Performance and Emission Characteristics of an Indirect Injection (IDI) Diesel Engine fuelled with Pongamia Methyl Ester (PME) and Isobutanol as an Additive

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Abstract—**The aim of this work is to investigate the performance and emission characteristics of an Indirect Injection (IDI) Diesel engine fuelled with Pongamia Methyl Ester (PME) biodiesel along with Isobutanol (IB) additive as an alternative fuel replacing the conventional diesel fuel. PME biodiesel is non-edible oil and it is one of the many fuels receiving attention as an alternative fuel for diesel engines. For this study a four-stroke single-cylinder IDI diesel engine was chosen and it is fuelled with five fuel samples containing IB with PME. The samples are prepared by volume percentage basis. Tests were conducted at five different loads with constant engine speed of 1500 rpm. The parameters studied are Brake Specific Fuel Consumption (BSFC), Break Thermal Efficiency (BTE), Exhaust Gas Temperature (EGT), Smoke and emissions. The percentage of 6 percent IB in PME is adjudged best choice and engine performance was evaluated with respect to neat biodiesel and conventional diesel fuel. The results indicate BSFC reduction by 2.6 percent compared with neat biodiesel, increase of BTE by 0.97 percent and exhaust gas temperature and smoke readings are reduced by 3 degree centigrade and 30 percent respectively for 6 percent IB when compared to conventional diesel fuel at maximum load. The exhaust gas emissions of the engine using 6 percent isobutanol in biodiesel were compared with conventional diesel fuel operation. The reduction percentages quantified are by 71 for HC, 0.02 for CO, 0.5 for CO_2 and 31 for NO. The studies conclude that this new fuel with 6 percent isobutanol in biodiesel is suitable for replacement in an IDI Engine because of combustion improvement.**

Keywords—IDI engine, Pongamia methyl Ester, Isobutanol, biodiese, additive, exhaust gas emissions.

I INTRODUCTION

Fuels derived from renewable biological resources for use in diesel engines are known as biodiesel. Biodiesel is environmentally friendly liquid fuel similar to petrol-diesel in combustion properties. Increasing environmental concern, diminishing petroleum reserves and agriculture based economy of our country are the driving forces to promote biodiesel as an alternate fuel. Biodiesel derived from vegetable oil and animal fats is being used in many countries to reduce air pollution and to reduce dependence on fossil fuel. Use of high viscosity oils will be possible in IDI engines since this engine contains swirl chamber and main chamber which take care of proper mixing and air entrainment. In this way IDI engines have better edge over DI engines in the usage of alternate fuels with different fuel parameters without much carbon formation and injector cocking. Only set back with the IDI engines is the aspect of more heat transfer through larger combustion chamber surface area resulting in lower thermal efficiency and higher compression ratio which calls for more power from the engine. Furthermore, NOx emission may be lower in the IDI than in DI engine, due to lack of air in the secondary combustion chamber and lower temperature in the main combustion chamber [1]. Pongamia methyl ester was chosen because it is non-edible oil and the plant is ubiquitous in south India. The oil yield of the seed is nearly about 30% and yield after transesterification is 80% from the raw oil with a kinematic viscosity of 4.46 cSt. T Venkateswara Rao et al. [2] conducted experimentation to analyze the emission and performance characteristics of a single cylinder compression ignition engine fuelled with mineral diesel, Pongamia (PME), Jatropha (JME) and Neem (NME) biodiesel blends at an injection pressure of 200 bar. It is observed that Pongamia Methyl Ester (PME) had better brake thermal efficiency when compared to the methyl esters of Jatropha and Neem. Puhan S et al. [3] have tried mahua oil ethyl ester (MOEE) in a four stroke naturally aspirated direct injection diesel engine and have reported an increase in BSFC when compared to diesel. It is also observed a slight increase in brake thermal efficiency, reduction in CO emission, increase in CO2 emission, 63% reduction in HC emission, reduction in NOx and 70% reduction in smoke. Altin R, et al.[4] have conducted performance and emission tests in a diesel engine fueled with methyl esters of sunflower oil, cotton seed oil, soya bean oil, refined corn oil, distilled opium poppy oil and refined rape seed oil and concluded that compared to diesel fuel, little power loss, higher particulate matter emission, lesser NOx emission were noted for vegetable oils. It is our endeavor to find vegetable oil methyl esters with their performance and emissions closer to diesel fuel and should recommend for replacement. Biodiesel depending on its kinematic viscosity needs some injection parameters to be changed. M. Pandian et al.[5], attempted to investigate the effects of injection parameters by using Pongamia biodiesel blends in a DI diesel engine [7.5kW, 1500rpm] and found that Changes in injection pressure, injection timing, and nozzle protrusion resulted in yielding optimal better values. Vegetable oils can be described as fatty acids with carbon chains similar in structure, length and carbon to hydrogen ratio (C: H) as that of conventional diesel [6]. However, they differ from the latter because of having oxygen in their molecular structure. They also have higher kinematic viscosity and density, lower calorific value, cetane number and stoichiometric ratio compared to mineral diesel [7-10].The use of vegetable oil results in increased fuel consumption i.e. increased brake specific fuel consumption (BSFC). Various studies found higher CO and HC emissions with vegetable oils and their blends, and lower NOx and particulate emissions compared to mineral diesel [11-16].

Ethanol addition to diesel-biodiesel blends increased brake thermal efficiency with reduction in carbon monoxide and smoke emissions and at the same time hydrocarbons, oxides of nitrogen and carbon dioxide emissions observed to be increased [17]. Many studies have been conducted on the performance of and emissions from engines fueled with diesel–alcohol blends, [18 and 19] and most of these investigations have concentrated on methanol and ethanol. Compared with ethanol and methanol, butanol has many advantages. It has a higher energy density than those of ethanol and methanol. Butanol has a high cetane number which makes it more suitable as an additive to diesel fuel. n-butanol is much less hygroscopic than ethanol and methanol are, preventing it from water contamination. Butanol is less corrosive to the materials in the fuel delivery and injection system, which allows it to be used in the existing pipeline. However, few studies have reported results from using isobutanol–diesel blends in diesel engines. Blending isobutanol with diesel can maintain good stability for a long time without phase separation. In this work, endeavor is made to investigate the viability of Pongamia methyl ester with isobutanol additive in a bid to replace the conventional diesel fuel for IDI engines without any modification. The experiments are conducted to study the engine performance and emission characteristics.

II EXPERIMENTAL SET-UP

The schematic diagram of the engine test bed is shown in Fig.1. A four-stroke single cylinder, forced air and oil cooled IDI diesel engine was used for experimentation. The engine specifications are shown in Table 1. Experiments were conducted with diesel, neat PME and Isobutanol (IB) in the biodiesel with different percentages i.e. 2%, 4%, 6%, 8% and 10%. During the test performance, exhaust emissions and smoke density parameters were measured by using instruments indicated in the diagram. Fuel consumption is measured to calculate Brake Specific Fuel Consumption (BSFC) and Break Thermal Efficiency (BTE). Exhaust gas temperatures and smoke readings were also recorded for all loads. Delta 1600-L exhaust gas analyzer(German Make) is used to measure CO_2, CO, HC and NO in exhaust gases at all loads and graphs are drawn to analyze the emissions.

Table 1 Specifications of the IDI- Diesel Engine.

Engine manufacturer	Bajaj RE Diesel Engine
Engine type	Four Stroke, Forced air and Oil Cooled
No. Cylinders	One
Bore	86.00mm
Stroke	77.00mm
Engine displacement	447.3cc
Compression ratio	24±1:1
Maximum net power	5.04 kW @ 3000 rpm
Maximum net torque	18.7 Nm @ 2200 rpm
Idling rpm	1250±150 rpm
Injection Timings	8.50 to 9.50 BTDC
Injector	Pintle
Injector Pressure	142 to 148 kg/cm2
Fuel	High Speed Diesel
Starting	Electric Start

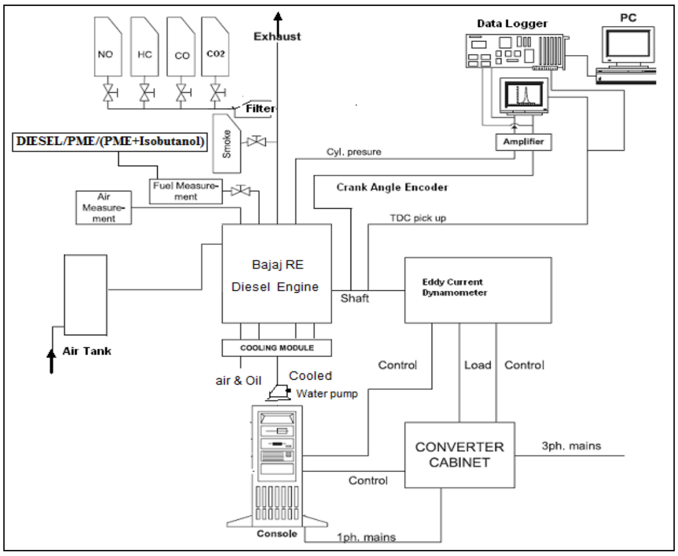

Fig.1. Schematic arrangements of the engine test bed, Instrumentation and data logging system

III RESULTS AND DISCUSSION

Engine performance:

The performance test results of the engine were compared for diesel, Pongamia methyl ester (PME) and isobutanol (IB) additive blends for various percentages.

• Brake Specific Fuel Consumption (BSFC):
Fig.2 envisages that the Brake specific fuel consumption verses Brake power. A smoother trend of the curve is observed for the additive blend of 6% (dark blue line).The Brake Specific Fuel Consumption for the 6% additive blend is observed on higher side i.e. 0.3061 kg/kW-hr at maximum load compared with conventional diesel fuel but it is lesser than biodiesel and other additive samples shown in the figure 2.

• *Brake Thermal Efficiency:*
Fig.3 gives the details of Brake thermal efficiency versus brake power of neat diesel, bio-diesel and additive blends. The figure shows that the thermal efficiency is increasing with isobutanol additive percentage even though calorific value of additive is low compared to the diesel and biodiesel. This is due to improved rate of combustion with additive. At 6% isobutanol additive blend yielded Brake thermal efficiency which is improved by 0.97% compared with conventional diesel fuel.

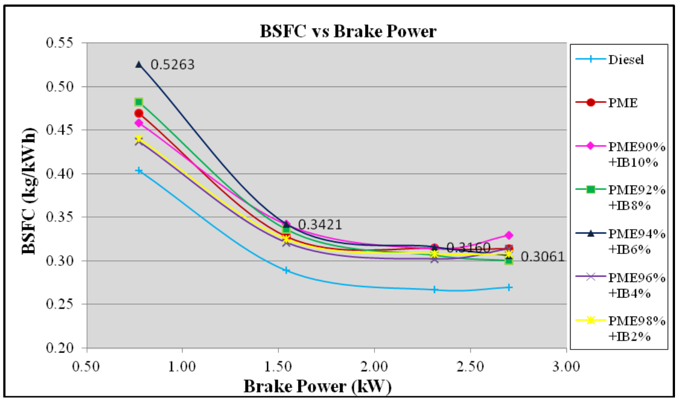

Fig.2. Variation of BSFC verses Brake power

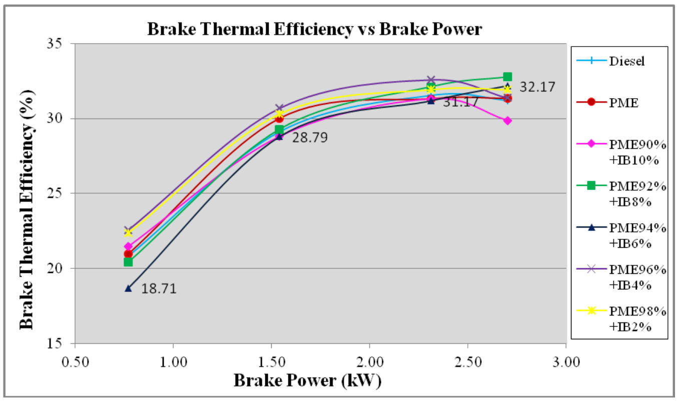

Fig.3. Variation of BTE verses Brake power

EXHAUST GAS EMISSIONS:

• *Exhaust gas temperature:*
The variation in exhaust gas temperature for all of the tested fuel samples is shown in Fig.4. In general the exhaust gas temperature for biodiesel is high when compared to conventional diesel fuel. The fuel combinations with isobutanol in biodiesel do not increase exhaust temperatures abnormally with respect to the conventional diesel as is observed in the Fig.4. 6% isobutanol additive in PME reduces Exhaust gas temperature up to 3 ^{0}C at maximum load.

• *Engine smoke levels:*
The decrease in smoke level in exhaust with respect to the neat diesel fuel operation is appreciable (30% at maximum load operation) as shown in Fig.5. This is an indication of better utilization of oxygen in combustion with 6% additive of isobutanol in biodiesel.

• *Hydrocarbon (HC) and Carbon monoxide (CO) emissions:*
The HC and CO emission versus brake power at constant speed is shown in Fig.6 & Fig.7. Previous studies on IDI engine indicates lower emissions in exhaust. Additive mixing in biodiesel further reduced the HC and CO emissions. 6% isobutanol additive in biodiesel has reduced HC and CO emissions by71% and 0.02% respectively at maximum load.

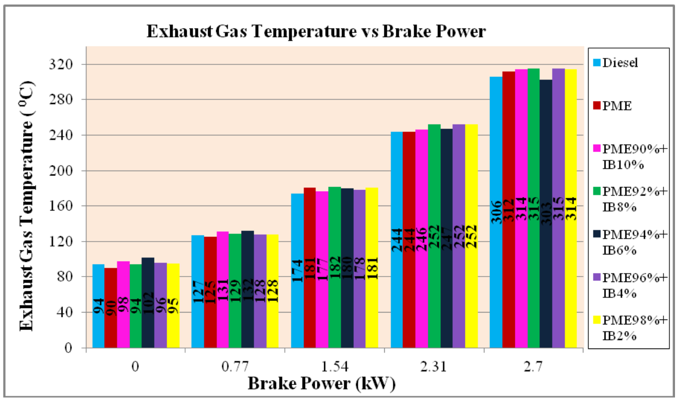

Fig.4. Variation of exhaust gas temperature verses Brake power

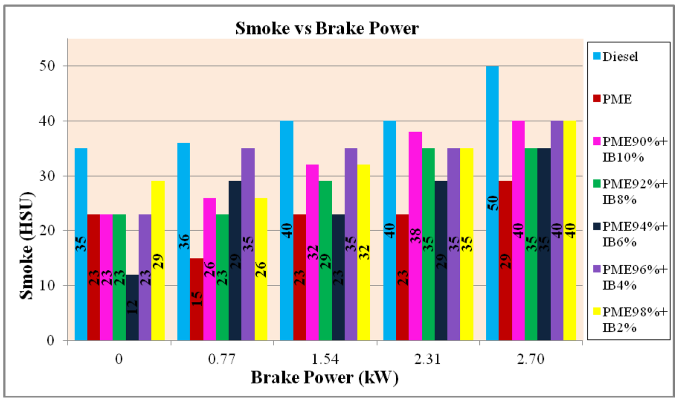

Fig.5. Variation of smoke level verse Brake power

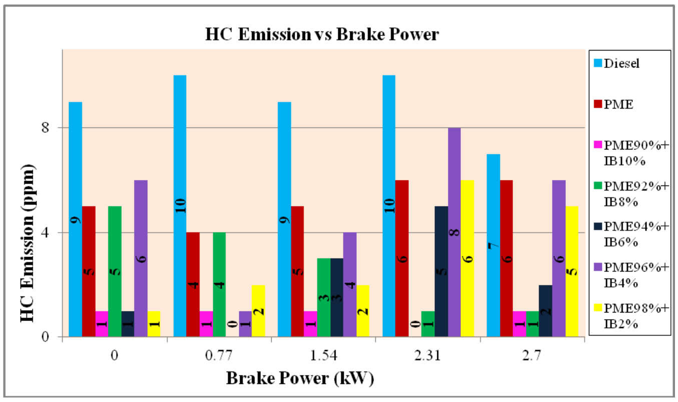

Fig.6. Variation of hydrocarbon emission verses Brake power

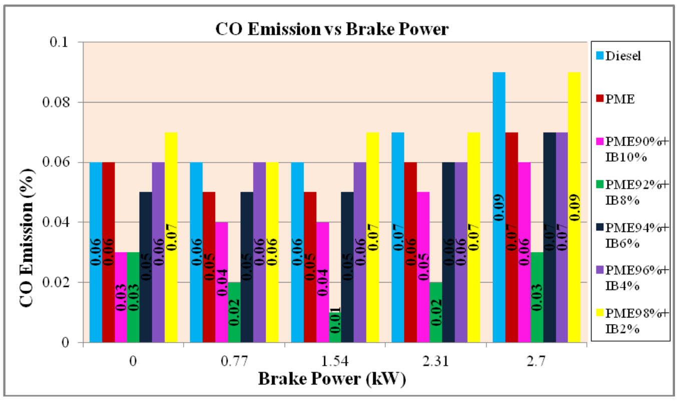

Fig.7. Variation of CO emission verses Brake power

• Carbon Dioxide (CO_2) and Nitrogen Oxide (NO) emissions: CO_2 emission decreased by very lesser quantities as envisaged in Fig.8 because of combustion improvement. Nitrogen Oxide (NO) Emission reduced by 31% at high loads with the 6% isobutanol additive compared with conventional diesel fuel as shown in Fig.9.This may because of colder combustion.

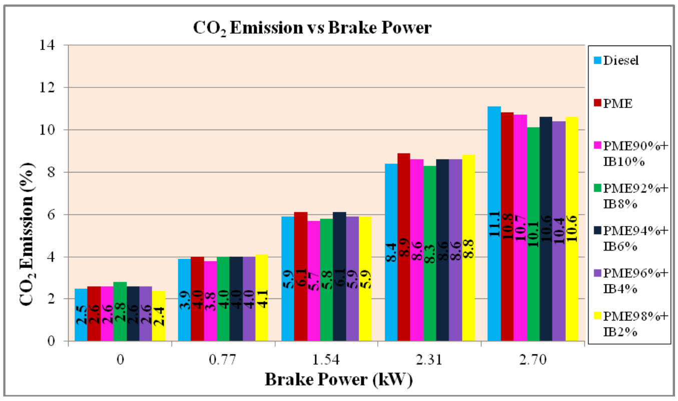

Fig.8 Variation of CO2 emission verses Brake power

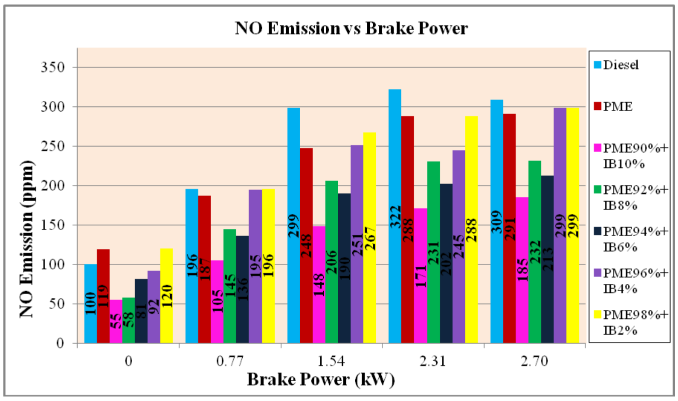

Fig.9. Variation of NO emission verses Brake power

IV CONCLUSIONS

Small quantities of isobutanol are used as an additive to the Pongamia methyl ester and used in an IDI engine. The performance and emissions are evaluated with the suitable isobutanol percentage which gives maximum benefits. It is observed that fuel containing 6% additive in biodiesel performed maximum as replacement to the diesel fuel. The following conclusions may be drawn from the present investigation:

(1) The engine load of 2.70 kW was tried at 1500 rpm for stable operation of the variable speed engine selected. It is observed that 6% additive in biodiesel has given smoother performance.

(2) Thermal efficiency and specific fuel consumption have improved with 6%additive in biodiesel. Exhaust temperatures have reduced for 6 percent additive in biodiesel, which indicates prevalence of low combustion temperatures in the main chamber.

(3) Smoke in HSU in exhaust gas reduced by 30% in case of 6% isobutanol additive in biodiesel at high load.

(4) Research on IDI engine indicates lower emissions in exhaust. Additive mixing further reduced the HC emission and CO emission to greater extent.

(5) CO_2 and NO emission are also reduced at higher loads especially with the additive.

It is concluded that 6% isobutanol additive in PME gives optimum performance indicating suitability to replace diesel fuel.

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