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Experimental Studies On Performance and Exhaust Emission of a Direct Injection (DI) Diesel Engine By Using Mixtures of Jatropha And Pongamia Pinnatta Methyl Ester and Its Diesel Blends

Swapna G.K, Dr. M. C. Math

***Abstract*— In the present study, four stroke 3.75kW direct injection diesel engine was tested with five different mixtures of Jatropha and Pongamia pinnatta methyl esters. Five mixtures of Jatropha – Pongamia pinnatta were prepared by varying the amount of Jatropha and Pongamia pinnatta in the blend. In the first case JP10 was prepared by adding 10% (by vol.) of Pongamia pinnatta with 90% (by vol.) of Jatropha. Similarly, Jatropha 80% and Pongamia pinnatta 20% (JP20), Jatropha 70% and Pongamia pinnatta 30% (JP30), Jatropha 60% and Pongamia pinnatta 40% (JP40), Jatropha 50% and Pongamia pinnatta 50% (JP50) were prepared. In this work, methyl esters of Jatropha and Pongamia pinnatta were prepared by using two-stage transesterification process. In the first-stage, esterification reaction was carried with methanol (35%, by volume) in presence of H_2SO_4 (4%, by volume) as a catalyst. In the Second-stage, transesterification reaction was completed with methanol (35% by volume) in presence of NaOH (0.6% by weight) as a catalyst. First-stage reaction was carried out at 55°C for 10 min. Second-stage reaction was carried out at 55°C for 90 min. Maximum methyl ester yield of about 93% was obtained with above reaction conditions. Conventional diesel oil and Jatropha – Pongamia pinnatta methyl ester (JPME) fuel blends (B5, B15, B25, B35, B45 and B55) were used for conducting the short term engine performance test at varying loads (0%, 25%, 50%, 75% and 100%) by keeping engine speed (1500 rpm)constant. The brake specific energy consumption (BSEC, in MJ/kW-hr) and brake thermal efficiency (BTE, in %) were calculated from recorded data. It was found that Jatropha – Pongamia pinnatta methyl ester (JPME) could be easily substituted up to 25% in diesel oil without any significant modification in the existing diesel engine and without any significant difference in BSEC and BTE. It was also found that B5 of all test samples have highest BTE (%) than all other test samples at 50% rated load. It was also found that B55 of all the test samples have minimum BTE (%) than all other test samples at 100% rated load. BTE has decreased by 0.95% for JP30B5 test sample in comparison with conventional diesel oil at 50% rated load. It was also found that all the test samples (JP10, JP20, JP30, JP40 and JP50) have minimum BSEC (17.42 MJ / kW-hr) at 50% rated load.**

An attempt has also made to find emission level of diesel engine with selected test samples, the results show that UNBHC (unburned hydrocarbon, in PPM) and CO (carbon monoxide, in %) emissions were reduced by 58% and 75% respectively for JP30B55 test sample than conventional diesel oil at zero loads. However, NO_X emission was increased by 40% than

conventional diesel oil for JP30B55 test sample. Based on performance and emission characteristics, JP30B5 blend can be used as a fuel for diesel engine.

Index Terms*— *BTE, BSEC, CO, Jatropha, Methyl esters, NO_X, Pongamia pinnatta , UNBHC.

I. INTRODUCTION

Direct injection diesel engines have widely used as power producing devices in automobiles, because of their excellent fuel economy over spark ignition engines. However, fluctuating prices of diesel oil, stringent emissions regulations and depletion of petroleum reserves at a faster rate are forcing researchers to find an alternative automotive fuel [1]. In this direction over last 50 years considerable research has done to use biodiesel in unmodified diesel engine without losing power and efficiency [2-3]. In this work, an attempt has made to study the performance and emission characteristic of methyl ester of Jatropha – Pongamia pinnatta mixtures in a single cylinder direct injection diesel engine.

The main objectives of study are:

To study the engine performance using selected test fuels.

To study the effect of using selected fuel blends on the emission level from diesel engine exhaust.

To analyze diesel engine exhaust pollutants.

II. EXPERIMENTAL SET UP

Performance and exhaust emission test have carried out on computerized single cylinder direct injection and constant speed diesel engine. Table 1 shows engine specifications. Figure1 shows schematic diagram of experimental set up. It has fitted with diesel engine, diesel fuel tank, and biodiesel fuel tank. It has a data acquisition system, computer, an operational panel and gas analyzer (QROTECH QRO-401 Emission Analyzer). It has various sensors to measure the oil pressure and exhaust gas temperatures etc.

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Swapna G.K, Visvesvaraya Technological University, Department of Thermal Power Engineering, Mysore-19(India)

Dr. M. C. Math, Visvesvaraya Technological University, Department of Thermal Power Engineering, Mysore-19(India)

Table 1 Engine specifications

Make	Kirloskar (India)
Model	TAFI
Number of strokes	Four
Number of cylinders	One
Compression ratio	16.5:1
Rated power	3.75 kW
Dynamometer rated torque	2.4 kg-m
Rated speed	1500 rpm
Bore diameter	80mm
Stroke length	110mm
Aspiration	Natural

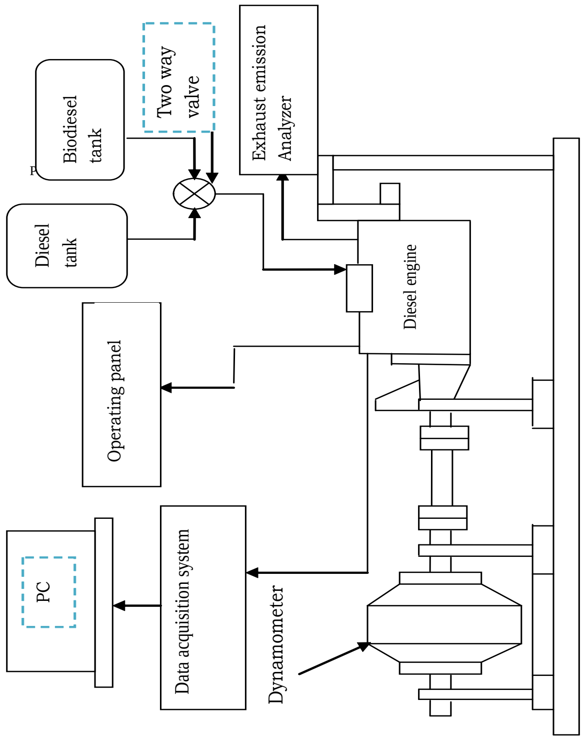

Figure1 Schematic diagram of experimental setup

III. MATERIAL AND EXPERIMENTAL METHODS

Methyl ester (B100) produced from five mixtures such as JP10, JP20, JP30, JP40 and JP50 are used as a fuel for diesel engine. Performance and emission test were carried out by using blends such as B5, B15, B25, B35, B45 and B55 of JP10, JP20, JP30, JP40 and JP50 methyl esters with conventional diesel oil. The required blends such as B5, B15, B25, B35, B45 and B55 were prepared by adding the required volume of JPME (B100) to the required quantity of conventional diesel oil and mixtures were stirred thoroughly by using motor operated mechanical stirrer. The engine has run for some time until oil temperature and cooling temperature are stabilized, at that time gas analyzer was calibrated with zero emission. After the warm up period, test conditions are set and the engine has allowed for attaining a steady state. For each of the test fuel, the engine was run on five different loads (0%, 25%, 50%, 75%, and 100%). During engine test observations such as fuel rate, air rate, cooling water flow rate, exhaust gas and cooling water temperatures and exhaust emissions were recorded. The performance parameters such as BSEC (MJ/kW-hr) and BTE (%) were calculated by using fundamental relations from recorded data while varying the load on the engine from 0% to 100%. The tests were first conducted with conventional diesel oil and subsequent tests are conducted with all other test samples. The engine speed was maintained at 1500rpm for all test samples.

IV. RESULTS AND DISCUSSION

A. *PERFORMANCE ANALYSIS*

Engine performance parameters such as BSEC (MJ/kW-hr) and BTE (%) for diesel oil and its blends with methyl ester of JP10, JP20, JP30, JP40 and JP50 were calculated. These results are analyzed and represented graphically as shown in Figure 2.1 to 3.5.

a) EFFECT OF LOAD ON BRAKE SPECIFIC ENERGY CONSUMPTION (BSEC)

BSFC is not a reliable parameter to compare fuel blends as the calorific value and density of blends are different [4]. This is because they follow slightly different trend. Hence, in this work BSEC (MJ/kW-hr) was calculated and presented the variation of BSEC (MJ/kW-hr) with load (%) for all selected test samples. Figure 2.1 to 2.5 shows the variation of BSEC (MJ/kW-hr) with load (%) for B5, B15, B25, B35, B45 and B55 blends of JP10, JP20, JP30, JP40 and JP50 with conventional diesel oil. It was observed from the Figure 2.1 to 2.5 that B55 of JP10, JP20, JP30, JP40, and JP50 methyl esters has maximum BSEC (MJ/kW-hr) of 1.147, 1.265, 1.19, 1.21 and 1.20 times respectively higher than conventional diesel oil at 25% rated load. It also shows that B5 of JP10, JP20, JP30, JP40, and JP50 methyl esters has minimum BSEC (MJ/kW-hr) which is 1.05 times higher than conventional diesel oil at 50% rated load. For all the selected test fuel, BSEC decreased with increase in the load up to 50% of rated load and then it has increased with increase in load.

b) EFFECT OF LOAD ON BRAKE THERMAL EFFICIENCY (BTE)

Figure 3.1 to 3.5 shows variation of brake thermal efficiency (BTE) (%) with load (%) for B5, B15, B25, B35, B45 and B55 of JP10, JP20, JP30, JP40 and JP50 with conventional diesel oil. For all test samples, BTE (%) has increased with the increase in load (%) and reached maximum value at 50% rated load. BTE (%) of conventional diesel oil is highest at all load ranges. This can also be seen from Figure 3.1 to 3.5 that with the increase in the percentage of ester in the blends, the BTE has decreased. It was observed from the Fig. 3.1 to 3.5 that B5 of JP10, JP20, JP30, JP40, and JP50 methyl esters has maximum BTE (%) were 29.38%, 29.38 %, 29.98 %, 29.59 %, and 29.7 % respectively at 50% rated load. It also shows that B55 of JP10, JP20, JP30, JP40, and JP50 methyl esters has minimum BTE (%) of 23.26%, 23.57% , 21.9%,22.84% and 22.64% at 100% rated load. The low efficiency may be due to low volatility, slightly higher viscosity, and higher density of methyl esters. This affects mixture formation of fuel and thus leads to slow combustion [5]. From these figures it was also observed that among the entire test samples, B5 of JP30 has maximum brake thermal efficiency (29.98%) at 50% rated load and B55 of JP30 has minimum brake thermal efficiency (21.9%) at 100% rated load.

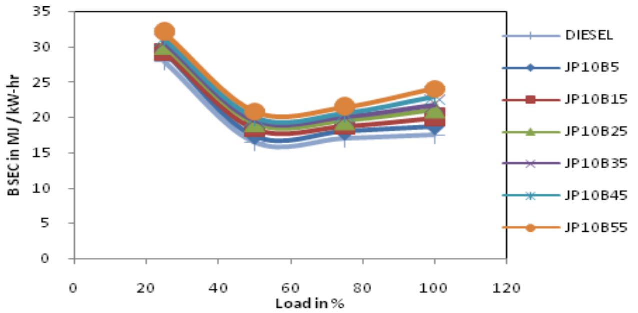

Figure 2.1. Effect of Load on BSEC (MJ/kW-hr)for JP10ME at 180bar Pressure

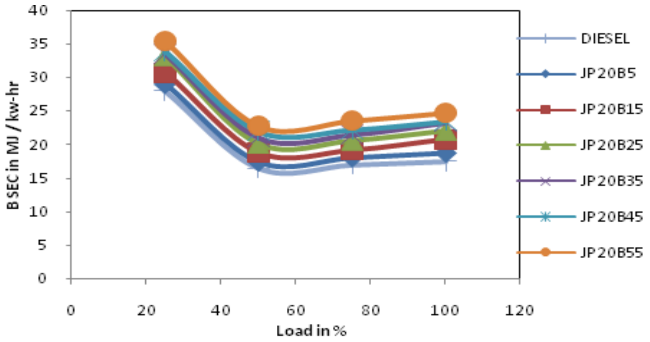

Figure 2.2. Effect of Load on BSEC (MJ/kW-hr)for JP20ME at 180bar Pressure

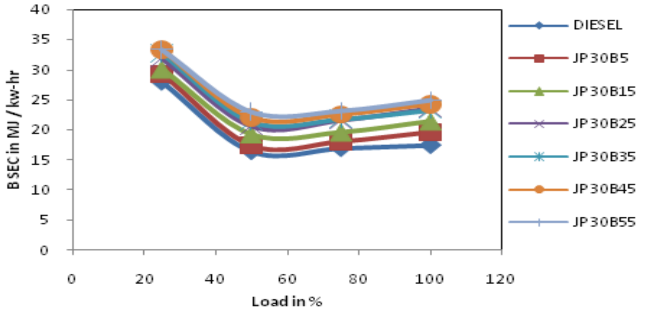

Figure 2.3. Effect of Load on BSEC(MJ/kW-hr) for JP30ME at 180bar Pressure

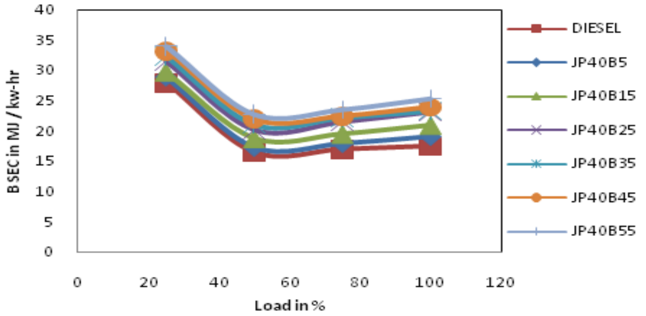

Figure 2.4. Effect of Load on BSEC(MJ/kW-hr) for JP40ME at 180bar Pressure

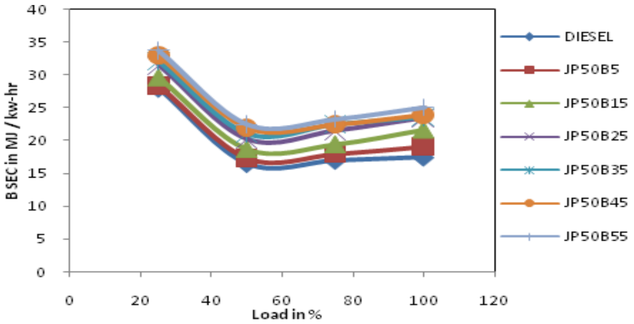

Figure 2.5. Effect of Load on BSEC(MJ/kW-hr) for JP50ME at 180bar Pressure

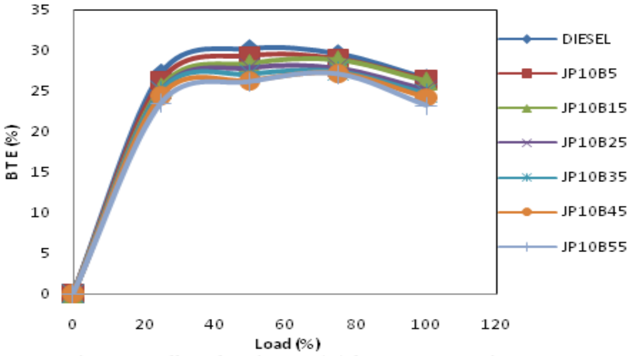

Figure 3.1. Effect of Load on BTE(%) for JP10ME at 180bar Pressure

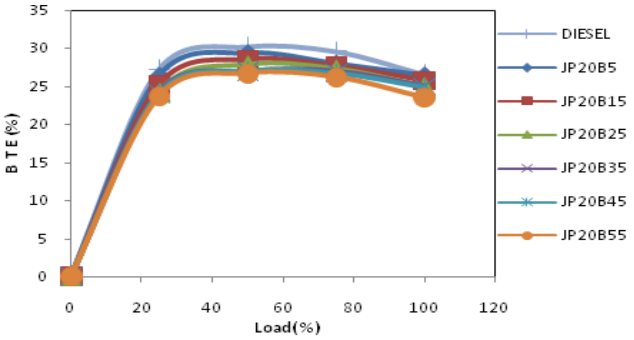

Figure 3.2. Effect of Load on BTE(%) for JP20ME at 180bar Pressure

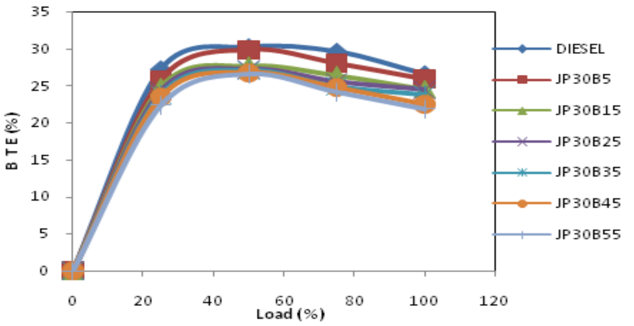

Figure 3.3. Effect of Load on BTE (%) for JP30ME at 180bar Pressure

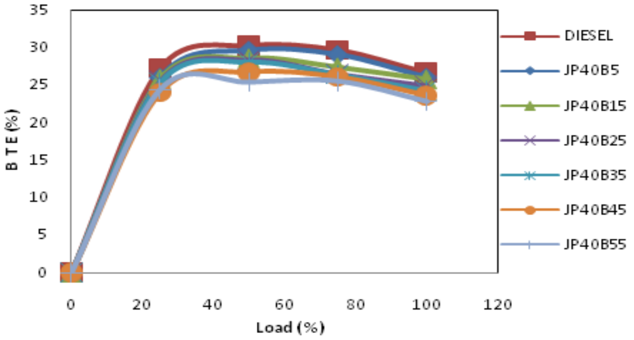

Figure 3.4 Effect of Load on BTE (%) for JP40ME at 180bar Pressure

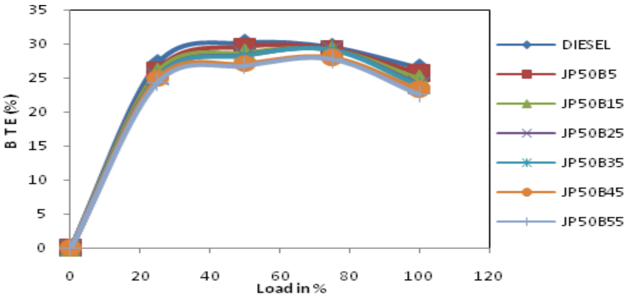

Figure 3.5 Effect of Load on BTE (%) for JP50ME at 180bar Pressure

B. EMISSION ANALYSIS

Considerable research work has done on experimental investigation of emission characteristics of diesel engine using methyl ester and their blends as a fuel [6]. Engine exhaust emission such as carbon monoxide (CO), oxides of nitrogen (NOX), unburned hydrocarbon (UNBHC) measured with five level gas analyzer (QROTECH QRO-401 Emission Analyzer) was carried out. The sensor of the gas analyzer was exposed to exhaust gas and readings were recorded by varying the load on the engine. The engine speed was kept constant at 1500 rpm.

a) OXIDES OF NITROGEN (NOX)

Figure 4.1 to 4.5 shows variation of oxides of nitrogen (NOX) emission with load (%) for B5, B15, B25, B35, B45 and B55 of JP10, JP20, JP30, JP40 and JP50 respectively. The results were compared with the NOx emission of conventional diesel oil. It is evident from the Figure 4.1 to 4.5 that as the load on the engine increased, NOx emission also increased gradually and reached a maximum value at part loads for all test fuels. Increase in NOx emission level with an increase in load has observed because of the formation of NOx depends on combustion gas temperature and the availability of oxygen. As the engine load increases the combustion gas temperature increases due to increase in the amount of fuel burned and hence NOx emission increases [7]. Figure 4.1 to 4.5 also indicates that there is a gradual increase in the NOx (PPM) emission with an increase in the percentage of methyl esters in the blend at any brake load. Figure 4.1 to 4.5 also shows that B5 of JP10, JP20, JP30, JP40 and JP50 has minimum NOx emissions (205 PPM, 202 PPM, 210 PPM , 206 PPM and 204 PPM) respectively at 0% rated load. It also shows that B55 of JP10, JP20, JP30, JP40 and JP50ME has maximum NOx emissions (512 PPM, 509 PPM, 520 PPM,463 PPM, 460 PPM) at 100% rated load. It was also observed that among all the test samples B55 of JP30 has maximum NOx (520 PPM) emission at 100% rated load.

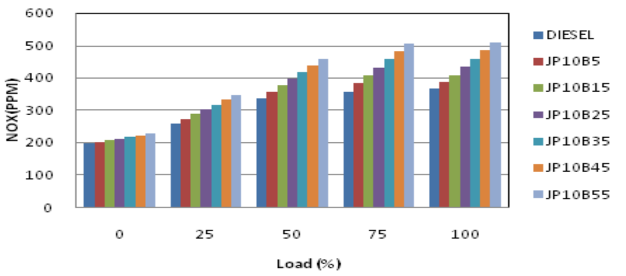

Figure 4.1 Effect of Load on NO$_x$ (PPM) for JP10ME at 180bar Pressure

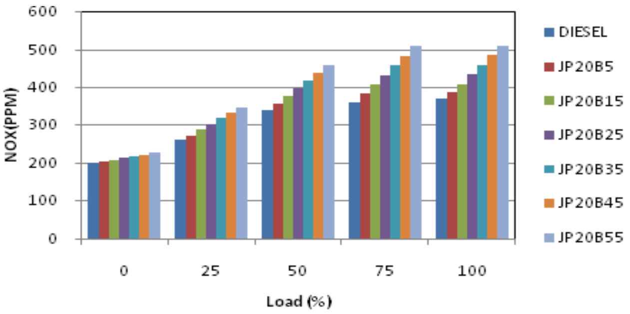

Figure 4.2 Effect of Load on NO$_x$ (PPM) for JP20ME at 180bar Pressure

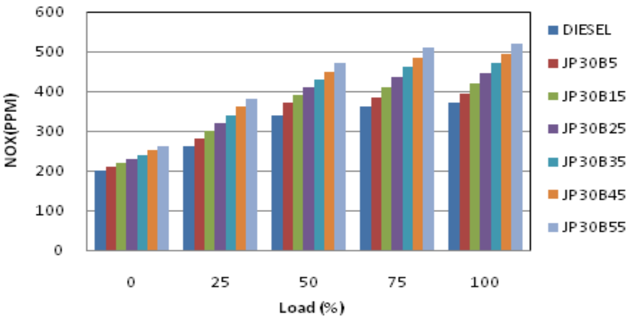

Figure 4.3 Effect of Load on NO$_x$ (PPM) for JP30ME at 180bar Pressure

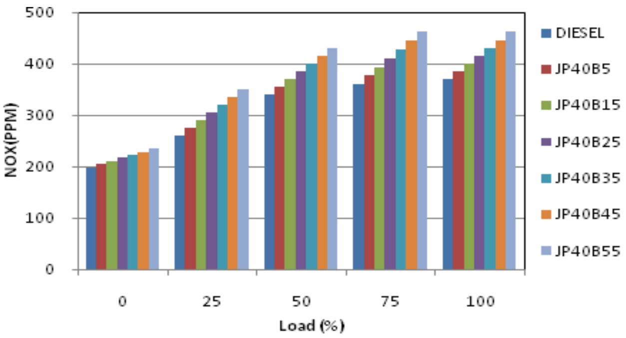

Figure 4.4 Effect of Load on NO$_x$ (PPM) for JP40ME at 180bar Pressure

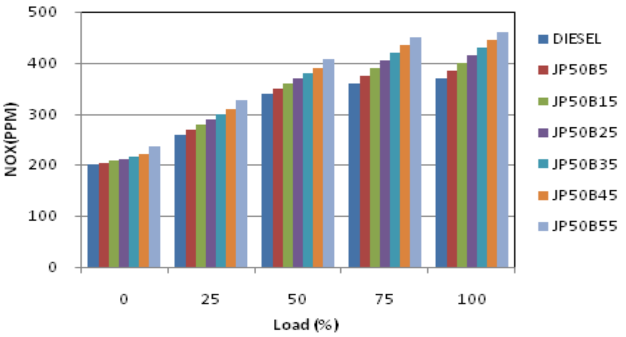

Figure 4.5 Effect of Load on NO$_x$ (PPM) for JP50ME at 180bar Pressure

b) Effect of load on carbon monoxide (CO) emission

Figure 5.1 to 5.5 shows variation of carbon monoxide (CO) emission with load (%) for B5, B15, B25, B35, B45 and B55 of JP10, JP20, JP30, JP40 and JP50 respectively. The results were compared with the CO emission of conventional diesel oil. It is evident from Figure 5.1 to 5.5 that as the loads on the engine increased, CO emission also increased gradually at low and part loads and increased significantly at higher loads for all test fuels. Figure 5.1 to 5.5 shows that CO emission for methyl esters and their blends of test fuels are lower than conventional diesel oil at all loads range. This is due to higher oxygen content in esters and their blends which will promote further oxidation of CO during the engine exhaust process [8]. Figure 5.1 to 5.5 also indicates that there is a gradual decrease in the CO emission with an increase in the percentage of methyl esters in the blend at any brake load. Figure 5.1 to 5.5 also shows that B55 of JP10, JP20, JP30, JP40 and JP50 has minimum CO emissions of 0.03%, 0.04%, 0.02%, 0.025% and 0.035% respectively at 0% rated load. It also shows that among all the test samples B55 of JP30 has minimum carbon monoxide emission (0.02%) at 0% rated load.

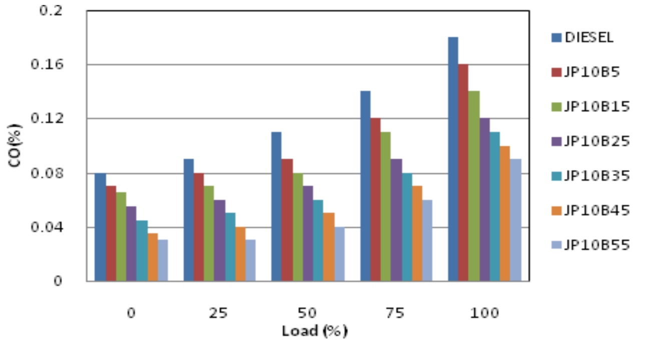

Figure 5.1 Effect of Load on CO (%) for JP10ME at 180bar Pressure

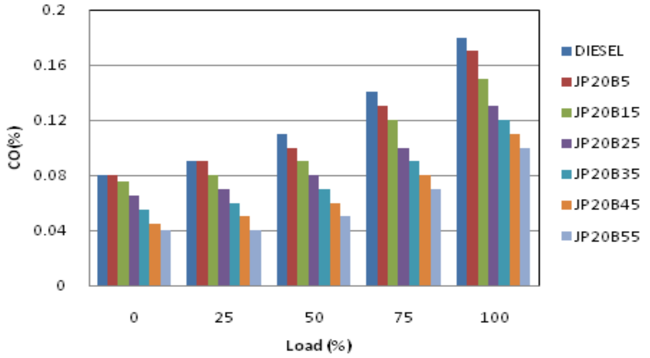

Figure 5.2 Effect of Load on CO (%) for JP20ME at 180bar Pressure

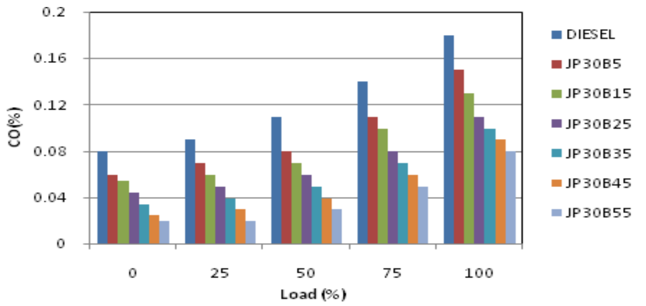

Figure 5.3 Effect of Load on CO (%) for JP30ME at 180bar Pressure

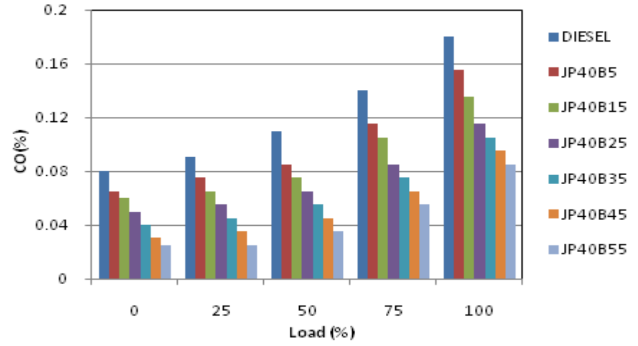

Figure 5.4 Effect of Load on CO (%) for JP40ME at 180bar Pressure

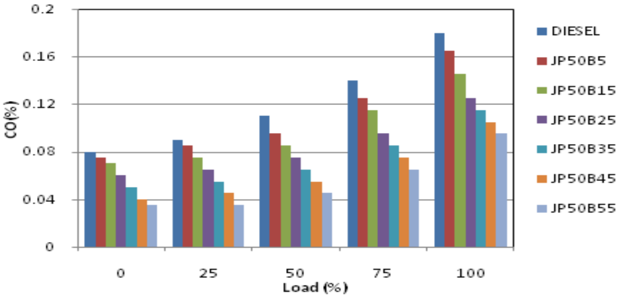

Figure 5.5 Effect of Load on CO (%) for JP50ME at 180bar Pressure

c) *Unburned hydrocarbon (UNBHC)*

UNBHC is also a crucial factor in determining the emission behavior of the engines because it is the direct result of incomplete combustion [9]. Fig 6.1 to 6.5 shows variation of UNBHC (PPM) emission with load (%) for B5, B15, B25, B35, B45 and B55 of JP10, JP20, JP30, JP40 and JP50 respectively. The results are compared with the UNBHC (PPM) emission of conventional diesel. Figure 6.1 to 6.5 shows that as the loads on the engine increased, UNBHC (PPM) emission also increased gradually at low and part loads, and increased significantly at higher loads for all test fuels. At higher engine load, less quantity of oxygen will available for the reaction when more fuel has injected into the engine cylinder. Figure 6.1 to 6.5 shows that UNBHC (PPM) emissions for methyl esters and their blends of test fuels are lower than conventional diesel at all load ranges. This is due to higher oxygen content in esters and their blends which will promote further oxidation of HC during the engine exhaust process [8]. The lower HC emission for methyl esters and their blends may also be due to their higher cetane value. Figure 6.1 to 6.5 also indicates that there is an increase in the percentage reduction of UNBHC emission with an increase in the percentage of methyl esters in the blend at any brake loads. Fig. 6.1 to 6.5 also shows that B55 of JP10, JP20, JP30, JP40 and JP50 have minimum UNBHC emission (6 PPM, 7 PPM, 5 PPM, 5.5 PPM and 6.5 PPM) respectively at 0% rated load. It was also observed that among all the test samples B55 of JP30 has minimum UNBHC (5 PPM) emission at 0% rated load.

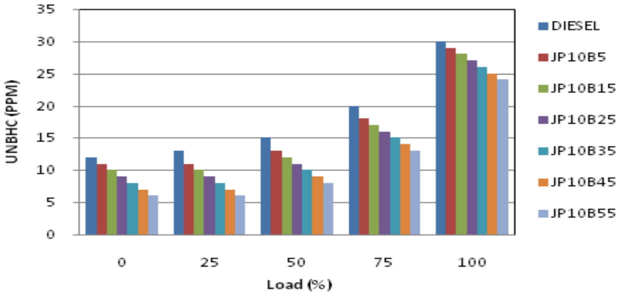

Figure 6.1 Effect of Load on UNBHC (PPM) for JP10ME at 180bar Pressure

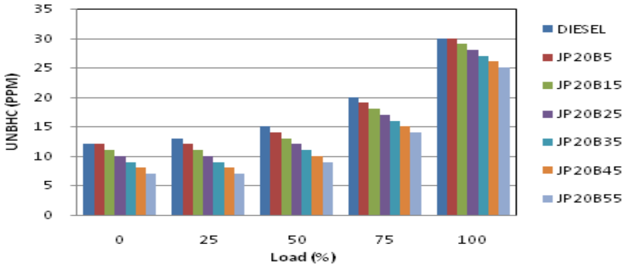

Figure 6.2 Effect of Load on UNBHC (PPM) for JP20ME at 180bar Pressure

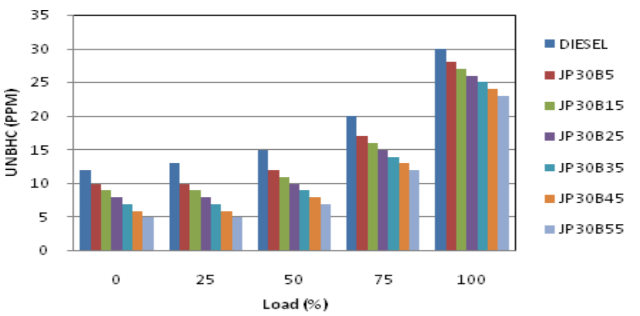

Figure 6.3 Effect of Load on UNBHC (PPM) for JP30ME at 180bar Pressure

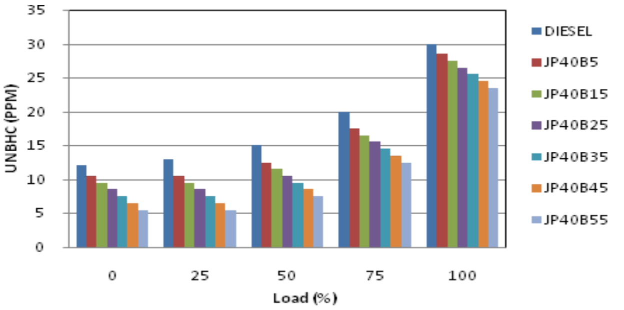

Figure 6.4 Effect of Load on UNBHC (PPM) for JP40ME at 180bar Pressure

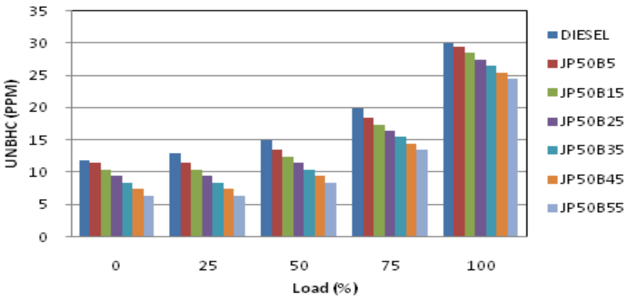

Figure 6.5 Effect of Load on UNBHC (PPM) for JP50ME at 180bar Pressure

V. CONCLUSION

Based on experimental investigation on a single cylinder diesel engine fuelled with JPME and their blends following conclusions have been arrived.

B5 of JP10, JP20, JP30, JP40, and JP50 methyl esters has minimum BSEC which is 1.05 times higher than conventional diesel oil at 50% rated load. It is also concluded that BSEC increases with increase in the percentage of ester in the blends.

B5 of JP30 has maximum BTE (29.98%) at 50% rated load B55 of JP30 has minimum BTE (21.9%) at 100% rated load. It is concluded that BTE decreases with increase of ester in the blends.

B5 of JP10, JP20, JP30, JP40, and JP50 methyl esters has minimum NOX emission at 0% load but B55 of JP10, JP20, JP30, JP40, and JP50 methyl esters has maximum NOX emission at 100% rated load.

B55 of JP10, JP20, JP30, JP40, and JP50 methyl esters has minimum CO at 0% rated load .With increase in the percentage of ester in the blend CO decreases.

B55 of JP30 has minimum UNBHC at 0% rated load .With increase in the percentage of ester UNBHC decreases.

It can be concluded that up to 30% Pongamia pinnatta can be blend with Jatropha without significant power and efficiency loss in comparison with diesel oil. It can also be concluded that up to 25% ester can be blend with conventional diesel without significant modification in the engine and without loss of power and efficiency. Blends of two sources such as Jatropha –Pongamia pinnatta in a different proportion can be used as source for the production of biodiesel which will reduce dependence on single source.

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She is doing M.Tech in the Department of Thermal Power Engineering at Visvesvaraya Technological University College, Mysore (India). She obtained her M.B.A. in Human Resource Management from Karnataka State Open University (KSOU), Mysore (India) in 2007. She obtained her B.E. in Industrial Production Engineering from Sri Jaya Chamarajendra Engineering College (SJCE), Mysore (India) in 2004

He is working as Associate Professor in the Department of Thermal Power Engineering at Visvesvaraya Technological University, Mysore. He obtained his Ph. D in IC engines and biodiesel from Jawaharlal Nehru Technological University, Hyderabad (India) in 2013. He did his M.Tech in Thermal Power Engineering from Visvesvaraya Technological University, Belgaum (India) in 2006 and B.E in Mechanical Engineering from Karnataka University, Dharawar (India) in 1996. He published 12 technical papers in International / national journal and conferences. He authored 6 textbooks on thermal engineering. He guided three international projects on super mileage vehicles which were participated in Shell Eco-Marathon competition held at Malaysia and Manila during 2011,12 and 13. He is a life member of ISTE. He is guiding two research scholar in the area of dual fuel and flexi fuel vehicle.