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Experimental Investigation on the Performance and Emission of a Diesel Engine Fueled with Palm Biodiesel oil and its Blends

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Abstract: In the present days the price and usage of petroleum products are increased more and more, due to this the search of alternative fuels has gain more importance in order to replace it. Coming to the diesel engines the best alternative fuel is Biodiesel, because it can be used directly without changing the engine modifications. Performance and emission characteristics of diesel engine were reviewed in this work. This study was conducted using biodiesel prepared from the raw oils of palm. Performance and exhaust emissions of diesel engine have been experimentally investigated with palm oil (P100) and its blend (P10, P20, P40, P60 and P80) with diesel fuel. Engine performance parameters namely break thermal efficiency, specific fuel consumption (SFC) and mechanical efficiency of CO, HC, CO_2 and NOx were determined for different loading conditions and at constant engine speed of 1500 rpm. The test result indicates that there is a slight decrease in brake thermal efficiency and increase in specific fuel consumption for all the blended fuels when compared to that of diesel fuel with respect to increase in load. The drastic reduction in carbon monoxide and hydrocarbon were recorded for all the blended fuels as well as with neat biodiesel. However, in the case of oxides of nitrogen, there is a slight increase for all the blended fuels and with neat biodiesel when compared to diesel fuel with respect to increase in load. On the whole, Palm oil and its blends with diesel fuel can be used as an alternative fuel for diesel in direct diesel engines without any significant engine modification.

Keywords: Palm oil, Performance, Emission and Consumption.

I. INTRODUCTION

Diesel engines have low fuel consumption and high efficiencies and therefore, the use of diesel engines rapidly have increased in recent times. Nowadays, diesel engines are used in transportation, energy generation, irrigation purposes and many other sectors [1] and led to increase in the demand of diesel fuel, which is presently anxious with emissions and environmental problem. The diesel fuel can be substituted by the renewable sources of energy like biodiesel [2]. The increase in exhaust emissions from diesel engine using diesel is the main difficulty, responsible for global warming, depletion of ozone layer, and acid rains are created problems for environment and human health [3]. The rapid rise in petroleum fuel prices have caused encouraged R&D on renewable biofuels source like: biogas, ethanol and vegetable oils, etc [4]. Replacement of fossil diesel with biodiesel in diesel engines can significantly improve our environment. The main advantages of using biodiesel are renewable, biodegradable, non toxic, can be used without modifying existing engines, and produce less harmful gas emissions such as sulphur oxide [5]. Chemically, biodiesel is a mixture of methyl esters with long-chain fatty acids and is typically made from nontoxic, biological resources such as animal fats, vegetable oils [6], or even used cooking oils [7]. The use of this alternative fuel may also provide economic benefits in meeting the energy needs of industry. It has significantly lower emissions than petroleum-based diesel and in addition, biodiesel is better than diesel fuel in terms of sulfur content, flash point, aromatic content and biodegradability [8]. Biofuels are proved to be very good substitutes for the existing petro fuels. The essential minimum requirements for biofuels to be a more sustainable alternative for fossil fuels are that they should be produced from renewable raw material and that their use has a lower negative environmental impact. Plant oils are renewable and have low sulfur in nature.

II. RELATED WORK

The concept of using vegetable oil as an engine fuel is developed by Rudolf Diesel (1858- 1913).First he done the experiment on peanut oil in 1900. Unfortunately Diesel was died in 1913 before his vision of a vegetable oil powered

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engine. After that the petroleum companies introduced diesel as an engine fuel, because of its best fuel properties it gain more importance than vegetable oils. But after 1970's the usage and price of this diesel becomes more and more hence every country want to replace it with an alternative fuel. Hence the research of fuel from vegetable oils starts again [9-10]. The research is not only limited for vegetable oils, lot of researches were also developed on producing the fuel from edible, non edible oils, animal fats and leaves etc. The fuel produced from these sources is called as Biodiesel because Bio means "Nature" since it comes from the natural sources and used for the running of the engine, hence it is called BIODIESEL. Vegetable oils also have the fuel properties such as density, cetane number, calorific value, heat of vaporization etc. But straight vegetable oils cannot be used directly in the running of the engine because these have high viscosity, high density and low volatility. These properties of the oil may cause poor atomization of fuel, sticking of piston ring, cold starting trouble etc.

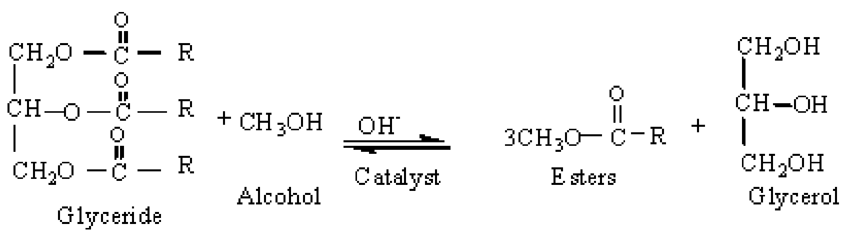
Hence the required properties of the fuel for this oil can be enhanced through a process called "Transesterification" [11-12]. The main purpose of producing biodiesel is, it produces fewer emissions compared to diesel and it is also a renewable source. Today many people doing researches on the performance and emission of the engine with different oils such as Pongamia oil, Jatropa oil, Neemseed oil, Fish oil etc. Recently one of the experiment is done with fish oil and its blends without engine modifications , the results says that by using this; the performance of the engine (B.P, Brake thermal efficiency) is slightly less compared to diesel. Coming to emissions it produces less HC, CO and SMOKE emissions compared to diesel but, the NOx were increased [13]. Another experiment is done by using a HHO generator for the existing engines to reduce pollution and to increase fuel efficiency. By using this they conclude that; the performance of the engine is increased 30-40% than the previous [14].

Coming to Palm oil, there are many advantages are there by using palm oil for the production of biodiesel. Because, palm oil an oleaginous tropical plant, has the highest oil productivity per unit of land on earth. The yield of palm oil is 5000 kg/hectare, which is high compared to the yielding capacity of others oils. Among other crops for producing fuel, palm oil demonstrates good competitiveness. Palm oil blended diesel has emerged as an alternative fuel for an internal Combustion engine satisfying certain criteria, such as requiring minimum engine modification, Offering uncompromised engine life and not being hazardous to human health and the Environment during production, transportation, storage and utilization [15]. In order to increase the performance and controlling the emissions, the engine modifications were done, the modifications effect on both performance and emissions of the engine. [16] One of the modifications was changing the fuel injection pressure. Fuel injection pressure is the common modification done on the engine to change the pressure of fuel injected into the combustion chamber. [17] By changing the fuel injection pressure 240bar with linseed oil they get the good results. [18]

III. PRODUTION OF BIODIESEL

Palm oil is selected for the analysis. Palm oil is converted into Biodiesel through Transesterification. In Transesterification reaction we mix palm oil with Methanol and heated to a temperature 60-70^{0}C, in the presence of a base catalyst alcoholic KOH (potassium hydroxide). The ratio of proportions of palm oil, methanol, and base solution are 10:5:3. After the reaction is completed we got two products, one is Biodiesel and other is Glycerin. Now we separate Biodiesel from Glycerin by means of a separating funnel. After that the Biodiesel obtained is water washed twice to get pure Biodiesel. The chemical reaction is represented as

CH2OCOR' +
CH2OH +



3ROH =
R'COOR [11]
(Vegetable oil)
(Glycerin)

(Alcohol)
(Biodiesel)

Now the Biodiesel is checked for its fuel properties like Viscosity, Density, Flash and Fire point, acid value, Cloud and Pour point. The viscosity was measured with Redwood viscometer (IS: 1448 (P25)) at 400C. Flash and Fire point were measured with Pensky Marten flash point apparatus (IS: 1448(P66)). The density was measured with Hydrometer (IS: 1448(P16)). Acid value can be measured according to ASTM D974 by indicator titration method. Cloud and Pour points were found by using a test tube ,thermometer rapid cloud and pour point tester (IS: 1448(P10)). A flowchart of the commercial production of palm biodiesel in Malaysian biodiesel industry is shown in Figure 3.

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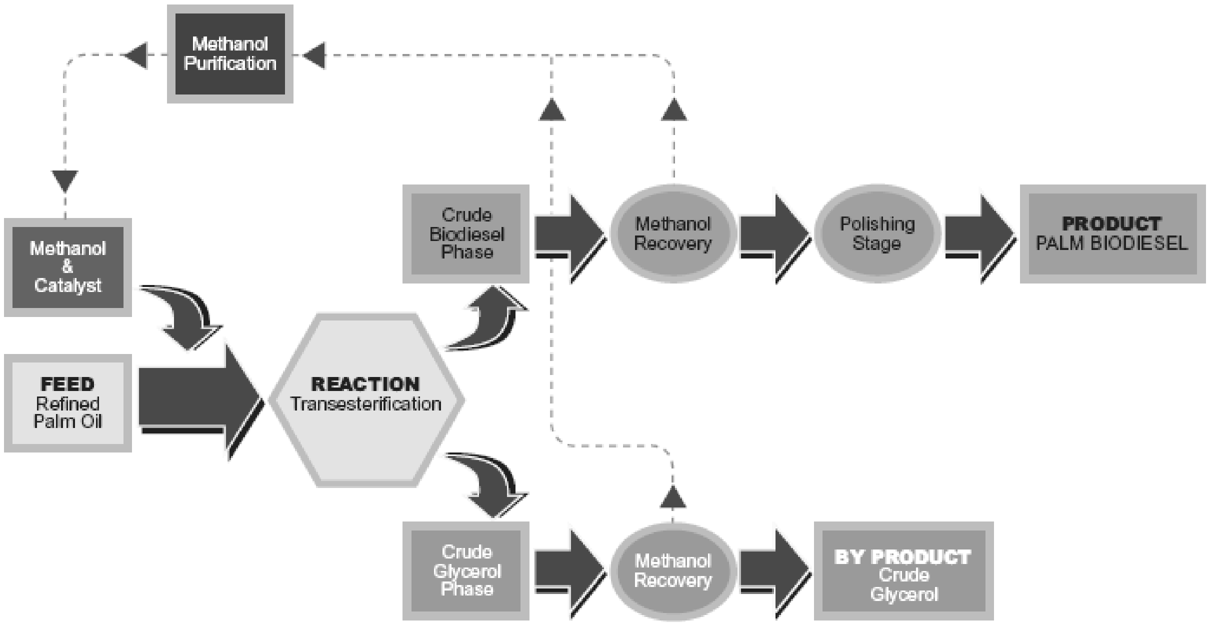

Figure 3.1: Flowchart of commercialized palm biodiesel production

Table 3.1-Properties of the Palm Oil Biodiesel

Property	**Value**
Viscosity	5.7 mm^2/sec
Density	0.867 g/ml
Flash point	160 ^{0}c
Fire point	192 ^{0}c
Acid value	0.43 mg of KOH/gm
Cloud point	18 ^{0}c
Pour point	16 ^{0}c
Calorific value	40,062 KJ/KG
Saponification value	199.46
Cetane number	65

IV. EXPERIMENTAL AND PROCEDURE

The analysis is done on the Computerized Variable Compression ratio multi fuel direct injection water cooled engine. The experiment is done at constant compression ratio (18) of the engine. Initially we have done the base line tests, which are with diesel at fuel injection pressures 180 bar, and then experiment is repeated with different ratios of palm oil biodiesel blends (P10, P20, P40, P60 and P80).

Engine specifications

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
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

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Table 4.1 Compositions of different % of Palm oil batches

Batch Code	Palm oil %	Diesel %
P0	0	100
P10	10	90
P20	20	80
P40	40	60
P60	60	40
P80	80	20
P100	100	0

V. RESULTS AND DISCUSSION

The analysis is done using palm oil and biodiesel blends at different proportions with different injection pressures, the results are shown in below

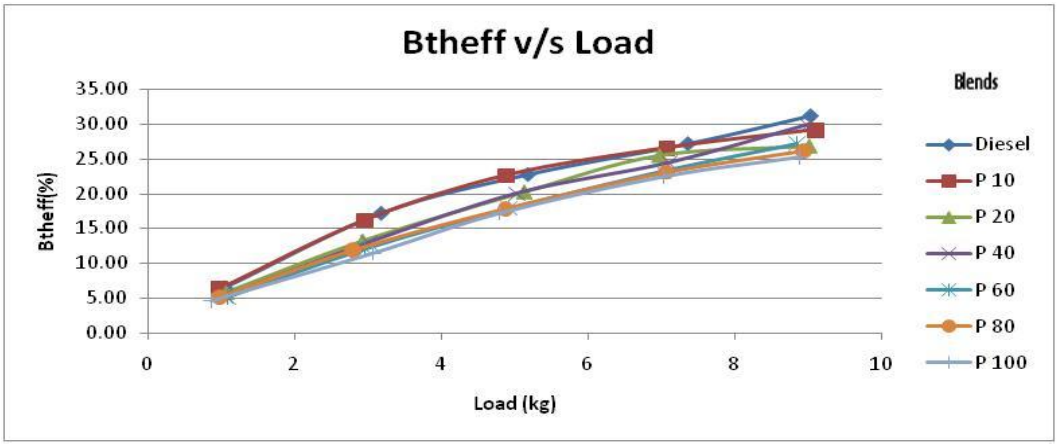

Figure 5.1: Comparison of Btheff (%) for various palm biodiesel blends with diesel (for different load)

The variation in Break thermal efficiency (BTE) of the engine with diesel fuel, palm oil and its blend is shown in Figure 5.1. Thermal efficiency is the ratio between the power output and the energy introduced through fuel injection, the latter being the product of the injected fuel mass flow rate and the lower heating value. It can be seen from Figure 5.1 that t Figure shows (i) as load increases Btheff increases for all blends. from lower load to partial load and lower load to full load its increases for B10,B20 blends are 72.25% ,71.09% and 78.48%,78.16%espectively.(ii)Comparing break thermal efficiency of diesel engine for pure diesel to B10,B20,B40 fuel Decrease in break thermal efficiencies of engine At partial load are 0.48%,11.89%,11.68% and At full load pre 6.38%,13.87%,4.2% respectively . This is due to the higher viscosity, density and lower heat value than the diesel fuel. The higher viscosity leads to decreased atomization, fuel vaporization and combustion and hence the thermal efficiency of biodiesel is lower than that of diesel fuel. So at partial load B10 and for full load B40 is better performance and Btheff of engine near to diesel fuel as fuel

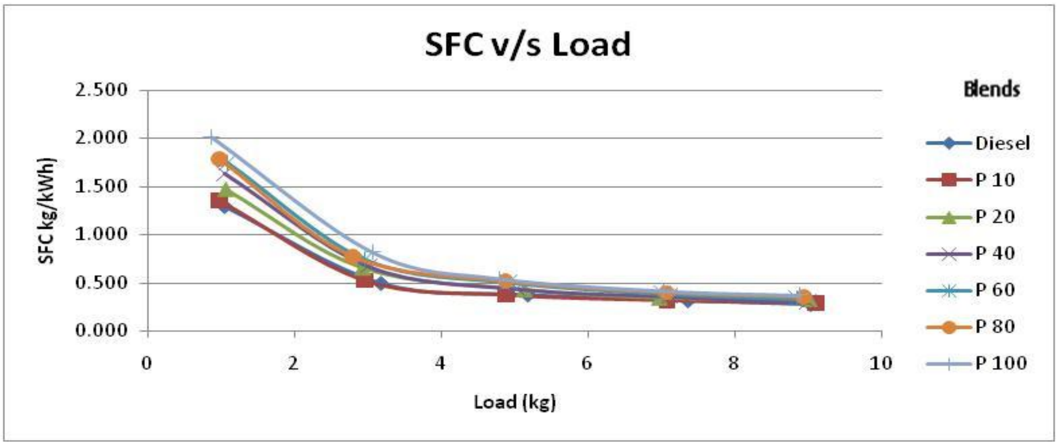

Figure 5.2. Comparison of SFC (kg/kWh) for various palm biodiesel blends with diesel (for different load)

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Figure 5.2 shows (i) As load increases SFC (specific fuel consumption) decreases for all blends (ii)Comparing SFC of diesel engine for pure diesel to B10,B20,B40 fuel increases in SFC of engine At partial load are 1.51%,14.51%,18.03% and At full load pre 7.88%,18.54%,8.67% respectively so at partial load B10 and for full load B10 ,B40 is better performance and SFC of engine near to diesel fuel as fuel. It is seen that SFC is highest for pure biodiesel and lowest for diesel because of high viscosity, density, low volatility and low heat content of pure biodiesel when compared with that of diesel.

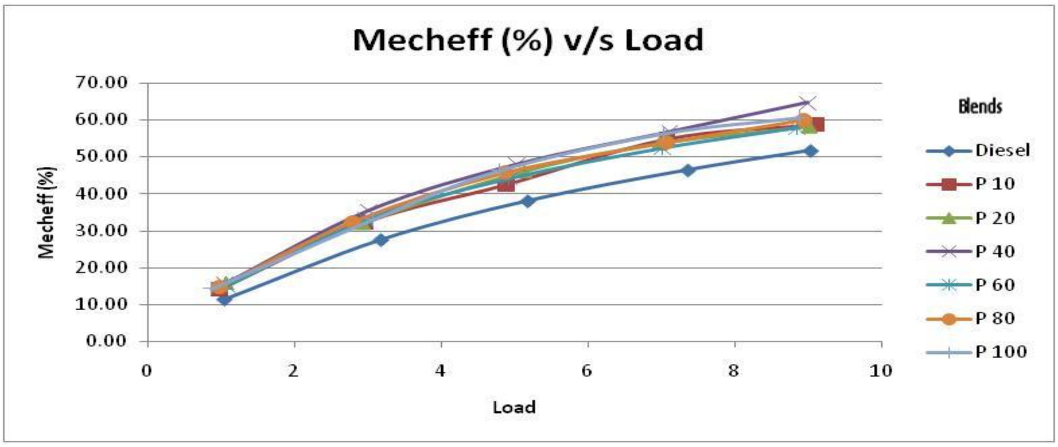

Figure 5.3 Comparison of Mecheff (%) for various palm biodiesel blends with diesel (for different load)

Figure shows (i) As load increases Mecheff (Mechanical efficiency) increases for all blends(ii)Comparing Mecheff of diesel engine for pure diesel to B10,B20,B40 fuel increases in Mecheff of engine At partial load are 11.67%,21.24%,26.00% and At full load pre 13.77%,12.65%,24.99% respectively so at partial load as well as at full load B40 fuel is better engine performance and at lower load Mecheff of engine Increases for B20, B40 ,B60 are 40.88%, 37.18% , 33.30% so these blends having good engine performance at lower load.

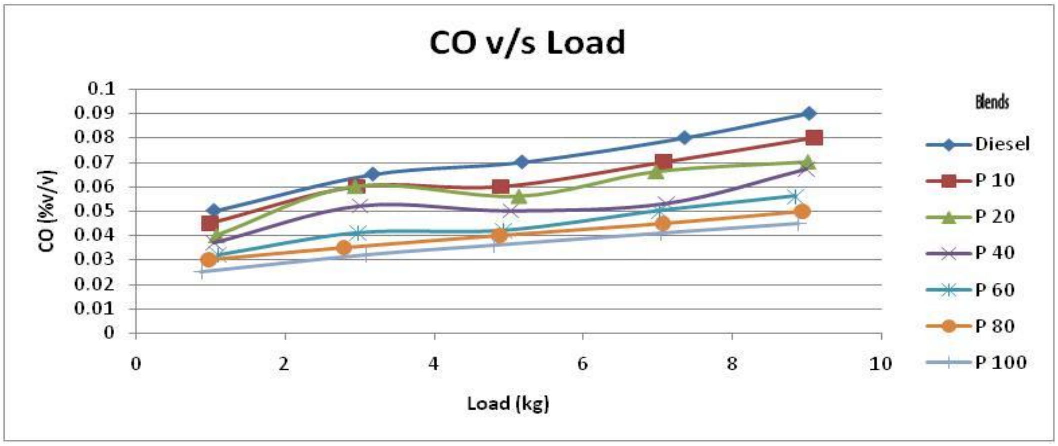

Figure 5.4 Comparison of CO (%v/v) Emission for various palm biodiesel blends with diesel (for different load)

Figure5.4 shows (i) As load increases CO (Carbon monoxide) Emission increases for all blends(ii)Comparing CO Emission of diesel engine for pure diesel as fuel maximum CO emission decreases for B60, B80and B100(pure biodesel) blends. for B60,B80,B100 fuel decreases in CO Emission of engine At partial load are 40%,42.86%,48.17% and At full load pre 37.78%,44.44%,50% respectively . at partial load as well as at full load B100 fuel is better engine emission characteristics CO emission is highest for pure biodiesel because of poor spray characterization that results in improper combustion which gives rise to CO formation.

Figure shows (i)As load increases HC(Hydro carbon) Emission increases for all blends (ii)Comparing HC Emission of diesel engine for pure diesel as fuel HC emission decreases maximum for B60, B80and B100(pure biodiesel) blends. for B60,B80,B100 fuel decreases in HC Emission of engine At partial load are 30.95%,35.71%,47.72% and At full load pre 29.17%,35.42%,43.75% respectively at Lower load, partial load and at full load B100 fuel maximum decreases in HC emission. Compared to diesel, the oxygen availability in the bio diesels is more. So the HC emissions are less than diesel. The emissions of unburnt hydrocarbon for biodiesel exhaust lower than that of diesel fuel

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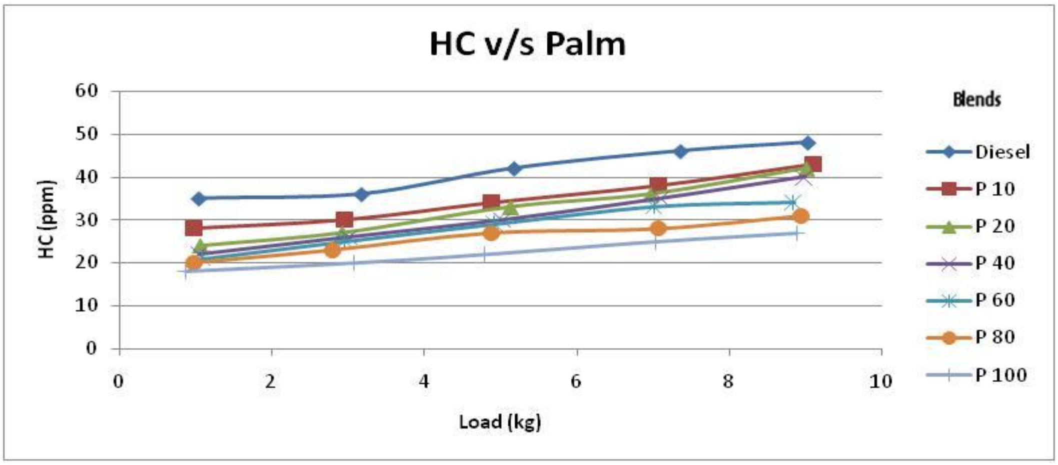

Figure 5.5 Comparison of HC (ppm) Emission for various palm biodiesel blends with diesel (for different load)

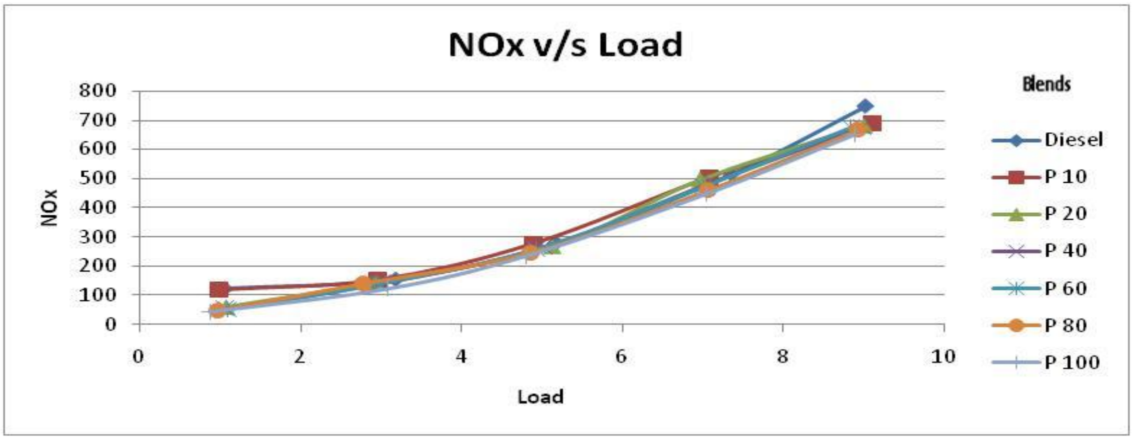

Figure 5.6 Comparison of NOx (ppm) Emission for various palm biodiesel blends with diesel (for different load)

Figure 5.6shows (i)As load increases No_x (Nitrogen oxide) Emission increases for all blends (ii)Comparing No_x Emission of diesel engine for pure diesel as fuel No_x emission decreases maximum for B60, B80and B100(pure biodiesel) blends. for B60,B80,B100 fuel decreases in No_x Emission of engine At partial load are 7.86%,12.14%,16.07% and At full load pre 9.88%,10.68%,13.22% respectively, So at partial load and at full load B100 fuel maximum decreases in No_x emission. The NOx emission and its blends are slightly higher than diesel fuel for all loading conditions. This is due to higher viscosity of blended fuels and increase in heat release rate when compared with diesel fuel

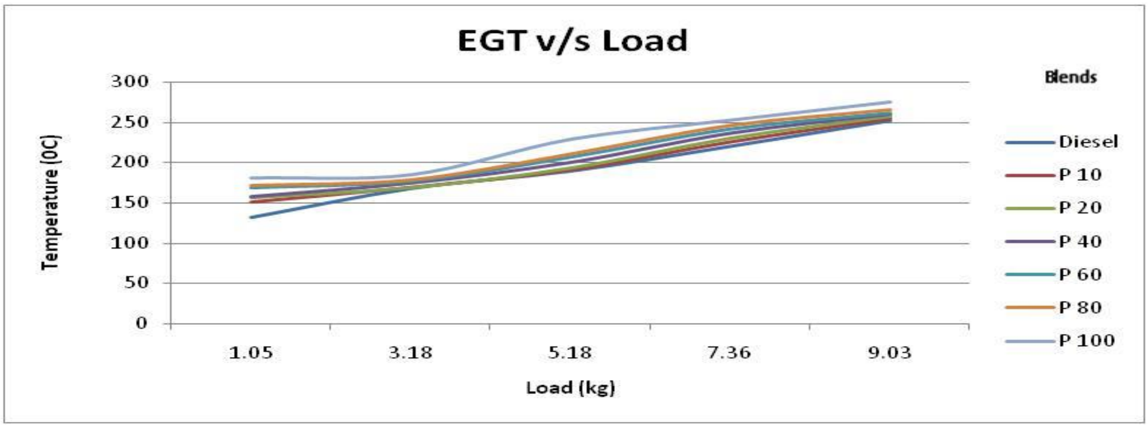

Figure 5.7 Comparison of EGT (°C) for various palm biodiesel blends with diesel (for different load)

Figure 5.7 shows (i)As load increases EGT (Exhaust Gas Temperature) increases for all blends (ii)Comparing EGT of diesel engine for pure diesel as fuel EGT increases minimum for B10,B20,B40 blends. For B10, B20, B40 fuel

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Increases in EGT of engine. At partial load are 0.6%, 2.22%, 5.76% and At full load pre 1%, 2.15%, 2.99% respectively. At, partial load and at full load B10 fuel minimum increases in EGT. The EGT of P80 is very close to diesel fuel due to higher viscosity, which results in poorer atomization, poorer evaporation and extended combustion.

VI. CONCLUSIONS

During the present investigation several tests were carried out on a four stroke single cylinder inject diesel engine using diesel and Palm biodiesel at different proportions. From the experimentation following conclusions were drawn.

i. Break thermal efficiency (BTE) in case of diesel, P10, P20, P40, P60 and P80 the thermal efficiency, decreases with increasing proportion of biodiesel in the test fuels. This is due to the higher viscosity, density and lower heat value than the diesel fuel.
ii. Hydrocarbon emission increases with that of load for all prepared test fuels. It is understood that biodiesel produces less HC emission in comparison to that of diesel because of better combustion of the test fuel and its blend with additive due to presence of oxygen.
iii. It is observed that CO emission decrease with increase in load for all prepared test fuels. CO emission is highest for pure biodiesel because of poor spray characterization that results in improper combustion which gives rise to CO formation.
iv. Without engine modifications (i.e. at 210bar standard engine pressure) P20 and P40 gives the best results both in performance and emissions
v. With engine modifications (i.e. by changing the fuel injector pressure to 230bar) 100% palm oil (i.e. P100) shows the best results both in performance and emissions.

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