Effect of Fuel Injection Strategies on Bio-Diesel Engine Vibration Performance

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***Abstract*—Recent scenario says that traditional fossil fuels are depleting day by day. The environmental pollution issues also arise globally. Hence alternative fuels are the need of the hour now. Biodiesel comes forward as the best alternative fuel because it can be used directly without any modification to diesel engine up to certain level. Currently, 20 % bio diesel blend with 80% diesel is used. But bio diesel has certain limitations such as high viscosity, high density, and lower calorific values. These limitations restrict the blending percentage of biodiesel with diesel. To overcome these limitations, many researches recommended modifications in injection parameter. But all these studies focused on emission and performance only. In this experimental study, vibration performance analysis of Diesel engine was carried out by using different fuel blends and varying injection parameters. Experiments were performed on Single cylinder diesel engine using two Jatropha Bio-Diesel blends, three different Injection pressures and three Injection timings. Injection pressure was set at 130, 170 and 210 bar while Injection timing was set at 20.5°bTDC, 23°bTDC, 25.5°bTDC. Experimental study shows that fuel injection pressure significantly affect on engine vibration.**

***Keywords*— Diesel Engine, Injection Pressure, Injection Timing, Jatropha Biodiesel, Vibration**

I. INTRODUCTION

DEVELOPMENT in the field of automobile field and industrialization, demand of fossil fuels increased tremendous. Due to the overuse of fossil fuels environmental problems arises. Also, increased fuel prices & strict emission standards lead towards alternative fuels. Biodiesel is a best suitable option for the fossil fuels. Due to increased demand lots of researches are going on biodiesel and its suitability to diesel engine. Currently, 20% biodiesel is used in diesel engine without any modifications to engine. Researches show that with certain modification to engine, fuel blending can be increased. Many researches are in the area of performance and emissions analysis. But the effects of biodiesel on engine vibration performance were not reported so far. Vibration analysis of biodiesel engine can give idea about possible damage to engine due to improper combustion.

Rudolf Diesel presented an engine based on compression ignition diesel engine. Rudolf Diesel suggested that diesel engine can be fed by vegetable oil and this possibility could help agriculture development. [1] Biodiesel is mixed with diesel fuel and then used in combustion engines. One of advantage of biodiesel is its less pollution in comparison with diesel fuels. [2]

Though the biodiesel can be used directly with diesel engine without any significant modifications, biodiesel have certain limitations. Biodiesel have higher cetane number than diesel fuel. This leads towards the shorter chemical delay. Number of researches has shown that the physical ignition delay tends to increase by applying pure bio-diesel or its blend with diesel fuel. This is mainly due to higher kinematic viscosity and surface tension of the bio-diesel which cause longer time on bio-diesel fuel droplet evaporation. Due to such a change in fuel thermo-physical properties, break up, atomization and evaporation of bio-diesel fuels take longer time and this has a direct effect on engine combustion and emission characteristics. Hence, injection strategies are much more important in bio-diesel driven engines comparing to diesel engine. [3] Higher viscosity and density of biodiesel fuel causes to poor atomization and mixture formation of air which results in improper combustion process and lower thermal efficiency. [4] Spray pattern of diesel and various biodiesel blends shows that as fuel blending increases, soot mean diameter & spray length also increases. This may lead towards improper combustion. [5]

The present design and operating parameters of the engine are standardized only for diesel fuel. For all other fuels, the operation parameters of the engine need to be optimized with the view of specific fuel properties. [6] An increase in injection pressure results in smaller droplets and uniformity of atomization. The mean droplet diameter increases if the diameter of orifice is increased as increase in viscosity. It also increases the mean droplet diameter. [7] The injection timing have significant effect on the ignition delay because the air temperature and pressure change significantly close to TDC. When we advance the injection timing, the initial air temperature and pressure get lowered. So ignition delay will increase. While retarding the injection timing, air temperature and pressure are slightly higher, results in shorter ignition delay. [8]

So far, Fuel type and injection strategies have significant effect on combustion phenomenon. This may lead towards change in engine vibrations. [9] So, performance and emission are not only criteria for fuel and Injection strategy selection but Vibration level also.

IC engines naturally produce high levels of vibration energy when running. This effect which in most instances is undesirable since it gives rise to acoustical disturbances and may eventually lead to fatigue failure of engine components. However, while a certain amount of vibration energy is unavoidable, it can be used to give quality indicators for condition monitoring of engines. This concept leads to the use of vibration analysis for condition monitoring of IC engine. [10] The irregular and erratic combustion inside the combustion chamber results in knocking leading to erosion and damage to combustion chamber and piston head. [11] Sound and vibration resulting from combustion engine have directly effected on users. Diesel engine used in agriculture equipment such power tiller directly effect on wrist and arm of the operator. [12]

In this experimental study, vibration performance of single cylinder diesel engine is focused. Jatropha biodiesel blends B20 and B40 are used. Injection strategies such as Injection pressure and injection timing are modified. Vibration signals are being measured using accelerometer. RMS values of acceleration are used for vibration level comparison.

II. MATERIALS AND METHODS

A. Biodiesel and its blends

Biodiesel is non polluting fuel made from organic oils. It is chemically called as free fatty acid methyl ester. Biodiesel is obtained from organic oil and fats after transesterification. Organic oil is of two types, Edible oil and non edible oils.

In present study, non edible oil was used. Non edible oil was preferred due to cost of production and deficit supply of edible oil. Jatropha Methyl ester blended with diesel. B20 (20% biodiesel and 80% diesel) and B40 (40% biodiesel and 60% diesel) were used.

TABLE I
PROPERTIES OF DIESEL AND BIODIESEL

Sr. No	Property	Unit	Diesel	B20	B40
1	Density	g/cm^3	0.8051	0.8170	0.8366
2	Viscosity	cSt	01.14	1.33	02.23
3	Cetane No	-	48	49	50
4	Gross Calorific Value	Kcal/Kg	9981	9635	9371

Biodiesel blends purchased from SVM Agro Processor, Nagpur. Fuel properties testing were carried out at Nikhil Analytical and Research Pvt Ltd. Sangli. TABLE I shows properties of Fuels used for experiment.

B. Engine Specifications

In present study, single cylinder diesel engine of Kirloskar make was used. Engine setup was available at RIT, Islampur. The technical specification of engine showed in TABLE II.

TABLE II
TECHNICAL SPECIFICATION OF ENGINE

Engine Parameter	Specification
Engine Make	Kirloskar TV1
No. of cylinder	1
Rated power	5.2 Kw
Speed	1500 rpm
Method of cooling	Water cooled
Compression Ratio	17.5:1
Injection timing	23°bTDC

C. Design of experiments

The experimental design for vibration measurement of engine is being planned with considering 3- level and 4 factors. Four factors considered are Fuel blend, Injection pressure, injection timing and engine load. Each factor has three levels. L_{27} array was used to form experimental design matrix. TABLE III shows experimental design matrix

TABLE III
EXPERIMENTAL DESIGN MATRIX

Sr No	Injection Timing °bTDC	Injection Pressure Bar	Fuel Blends	Engine load N-m (%)
1	20.5	130	Diesel	50
2	20.5	130	B20	75
3	20.5	130	B40	100
4	20.5	170	Diesel	75
5	20.5	170	B20	100
6	20.5	170	B40	50
7	20.5	210	Diesel	100
8	20.5	210	B20	50
9	20.5	210	B40	75
10	23	130	Diesel	75
11	23	130	B20	100
12	23	130	B40	50
13	23	170	Diesel	100
14	23	170	B20	50
15	23	170	B40	75
16	23	210	Diesel	50
17	23	210	B20	75
18	23	210	B40	100
19	25.5	130	Diesel	100
20	25.5	130	B20	50
21	25.5	130	B40	75
22	25.5	170	Diesel	50
23	25.5	170	B20	75
24	25.5	170	B40	100
25	25.5	210	Diesel	75
26	25.5	210	B20	100
27	25.5	210	B40	50

D. Experimental setup

The experimental study was carried out on single cylinder diesel engine. A Kirloskar make water cooled engine was coupled with eddy current dynamometer.

Vibration measurement was carried out by using single axis accelerometer of make Bruel & Kjaer (Model 4534-B 30883). The frequency range of accelerometer was 0 to 12800 Hz. And operating temperature was -55^{o} to 125^{o}

For vibration signal recording and signal processing, Bruel & Kjaer FFT analyzer was used. A Fig.1 shows experiment setup for engine and data acquisition system for vibration measurement.

Fig. 1. Experimental Setup

Fig. 3. Injection Pressure Calibration Bench

E. Engine modifications

In present experimental study, to investigate the effect of fuel injection strategies on biodiesel engine vibration performance, modifications to injection pressure and injection timing has been done.

Injection pressure was changed by changing injector spring tension by adjusting screw. Initially pressure was at 170 bar. Then it was modified to 130 bar and 210 bar. Fig. 3 shows a Bosch-Mico make fuel injector of single cylinder diesel engine. The modified injector was calibrated on Injector Pressure Calibration bench at Authorized Bosch Service center. Fig. 4 shows a Injector Pressure calibration bench.

Injection timing was also modified. Initially injection timing was 23^{o}bTDC. Then by adjusting the no. of shims under the fuel pump body, injection timing was adjusted. For Kirloskar TV1 engine, reduction of shim thickness by 0.3 mm advanced the injection timing by 2.5^o crank angle. And adding 0.3 mm shim retard the injection timing by 2.5^o crank angle. [4] Hence, for study, 20.5^{o}bTDC, 23^{o}bTDC and 25.5^{o}bTDC these three injection timing was used.

F. Experimental Procedure

The experimental work started with standard engine setting, injection pressure at 170 bar and injection timing of 23^{o}bTDC. Initially diesel was used as fuel. Then injection pressure varied to 130 bar and 210 bar. After that, fuel was altered with B20 and test conducted for three injection pressure. Same procedure was carried out for B40 fuel blend. Test was performed for different injection timing viz. 20.5^{o}bTDC and 25.5^{o}bTDC.

Fig. 2. Fuel Injector

Vibration measurement carried out by using accelerometer. Vibration of engine was measured at three different locations viz. top of cylinder head, front of cylinder block and side of cylinder block. Bruel & Kjaer FFT analyzer and PULSE Labshop software was used for data recording and data processing.

III. RESULTS AND DISCUSSION

In present study, vibration performance of single cylinder engine are being analyzed by using different fuel injection pressure and with different fuel blends. Effect of injection pressure on engine vibration was determined. Also effect of fuel blends on engine vibration performance was determined.

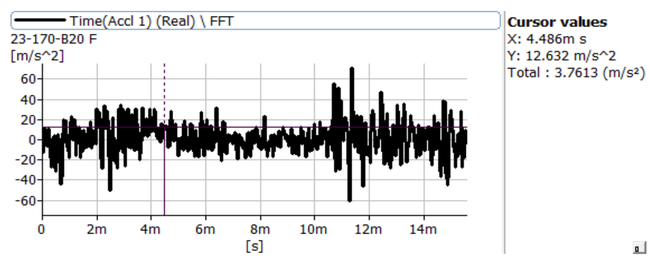

Fig. 4. Time domain graph

Vibration data was acquired for three fuel blends with three different fuel injection pressures at constant speed of 1400 rpm. A time domain graph in Fig. 4 shows time domain signals for engine running with 170 bar injection pressure and B20 fuel. The peaks of time domain show peak pressures in combustion process. Fig. 5 shows frequency graph for time domain signals. Peaks in frequency graph indicate peak amplitude of different component of engine.

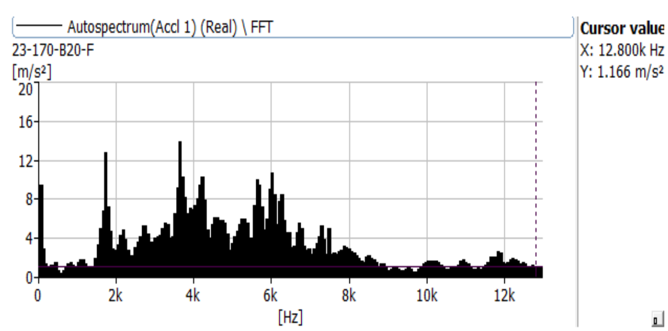

Fig. 5. Frequency domain graph

In case of Diesel, Overall vibration acceleration RMS value was 54.092 m/s^2 at 130 bar while at 170 bar and 210 bar, it was 53.059 m/s^2 and 51.841 m/s^2 respectively. Same trend was observed in case of B20 blend and B40 blend.

With increase in injection pressure, reduction in vibration was observed while with decreasing injection pressure, increment in vibration was observed. Hence for any fuel blends, higher injection pressure gives low vibration into engine while low injection pressure gives high vibration level.

Increasing injection pressure causes to improved atomization of diesel and better fuel- air mixing. Ignition delay period is minimized. This results in proper and complete combustion which help to reduce vibration level. Spray penetration is improved by higher injection pressure which helps for air utilization and air-fuel mixing.

In another case, it was observed that no significant difference in vibration levels of diesel, B20 and B40 at standard engine setting. But when we changed the injection pressure, difference between vibration levels of engine was observed. The vibration acceleration RMS values were 50.042 m/s^2, 45.922 m/s^2 and 45.119 m/s^2 for diesel, B20 and B40 respectively at 170 bar. At 210, vibration values were 39.731 m/s^2, 35.866 m/s^2 and 32.550 m/s^2 for Diesel, B20, B40 respectively. Hence it was observed that B40 blend has less vibration.

TABLE IV
VIBRATION LEVEL COMPARISON

Injection Timing °bTDC	Injection Pressure Bar	Fuel blend	Vibration acceleration RMS m/s^2
23	130	Diesel	54.092
23	130	B20	53.059
23	130	B40	51.841
23	170	Diesel	50.042
23	170	B20	45.922
23	170	B40	45.119
23	210	Diesel	39.731
23	210	B20	35.866
23	210	B40	32.555

IV. CONCLUSION

Present study was carried out for vibration measurement of diesel engine with different fuel blends and different injection pressure. One of the objectives of study was to investigate effect of fuel injection pressure on engine vibration. Result obtained show that higher injection pressure gives low vibration due to improved combustion process. While low injection pressure cause to increased vibration level because of improper combustion. Another observation state that B40 blend has low vibration at any injection pressure than other to fuels. Further studies on effect of parameters such as injection timing and pressure and fuel blends and their interactions on vibration level is being analyzed through Taguchi Design of experiments to its full depth as a future scope. Also the percentage contribution of each factor will be evaluated.

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