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Polanga Oil Methyl Ester as a Potential Fuel for Twin Cylinder Diesel Engine

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Abstract

In the present study, an experimental investigation is made to evaluate the performance and emission characteristics of a twin cylinder diesel engine using different blends of methyl ester of Polanga oil with mineral diesel. Polanga methyl ester is blended with diesel in proportions of 20%, 40%, 60% and 100% by mass and studied under various load conditions in a diesel engine. The performance parameters are found to be very close to that of mineral diesel. The brake thermal efficiency and brake specific fuel consumption of 20% and 40% blended fuels are better than mineral diesel under certain loads. The emission characteristics are also studied and levels of carbon monoxide, nitrogen oxide and hydrocarbons emissions of all blended fuels are found to be lower than pure diesel under all load conditions.

Keywords**—**Polanga oil, twin cylinder, diesel engine, emission.

1. Introduction

Energy is the vital element for the economic growth of a country. It enhances economic prosperity, personal comfort and quality of life. The recent trends of energy used in major parts of the world, demands more amount of commercial energy (namely oil and electricity) to cater the need of rapidly increasing population and improvement in quality of life. The combustion of fossil fuel generates huge quantity of harmful pollutants which include carbon dioxide (CO2), carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NOx), oxides of sulphur (SOx), benzene

(C_6H_6), polyaromatic hydrocarbons (PAH), aldehydes and particulate matter (PM) [1, 2]. These pollutants are precursor of the major environmental hazards like global warming, climatic change, erratic monsoon etc. Worldwide efforts have been made to optimize the use of fossil fuel to its minimum level and to mitigate these pollutants from both vehicular and power plant sources by improving fuel quality and adopted technology. Further most of the developing countries including India are facing a lot of challenges because of inadequate and limited reserves of fossil fuel as well as technology. Keeping in view the global energy crisis, dependence on imported fossil fuels, global warming and affect on human health due to hazardous emissions emitted by fossil fuel based sectors, global interest is generated to do more research work to find out the viable alternative fuels. Agarwal and Das [3] stated that the higher viscosity of plant oil creates some engine problems like poor fuel atomization which leads to poor engine performance, ring sticking, injector pump failure and injector deposit etc. Wang et al. [4] conducted experiment using vegetable oil blends with diesel and presented that lower NOx and a small change in CO emission compared to diesel. Senthilkumar et al. [5] carried out experiment using Jatropha oil-diesel blend and reported that EGT, HC, smoke and CO emissions are higher than mineral diesel. Agarwal et al. [6] conducted experiments using preheated Karanja oil. It was observed that during the engine operation on Karanja oil both in preheated and blended form, the performance and emission parameters were found to be similar with fossil diesel for lower concentrations of blend. Whereas, for higher concentrations of blend, performance and emissions were observed to be marginally low. Deshpande [7] used blends of linseed oil and diesel to run the CI engine. Minimum smoke and maximum brake thermal efficiency were noted in this study. Nazar et al. [8] analyzed the performance of coconut oil in diesel engine in biodiesel and neat mode. It was reported that neat coconut oil and its methyl ester can be directly used in diesel engines without any modifications. Engine performance with coconut oil methyl ester was better than with neat coconut oil. Alltiparmak et al. [9] examined the effect of blends of tall oil bio-diesel with diesel fuel as substitute fuels for diesel. It was found that the performance parameters such as power output and engine torque with tall oil biodiesel-diesel blends increased up to 5.9% and 6.1% respectively. It was also observed that CO emissions decreased to 38.9% and NOx emissions increased up to 30% with this fuel blends. The variation of smoke opacity was insignificant. Malhotra et al. [10] conducted experiments taking Karanja and Jatropha bio-diesel in diesel engine with and without catalytic converter. It was reported that Bio-diesel blending in diesel helps to improve the physico-chemical properties. Blends of biodiesel in diesel had shown significant benefits in terms of emissions particularly those of CO and particulate matter. Use of catalytic converter found to be helpful in reduction of CO emissions in a diesel vehicle. The use of biodiesel which has in-built oxygen further helps in improving the efficiency of catalytic converter; there by further reduction of CO. Nabi et al. [11] investigated the exhaust emissions and combustion characteristics using neat diesel oil and diesel–biodiesel blends. From the investigation it was found that diesel-bio-diesel blends showed lower carbon monoxide (CO) and smoke emissions but higher oxides of nitrogen (NOx) emission as compared to conventional diesel fuel. However, when EGR was applied, NOx emission with diesel–biodiesel blends was slightly reduced as compared to diesel. Centinkaya et al. [12] conducted experiments with objective to reduce the production cost of Biodiesel using low cost feedstock such as waste oils, used cooking oil and animal fats. They investigated the road performance of diesel engine fuelled with used cooking oil biodiesel. The results showed that the performance parameters like engine torque and brake power using used cooking oil bio-diesel were 3–5% less than those of base line diesel. Dincer [13] reported that use of biodiesel in diesel engine shows lower emission parameters such as CO, CO2, ozone-forming hydrocarbon and particulate matter and higher NOx emission compared to fossil diesel. Agarwal and Rajamanoharan [14] conducted experiments using preheated and blended Karanja oil in diesel engine. It was observed that during the engine operation on Karanja oil both in preheated and blended form, the performance and emission parameters were found to be similar with fossil diesel for lower concentrations of blend. Whereas, for higher concentrations of blend, performance and emissions were observed to be marginally lower.

2. Polanga oil as a potential fuel for diesel engine

Calophylluminophyllum, commonly known as Polanga, is a non-edible oilseed ornamental evergreen tree. The press cake that is left after oil extraction is a valuable waste product, since it contains both nutrients taken from the soil, and energy. The slurry that is left after digestion can be used as a fertilizer for the Polanga plantation. In this way, all parts of the plant can be optimally used for energy purposes.

3. Development of polanga bio-diesel fuel

Firstly, the crude Polanga oil is collected from the crusher mill, which is a clear, viscous and dark brown in colour. Then it is filter with a nylon mesh cloth filter. After filtration, the phosphorus in the crude oil is removed by a chemical process called degumming. In this process the oil is treated with 1% v/v phosphoric acid. After degumming, The Polanga oil is processed for bio-diesel production by transesterification method. The first step of biodiesel production i.e. esterification of crude oil, in which degummed polanga oil is mixed with 22% volume/volume (v/v) ratio methanol and1% v/v ratio sulphuric acid. The mixture is then heated in a constant temperature bath for one hour with continuous stirring at 65 °C. This esterified mixture is then transesterified. In this process, acid esterified Polanga oil is taken in transestrification unit in which a reagent mixture is mixed with this esterified oil. A reagent mixture is prepared with anhydrous methanol (22% v/v) and base catalyst (0.5% v/v ratio) of potassium hydroxide (KOH). The total mixture is then continuously stirred at a constant speed below a temperature of 65 °C (i.e. the boiling point of methanol) for about 2.0 hours. Then the stirring and heating is stopped and the mixture is allowed to settle down for about 24 hours. After settling, glycerol which is dark in colour is obtained in the lower layer and separated through separating valve. The upper layer which is Polanga methyl ester is collected separately. Then water washing of methyl ester is performed 2-3 times to remove extra esters and KOH if any. It is then heated above 65 °C to remove additional methanol to obtained pure Polanga bio-diesel (PB) or Polanga oil methyl ester (POME).

4. Blend oils preparation method

In the present work, the blends used are P20, P40 and P60. The blend P20 is prepared by mixing 20% Polanga oil with 90% diesel by weight basis followed by the preparation of other blends P40 & P60. Firstly, the sample of various concentrations of this oil and diesel are weighed and taken in a container. The mixture formed is stirred for one hour by a stirring unit. After preparation of the above blends, some of the important properties of the test fuels are carried out before use in engine. Fuel properties like density, kinematic viscosity, flash point, fire point, cetane number and calorific value, cloud point and pour point etc are estimated using various ASTM methods and instruments as shown in Table-1. The properties of test fuels are shown in Table-2.

Table 1: ASTM methods and instruments used for measurement of fuel properties

Properties	ASTM Methods	Instruments
Density at 25^{o}C(kg/m^3)	D 1298	Hydrometer
Kinematic viscosity at 40^{o}C (cSt.)	D 445	Kinematic Viscometer
Calorific value (MJ/kg)	D 240	Bomb Calorimeter
Cetane number	D 613	Ignition Quality Tester
Flash point (^{o}C)	D 93	Pensky-Martens closed cup tester
Fire point (^{o}C)	D 93	Pensky-Martens closed cup tester

Table 2: Properties of Diesel, Polanga bio-diesel & its blends

Properties	Diesel	PB100	PB60	PB40	PB20
Density at 25^{o}C(kg/m^3)	825	869	860	854	852
Kinematic viscosity at 40^{o}C (cSt.)	2.76	3.99	3.61	3.30	2.98
Calorific value (MJ/kg)	42.5	41.2	41.4	41.8	42.1
Flash point (^{o}C)	73	117	96	91	87
Fire point (^{o}C)	103	121	110	106	105
Cloud point (^{o}C)	-12	12.8	9.3	5.98	4.78
Pour point (^{o}C)	-16	4.5	3.7	3.2	2.4

5. Experimental setup & procedure

The experimental setup consists of a twin cylinder 4-stroke water cooled diesel engine coupled with generator and bulb loading devices. The detailed specifications of the engine are given in Table-3. The experiment is conducted in two modes of operation such as in diesel mode as well as in blending modes. Initially, the engine is started with diesel, after warm-up of the engine, the readings are taken. The engine is operated on diesel first and then on biodiesels blends of Polanga. Different fuel blends and diesel are subjected to performance and emission tests under different loads such as at no load, 20%, 40%, 60% and 100% of rated load of the engine. The performance data's are analyzed regarding thermal efficiency, brake specific fuel consumption, exhaust gas temperature and emissions such as CO, HC, CO_2, NO and smoke. Manometer is used to measure the air flow. The engine is always operated at its rated speed of 1500 rpm, injection timing of 23^o before top dead centre (BTDC) and injection pressure of 212 bar. The fuel flow rate is measured with the help of a burette. The temperature of exhaust gas is measured with the help of a mechanical thermocouple. The AVL make 5-gas analyzer (model no. AVL Digas 444) used to measure exhaust gas emission parameters and AVL smoke metre is used to measure smoke opacity. The schematic diagram of the experimental setup is shown in Figure 1.

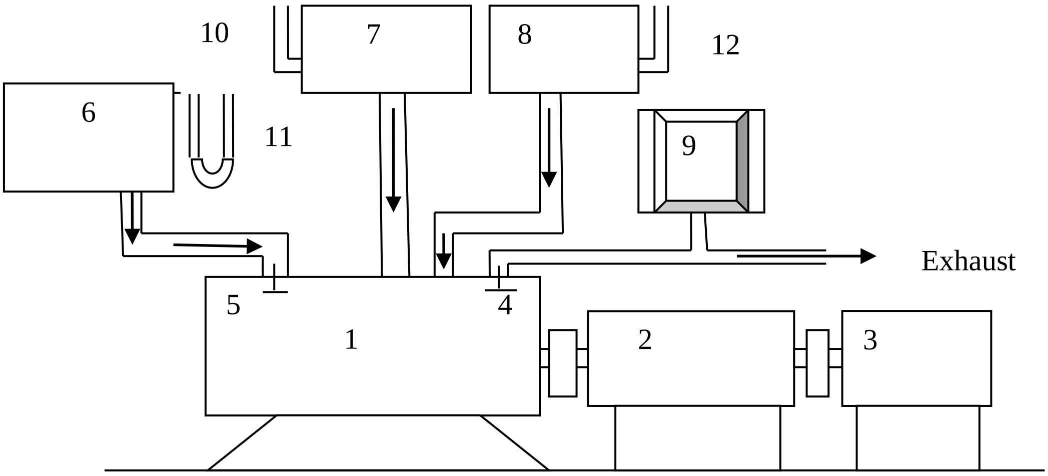

Figure 1: Schematic diagram of the test engine set up

1. Engine, 2. Generator, 3. Loading unit, 4 & 5. Exhaust &inlet valve, 6. Air tank 7. Diesel tank, 8. Blended tank, 9. Exhaust gas analyzer, 10&12. Fuel burret.

Table 3: Test engine specification

Parameters	Description
Make	Kirloskar oil Engines Ltd, India
Engine type	4 stroke Twin Cylinder Direct Injection C.I. Engine
Model	AV-1
Rated power	10.34 kW at 1500 rpm
Compression ratio	17.5:1
Bore x stroke	110 mm x 114 mm
Injection pressure	212bar
Injection Nozzle Opening	23°bTDC
Lubricating oil	SAE 20 W40
Cooling type	Water cooled
Dynamometer	Eddy Current Type (10kW, 43.5 A)

6. Results and discussion

6.1. Brake specific energy consumption (BSEC)

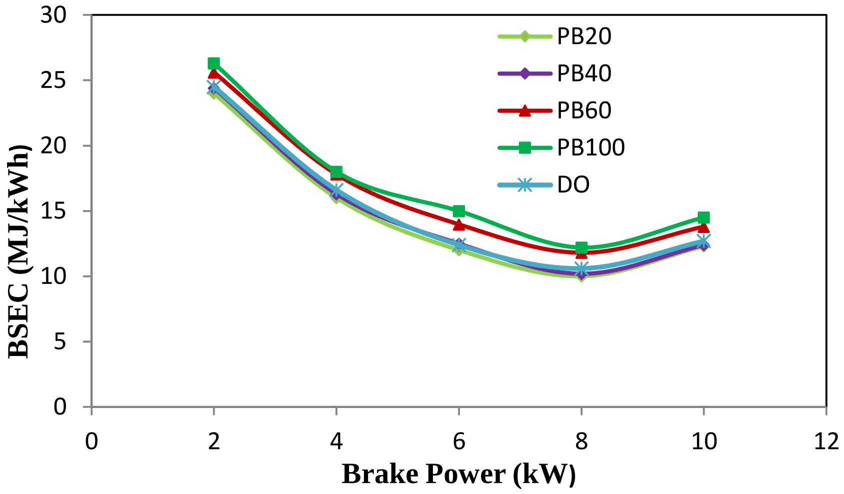

Figure 2: Variation of BSEC with brake power

Figure 2 shows the variation of the brake specific energy consumption with load. When two different fuels of different heating values are blended together, the fuel consumption may not be reliable, since the heating value and density of the two fuels are different. In such cases, the brake specific energy consumption (BSEC) will give more reliable value. It is observed that with increase in load up to 8 kW, BSEC decrease for both mode of operation due to better combustion as a result of higher cylinder charge temperature. However, at highest load, BSEC values for both modes of operation are increased due to insufficient oxygen. Again it is observed from the figure that the BSEC for PB20 and PB 40 is lower as compared to that of diesel fuel. The availability of the oxygen in the Polanga methyl ester-diesel fuel blends may enables complete combustion and the negative effect of increased viscosity would not have been initiated. However, the blends PB60 and PB100 shows higher BSFC compared to base line diesel. This could be due to the lower calorific value, high viscosity of the Polanga bio- diesel and the high mass flow of fuel entering into the engine (specific gravity of PB more than diesel).

6.2.Brake thermal efficiency (BTE)

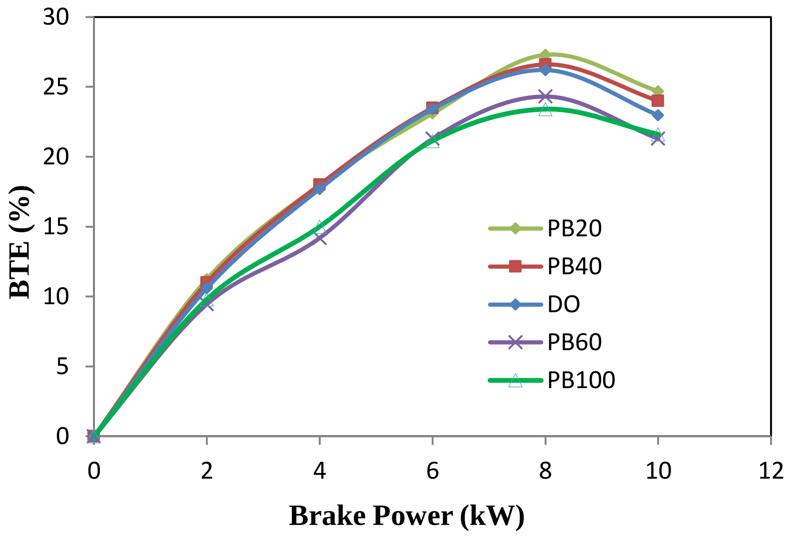

Figure 3: Variation of BTE with brake power

Figure 3 explains the variation of BTE in both modes of operation for all test fuels under different brake power output. It is found that there is a continuous increase in BTE for all test fuels for both modes of operation up to 8 kW load. This is due to the higher cylinder charge temperature. However, at highest load, the BTE decreases due to inferior combustion as a result of insufficient oxygen for both modes of operation. Furthermore, the BTE for 20% and 40% blends show slightly higher value than diesel.The higher thermal efficiencies may be due to the additional lubricity provided by the fuel blends. Further increase in blend percentage in diesel, BTE decreases considerably. This may be due to lower calorific values and higher fuel consumption. The highest values of BTE are observed to be 28.4%, 27.2% and 26.3% for PB20, PB40 and diesel respectively, at 8 kW load.

6.3. Exhaust gas temperature (EGT)

The variation of EGT values with brake power under both modes of operation are shown in Figure 4. It is found that EGT values increase with increase in loads, for both modes of operation. The reason may be with increase in load, the energy input into the engine cylinder increases.Exhaust gas temperature is an indicative of the quality of combustion in the combustion chamber. The blended fuels show higher EGT compared to base line diesel. This may be due to heat release occur in the later part of the power stroke as a result of higher viscosity and larger fuel droplet size of the blended fuels compared to diesel. So this may result in lower time for heat dissipation and higher exhaust gas temperatures.

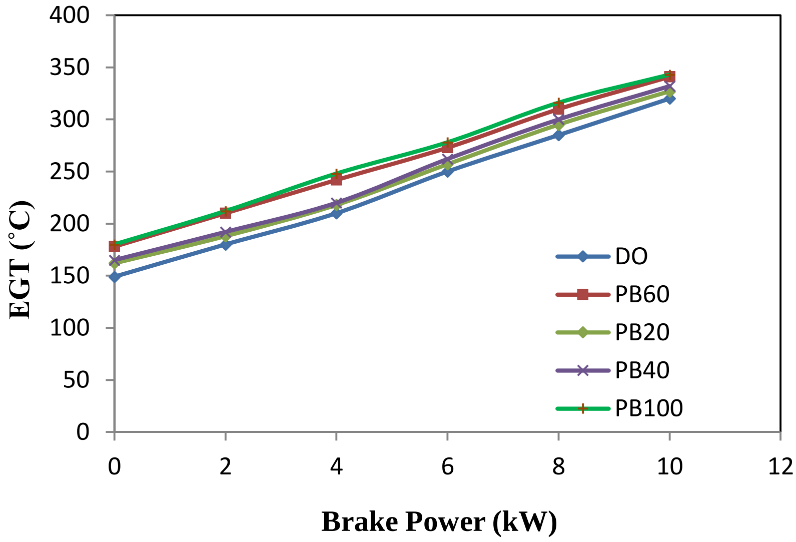

Figure 4: Variation of EGT with brake power

6.4. Carbon monoxide (CO) emission

The variation of CO emission with different brake power for all test fuels is shown in Figure 5. It is found that with increase in loads, the CO emission decreases and at highest load it increases for all test fuels. This is due to better combustion at higher loads as a result of higher charge temperature, but at highest load, the fuel richness causes incomplete combustion. Again, CO emission for blends 20% and 40% is considerable lower than diesel. This is due to availability of oxygen in blended fuels which enhances the combustion process. The other reason may be due to lower carbon to hydrogen ratio in the bio-diesel. But for 60% and 100% blends, the CO emission is comparable with diesel. This is due to the negative effect of increased viscosity suppresses the combustion process. Hence, more CO compared to the blends 20% and 40%.

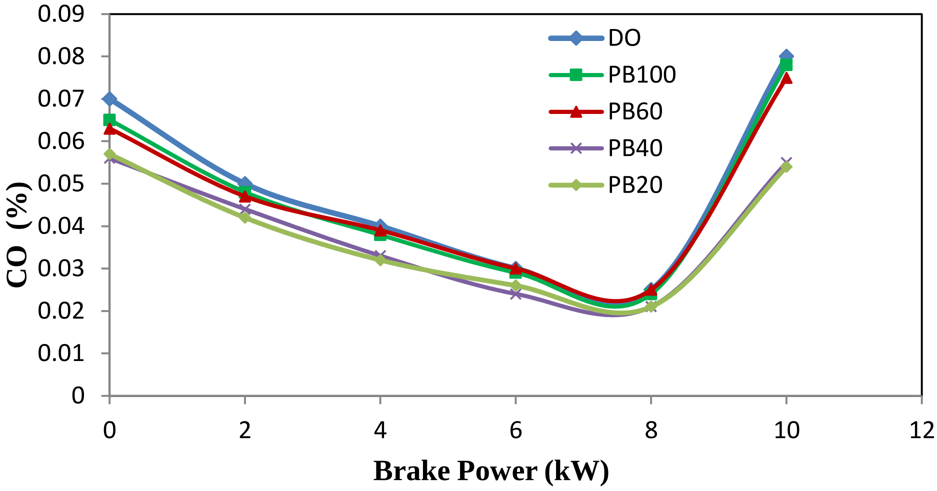

Figure 5: Variation of CO emission with brake power

6.5. Hydrocarbon (HC) emission

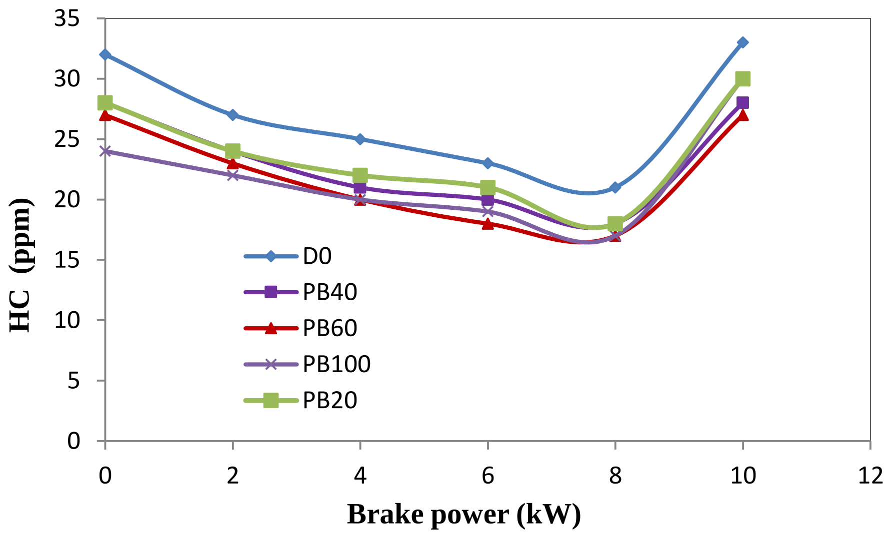

Figure 6: Variation of HC emission with brake power

Figure 6 indicate that the HC emission trends are similar with CO emission. However, a significant reduction in HC emission is achieved in case of all blended fuels compared to diesel. As the cetane number of ester based fuel is higher than diesel, it exhibits a shorter delay period and results in better combustion leading to low HC emission. Also the intrinsic oxygen contained by the POME is responsible for the reduction in HC emission.

6.6. Nitrogen oxide (NO) emission

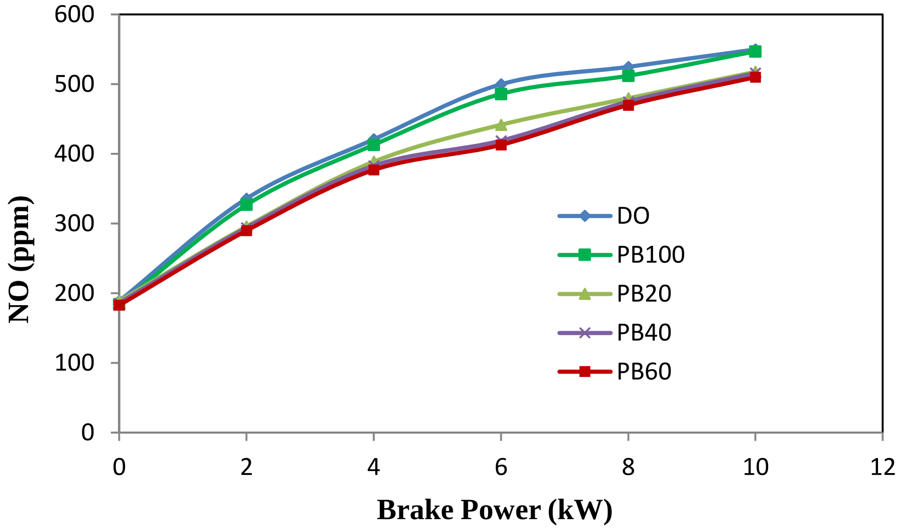

Figure 7. Variation of NO emission with Brake Power

Figure 7 shows the variation of NO emission for all test fuels under different brake power. It is found that with increase in load, NO emission increases due to increase in energy input for all test fuels. However, with increase in blend percentage in diesel, NO emission decreases. This could be attributed to the lower peak combustion temperature as a result of lower energy released by blended fuels. But the reduction is remarkable for the blends 20%, 40% and 60%. However, for 100% methyl ester, the NO emission is comparable with diesel may be due to availability of oxygen and residence time.

7. Conclusion

Polanga methyl ester seems to have a potential to use as alternative fuel in twin cylinder diesel engines. Blending with diesel decreases the viscosity considerably. The following results are made from the experimental study

- The brake thermal efficiency of the engine with Polanga methyl ester-diesel blend(20% & 40%) is marginally better than with neat diesel fuel.
- Brake specific energy consumption is lower for Polanga methyl ester-diesel blends(20% & 40%) than diesel at all loading.
- The exhaust gas temperature is found to increase with concentration of Polangamethyl ester in the fuel blend due to coarse fuel spray formation and delayedcombustion.

- The emission characteristics of all blended fuels are better than pure diesel exceptCO2 emission
- PB20 and PB 40 can be accepted as a suitable fuel for use in standard diesel engines without any modification.

8. References

[1] F. Kelly, "Australia seeks to hike Oilseed Production," Inform Vol. 8, no.17, pp 834, 1996.

[2] S. Bari, W. C. Yu, and T. H. Lim, "Performance deterioration and durability issues while running a diesel engine with crude palm oil," Proceedings of Institution of Mechanical Engineers. Part D: Journal of Automobile Engineering, Vol. 216, no. D1, pp.785, 2002.

[3] A. K. Agarwal,and L. M. Das, "Biodiesel development and characterization for uses a fuel in compression ignition engine," J Eng. Gas Turbine Power, Vol. 123, no.2, pp.440, 2000.

[4] Y. D. Wang, T. AL-Shemmeri, P. Eames, J. McMullan, T. Hewitt, and Y. Huang, "An experimental investigation of the performance and gaseous exhaust emission of a diesel engine using blends of a vegetable oil," Applied Thermal Engineering, Vol. 26, no.14-15, pp.1684, 2006.

[5] M. Senthilkumar, A. Ramesh, and B. Nagalingam, "Experimental investigation on Jatropha oil-methanol dual fuel engines SAE 2001-01-0153, 2001.

[6] A. K. Agarwal, and K. Rajamanoharan, "Experimental Investigations of performance and emissions of Karanja oil and its blends in a single cylinder agricultural diesel Engine,"Applied Energy, Vol. 86, no.1, pp.106, 2009.

[7] N. V. Deshpande, "Bio-diesel: An alternative fuel for compression ignition engines", Proceedings on Recent trends in alternative fuels, Nagpur, India, 2002.

[8] J. Nazar, A. Remesh and B. Nagalingarn, "Investigation on the use of coconut oil and its Bio-diesel in a DI Diesel Engine," SAE International 2006 28-0005, 2006.