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Comparative experimental analysis of CRDI Single Cylinder Diesel Engine using Diesel fuel and Neat Palm Methyl Ester

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ABSTRACT
An experimental study was done to evaluate the performance and emission analysis on Common Rail Direct Injection (CRDI) engine fuelled with diesel and neat palm methyl ester (PME) at different part loads (no load, 0.77, 1.54, 2.31, & 2.695 kW). By varying the fuel injection pressures from 200 to 500 bar, fuel injection duration 1000 µ.sec, fuel injection timing at 22^0 (BTDC) and at rated speed 1500 rpm were employed uniformly for both the fuels. CRDI engine ensures that the fuel injection timing, quantity of the fuel and atomization was controlled electronically by using a programmable control module (PCM). Here it is set the injection timing based on compromise between load, BSFC and rated speed. Engine performance data, Smoke, HC, NOx, CO and CO_2 emissions were recorded. Investigations indicate the running condition of the engine with neat PME was good in most of the parameters when compared to diesel fuel and it was observed that PME reduces the BP and increases the BSFC than diesel because of its lower heat value. By the experimental observation PME increases the BTE; lowers the smoke and emissions almost equal but lower at particular loads than in the case of diesel fuel.
Keywords -Common Rail Direct Injection (CRDI), Palm Methyl Ester (PME), Injection pressures, Performance and Emissions

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I. INTRODUCTION

Diesel engines are low fuel consumption engines and results in higher efficiencies and therefore, the use of diesel engines has rapidly increased in recent times. Nowadays, diesel engines are used in energy generation, transportation, irrigation purposes and many other sectors and led to increase the demand of diesel fuel, which is presently concerned with emissions and environmental problems. The diesel fuel can be substituted by the renewable sources of energy like biodiesel in view of possible depletion in the petroleum resources.

The increase in the exhaust emissions from the diesel engines using diesel fuel is the main difficulty, responsible for global warming, depletion of ozone layer, and acid rains are created problems for environment and human health. The rapid rise in petroleum fuel prices has made it inevitable to pursue research in renewable biofuel sources like: bio gas, ethanol and vegetable oils, etc [1-2]. Replacement of fossil diesel with biodiesel in diesel engines can significantly improve our environment. Advantages of biodiesel, it is a renewable and clean burning fuel with enriched oxygen in its molecular stricture helps in complete combustion [3]. It possesses high cetane number, lubricity, flash point and minimal sulphur, aromatic content [4]. The disadvantage includes low calorific values, high viscosity, high bulk modulus and hygroscopic.

Many researchers [5-7] have reported that the use of biodiesel in diesel engines reduce the CO, HC and increase the NOx emissions. The reasons for high NOx emissions is not clearly defined but there are many contributing factors like physiochemical property of the fuel, Cetane number, bulk modulus, speed of sound, viscosity, fuel injection timing and injection pressures etc.

In diesel engine if the fuel is less compressible inside the combustion chamber during the combustion process and the speed of sound is greater, the fuel injection pressure will develop faster and the fuel will be injected sooner [8]. When the start of injection is advanced the exhaust NOx emissions increase. Experimental reviews on common rail direct injection (CRDI) diesel engines and injection pressures revels that by using biodiesel blends in CRDI light duty diesel engine, Zhang and Boehman [9] observed slightly lower NOx levels for biodiesel blends compared with the standard diesel fuel at low load conditions, but much higher NOx emissions at high load, and it can be regulated with injection timing adjustment. In an experimental investigation on the influence of fuel on fuel injection system was explained by Kegl and Hribernik [10] revel that injection pressure, injection duration and injection timing increased with increase in biodiesel content in most of the regimes. They also attributed the advanced injection timing will lead to the higher sound velocity and higher bulk modulus of the blends.

The main aim of this studies is to compare the performance and emissions exhausted by CRDI diesel engine using diesel and biodiesels (PME). The main purpose of the CRDI system invention and its development is to consume less fuel and obtain more power and torque. At the same time, this common rail technology has lesser noise and vibration than the conventional diesel engines. The electronically controlled injection into the combustion chamber can perform a clean and efficient combustion. In addition to this, the reduced emission values after combustion are further reduced by the catalytic converter. Noise, vibration and harshness (NVH) are improved with CRDI as a result of the timing flexibility and engine sounds quieter and has a better quality of sound. It also runs smoother. It has fuel consumption benefits because of reason increased injection pressures produce a finer sprays of the fuel (atomization) that burns more efficiently.

II. METHODS AND MATERIALS

Biodiesel is derived from various feed stocks like edible, non-edible oils and animal fats etc. It is commonly prepared by transesterification process from the feedstock of oils using a base catalyst. For esterification process acid catalyst, H_2SO_4 is mixed in 1% of oils proportion and for transesterification process base catalyst 1% of NaOH is mixed and acids with methanol. Methanol is alcohol and it takes lower reaction time and cost. In this reaction, 100 ml. of Triglyceride (raw oils) reacted 10 ml. methanol in the presence of catalyst (acid) to form 100 ml. of methyl ester (Biodiesel) and 10 ml. of glycerol. Fig.1 represents the mechanism of transesterification process and Table.1 represents the PME characterization.

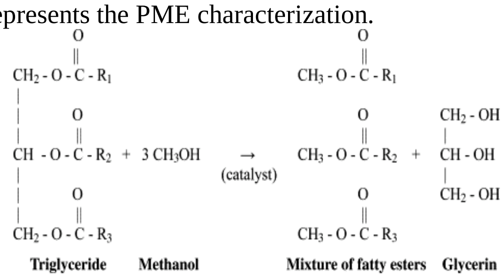

Fig.1. Transesterfication process

Table.1 Charaterization of PME and Diesel

S.No	Property	PME	Diesel
1	Density (kg/m^3)	860	830
2	Viscosity (cSt)	4.1	2.75
3	Calorifice Value (Kj/Kg)	38000	43000
4	Latent heat (Kj/Kg)	300	250
5	Catane Number	52	47

III. EXPERIMENTATION

Experimentation was conducted on Kirloskar AV1, single cylinder four stroke diesel engine assisted by Common Rail Direct Injection (CRDI) system as shown in the Fig.2.

1. CRDI SYSTEM 2.EDDY CURRENT DYNAMO METER 3. DIESEL ENGINE 5.FUEL TANK
4. FUEL INJECTOR 6. CRANK ANGLE ENCODER 7. INJECTION DURATION CONTROLOR
8. COMPUTER INTERFACED TO CRDI SYSTEM 9. EXHAUST TEMPERATURE INDICATOR

Fig.2 CRDI Engine test rig

The rated power was arbitrarily fixed for the diesel engine. It was operated at a constant speed of 1500 rpm by maintaining different injection pressures from 200 to 500 bar at various load conditions. The fuel injection duration was maintained at in and around 1000 µ.sec to maintain the rated engine speed at 1500 rpm for the corresponding pressures.

The engine was fuelled with neat diesel to provide the baseline data and then it was fuelled with neat Palm Methyl Ester (PME) at different injection pressures [D/BD]: 209/210, 250/255, 310/318, 400/410 and 450/465 bar, fuel injection duration 1000 µ.sec, fuel injection timing at 22^0 (BTDC) and at rated speed 1500 rpm were employed uniformly for both the fuels. Loading of the engine was taken up by Eddy current dynamometer. The AVL Smoke meter and AVL five gas analyzer was used to measure the smoke present in the exhaust and also emissions like HC, CO, CO_2, O_2 and NOx at the time of engine running condition. The detailed engine specifications were presented in Table.2.

Table.1 Technical specifications of CRDI Engine

S.No	Discription	Range
1	Engine	Kirloskar-vertical
2	Engine type	Vertical, 4stroke
3	Cylinders	1
4	Bore (mm)	80
5	Stroke (mm)	110
6	Speed (rpm)	1500 rpm
7	Power (kW)	3.7
8	Speed (rpm)	1500
9	Injection pressure	200-250 bar
10	Injection timing	20^0 BTDC

IV. RESULTS AND DISCUSSIONS

In this experiment engine's actual injection timing is 23^0 BTDC. But with the Palm Methyl Ester (PME), the engine run at an injection timing of -22^0 (because of higher Cetane number of the biodiesel) to verify the engine performance and it was concluded that injection timing at advance of -22^0 w.r.t TDC proved beneficial to replace diesel fuel with Palm biodiesel. Appreciable benefits were observed at most of the emission results at -22^0 proved efficient in most of the aspects of emission performance. In this experiment, cylinder pressure is plotted against the crank angle based on the real time combustion data using C7112 software designed by Apex innovations, Pune, India.

It can be observed two-pronged combustion when it was measured the data at every 4^0 of crank angle i.e. least count is four degrees of crank angle. Performance data BSFC, BTE, Equivalence Ratio are plotted against the Brake Power (Load) quoting injection duration and Injection Pressure (Figures 3 to7). Emissions data HC, CO, CO_2, NOx, and smoke are plotted against Brake Power (kW) for both the fuels to create suitable comparison (Figures 8 to 12). CRDI engine increases the injection pressure and keeps the injection duration constant. It was observed an increase of Brake Thermal Efficiency (BTE) for the Palm Methyl Ester by 4.42 % at $3/4^{th}$ load and 3.19 % at full load as shown in the Fig 3. The maximum peak pressures at full load for diesel and biodiesel are 58.9 bar and 61.2 bar respectively as shown in the Fig 4 and it shows higher peak pressures for biodiesel are owing to higher bulk modulus.

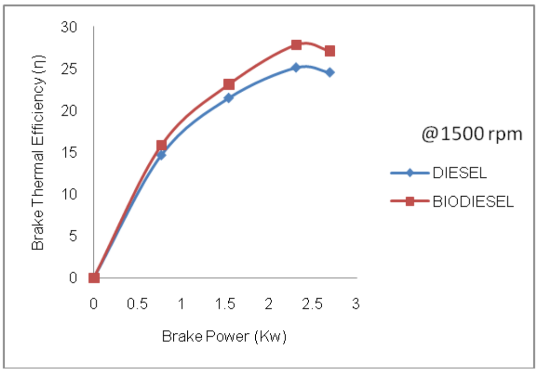

Fig.3 BP Verses BTE

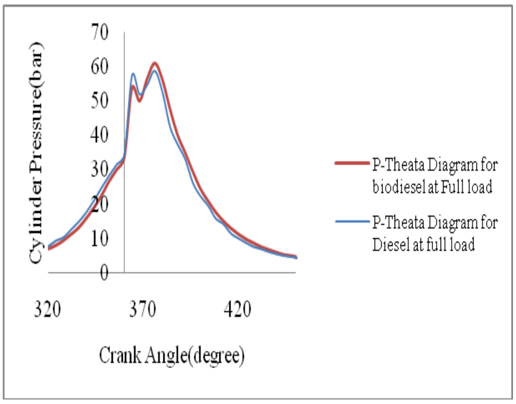

Fig.4 Cylinder Pressure verses Crank Angle

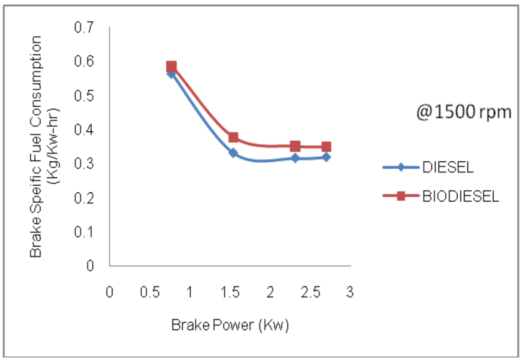

Fig.5 BSFC Vs Brake Power

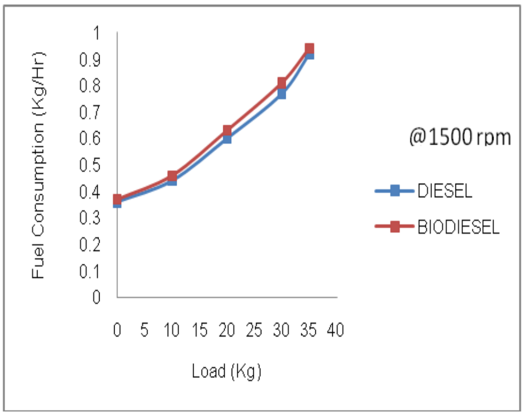

Fig.6 Fuel Consumption verses Load

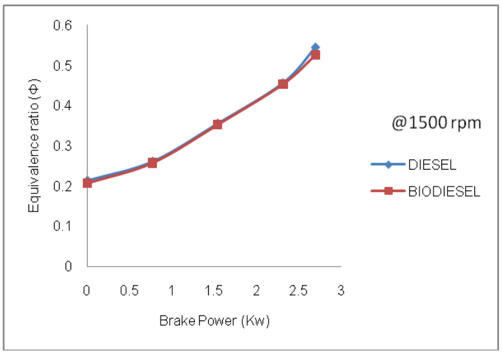

Fig 7. Equivalence Ratio Vs Brake Power

Due to lower calorific value and higher kinematic viscosity of the used biodiesel compared to the diesel fuel, biodiesel fuel consumption is marginally more in the engine performance as shown in Figures 5 & 6. Hence the Brake Specific Fuel Consumption (BSFC) of biodiesel is more compared to the diesel fuel. By the observations and calculations equivalence ratio is within in the limit indicating engine is fit worthiness confirming the parameter validity as shown in the Fig 7.

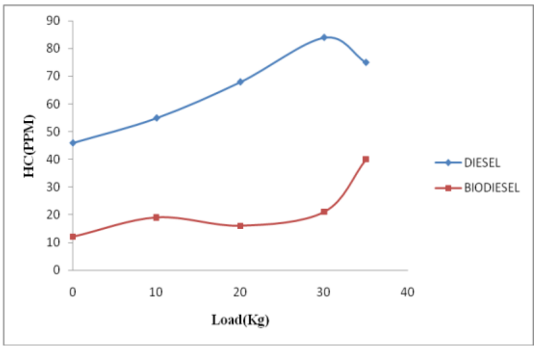

Fig 8. Hydrocarbons Vs Load

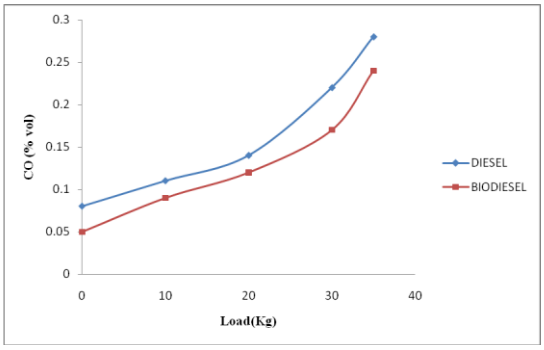

Fig 9 Carbon Monoxide Vs Load

Figures 5 to 7 reveal that the -22^0 BTDC injection advancement with the implementation of biodiesel proved beneficial. There is a 0.3376 kg/kW-hr for biodiesel at -22^0, 0.3487 kg/kW-hr for diesel fuel making advantage in brake specific fuel consumption difference of 0.011 kg/kW-hr (Fig 5). Similarly, for diesel fuel brake thermal efficiency 24% and for the biodiesel at -22^0 injection advancement the brake thermal efficiency level is 27.72%, with an obvious increase of 3.72% (Fig.3)

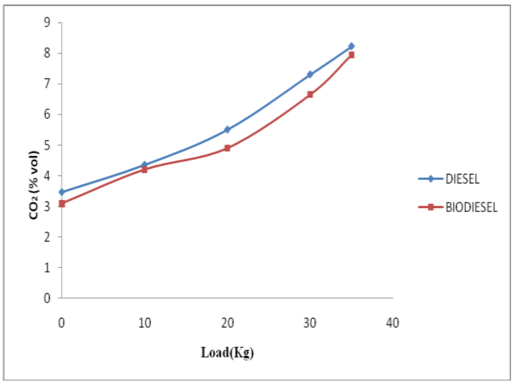

Fig 10. Carbon dioxide Vs Load

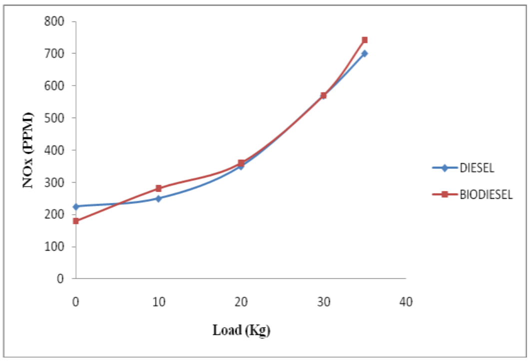

Fig 11. Nitrogen Oxide Vs load

There is a consistent equal equivalence ratio (Figure 7) for the biodiesel and diesel. This can be acclaimed to the higher bulk modulus of the biodiesel which interacts at higher injection pressures. The injection pressure variation is marginal and there is visible increase in injection pressures for the biodiesel purportedly to tackle higher viscosity and density of the fuel.

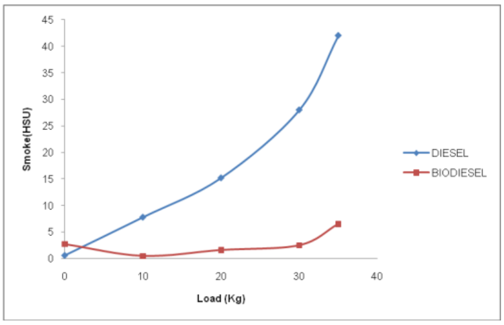

Fig 12. Smoke Vs Load

HC and CO performance is better for the biodiesel implementation at -22^0 before TDC (Figures 8 & 9,). Figure 12 indicate smoke levels which envisage better performance at -22^0 injection timing for biodiesel application. The higher bulk modulus of the biodiesel completely changes the burning philosophy of the engine with respect to the load which demands more fuel. Figures from 3 to 12 elucidate the engine parameters change using different fuels in the same load range but with different injection pressures. Finally, to conclude from the experimentation, the biodiesel application at -22^0 injection advance timing is yielding better results.

Summary: The usual engine with conventional system makes use of the governor to control the fuel flow but in the case of CRDI engine the governor's function is put to rest since entire fuel injection is taken over by the electronic injection system.

V. CONCLUSION

From the results of experimental investigation on CRDI diesel engine fuelled with PME the following conclusion are drawn.

- Better BSFC, brake thermal efficiency and performance for biodiesel at higher injection pressures at maximum load with -22^0 BTDC Injection timing in comparison to the diesel fuel.
- Reduction in CO and HC is remarkable in the case of selected neat biodiesel (PME).
- Higher bulk modulus of the biodiesel tells upon the engine performance at higher pressures of injection keeping the injection duration constant at 1000 microseconds. Where as in the conventional case the governor will be controlling the fuel update by increasing the injection duration and keeping the injection pressure constant at 200 bar approximately as load is increasing.
- Finally, it is concluded that the replacement of diesel fuel with biodiesel recommended for better results for the injection at -22^0 BTDC with one-degree injection retardation with reference to the engine specified Injection Advancement, i.e., -23^0 BTDC.

REFERENCES

[1]. Sharath Satya, Aditya Kolakoti, Naga Raju B, Shyam Sundar R and Ranga Rao. Optimization of palm methyl ester and its effect on fatty acid compositions and cetane number. Mathematical Models in Engineering, 5(1), 2019, 25-34. https://doi.org/10.21595/mme.2019.20469

[2]. Y Rajesh, Aditya Kolakoti, B.G. Chandra Sheakar and J Bhargavi. Optimization of biodiesel production from waste frying palm oil using definitive screening design. International Journal of Engineering, Science and Technology. 11(2),2019, 48-57. http://dx.doi.org/10.4314/ijest.v11i2.4

[3]. Aditya Kolakoti and BV Appa Rao. A comprehensive review of biodiesel application in IDI engines with property improving additives. i-Manager's Journal on Mechanical Engineering. 5(4),2015, 35-45.

[4]. Victor Talamala, Prasada Rao Kancherla, V Appa Rao Basava and Aditya Kolakoti. Experimental investigation on combustion, emissions, performance and cylinder vibration analysis of an IDI engine with RBME along with isopropanol as an additive. Biofuels, 8(3),2017, 307-321. https://doi.org/10.1080/17597269.2016.1226723

[5]. Qi DH, Geng LM, Chen H, Bian YZ, Liu J and Ren XC. Combustion and performance evaluation of a diesel engine fuelled with biodiesel produced from soybean crude oil. Renewable Energy. 34, 2009, 2706–13.

[6]. Devan PK and Mahalakshmi NV. Study of the performance, emission and combustion characteristics of a diesel engine using poon oil-based fuels. Fuel Process Technol. 90,2009, 513–9.

[7]. Aditya Kolakoti and BV Appa Rao. Effect of fatty acid composition on the performance and emission characteristics of an IDI supercharged engine using neat palm biodiesel and coconut biodiesel as an additive. Biofuels. 2016. https://doi.org/10.1080/17597269.2017.1332293

[8]. Aditya Kolakoti and B V Appa Rao. System and method for a supercharged IDI engine run by biodiesel. Indian Patent No. 201741014482, 2017

[9]. Zhang Y and Boehman AL. Impact of Biodiesel on NOx Emissions in a Common Rail Direct Injection Diesel Engine. Energy Fuels. 21(4), 2007, 2003–12.

[10]. Kegl B, Hribernik A. Experimental Analysis of Injection Characteristics Using Biodiesel Fuel. Energy Fuels. 20,2006, 2239–48.

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