direction (Y direction) at various fuel blends(0%, 10%, 20% and 30%) at 8 kg load. From figures it is observed that magnitude of vibration acceleration in linear direction is more than lateral direction. It is observed that as increased in in compression ratio the vibration acceleration firstly decreases upto 17 compression ratio and then it gets increases for 18 compression. It is also found that in lateral direction as increased in compression ratio the amplitude of vibration acceleration increases.

IV. CONCLUSIONS

Experimental investigations are carried out on a single cylinder CI diesel engine for vibration analysis using Simarouba biodiesel as an alternative fuel. Vibrations accelerartions are measured with the help of vibro-meter at cylinder head in linear and lateral directions. From the above investigations, the following conclusions are found.

A. The maximum vibration amplitude is related to the rate of pressure rise and the maximum pressure in the cylinder during ignition, as the rate of pressure rise increases the vibration amplitude also increases.

B. The vibration acceleration values in linear directions were more than that in lateral directions.

C. Fuel blends significantly influenced the vibration, showed that B0 and B20 have the lowest vibration, as compared to S10 and S30 have the highest vibrations.

D. Vibration Amplitudes also depends upon load on engine head, as load on engine increases vibration acceleration amplitude also increases in linear direction.

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