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Effect of Supercharging & Injection Pressure on C.I. Engine Performance Characteristic with Palm Biodiesel - Diesel Blend

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Abstract: **The progressive depletion of fossil fuel and increasing amount of fuel consumption for producing energy led to search for biodiesel as an alternative fuel for diesel engine. In the present investigation experimental work is carried out to estimate the performance characteristics of a single cylinder, four stroke C.I. engine fueled with Palm biodiesel blended with diesel. Tests have been conducted using diesel and palm bio diesel with blends of D100, D50, D0 where diesel is denoted by D100 and Palm biodiesel is denoted by D0, with compression ratio 18 and an engine speed of 1500 rpm at different loading conditions. Present work also deals with effect of supercharging on engine performance characteristics. SFC was more for blend (D50) and bio diesel (D0) compare to diesel. It shows improvement with injection pressure forD0 in normal as well supercharging condition. Optimum SFC was obtained for D0 when engine run at supercharged condition, compared to diesel. The Brake thermal efficiency of for bio diesel and blend were lower than diesel. BTHE improves with IP and supercharging for diesel and palm bio diesel both.**

Keywords — Blend, Diesel, Injection Pressure (IP), Palm biodiesel, Performance Characteristics, Supercharging.

I. INTRODUCTION

The non renewable fossil fuel has encouraged the search for petroleum substitutes. Biodiesel is petroleum-based fuel derived from vegetable oils, animal fats and waste cooking oil including triglycerides [2]. The crises of petroleum, the fast increasing prices and concerning availability of petroleum led to introduction of renewable source of energy. Also there is growing concern for the environment and the adverse effect of greenhouse gases which needs to be dealt with. This has revived more and more benefits in the use of biodiesel as a substitute for fossil fuels. Bio diesel is getting attention from world countries due to its environmental friendly characteristics while it still able to be diesel engine fuel without requiring any complex modifications to the engine itself. Different research works have proved that performance of biodiesel is almost like diesel engines. With advanced fuel injection systems, fuel injection pressures have risen to considerable amount in comparison to older mechanical fuel injection systems. Supercharging especially with bio diesel is also helpful to improve performance of an engine [15]. It is therefore very important to investigate the effect of fuel injection pressure and supercharging on comparative performance, emissions and combustion characteristics of biodiesel and diesel for effective utilization of biodiesel in modern CI engines. Present work aims to show the significance of bio diesel in internal combustion engines with chosen parameters inlet air pressure and injection pressure and their effect of engine performance characteristics like fuel consumption, brake power and thermal efficiency. In this work two different conditions (normal and supercharging) were analyzed for comparing the results of C.I. Engine fueled by (a) 100% diesel (D100) (b) Blend of diesel & Biodiesel (D50) (c) 100% Biodiesel (D0).

II. LITERATURE REVIEW

Different researchers around the world have carried large number of experiments with biodiesel as a replacement fuel in diesel engines. R. El - Araby et al. (2017) [3] studied characteristics of palm oil biodiesel–diesel fuel blend. They investigate the key properties (density, kinematic viscosity and flash point) of palm oil, palm oil methyl ester in a blend with diesel fuel. They found the properties of palm oil/-palm oil biodiesel blends showed no significant difference in fuel properties of the blends up to 30% volume of oil/ biodiesel of palm. M.S. Gad et al. (2017) [6] studied the performance and emissions characteristics of C.I. engine fueled with palm oil/palm oil methyl ester blended with diesel fuel. They concluded that thermal efficiency of palm biodiesel and oil blends with diesel fuel was lower compared to diesel fuel and specific fuel consumptions were found to be higher. Higher exhaust gas temperatures are recorded for biodiesel and oil blends compared to diesel fuel for the entire engine load. Exhaust gas temperature values for diesel, B20, B100 and PO20 are 302, 312, 371 and 322 ^{0}C, respectively at full load. Air- fuel ratios for diesel-palm biodiesel blends (B20, B100) and palm oil blend (PO20) were lower than diesel fuel. Exhaust emissions of CO and

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HC were reduced relative to conventional diesel fuel. NOX emissions increased relative to conventional diesel. The NOx emission for diesel, B20, B100 and PO20 are 174, 190, 285 and 301 ppm respectively, at full load operation. The results proved that performance and exhaust emissions of a diesel engine using palm oil methyl ester blends up to 20% with diesel fuel are reasonable.

R. Samsukumar et al. (2015) [18] investigated performance and emission analysis on C.I Engine with palm oil biodiesel blends at different fuel injection pressures. The experiments were done at injection pressure 210 bar (without engine modification), 190 bar and 230 bar (with engine modification). It was found that for using pure biodiesel engine modification is required. Blend B20 gives best result for run on engine without any modifications. M.H. Mosarof et al. (2015) [7] studied on implementation of palm biodiesel based on economic aspects, performance, emission, and wear characteristics. According to their study performance and exhaust emissions using palm oil fuel and its blends with conventional diesel fuel in stationary diesel engines are comparable to those of conventional diesel fuel. Moreover, palm oil fuel is environment-friendly and exhaust emission is much cleaner with reduced black smoke, CO, HC, and absence of SO2 excluding NOX. Wear analysis also showed that palm oil does not seriously affect engine and bearing components, does not degrade lubricating oil, and produce comparable amounts of carbon deposits. Palm oil and its blends improve the anti-wear characteristics of the engine components. Compared with pure conventional diesel fuel, palm oil and its emulsion with ordinary diesel fuel show slightly higher specific fuel consumption. The high fuel consumption of palm oil fuel and its blends can counteract the lower heating values such that the engines consume an equal amount of energy. The ignition delays for palm oil fuel are shorter than those for diesel fuel. Generally, economic prospects for this fuel are not yet promising because of factors such as production cost and fuel economy.

Dheeraj Joshi et al. (2014) [16] studied the effects of supercharging on the performance of C.I engine using blends of pre-heated cotton seed oil and diesel as alternate fuel. They found increase in brake thermal efficiency of CSO –C20 when supercharged as compared to pure diesel because of complete combustion. The smoke and emissions for the blends when supercharged are less as compared to pure diesel. The mechanical efficiency about 10% -20% was increased with the effect of supercharging on the engine in a reasonable manner and gave away the positive results, which is much higher than the mechanical efficiency of the engines using pure diesel as a fuel. Donepudi Jagadish et al. (2011) [17] studied the effect of supercharging on performance and emission characteristics of CI engine with diesel ethanol ester blends. They concluded with no supercharging E20B (blend of 20% ethanol, 10% ester, 70% diesel by volume) and E30B (blend of 30% ethanol, 10% ester, 60% diesel by volume) showed a reduction in values of brake specific fuel consumption in comparison to diesel at higher loads, and the same with E10B (blend of 10% ethanol, 5% ester, 85% diesel by volume) at lower loads. Brake specific fuel consumption values are further decreased with supercharging for all the blends. Brake thermal efficiency is high with E20B and E30B when compared with diesel and with super charging E10B showed much improvement, E20B and E30B showed a noticeable improvement. NOx values are lowered with ethanol, ester and diesel blends when compared with pure diesel operation and with supercharging NOx formation is little increased. Unburned HC and CO emissions seem to increase as the ethanol percent increases in the blend, but with supercharging these emissions are little lowered.

In this study effect of supercharging and injection pressure on engine performance have been investigated for palm bio diesel, pure diesel and their blend to explore prospects of Palm biodiesel/blends for its utilization in CI engines.

III. PALM OIL

The performance and emission characteristics of biodiesel fueled engine depend purely upon the thermo physical properties of the biodiesel [1]. Basically the biodiesels are derived from vegetable oils via a popular process, transesterification in the presence of a catalyst and alcohol as a reactant [5]. Due to the availability and cost factor methyl alcohol is commonly used and the derived biodiesel is also known as fatty acid methyl ester. The purpose of the transesterification process is to lower the viscosity of the oil.

Sr. no.	Properties	Palm Bio Diesel	Diesel
1	Kinematic viscosity at 40° C (cSt)	4.57	3.06
2	Density@15°c kg/m^3	879	833
3	Flash point (°C)	136	67
4	Fire point (°C)	153	138
5	Cetane number	62	52
6	Calorific Value (KJ/Kg)	40560	44800
7	Cloud point (°C)	31	-40
8	Pour point (°C)	17	-25

Table 3.1 Comparison of properties Palm biodiesel vs Diesel

IV. EXPERIMENTAL SET UP

The set up consists of single cylinder, four stroke, water cooled computerised research engine in which loading has been provided by eddy current dynamometer. Set up is provided with necessary instruments for combustion pressure, Diesel line pressure and crank-angle measurements. Signals are interfaced with computer for pressure crank-angle diagrams. Instruments are provided to interface airflow, fuel flow, temperatures and load measurements. The setup has stand-alone panel box

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consisting of air box, two fuel flow measurements, process indicator and hardware interface. Lab view based Engine Performance Analysis software package "Engine soft" is provided for on line performance evaluation.

Fig 4.1 Front view of experimental setup

Fig 4.2 Side view of experimental setup

Engine manufacturer	Apex Innovations (Research Engine test set up)
Software	Engine soft Engine performance analysis software
Engine type	Single cylinder four stroke multi fuel research engine
No. of cylinder	1
Type of cooling	Water cooled
Cubic Capacity	0.661 litres
Rated Power	3.5 kW @ 1500 rpm
Cylinder diameter	87.5 mm
Orifice diameter	20 mm
Stroke length	110 mm
Connecting rod length	234 mm
Dynamometer	Type: eddy current, water cooled, with loading unit

Table 4.1 Technical specifications of engine

In this experiment, single cylinder water cooled diesel engine coupled with eddy current dynamometer is used. The set up is fully computerized and provided with all types of sensors to note readings. Engine performance such as break power, indicated power, break specific fuel consumption etc. are found from the experiments. Inlet air pressure & injection pressure are taken for the optimization for same compression ratio at different load. Two different conditions are used in this research for C.I. Engine using palm biodiesel. In normal condition atmospheric air as inlet air is supplied to engine and in supercharging condition continuous flow of air with the use of air compressor is supplied to engine. Performance tests were carried out using pure diesel, blended diesel & bio-diesel fuel for different load condition and different injection pressure for both conditions. For all fuels tests were conducted with compression ratio 18 and at rated speed of 1500 rpm at three injection pressures (Low – 140 bar, Medium – 180 bar, High – 220 bar) and for each injection pressure different load was applied for both normal and supercharged conditions.

V. RESULTS AND DISCUSSIONS

An alternative fuel used in engines is always evaluated on the basis of both engine performances and its environmental impacts. As such, various parameters defining the performance of diesel engine which have been evaluated and analyzed in this section. The relationship between different variables were shown in figures and discussed in following sections. The investigation was done with three extreme fuels, namely pure Diesel (D100), pure Palm biodiesel (D0) and Blended Palm biodiesel (D50). In this work performance parameters were considered at different injection pressure and different inlet air condition for different load condition with different blends.

5.1 Specific Fuel Consumption

The variation in specific fuel consumption show decrease with increase in load for all fuels (fig. 5.1). It may be due to more increase in brake power with load as compared with fuel consumption. With addition of palm biodiesel of various proportions of 0%, 50% & 100% specific fuel consumption increased for all load conditions. It means as the concentration of palm biodiesel increased SFC also increased. SFC is always higher for biodiesel compare to mineral diesel as it is having less heating value and more amount of fuel is needed to maintain the power output [10].

As injection pressure was increased, SFC for biodiesel (D0) decreased (improved) for both conditions. It was also observed that when injection pressure increased from 140 to 180 bar SFC decreased slightly but increased again with further increase in injection pressure 220 bar for normal conditions. However in supercharging mode SFC reduces for higher IP 220 bar. The decrease in SFC can be attributed to the more efficient utilization of the fuel at higher injection pressures because of better atomization of fuel with supercharging conditions [12]. Optimum specific fuel consumption were obtained for D0 when engine run in supercharged condition compared to diesel, which is nearest to the diesel fuel.

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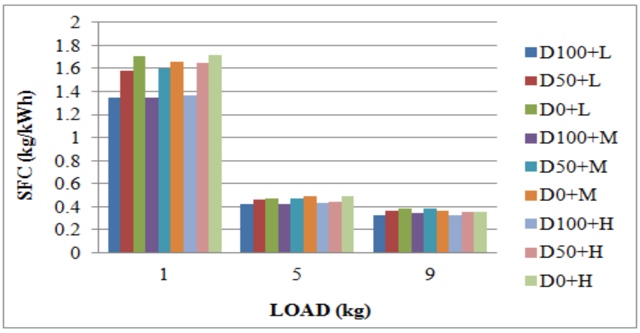

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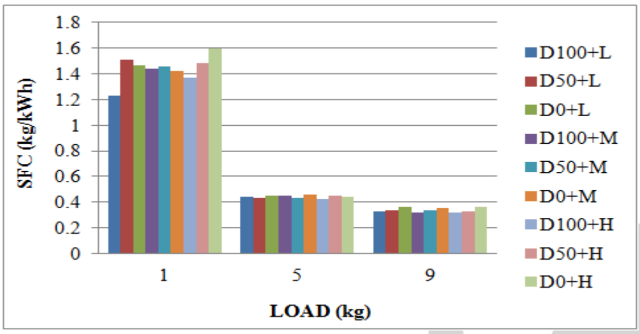


(b)

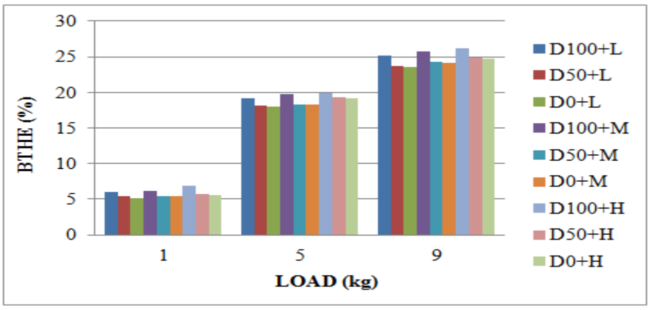
Fig 5.1 Specific Fuel Consumption Vs Load for (a) Normal mode (b) Supercharging mode

5.2 Brake Thermal Efficiency

Brake thermal efficiency is one of the most important engine performance parameter which indicates the percentage of fuel energy converted to useful power output. Fig 5.2 shows variation of brake thermal efficiency (BTHE) with different load and different fuel for low, medium & high injection pressure of the engine running at normal & supercharging condition. Figure shows that the brake thermal efficiency increased significantly with increase in the load for all fuels in both conditions as lesser losses are encountered at higher loads.

The brake thermal efficiency was higher by about 6.25 % with diesel fuel as compared to that of bio diesel (D0) at 9 kg load with high IP (Fig. 5.2 a). BTHE for bio diesel blends were lower than with diesel in all cases. It was mainly due to lower heating value and poor combustion characteristics due to high viscosity of bio diesel fuel [10]. It was observed that increasing IP generally improves BTHE of test fuels. Increasing IP was more effective in increasing BTHE of mineral diesel in comparison to Palm biodiesel blends, which suggests that higher injection pressure was more effective in improving the spray characteristics of fuels with lower viscosity which was diesel in this case. Improvement was found (Fig. 5.2) for higher injection pressure of 220 bar (11.02% for diesel and 4.67% for palm bio diesel) because of better combustion due to finer breakup of fuel droplets providing more surface area and better mixing with air.

BTHE have slightly higher values with all test fuels in supercharging conditions (Fig. 5.2 b) may be due to better combustion of fuels [17]. BTHE is higher by 10.51% for pure diesel and 16.78% for palm bio diesel with comparison to normal condition at 220 bar IP. On comparing all combinations of injection pressures and inlet condition for air with several sets of readings (Fig. 5.2), it was found that with the combination of injection pressure 220 bar and supercharging, the engine delivers highest brake thermal efficiency.



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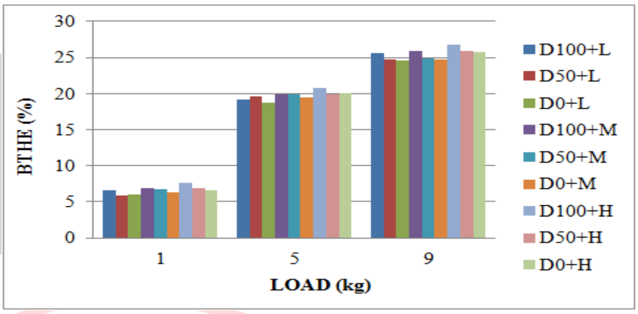
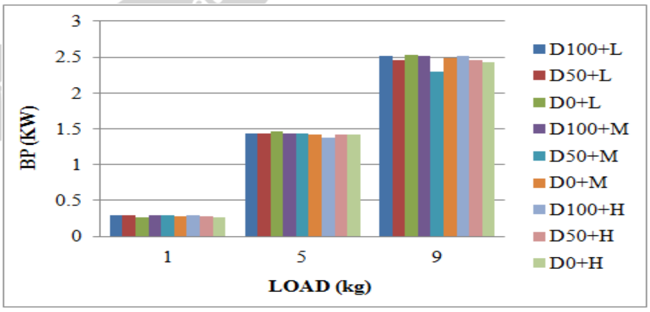


(b)

Fig 5.2 BTHE Vs Load for (a) Normal mode (b) Supercharging mode

5.3 Brake Power

Figure 5.3 shows brake power for various blends for different loads. It was evident from figure that as load increases BP increases for all test fuels in both conditions. There was not significant improvement in BP with increase in injection pressure. BP increases 13.7% for diesel and 7.4% for palm biodiesel with supercharging conditions at 220 bar IP. BP is having highest values at 140 bar IP for diesel and 180 bar IP for biodiesel, both with supercharging condition (Fig. 5.3 b).



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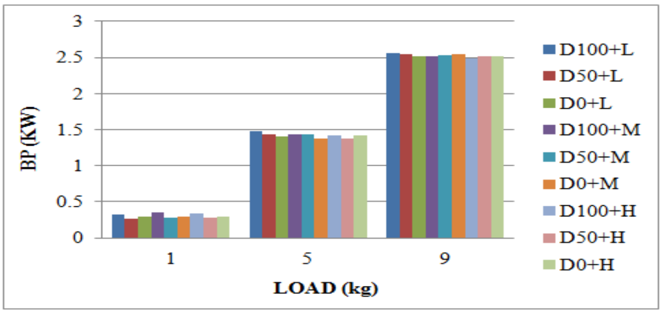

(b)

Fig 5.3 BP Vs Load for (a) Normal mode (b) Supercharging mode

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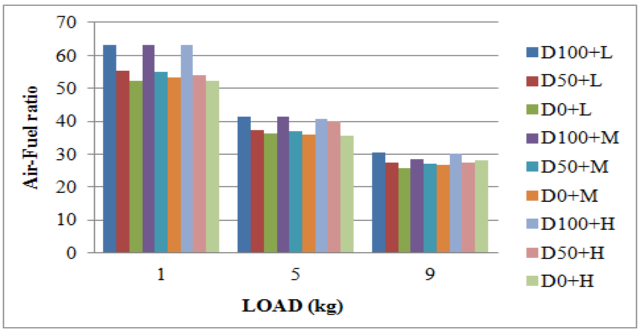
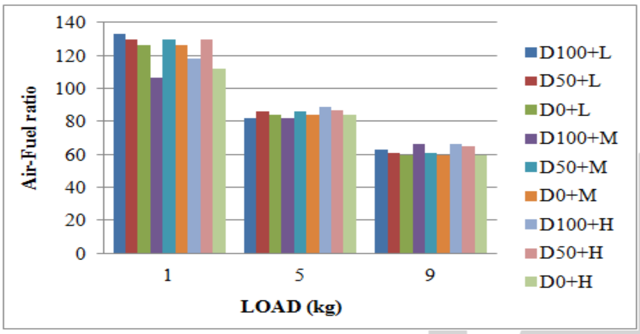
5.4 Air Fuel Ratio



(a)



(b)

Fig 5.4 A/F ratio Vs Load for (a) Normal mode (b) Supercharging mode

Effect of engine load variation on air fuel ratio for various blends and injection pressure was shown in figure 5.4.

Air–fuel ratio is the mass ratio of air to fuel present in a combustion process which directly affects the performance of the engine. With increase in engine load, air-fuel ratio decreased for all tested fuels due to the increase in fuel consumption. Air-fuel ratios for D50 and D0 were lower than diesel fuel due to increase in fuel consumption with increase percentage of biodiesel. However the oxygen content of palm biodiesel and its blend led to a slight reduction of air- fuel ratios with increased load compared to diesel fuel [8]. Variations of injection pressure have not much effect on A/F ratio. Air- fuel ratio for all test fuels increased drastically with supercharging conditions as more amount of air was introduced at inlet of an engine.

VI. Conclusion

Performance characteristics of diesel engine fueled with diesel and Palm bio diesel blend for variation of injection pressure and air inlet condition were investigated. Trials with three values of injection pressures (Low – 140 bar, Medium – 180 bar, High – 220 bar) and three fuels (pure Diesel (D100), Palm biodiesel (D0) and Blended Palm biodiesel-diesel (D50)) with variation in inlet condition of air have been analyzed. The results may be summarized as follows:

- The fuel consumption of all blends were slightly more than the diesel at all varying loads. As injection pressure was increased, SFC for biodiesel (D0) decreased (improved) for both normal as well supercharged conditions. In supercharging mode SFC reduces for higher injection pressure.
- Optimum specific fuel consumption were obtained for D0 when engine run at supercharged condition, compared to diesel, which is nearest to the diesel fuel.
- The brake thermal efficiency was higher by about 6.25 % with diesel fuel as compared to that of bio diesel (D0) at 9 kg load with high IP. BTHE for bio diesel blends were lower than with diesel in all cases. Increasing fuel injection pressures generally improved the thermal efficiency of test fuels. Increasing IP was more effective in increasing BTHE of mineral diesel in comparison to Palm biodiesel blends.
- For higher IP, BTHE increases by 11.02% for diesel and 4.67% for palm bio diesel. BTHE have slightly higher values with all test fuels in supercharging conditions. BTHE is higher by 10.51% for pure diesel and 16.78% for palm bio diesel with comparison to normal condition at higher IP. At IP 220 bar with supercharging, the engine delivers highest brake thermal efficiency for all test fuels.
- As load increases BP increases for all test fuels in both conditions. There was not significant improvement in BP with increase in injection pressure. BP increases 13.7% for diesel and 7.4% for palm biodiesel with supercharging conditions at 220 bar IP. BP is having highest values at 140 bar IP for diesel and 180 bar IP for biodiesel, both with supercharging condition
- Variations of injection pressure have not much effect on A/F ratio. But with supercharging conditions it improves significantly.

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