Effect of Operating Parameters and Antioxidant Additives with Palm-Biodiesels to Improve the Performance

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Abstract **- It is an overwhelming argument that the use of biodiesel in diesel engine causes slight decrease in performance and reduction in exhaust emissions but at the expense of oxides of nitrogen (NOX) emission. In order to improve the performance without sacrificing the advantage in terms of exhaust emissions, it is essential to vary the engine operating parameters such as compression ratio (CR), injection pressure (IP) and injection timing (IT). Nowadays, treatment of biodiesel with antioxidant additive is a promising approach to reduce the NOX emission because it reduces the hydrogen free radicals, which is responsible for prompt NOX formation during combustion process. Hence, in the present review a detailed study has been carried out with the operating parameters and antioxidant additives used in biodiesel operated diesel engine so that its performance can be improved.**

Index Terms **- Palm oil methyl ester (POME20), advanced injection timing, higher alcohols, 1-butanol, standard injection timing.**

I.INTRODUCTION

In developing countries like India, transportation is vital for everyday activities and in the growth of economic condition. There are different modes of transportation such as road, water, air etc., in which fossil fuels are used abundantly. Besides transportation sector, the fossil fuels are used in power generation agricultural equipment and even in mine locomotives. In India, the consumption of diesel fuel is about 88.2 billion liters in the year 2020. During the last six decades, crude oil consumption rate in India have increased 16 times because of faster rate of vehicle population, industrial growth and agricultural development. Due to increasing usage of petroleum derived fuels, the cost of the crude oil is increased with the demand. India spends thousands of crores to import the crude oil for different application and it leads to lowering the Indian economy. The biodiesel is produced from different sources and it may either from conventional or non-conventional sources. Some biodiesel blends can be directly used in engines without any modification, and some requires slight modifications like piston-cylinder coating, injection advance etc., to obtain the same performance to that of fossil fuel. Balamurugan et al (2018) revealed that the production of bio diesel from corn oil is possible, biodiesel was prepared from corn oil by using transesterification process. The research paper also reveals that increasing the percentage of corn oil bio diesel reduces the Break thermal efficiency, Brake specific fuel consumption. At 80% of full load, the BTE was 46.07% for diesel, and decreased by 2.79%, 7.72% and 15.35% for B10, B20 and B30 respectively. The addition of corn oil biodiesel with normal diesel increased the viscosity and decreased the volatility which in turn resulted in poor atomization and spray characteristics. Moreover, the percentage increase in biodiesel increased the BSEC. At 80% load on the engine, the increase in BSEC was 5.41%, 35.33% and 40.36% for the addition of 10%, 20% and 30% biodiesel with diesel. The peak cylinder pressure was less for all blended fuels when compared with that of diesel. The peak cylinder pressure was 71.95 bar at −1° for diesel, and 67.74 bar at −1°, 67.58 bar at −1° and 67.31 bar at −1° for B10, B20 and B30 respectively. Moreover, at all load ranges, the Nox emission was less for all blended fuels when compared with that of diesel. At 80% load on the engine, the decrease in Nox emission was 7.97%, 11.58% and 12.81% for B10, B20 and B30 respectively. Nagaraja et al (2017) study expresses that corn oil methyl has low exhaust emissions and increase in performance. It gives better performance and a potential substitute to fossil fuels.

Specific Fuel Consumption (SFC) of B100 at the full load condition is found to be 4% lower than that of (D100). The maximum Brake Thermal Efficiency (BTE) of B100 is found to be 8.5% higher than that of the D100 at full load. The BTE varies from 0 to 27.92% and 36.5%. Also, B20 and B40 it varies from 0% to 33.32% and 33.82%. It is 5.9% higher than D100. Also, B60 and B80, the BTE varies from 0% to 35.14% and 35.37% and it is 7.45% higher than D100. As a whole the maximum BTE of B100 is 8.56% higher than D100 for maximum load condition. Also, the maximum BTE of part load for different blends is varied from 5.9% to 7.45% which is higher than D100. The exhaust gas emissions like Carbon Monoxide (CO), Carbon Dioxide (CO2), Hydrocarbon (HC) and Nitrogen Oxide (Nox) are found to be 2.3 to 18.8% lower compared to D100 for part as well as full load. The heat release rate of biodiesel and it blends are found to 16% to 35% lower as compared to D100 for part load, whereas for full load it is 21% lower than D100. M.S Gad et al (2017) Is a study of palm oil and palm oil methyl ester blends up to 20% with diesel fuel gave better performance and exhaust emissions compared to other blends on a diesel engine. The paper tells that Nox emissions were increased relative to conventional diesel. There are increases in fuel consumption of biodiesel and oil blends proportional to the amount of biodiesel or oil blended to the diesel fuel. Specific fuel consumption values for diesel, B20, B100 and PO20 are 0.28, 0.316, 0.346 and 0.325kg/kW.hr, respectively at full load. Thermal efficiency is slightly lower for biodiesel blends B20 and B100 compared to diesel fuel at all engine loads. Thermal efficiency is slightly lower for palm oil blends PO20, B20 and B100 compared to diesel fuel at all engine loads. Thermal efficiencies for diesel, biodiesel blend B20, B100 and PO20 fuels are 28.7, 27.7 and 24.7 and 26.8%, respectively at full load. A higher exhaust gas temperature is recorded for biodiesel and oil blends compared to fossil diesel for the entire engine load. Exhaust gas temperature values for diesel, B20, B100 and PO20 are 302, 312, 371 and 322 C, respectively at full load. The increase in Nox emission for B20, B100 and PO20 was due to increase in oxygen content compared to diesel fuel. The values of Nox emission for diesel, B20, B100 and PO20 are 174, 190, 285 and 301 ppm respectively, at full load operation. K.Nantagopal et al (2017) evaluated that addition of oxidant inhibitors raised the kinematic viscosity, density, flash point as well as oxidation stability but reduced the calorific value. The addition of antioxidant additive increased power output. It can be observed that the maximum brake thermal efficiency for diesel fuel was 33.56% and 30.83% for Calophyllum inophyllum biodiesel fuel. Notably, the maximum BTE has been decreased significantly for CIME with BHT 500 ppm than that of other tested biodiesel samples with for various antioxidant concentrations. As expected, the BSFC of tested fuel samples decreases with increase in brake mean effective pressure under all engine loads. The increase in BSFC was observed to be about 9.4% for CIME fuel compared to neat diesel. The BSFC of BHT 500 ppm addition with CIME fuel was slightly (about 4.38%) higher than that of pure Calophyllum inophyllum biodiesel at 100% engine load. The BHT 500 ppm addition with Calophyllum inophyllum biodiesel has shown lowest peak cylinder pressure than that of other antioxidant concentrations at 100% load. The peak in-cylinder pressure was 85.63 ± 0.67 bar for diesel and 84.23 ± 0.73 bar for CIME, 73.59 0.89 ± bar for CIME with Ethanox 200 ppm, 73.43 ± 0.67 bar for Ethanox 500 ppm, 82.53 ± 0.39 bar for Ethanox 1000 ppm, 83.77 ± 0.79 for BHT 200 ppm, 61.96 ± 0.88 bar for BHT 500 ppm and 77.83 ± 0.98 bar for BHT 1000 ppm respectively.

II. MATERIALS AND METHODS

In the present work palm oil methyl ester is prepared by transesterification process. Then higher alcohol in volume basis is added to corn oil methyl ester. The following sections discuss the preparation biodiesel and blending of higher alcohols to it. The Transesterification process is a reversible reaction and carried out by mixing the reactants – fatty acids, alcohol and catalyst. A strong base or a strong acid can be used as a catalyst. At the industrial scale, mostly sodium or potassium methanol ate is used. The end products of the transesterification process are raw biodiesel and raw glycerol. There are several other processes to prepare biodiesel but still Transesterification is preferred over them. This is due to high cetane number with reduced viscosity, low boiling point, flash point and zero glycerides while doing transesterification.

The transformation of vegetable oil (triglycerides) into alkyl ester is accomplished through three stages

Transesterification process. The first is called as acid catalyzed esterification process and then followed by alkali catalyzed esterification process and there after purification process. In Acid catalyzed esterification process, the solution of palm oil with methanol (molar ratio of12:1 M ratio) and 1% v/v (of oil) sulphuric acid is heated at 60 C for 45 min in order to get the maximum yield. By this process we can minimize the acid value of corn oil. In the alkali catalyzed esterification process, the free unsaturated fat substance of vegetable oil is decreased essentially so the oil will be appropriate for diesel engine application. Amid this procedure, the arrangement of corn oil with methanol (molar proportion 6:1) and 1% (w/w of oil) KOH is warmed to 60 C and stirred at steady rate for 30 min term. From that point forward, the entire arrangement is kept inert for 12 h term with the goal that the glycerin in present in the arrangement isolated at the base of compartment.

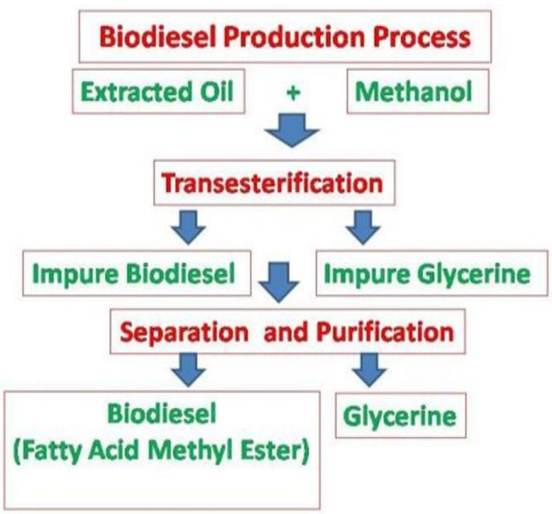

Figure.1 Flowchart of Transesterification Process

The final product contains little measure of methanol alongside corn oil methyl ester which undergoes a purification process. In the purification procedure, the biodiesel is washed by refined water for the expulsion of methanol content then it is heated over 750 C. The last yield of palm oil methyl ester (POME) is around 85%.

2.1 Fuel Properties

Table.1. Physical and chemical properties of POME, Diesel and additive 1-Butanol

Properties	Test Method	POME	Diesel	1-Butanol
	ASTM D 6751			
Calculated cetane Index	ASTM D 613	52.1	48	17
Net Calorific value kJ/kg	ASTM D 4809	39030	42500	33100
Flash point (^{0}c)	ASTM D 93	167	54	35
Density@15^{0}c in gm/cc	ASTM D 1298	0.8938	0.830	0.8100
Kinematic Viscosity@40^{0}C in CST	ASTM D 445	4.70	2.72	2.63

III. EXPERIMENTAL ENGINE TEST SETUP

The experiments are conducted to evaluate the performance and emission characteristics in a single cylinder, four stroke, water cooled, DI diesel engine using neat biodiesels as a fuel. An eddy current dynamometer is connected with this engine as a loading device at constant engine speed. AVL 5-gas analyzer and AVL 437 smoke meter are used to determine the emission characteristics of the engine. Pressure during combustion is measured using piezo electric pressure transducer and it is connected to the data acquisition system. An engine to operate at different load conditions with a constant speed of 1500 rpm has been made and experiments are conducted to evaluate the performance and emission characteristics of the DI diesel engine. The engine is allowed to run for a few minutes until the exhaust gas temperature, the cooling water temperature, the lubricating oil temperature, as well as the emission parameters have attained steady-state values. Initially the engine is fueled with diesel fuel and the engine allowed running at different load conditions. Whenever operations such as changing fuel, the engine is allowed to run for at least 30 min for each operation so as to attain steady state condition for particular mode of operation. All the parameters are continuously measured for 10 min and the average results presented. The readings are taken until steady-state condition is obtained and it is repeated thrice. The results of the three tests are found to agree with one another within the experimental data that lie outside the probability of normal variations will incorrectly offset the mean value, inflate the random error estimates. The fuel consumption of 10 cc at performance measures.

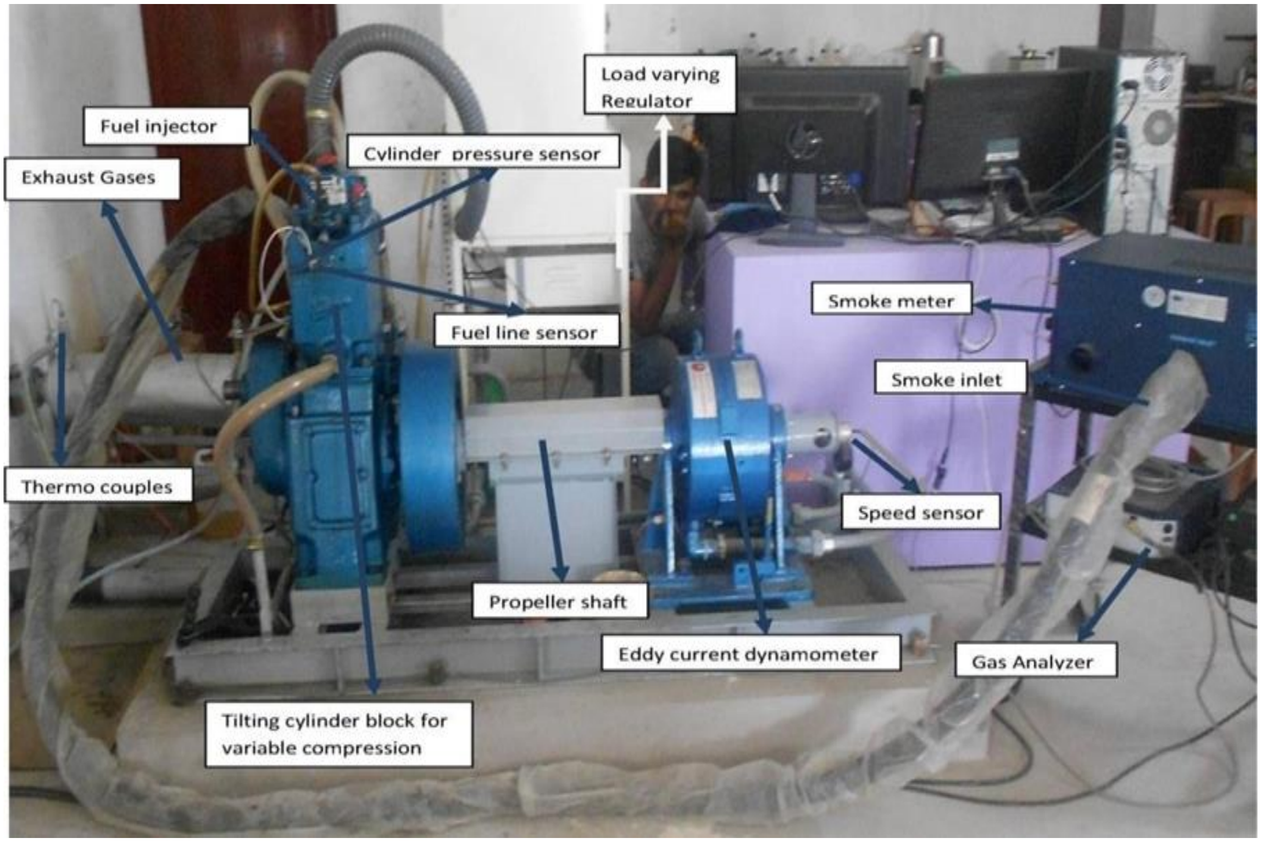

Figure.2 Single cylinder four stroke, variable compression ignition engine

Table.2. Specification of variable compression ignition engine

Engine Type	Single Cylinder 4-Stroke, Water Cooled diesel engine
Make Type	Kirloskar
Bore	87.5 mm
Stroke	110 mm
Connecting rod length	234 mm
Rated power	3.75 kW@1500 R.P.M
CR	Range from 12-18
Orifice diameter	20 mm
Dynamometer arm length	145 mm
Cooling media	Water cooled
Load indicator	Range 0-50 Kg, Supply 230V AC, Digital
Load sensor	Load cell, type strain gauge, range 0-50 Kg
Loading device	Eddy current dynamometer
Rotameter	Engine cooling 40-400 LPH; Calorimeter 25-250 LPH
Temperature sensor	Thermocouple, Type K
Speed indicator	Digital with non-contact type speed sensor

IV. RESULTS AND DISCUSSION

4.1. Engine performance parameters

4.1.1. Brake thermal efficiency

The Brake Thermal Efficiency (BTE) is defined as engine brake power output as a function of the thermal input from the supplied fuel. It can be used to estimate how well an engine can convert the heat from a fuel to mechanical energy.

Brake thermal efficiency=Power output/Heat supplied from the fuel

Heat supplied from the fuel=Mass of fuel consumption × Lower calorific value of fuel

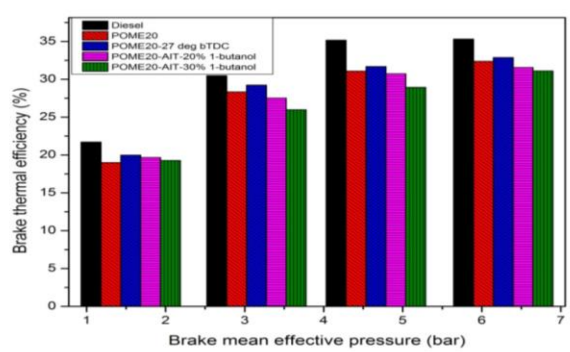

Fig.3 Brake Thermal Efficiency VS Brake Mean Effective Pressure

Brake Thermal Efficiency is defined as break power of a heat engine as a function of the thermal input from the fuel. It is used to evaluate how well an engine converts the heat from a fuel to mechanical energy. Brake thermal efficiency changes with change in injection timing and addition of higher alcohols. Fig.3 depicts the relationship between brake thermal efficiency and brake mean effective pressure. It is very clear from figure with increase in BMEP, the BTE is also increasing. this is due to low heat losses at the higher loads. At low loads, the rate of increase in BTE was low when compared with that at higher load ranges, this was due to the reduction in in-cylinder temperature and quenching effect by the high latent heat of corn oil biodiesel at higher load ranges, the decrease in in-cylinder temperature resulted in lower BTE. It was also observed with blending diesel with POME, BTE was decreasing. The BTE for pure diesel and POME20 are 21.72% and 19.01% respectively. When corn oil methyl ester is added to diesel viscosity increased and volatility decreased which resulted in poor atomization and spray characteristics. This resulted in improper combustion and lower BTE. From the graph we can also observe that at advanced injection timing of 27deg BTDC BTE increased by 4.77% compared to normal injection timing of 23deg bTDC. BTE increased at advanced injection timing due to longer physical ignition delay, it resulted in better mixing of fuel and air for better combustion. When injection timing is advanced to 27deg bTDC. Peak cylinder pressure is achieved when the piston is near TDC. This is resulted in high mean effective pressure to perform useful work.

When higher alcohol 1-Butanol is added to the POME, brake thermal efficiency decreased and the reduction in BTE is proportional to the concentration of higher alcohol in the blend. As concentration of 1-Butanol increased, the calorific value of blend decreased, this resulted in low brake thermal efficiency. The brake thermal efficiency of POME20-20% 1-Butanol at advanced injection timing decreased by 9.32%,9.71%,12.43%,10.64% compared to pure diesel at 1.56 bar,3.15 bar,4.66 bar and 6.27 bar respectively. In an earlier study, it was stated that the calorific value of fuel would be lower, if the fuel has more oxygen content. In the present study also, 1-butanol has higher oxygen content which leads to reduce the calorific value and the same is reflected in brake thermal efficiency also.

4.1.2 Brake Specific Fuel Consumption

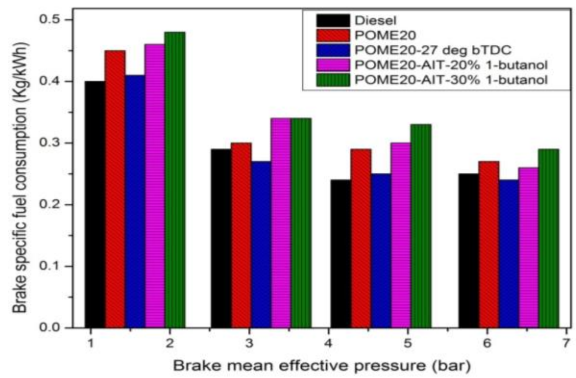

Fig.4 Brake Specific Fuel Consumption VS Brake Mean Effective Pressure

Brake-specific fuel consumption (BSFC) is a measure of the fuel efficiency of any prime mover that burns fuel and produces rotational, or shaft power. It is typically used for comparing the efficiency of internal combustion engines with a shaft output. It is the rate of fuel consumption divided by the power produced. It may also be thought of as power-specific fuel consumption, for this reason. BSFC allows the fuel efficiency of different engines to be directly compared. The above figure shows the relation between BSFC and BMEP. From figure we can observe that whenever BMEP increases BSFC decreases irrespective of fuels used. This is common for all injection timings. Main reason for decreasing of fuel consumption when increasing BMEP is the average or mean cylinder pressure. When pressure is increased inside the cylinder it leads to fine splitting of fuel particles inside the cylinder but in the case of low BMEP it is not happening like this, the particle size is increasing leading to reduction in combustion efficiency. In the case of higher BMEP swirling action also take place which allows to complete distribution of fuel inside the combustion chamber, so we may get better combustion efficiency. It is observed that BSFC is higher for POME20 compared to diesel. The BSFC of POME20 is 13.41% higher than that of diesel. Viscosity increased and volatility decreased due to mixing of corn oil methyl ester with diesel which resulted in poor spray pattern and non-homogeneous fuel distribution causing improper combustion. The increase in BSFC was also due to the higher premixed combustion of palm oil biodiesel blended fuels because of high viscosity and flash and fire points which led the lower percentage of combustion at constant volume. The decrease in in-cylinder temperature resulted in higher BSFC. BSFC also increased due to reduction of the fuel power supplied due to the low calorific value of corn oil biodiesel. It is also observed that POME20 at advanced injection timing of 270bTDC consumes 11.22% of higher fuel than diesel but BSFC is less compared to POME20 at 230bTDC. Progression in injection timing resulted in longer and stable combustion process which led to higher peak pressure just after the TDC. This favored in decreasing compression work and lowering BSFC. For diesel blend of POME20 with addition of 20% higher alcohol 1-butanol increased BSFC by 16.19% at advanced injection timing of 270bTDC compared to diesel. As well as for diesel blend of POME20 with addition of 30% 1-butanol increased BSFC by 22.73%at advanced injection timing of 270bTDC compared to diesel. It is observed that as higher alcohol concentration is increased BSFC increased. This is due to lower energy content of the higher alcohols. Higher oxygen content of the 1-butanol decreased the calorific value which led to consumption of more amount of fuel for same output.

V.CONCLUSION & FUTURE SCOPE

5.1 Experimental Performance Conclusion

In this work, the effect of performance characteristics of different concentration higher alcohol (1-butanol) blends at advanced injection with corn oil methyl ester (POME) were investigated and compared with baseline diesel fuel and neat biodiesel in a diesel engine. From the experimental results the following conclusions are drawn:

- The performance and combustion characteristics of palm oil blends are not as effective as diesel characteristics. The performance at standard injection timing is poor for POME20 compared to pure diesel.
- The advancement in the injection timing for the palm oil biodiesel resulted in good performance compared to standard injection performance.
- The addition of higher alcohol 1-butanol with palm oil biodiesel at advanced injection timing resulted in moderate performance and emissions as compared to the pure biodiesel.
- The better blend with regard to performance is POME20 at 270 bTDC.

5.2 FUTURE SCOPE

Advancing of injection timing for the palm oil biodiesel blend improved performance. The same blends with same alcohol at same percentages continue and analysis on emission and combustion properties. We hope these tests may give better emission control and better combustion values.

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