Effect of Fuel Injection Pressure on CI Engine Performance Using Preheated Karanja Oil as A Fuel

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Abstract:

This paper shows the performance of a four stroke, single cylinder C.I. engine with Karanja oil preheated to 80°C. The performance parameters considered for comparison are BSFC, BSEC, BTE and BP of the engine. The engine offers lower thermal efficiency when it is powered by preheated Karanja oil at higher speed. After investigation, it is concluded that Karanja oil can be used to some extent as an option to diesel in a C.I. engine without any engine modifications. From this study it is also concluded that with an increase of injection pressure from 180 bar to 208 bar, BTE increases from a value of 24.75 % to 26.88%, BSFC decreases from 0.43 to 0.39 kg/kWh and BSEC reduces to 13393kJ/kWh. The performance with neat Karanja (*Pongamia pinnata*) oil was found very close to performance with neat diesel at 208 bar Fuel Injection Pressure.

Keywords—Alternative fuel, Compression ignition engine, Neat Karanja oil, Preheated Karanja oil, Fossil diesel, Fuel injection pressure

Introduction

The continuing rise in prices, growing concern on environment from exhaust emissions, global warming and threat of supply instabilities have led to a growing concern for alternative fuel for diesel engines throughout the world, more so in the petroleum importing countries like India. Dependence on foreign sources of energy has been always a bane for any country, particularly for countries like India. It is the single biggest drain on the foreign exchange reserves of the country. This will put strains on the existing supply systems, increasing the risk of international conflicts over fossil fuels. Fossil fuel extraction is expected to peak during the current decade. Due to this, the conventional fuels especially petrol and diesel for internal combustion engines, are getting exhausted at an alarming rate. In order to conserve the fossil fuels or to plan for survival of technology in future, it is essential to plan for alternate fuels. Some of the pollutants released by the internal combustion engines are HC, CO, NOx, smoke and particulate matter. In view of this and many other related issues, these fuels will have to be replaced completely or partially by less harmful alternative, eco-friendly and renewable fuels for the internal combustion engines.
An increase of $1 per barrel of crude oil prices adds $425 million to Indian oil import bill [4]. From the point of view of long term energy security, it is necessary to develop new alternative fuels with properties comparable to petroleum based fuels. So, the prospects of biodiesel production from vegetable oils in India have already been mentioned by many authors [10]. The diesel fuel can not be replaced totally by the vegetable oils (in conventional diesel engines) because of the low cetane number, high

ignition temperature, high viscosity and incomplete combustion leading to increased emissions and decreased performance. Hence, only a partial replacement of diesel fuel is possible in conventional DI diesel engine. Some of these problems are mentioned in the literatures [1,2,3,6]. The technologies involved are direct use or blending of oils, microemulsion, pyrolysis, and transesterification [8]. The flash point of Karanja oil is higher than neat diesel; hence it is safe to use it in the engine. Gaseous emissions and performance of DI diesel engines are primarily influenced by combustion processes in turn controlled by fuel properties, injector opening pressure, atomization and also oxygen concentration in the fuel mixture [5]. Studies carried out so far have established that vegetable oils at room temperature cannot be used directly in compression ignition engines because of their high viscosity, which results in slow fuel flow in fuel lines and bigger droplets in the combustion chamber during atomization through the injector nozzle[**7**–9]. The bigger droplets form an inferior oil–air mixture in the combustion chamber because of poor atomization. Large droplets require more time for evaporation and subsequent mixing with the air. This poor state of mixture leads to incomplete combustion, resulting in heavy smoke emission, increased heat loss in the combustion process, and hence reduction in thermal efficiency. Vegetable oils have a high flash point compared with diesel fuel, leading to lower volatility characteristics of the oil–air mixture in the combustion chamber. The higher viscosities of vegetable oils compared with diesel fuel is attributed to their comparatively large molecular masses, i.e. around 20 times higher than that of diesel [**9**]. Vegetable oils are mainly composed of glycerides formed by the esterification of glycerol and a series of various fatty acids. One molecule of glycerol links three molecules of fatty acids to form a product of higher molecular weight called triglyceride. Each molecule of oil contains a substantial amount of oxygen. Researchers have suggested that straight vegetable oils can be used in diesel engines, but these have certain disadvantages of gumming, sticking of piston and cylinder due to heavier hydrocarbon chain. The viscosity of these oils is also more compared to that of diesel which leads to atomization and combustion problems. One way of using straight vegetable oils is to preheat the oil to reduce the viscosity as reported by A.K. Agarwal, K. Rajmanoharan, 2009 [11]. The results with preheating and without preheating show that with preheating the performance is similar to that of diesel. In the present study, non-edible vegetable oil Karanja, has been chosen to find out their suitability for use as a fuel in the diesel engine. The main objective of this study is to investigate the performance of a single cylinder, 4 stroke, constant speed, air cooled diesel engine with preheated karanja oil (straight Vegetable oil) at different fuel injection pressures (180 bar to 220 bar) and to decrease the viscosities of Karanja oil by heating it at 80^{o}C temperature with exhaust gas recirculation and to compare this with diesel fuel.

2. Methodologies and Test

The experimental setup is shown in Figure 1. The specifications of the engine are given in Table1. Tests were conducted using diesel and preheated Neat Karanja oil at various loads and injection pressures at the rated speed of 1500 rpm. The performance parameters like brake specific energy consumption (BSEC), Specific fuel consumption have been compared with Diesel fuel.

2.1Experimental details:
In this article, the performance parametric experiments have been elaborated. Engine tests were conducted at the SCHOOL OF ENERGY AND ENVIRONMENTAL STUDIES DEVI AHILYA VISHWAVIDYALAYA INDORE, India. To achieve the objectives, an experimental setup is required. For this, engine was a single cylinder, four stoke, direct injection, air-cooled, natural aspirated, vertical diesel engine manufactured by Kirloskar India Limited.

Main sections of setup are:

- Four stroke Signal cylinder engine.
- Load terminal
- Fuel tank and Fuel consumption measuring unit
- Air Consumption measuring unit
- Two heat exchanger incorporated exhaust gas pipe.

In the experimental setup there were two heat exchangers to pre-heat the Karanja oil. Karanja fuel line was rapped around outside of the exhaust pipe in ten folds as shown in fig1. Thermocouples were

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attached with air suction pipe of engine and two control valves fitted in the heat exchangers.

Two fuel tanks were employed for neat Karanja oil and Diesel separately. A four way valve is attached after fuel tank. The engine tests were conducted at the estimated speed of 1500 r/min at varying load. The high viscosity of vegetable oils (Plants oil) is the main restriction to the use of these oils. An appropriate viscosity reduction method is to be selected. Here, a heat exchanger employing exhaust gas recirculation was used to heat the oil. Temperature of exhaust gas varies with the load on the engine and the type of fuel being used. For carrying out the present study, involving a comparative evaluation, the maximum steady temperatures of 80◦C, and 35 ◦C was maintained with regulation by the recirculation of exhaust gases. The control valves were used to regulate the quantity of exhaust gas to preheat the oil to the desired temperature. Preheating of oils beyond 80 ◦C was not possible through uniformly exhaust gas recirculation for all the fuels and loads on the CI engine during the tests and so not been considered. The oils were, hence, fed to the engine at the two temperatures 35◦C, and 80 ◦C and the performance characteristics of engine were obtained and compared with that of diesel fuel. A four-way hand-operated control valve and two fuel meters were added to modify the engine fuel system for rapid switching between the diesel fuel and the oil sample. A counter-flow-type heat exchanger was employed to preheat the oils using exhaust gas recirculation. Two hand-operated control valves (v1 and v2) were used to regulate the quantity of exhaust gas to preheat the oil to desired temperatures. Figures.1 shows the complete arrangement of the apparatus.

2.2: Experimental setup:

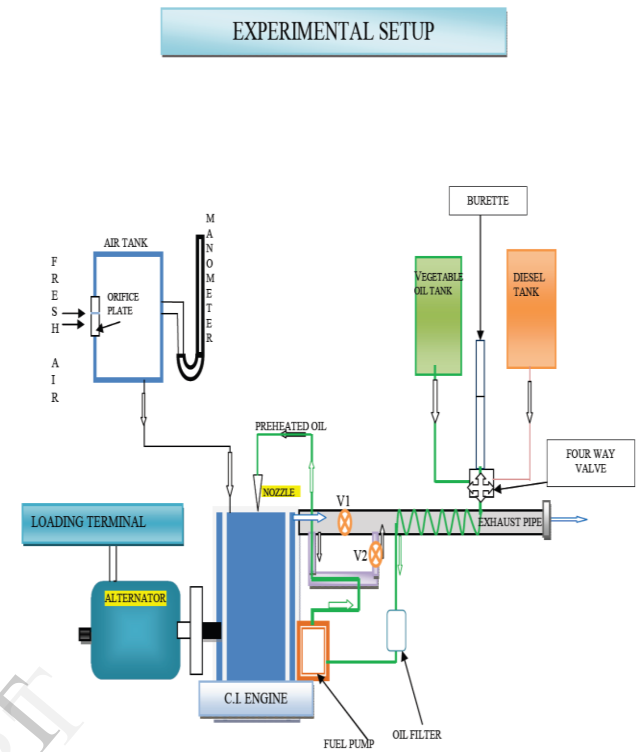

Table: 1: Engine specifications:

Type- AV 2310 SAR Kirloskar	Number of cylinders - single
Cooling system- Air cooled naturally aspired	Number of strokes - 4
Rated power- 7.4 kW	Brake horse power- 10 bhp
Speed- 1500 r/min	Cylinder diameter- 87.5mm
Stroke length- 110 mm	Compression ratio - 17.5:1
Injection pressure- 180 bar	Inlet valve opens - 4.5◦ Before TDC
Inlet valve closes - 35.5◦ After BDC	Fuel injection - 23◦Before TDC
Exhaust valve opens- 35.5◦ Before BDC	Exhaust valve closes- 4.5◦ After TDC
Loading device - alternator	

Alternator:

Manufacturer-	Kirloskar heavy electrical
Voltage-	230 single phase
Current-	16Amp
RPM-	1500(At maximum load)
Power Rating -	7.5kW

3. Results and Discussions

At first both fuels (Diesel and preheated neat Karanja oil were used and performance parameters were recorded for different loads and consecutive hours. After the experiment, it was found that BTE of Diesel is maximum at full load, and for neat Karanja at 70% -75% loads. Engine was run for 8 hours continuously and performance parameters (BTE, BP, exhaust gas temperature, BSEC, BSFC) were recorded. To assess the present condition of the engine, a constant speed test with diesel as a fuel was carried out and baseline data were generated. The data generated were documented and plotted in appropriate graphs for analysis. All the observations were recorded three or four times to obtain the correct value of each observation. Each experiment was conducted three to four times so as to minimize the influence of measurement and observation errors.

Initially, the injection pressure of engine was design pressure i.e.180 bar. At 180 bar pressure, experiments were conducted at different load and for consecutive hours to obtain the BTE, BSEC, and BSFC and exhaust gas temperature. Beyond 75% load (75% of rated load of the engine) the performance of the engine deteriorated rapidly, as may be seen in fig.2 & 4.It was observed that if the engine runs 8-10 hrs continuously, there is drastic decrement in BTE (24.75 percent to 6.39 percent) within 8th hour. An increment in fuel injection pressure to 208 bar, the BTE increased to 26.88%. With continuous running of engine at certain load indicates that there is no drastic decrement in performance of engine. It can be easily observed from fig. 2 that the engine fueled with Karanja oil at room temp does not give justifiable performance and it gave only 17% efficiency. Further increase in injection pressure beyond 208 bar (up to 220 bar) resulted is degradation of performance parameters (refer to fig. 5). At constant load of 70 percent, Fuel injection pressure (FIP) was optimized for maximum thermal efficiency of 26.88 percent (refer to fig.5). It can be seen from the fig.5 that injection pressure of 208bar is optimized pressure for highest efficiency. After this, injection pressure (nozzle pressure) was increased up to 220 bar and all recorded parameters were compared with 180 bar injection pressure data (refer to fig. 5, 6 & 7). It seems that in the CI engine, in order to achieve complete combustion in short time, the liquid fuel should be injected in droplets of smallest size to obtain largest surface–volume ratio. But the rate of burning depends on the rate at which the products of combustion removed from the surface and replaced by fresh oxygen. The size of the droplets depends on injection pressure. At lower injection pressure, rate of pressure rise during uncontrolled phase is lower too. Fig.6 shows the variation in BTE with load at 180 bar and 208 bar injection pressures of Karanja oil. It can be noted that highest brake thermal efficiency of Preheated Karanja oil is obtained at an injection pressure of 208 bar. Figure 5 shows that the brake thermal efficiencies obtained at 70 percent load i.e. 5kW at an injection pressure of 180bar is 24.75%, at 208bar it is 26.88%. At 220 bar injection pressure, the brake thermal efficiency obtained is 24.48 percent. The deviation in the values of brake thermal efficiency (BTE) with respect to load, for Diesel at room temperature, Karanja oil at room temperature and preheated Karanja are shown in fig. 2 and 4. As the viscosity of the non-edible vegetable oils under consideration is higher than diesel even at preheated oil temperatures, there is poor atomization of oil through the injector in the combustion chamber resulting in inferior oil–air mixture. This flammable mixture is less volatile than the diesel–air mixture, which results in poor combustion; hence increased injection pressure of engine evidently increases thermal efficiency. The improved thermal efficiency with preheating can be interpreted as due to lower viscosity and hence a better combustion process.

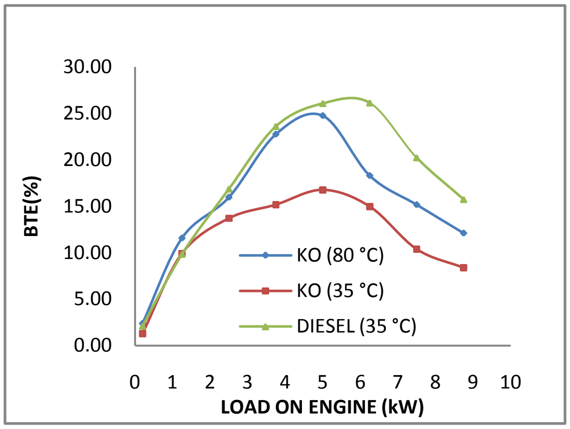

Fig: 2 Load Vs Brake Thermal Efficiency of Preheated Karanja oil, Karanja oil at room temperature & Diesel at room temperature.

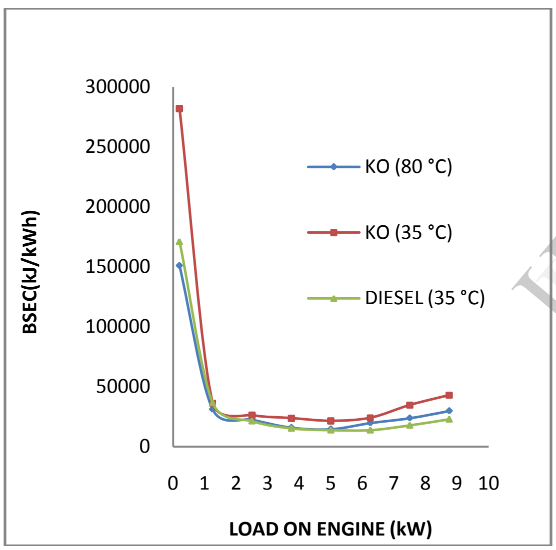

Fig:3 Load Vs Brake specific Energy consumption of Preheated Karanja oil, Karanja oil at room temperature &Diesel at room temperature.

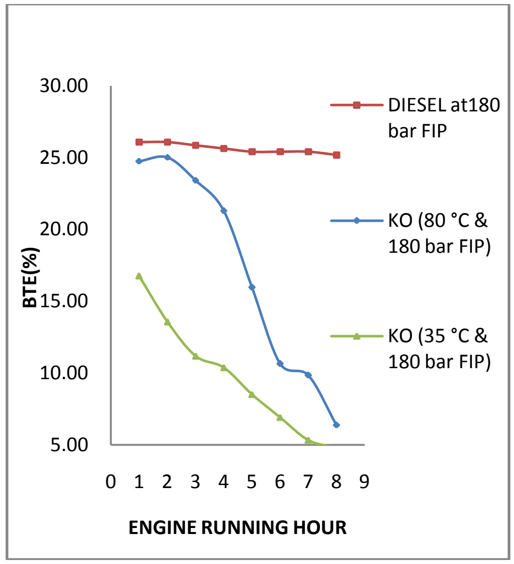

Fig:4 Engine Running Hour Vs Brake Thermal Efficiency of Preheated Karanja oil, Karanja oil at room temperature &Diesel at room temperature at 180 bar FIP

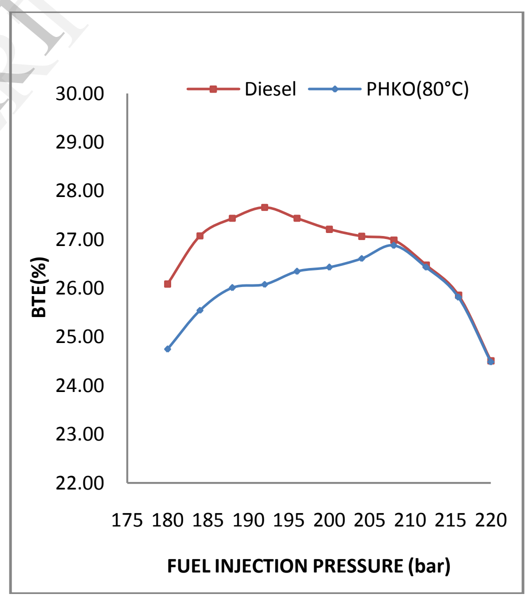

Fig:5 Fuel Injection Pressure Vs Brake Thermal Efficiency of Preheated Karanja oil and Diesel at room temperature .

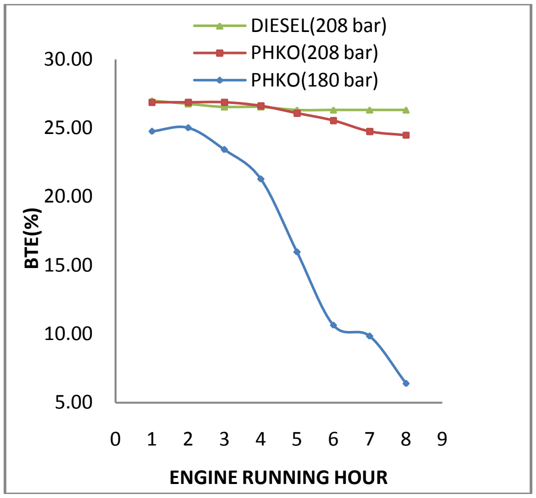

Fig:6 Engine Running Hour (8hrs) Vs Brake Thermal Efficiency of Diesel (208 bar FIP), Preheated Karanja oil (208 bar FIP) and Preheated Karanja oil (180 bar FIP)

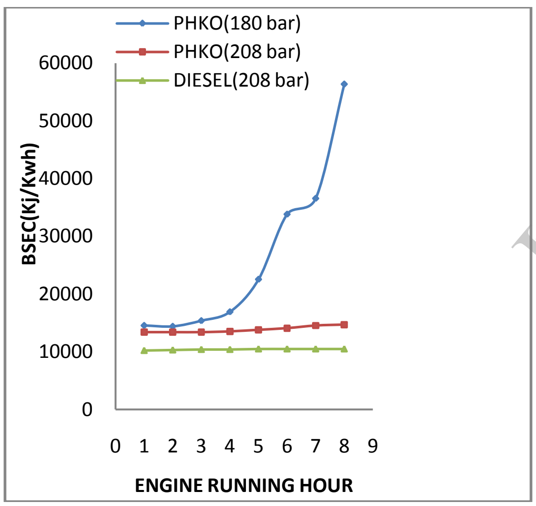

Fig:7 Engine Running Hour (8hrs) Vs Brake specific Energy consumption of Diesel (208 bar FIP), Preheated Karanja oil (208 bar FIP) and Preheated Karanja oil (180 bar FIP)

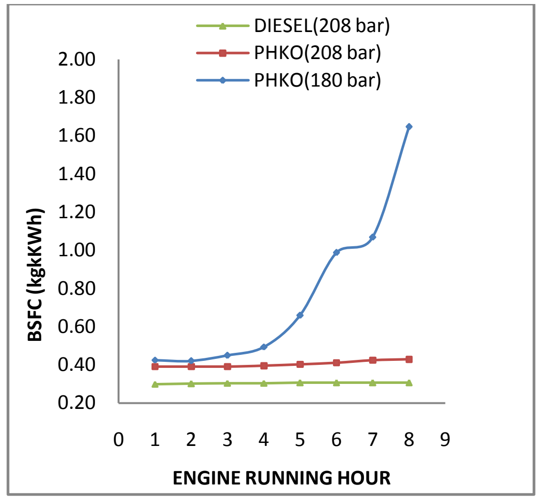

Fig:8 Engine Running Hour (8hrs) Vs Brake specific Fuel consumption of Diesel (208 bar FIP), Preheated Karanja oil (208 bar FIP) and Preheated Karanja oil (180 bar FIP)

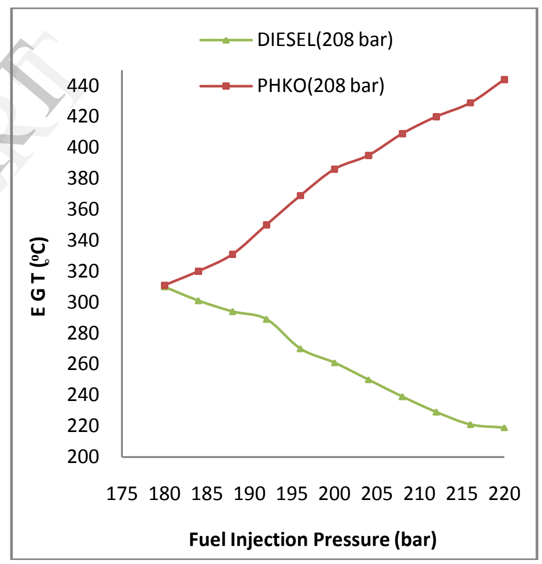

Fig:9 Fuel Injection Pressure Vs Exhaust Gas Temperature of Preheated Karanja oil (208 bar FIP) and Diesel at room temperature (208 bar FIP)

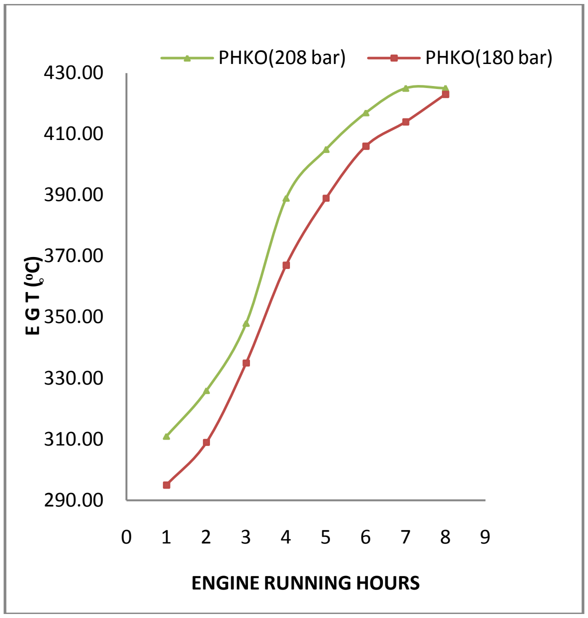

Fig:10 Engine Running Hour (8hrs) Vs Exhaust Gas Temperature of Preheated Karanja oil (208 bar FIP) and Preheated Karanja oil (180 bar FIP)

In increase in injection pressure upto 220 bar, increased the fuel penetration and improved atomization, resulted improvement in performance parameters as shown in fig.5 & 6. It may be observed from fig. 5, 6, 7 & 8 that the performance of engine for diesel fuel at 180 bar are: BTE about 26.09%, FC 0.31 and BSEC about 13798 kJ/kWh

Exhaust gas temperature (EGT): Fig.9 shows the variation of exhaust gas temperature with fuel injection pressure for diesel at room temperature (208bar) and preheated Karanja oil at 70 percent load condition. From Fig. 9, it may also be seen that the exhaust gas temperature of the engine on fossil diesel mode is lesser compared to all preheated Karanja oil operation at higher fuel injection pressure conditions considered. The exhaust gas temperature of the engine on diesel, at 208 bar fuel injection pressure, is 239°C, whereas on preheated Karanja oil, the EGT is 409°C. The exhaust gas temperature of the engine on preheated Karanja oil is higher compared to diesel at higher fuel injection pressures because of the higher retention of KO than diesel inside the cylinder and excess energy supply to the engine. It is also observed that the exhaust gas temperature of preheated Karanja oil of all operation are increased with increase in fuel injection pressure from 180 bar up to 220 bar, Whereas, with diesel, the exhaust gas temperature decreases with increase in fuel injection pressure. Figure 10 shows the exhaust gas temperature versus engine running hours on preheated Karanja oil at 180 &208 bar fuel injection pressure.

Conclusion

The engine was made to run with fossil diesel and Preheated Karanja oil for eight consecutive hours. The experiments were conducted for 180 bar, 184 bar, 188 bar, 192 bar, 196 bar , 200 bar, 204 bar, 208 bar, 212 bar, 216 bar and 220bar. The performance and exhaust gas temperature of the engine at different loads were investigated. The following results were obtained.

- The engine was tested for Karanja oil at room temperature, Karanja oil at 80°C and Diesel at room temperature at different terminal loads and brake thermal efficiency were recorded.
- The maximum brake thermal efficiency of engine fueled with preheated Karanja oil is at 70 to 75 percent loading.
- The brake thermal efficiency of the engine for preheated Karanja oil is less compared to fossil diesel at same condition.
- The brake thermal efficiency of the engine for preheated Karanja oil increased with increase in fuel injection pressure from180 bar to 208 bar pressure.
- The brake thermal efficiency of the engine for preheated Karanja oil at 208bar is almost close to diesel fuel at 208 bar at fifth hour of eight hour engine operation.
- The exhaust gas temperature of diesel is less compared to preheated Karanja oil all of operations at higher fuel injection pressures of 210 to 220 bar.

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Appendix

Notation:

BP: brake power
BTE: brake thermal efficiency
BSFC : brake specific fuel consumption
BSEC: brake specific energy consumption
DIESEL: fossil diesel at room temperature
EGT: exhaust gas temperature
FIP: fuel injection pressure
KO: Karanja oil
kW: kilowatt
PHKO: Preheated Karanja oil at 80 ^{o} C