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Research paper

Comparative vibration study of a diesel engine fueled with chicken fat biodiesel

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Abstract

Biodiesel is an alternative fuel and has become more attractive now a days due to its low emissions. The biodiesel can be used in existing diesel engines directly in pure form or blending with diesel. The diesel engine physical behaviour during its working is very important. The present work involves, comparative vibrational analysis of diesel engine using conventional diesel, chicken fat biodiesel and its blends with diesel at different engine load conditions. Tests are carried on single cylinder four stroke stationery engine and vibrations are measured using vibration tester. Results of the study shows that, vibration acceleration increased with engine load for all fuel blends and also increased with chicken fat biodiesel quantity in the blend. The higher vibrations with chicken fat biodiesel are due to development of higher peak pressures during combustion of oxygenated biodiesel compared to diesel.

Keywords: *Diesel Engine; Vibrations; Chicken Fat Biodiesel; Peak Pressure.*

1. Introduction

Day by day the alternative fuel become more important due to depletion of conventional petroleum-based fossil fuels. Many countries in the world made mandate by legislations and encourage researchers' interest in biofuels. European Union (EU) countries are aimed to get 10% of the transport fuel from renewable sources [1]. Biodiesel is the most prominence alternative fuel besides its environmental advantages and more suitable for CI engines due to low unburned hydrocarbons and carbon monoxide in the exhaust emissions [2]. The usage of biodiesel has been increased drastically due to its availability and requirement of no modification in the existing diesel engines [3]. Many researchers study the effect of biodiesel on engine performance and emission aspects only and there are very few studies about engine vibration.
In general engines develops disturbing forces of different frequencies, make the entire engine body to vibrate and results the passenger discomfort [4]. In CI engines mainly, the vibrations are influenced by pressure in the cylinder during combustion process. The development of pressure is dependent on type of fuel used and its properties. Some researchers examined the vibration characteristic of internal combustion engines, which were fuelled with alternative fuels. How et al [5] investigated combustion, vibration characteristics, performance and emissions of a high-pressured common rail diesel engine, which is fuelled with coconut biodiesel blends and revealed higher vibrations? Gravalos et al. [6] studied about vibration behaviour of a SI engine running with unleaded gasoline, alcohol blends and reported slightly increased vibration. Mohammed Faizan Shaikh and Sudhakar Umale [7] investigated noise and vibration analysis of diesel engine using diesel and Jatropha biodiesel. They observed that with increase in percentage of biodiesel blends, noise and vibration reduces comparably for most of the conditions. Erinç Uludamar et al. [8] studied vibration effect of canola (rapeseed), sunflower biodiesel and their blends with low sulphur diesel fuel. Fuels were tested in a four-cylinder four stroke diesel engine at 1300, 1600, 1900, 2200, 2500 and 2800 rpm engine speed. The results showed that with the use of biodiesel blend up to 40% proportions, vibration values get significantly lower at all engine speed. The least vibration value for most of the fuel was observed with the use of 60% biodiesel blend. Tiantian Yang ET. Al [9] investigated Vibration Characteristics of Compression Ignition Engines Fueled with Blended Petro-Diesel and Fischer-Tropsch Diesel Fuel from Coal Fuels. They obtained the combustion and vibration characteristics of a CI engine using CFT blended fuels. The four fuels used are diesel, 10%, 30%, and 70% CFT in petro-diesel, and pure CFT, respectively. A four-cylinder engine was operated at loads of 10, 50, 100, 150, and 200 (except 1200 rpm) Nm loads and speeds of 1200, 1600, 2000, and 2400 rpm. Maximum amplitudes of vibration signals of the engine head and block in the time domain reduce with the increase of CFT proportion. The results and conclusion of this study can pave the way for the optimal design and development of fuel blends based on vibration analysis. Li et al. [10] found that the advanced ignition of biodiesel is the main cause of the nonlinear increase in root mean square (RMS) of vibration response near the combustion top dead center (TDC).The study by Taghizadeh-Alisaraei et al. concluded that the RMS and kurtosis values of engine body vibration increase when ethanol is added to diesel [11]. Meanwhile, the RMS value of dual-fuel engine vibration is lower than that of diesel engine, and the frequency component distribution of dual-fuel engine vibration is narrow [12].

2. Materials and methods

2.1. Fuel

The chicken fat biodiesel (CFBD/B100) produced from waste chicken fat by transesterification process was used to study the vibrations of the diesel engine. The important key properties of chicken fat biodiesel, petroleum diesel (PD) and ASTM standards for biodiesel are given in table 1.

Table 1: Properties of CFBD and PD

Property	Unit	PD	CFBD/B100	ASTM Standards (D6751)
Density	g/cc	0.831	0.862	0.87-0.89
Kinematic Viscosity at 40°C	cSt	2.58	4.93	1.9-6.0
Flash Point	°C	50	160	130 minimum
Lower Calorific value	kJ/kg	42500	40170	37500
Cetane number	-	48	57	48-70

2.2. Vibration tester

Fig. 1 shows the vibration tester, model: ADV – 80, supplied by MCM instruments used for measuring engine vibrations. The detailed technical specification of the vibration tester is given in Table 2.

Fig. 1: Vibration Tester.

Table 2: Vibration Tester Specifications

Make	MCM Instruments
Model	AVD – 80
Velocity	0.1 to 199.9 mm/s
Acceleration	0.1 to 199.9 m/s^2
Displacement	0.5 to 2800 µm
Frequency	10 to 1000 Hz
Resolution	0.1 mm/s
Accuracy	2% ± 0.2
Display	LCD display

2.3. Engine

The diesel engine mounted on concrete foundation is considered for vibration testing. Engine vibration are measured at different loading (¼, ½, ¾ and full load) conditions running at constant speed of 1500 rpm with chicken fat biodiesel fuel and its diesel blends i.e., B100 (pure biodiesel), B40 (40% biodiesel and 60% diesel), B30 (30% biodiesel and 70% diesel), B20 (20% biodiesel and 80% diesel), B10 (10% biodiesel and 90% diesel) and B0 (pure diesel). As universally accepted blend is B20, the said blends which are nearer to universal blend were considered for the analysis. Cyclic movements (vibration) are measured and described in three different ways as

- Vibration Displacement
- Vibration Velocity
- Vibration Acceleration

Vibration displacement means the actual distance the object moves from its rest position. It is measured directly in millimeters or microns. Apart that is moving from rest, speeding up and slowing down is obviously accelerating and decelerating continuously. Vibration acceleration is measured in mm/sec^2. The third measuring parameter, the rate at which the object moves is vibrations velocity. Vibrations velocity is expressed in mm/sec. The number of vibrations per unit time is the vibration frequency, measured in Hz (Hertz = cycles/s). The vibrations velocity (V), displacement (D) and frequency (f) are related as $V = \Pi D f$.

The direction of vibration measurement is very important. Normal practice is to take vibration readings in three directions vertical (V), horizontal (H) and axial (A). In the present study, the same three direction are termed as

1) Engine vibrations in the direction parallel to piston axis (Z – axis or vertical)
2) Engine vibration in the direction parallel crank shaft (X – axis or axial)
3) Engine vibration in the direction perpendicular to axis of the piston and crank shaft that is Z and X – axis (Y – axis or horizontal)

The cylinder head with X, Y and Z direction are shown in Fig.2. In measuring the vibrations, only engine head is considered. Three measuring points are identified in each direction (i.e., Z, X and Y). Average value of three measuring points is considered for analysis.

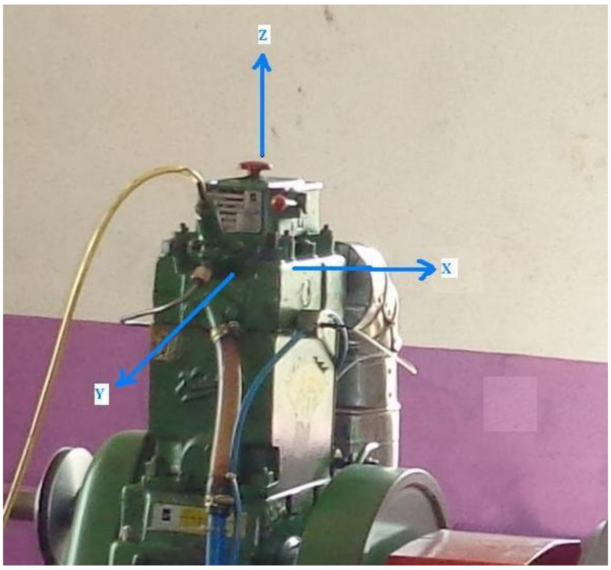

Fig. 2: Directional Indication for Engine Vibration Measurement.

3. Results and discussion

Fig. 3, 4 & 5 shows the variation of the engine cylinder head vibration displacement, velocity and acceleration respectively along Z – direction (vertical) of B0, B10, B20, B30, B40 and B100 fuels with engine load. All these vibrations increases with engine load up to 2.79 kW, later slightly decreased at 3.72 kW load. This may be due to increase of pressure development of fuels with engine load (see fig. 8), but at full load (3.72 kW) the engine gets stabilized and hence decreased vibrations are observed. These graphs also show that the engine vibrations with B100 (CFBD) fuels are higher than B0 (PD), because of oxygenated biodiesel fuel results complete and effective combustion, increased premixed combustion period due to early start of combustion and increased pressure development. The variation of vibration acceleration of engine cylinder head with engine load in X (axial) and Y (lateral) direction are shown in Fig. 6 & 7 respectively. The intensity of vibrations in X and Y directions is comparatively less than Z - direction, because of acting of majority of piston thrust in Z - direction only.

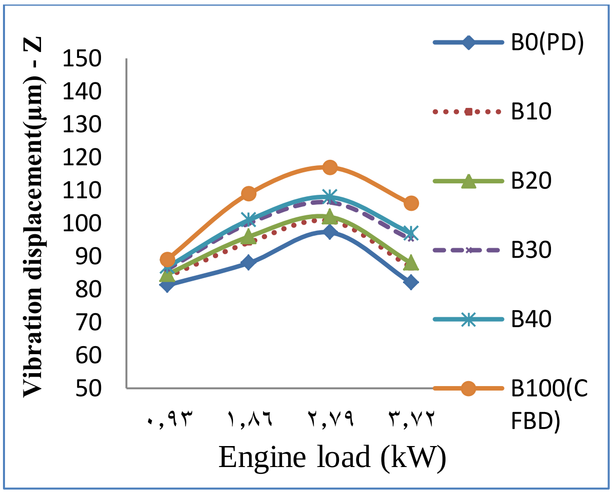

Fig. 3: Vibration Displacement in Z-Direction with Engine Load (BP).

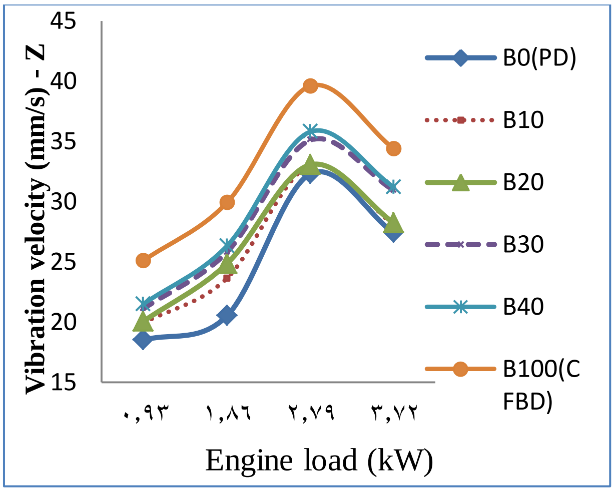

Fig. 4: Vibration Velocity in Z-Direction with Engine Load (BP).

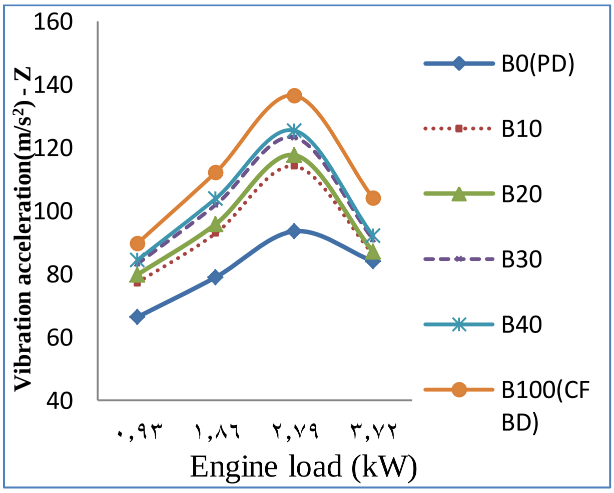

Fig. 5: Vibration Acceleration in Z-Direction with Engine Load (BP).

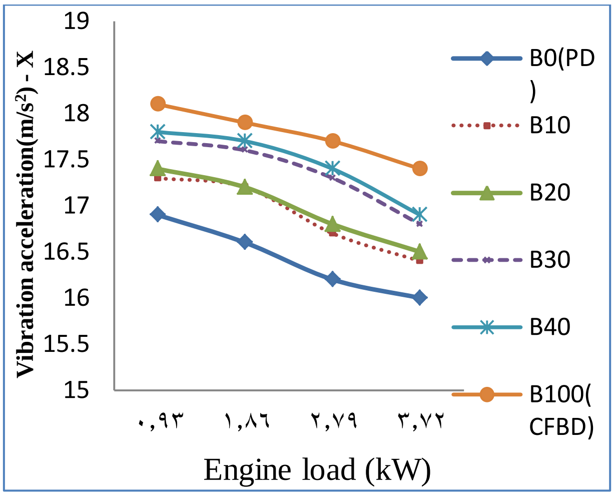

Fig. 6: Vibration Acceleration in X-Direction with Engine Load (BP).

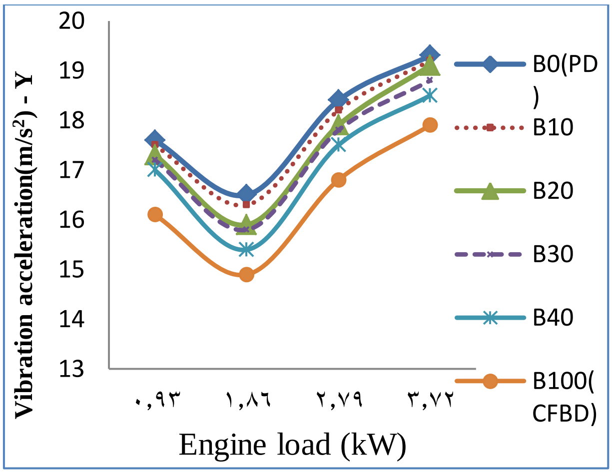

Fig. 7: Vibration Acceleration in Y-Direction with Engine Load (BP).

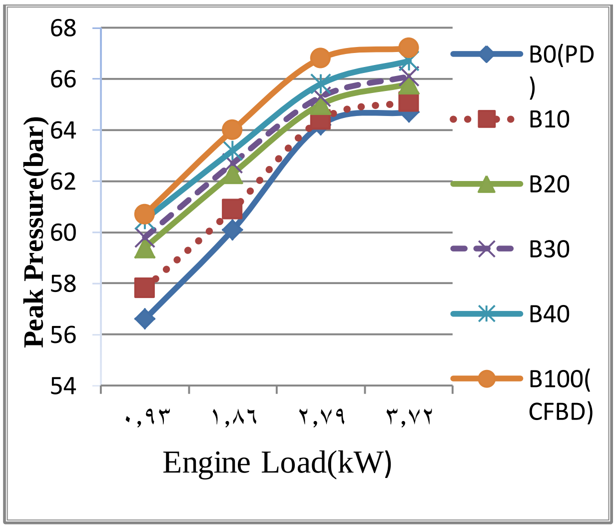

Fig. 8: Variation of Cylinder Peak Pressure With Engine Load (BP).

Fig. 8 shows the variation of cylinder peak pressure of B0, B10, B20, B30, B40 and B100 fuels with engine load. Peak pressure increases with increase in engine load for all fuels. Peak pressure of CFBD is higher than PD at all loads. Peak pressure also increased with percentage of CFBD (B100) blend in PD (B0). This is mainly due to more oxygen content in CFBD leads to complete combustion results higher pressure.

4. Conclusions

- Engine vibrations increases with engine load for all fuel blend. At higher load engine development of more power may be the reasons for higher vibrations, but at full load engine get stabilised and hence slightly reduced vibrations.
- Compared to diesel engine vibrations are more for chicken fat biodiesel and its blends at all engine loads This may be due to the development of higher peak pressures by more oxygenated biodiesel.
- Engine vibratin accelerations are observed very high in Z direction compared to X and Y because of acting of majority of piston thrust in Z - direction only.

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