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Boruah, D., Borah, U., Baruah, D. C. & Baruah, D.

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EXPERIMENTAL INVESTIGATION ON THE SUITABILITY OF KARANJA (Pongamia pinatta) BIODIESEL BLENDS FOR ENGINE APPLICATION.

Dibakor Boruah[1,2], Uditya Borah[3], D C Baruah[4], Dipal Baruah[3,4]

[1.] Faculty of Engineering, Environment and Computing, Coventry University, Coventry, UK
[2.] National Structural Integrity Research Centre (NSIRC), TWI Ltd, Cambridge, UK
[3.] Department of Mechanical Engineering, Girijananda Chowdhury Institute of Management & Technology-Tezpur, Tezpur, Assam, India
[4.] Department of Energy, Tezpur University, Tezpur, Assam, India

ABSTRACT It is now an established fact that bio-energy has the potential to augment a major part of the projected renewable energy provisions of the future. As the resources of petroleum are depleting with the increasing demand of fuels, bio-energy has come up as an effective means to supplement this energy demand as well as to mitigate the problem of environmental pollution. In respect of engine derived energy, bio fuels viz. biodiesel is gaining prominence as an alternative diesel fuel for its good quality exhaust, biodegradability and sustainability. Many feedstocks for biodiesel production have been investigated and experimented with. The feedstock characteristics, which are spatially varying, have considerable effect on the biodiesel characteristics as well as the engine performance.

In this study, fuel characteristics of bio-oil extracted from locally available Karanja (*Pongamia pinnata*) were evaluated and compared with petroleum diesel. Various fuel properties were evaluated according to ASTM standards. An experimental study was then undertaken to investigate the performance of a diesel engine using blends (B5, B20, B40, B60) of the extracted bio-oil. A comparative study of the engine performance, using different blends of the bio-oil and diesel, in terms of fuel power, indicated power, brake power, frictional power, brake thermal efficiency, indicated thermal efficiency, volumetric efficiency, relative efficiency, mean effective pressure, fuel consumption, specific fuel consumption, air consumption and specific output, was carried out. It was observed that the use of the biodiesel blends resulted in engine performance comparable to pure diesel, which suggests the suitability of Karanja biodiesel blends for engine application.

1. INTRODUCTION:

The concept of using vegetable oil as a bio-fuel originated from the demonstration given by Rudolf Diesel in Paris, 1990 when peanut oil was used as the feedstock. However, the use of vegetable oil as bio-fuel was not taken seriously until it was realised that the conventional fossil based fuels used in engines which produces a lot of emission are vanishing fast and therefore the invention of environment friendly bio-fuel is extremely important [2]. Vegetable oil and waste cooking oil are interesting alternative fuels for diesel engines in some specific applications [1]. Also, they can be produced almost everywhere in the world [3]. The use of biodiesel is attractive in the most distant places, where the transportation cost is increased for petroleum-derived fuels. Biodiesel due to its similarities with the diesel fuel has attained outstanding attention in recent times. It is an attractive alternative because of its renewability, non-toxicity, biodegradability, high flash point and low greenhouse emissions. Biodiesel is easy to handle because of its higher boiling point and it is an environment friendly fuel with low smoke emissions because biodiesel contains almost 10% oxygen [3,4]. In the recent developments, scientists have tried to use various vegetable oil in diesel engines but the greater challenge remains to be the high viscosity of the vegetable oil [5]. It is found that due to high viscosity of these vegetable oils proper atomization becomes very difficult and thus produces incomplete combustion and large carbon deposition in the engines. Therefore researchers have tried various less viscous blends instead of direct vegetable oils in the diesel engines. The best possible way to overcome viscosity is by producing bio diesel by trans-esterification method. Globally trans-esterification is recognized as the best technology to produce bio diesel [6]. It is also an established fact that catalysts, temperature and alcohol percentage plays a significant role in the trans-esterification process.

It is also observed that increase in viscosity of the fuel results in an increase in spray penetration and a decrease in spray angle.[7].Vegetable oils (peanut, sunflower, cottonseed and soybean oils)shows many characteristics opposite to what is found in other fossil fuels. However, a lower penetration and a larger spray angle despite high viscosities of the fuels was observed by Ryan and Bagby in a study[8]. The sampling collection method they applied shows that chemical reaction plays a significant role in increasing the atomization process of vegetable oil during the injection process which leads to shorter ignition delay. The basic challenges like scarcity of diesel, high fuel cost and greater pollution obtained for diesel fuel has opened the door for finding an alternative fuel which can compensate these problems. The use of bio diesel is found to be economically more viable than the modification of present diesel engines in short term. The alternative fuel should have similar characteristics of diesel so that it blends easily and should not need large modification to the existing diesel engines. The engine performance should not decrease considerably when the blends are used in the diesel engines. Therefore it is extremely important to assess the combustion characteristics of the engine when a particular bio diesel is used as the fuel.The properties of biodiesel differ depending on the source of plant oil/fat source; this is mainly related to their chemical structure, such as the number of carbons and the number of double bonds in the hydrocarbon chain [9].Vegetable oils have very less sulfur in their chemical composition. Therefore industrial production does not generate harmful substances to the environment [10].

The properties of biodiesel can be characterized by determining its density, viscosity, high heating value, cetane index, cloud and pour points, flash points etc according to ASTM norms.In this study, fuel characteristics of biodiesel abstracted from Karanja (*Pongamiapinnata*) were evaluated and compared with petroleum diesel. Various fuel properties such as density, viscosity, calorific value, ash content, cloud point, pour points, induction period and flash point were evaluated according to ASTM standards. A (5% v/v) blend of biodiesel and petroleum diesel were used to run a diesel engine and their performances were investigated and compared in terms of fuel power, indicated power, brake power, frictional power, brake thermal efficiency, indicated thermal efficiency, volumetric efficiency, relative efficiency, mean effective pressure, fuel consumption, specific fuel consumption, air consumption and specific output.

2. MATERIALS AND METHOD

2.1 Materials

The fuels used for the study is petroleum diesel and biodiesel. The biodiesel taken for study is abstracted from Karanja (*pongamiapinnata*) by the method of trans-esterification [11]. It is the process of converting vegetable oil to biodiesel by breaking of oil molecules in to lower alkyl esters with addition of alcohol in the presence of a suitable catalyst producing glycerol as a by-product. Karanja oil contains approximately 20% FFA [12]; therefore acid esterification was carried out to reduce the Free fatty acid concentration to less than 1%. Base catalyzed transesterification was then carried out. Finally glycerol was separated and the bio diesel was washed with hot distilled water to remove impurities and finally the biodiesel was isolated and blended with diesel.

2.2 Preparation of biodiesel blend with petroleum diesel

Biodiesel blends can be prepared by mixing biodiesel in different proportions (v/v) with petroleum diesel [13]. We have prepared four different blendsB5,B20,B40,B60 by blending 5%,20%,40%& 60% biodiesel with 95%,80%,60%&40% petroleum diesel,i.e. B5: 5% (volume) of biodiesel + 95% (volume) of petroleum diesel,B20: 20% (volume) of biodiesel + 80% (volume) of petroleum diesel,B40: 40% (volume) of biodiesel + 60% (volume) of petroleum diesel,B60: 60% (volume) of biodiesel + 40% (volume) of petroleum diesel.

2.3 Fuel characterization of biodiesel and blend

A fuel can be characterized by determining various physicochemical properties like viscosity, density, calorific value, pour point, cloud point, flash point, oxidation stability, ash content, acid value, Cetane number, water content etc [14]. These properties have been determined according to the ASTM standards and are listed in Table 1.

Table 1: Apparatus and method used for investigation properties of liquid fuel

SL No.	Property	Apparatus Used	Test Method	Units
1	Density	Specific Gravity Bottle	ASTM D 287	kg/m^3
2	Kinematic Viscosity	HAAKE Falling Ball Viscometer	ASTM D 445	mm^2/sec
3	Induction Period	743 Rancimat	ASTM D 2274	h
4	Cloud Point	Cloud Point Apparatus	ASTM D 97	℃
5	Pour Point	Pour Point Apparatus	ASTM D 97	℃
6	Calorific Value	Bomb Calorimeter	----------	kJ/kg
7	Ash Content	Muffle furnace	ASTM D 874	wt%
8	Flash Point	Penisky Martin Flash Point Apparatus	ASTM D 93	℃
9	Acid Value	Titration Method	ASTM D 664	mgKOH/g

2.4 Performance Test:

Diesel engine performance tests of biodiesel blend namely B5,B20,B40,B60and also the typical petroleum diesel are carried out in an Engine test rig. Technical details of the diesel engine are given in Table 2 below

Table 2: Basic technical specifications of the test engine

SL No.	Items	Specifications
1	Engine Make	Tata Indica
2	Engine power	39 kW
3	Cylinder bore	75 mm
4	Stroke length	79.5 mm
5	Compression ratio	22.1
6	No of cylinders	Four
7	Stroke type	Four
8	Dynamometer type	Eddy current, water cooled, with loading unit

The test procedure consists of a four cylinder, four stroke diesel engine connected to an eddy current type dynamometer for loading. The test engine is mounted with measuring arrangement so that all the required input parameters could be recorded simultaneously and fed into computer for further analysis. The engine was coupled with an electric dynamometer with the help of a V-belt and pulley to apply different engine loads. For assessment of engine performance, the fuel consumption was recorded along with shaft load and speed. The test engine is provided with measuring arrangement such that all the required parameters could be recorded with minimum errors. Temperature, pressure, speed, torque, volume flow rate of fuel and air are some of the basic measurements done in the test engine. The measuring devices viz., calorimeter, orifice meter, dynamometer, rota meter and fuel flow meter are provided with the standard test engine.

The performance of an engine can be determined by using the performance parameters such as power output, brake thermal efficiency, indicated thermal efficiency, volumetric efficiency, mean effective pressure, specific fuel consumption, engine emissions etc.

3. RESULTS AND DISCUSSION

3.1 Characterization of petroleum diesel, biodiesel and its blend.

The various properties of petroleum diesel, pure biodiesel and blended biodiesel (B5) obtained from various experiments were measured using standard methodologies and the results are shown in Table 3.

Table: 3 Properties of pure biodiesel, various blends and petroleum diesel

SL No	Properties	Units	Pure biodiesel	B5	B20	B40	B60	Petro-diesel
1	Density	kg/m^3	912.437	844.66	850.54	854.43	860.33	837.04
2	Kinematic viscosity	mm^2/sec	10.8341	2.775	3.112	4.23	5.19	2.35
3	Calorific value	KJ/kg	37717.32	44699.99	42978.66	41805.63	40224.45	45152.04
4	Ash content	wt %	.0141	.0168	.0163	.0158	.0151	.0185
5	Induction period	hr	8.24	9.29	10.42	11.13	12.22	NA
6	Pour point	°C	21	7	10	12	15	1
7	Cloud point	°C	18	-3	4	8	13	-18
8	Acid value	mg KOH/g	11.781	0.781	2.41	4.42	8.32	0.187
9	Flash point	°C	160	62	72	91	120	49

4.2 Diesel engine performance characteristics

The various engine parameters like indicated power (IP), brake power (BP) are plotted considering petroleum diesel and the different blends as the fuel at different RPM and load conditions.

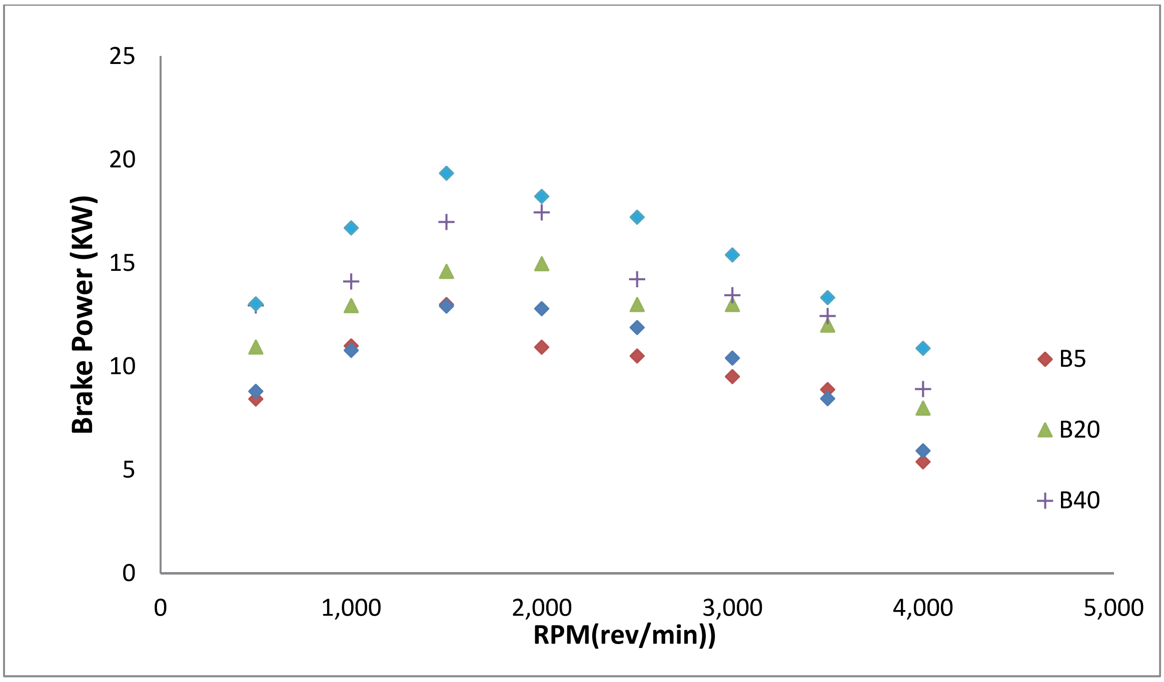

Fig-1: RPM Vs BRAKE POWER

The plot shows that the brake power increases with increase in speed for all the fuel. But the peak power occurs at a particular speed and on further increase in speed the brake power drops. The effect of friction becomes very prominent beyond the optimum speed and thus the brake power decreases considerably. From the figures, increased brake power for B20, B40 and B60 was because of complete combustion of oxygenated fuel and the lower power output in case of B5 was due to increased viscosity and presence of relatively lesser oxygen. The peak power occurs at 1500 rpm for all the fuels. The peak power values for diesel, B5, B20, B40 and B60 are 11.594, 12.921, 13.554, 15.82, 19.345 kW respectively. Of course, it was reported that there were surprising increases in power or torque of engine for pure biodiesel. Song and Zhang [15-16] observed that the engine brake power and torque increased with the increase in biodiesel percentage in the blends. And they contributed to the higher oxygen content, the higher biodiesel consumption, an advance of injection timing and a shorter ignition delay time.

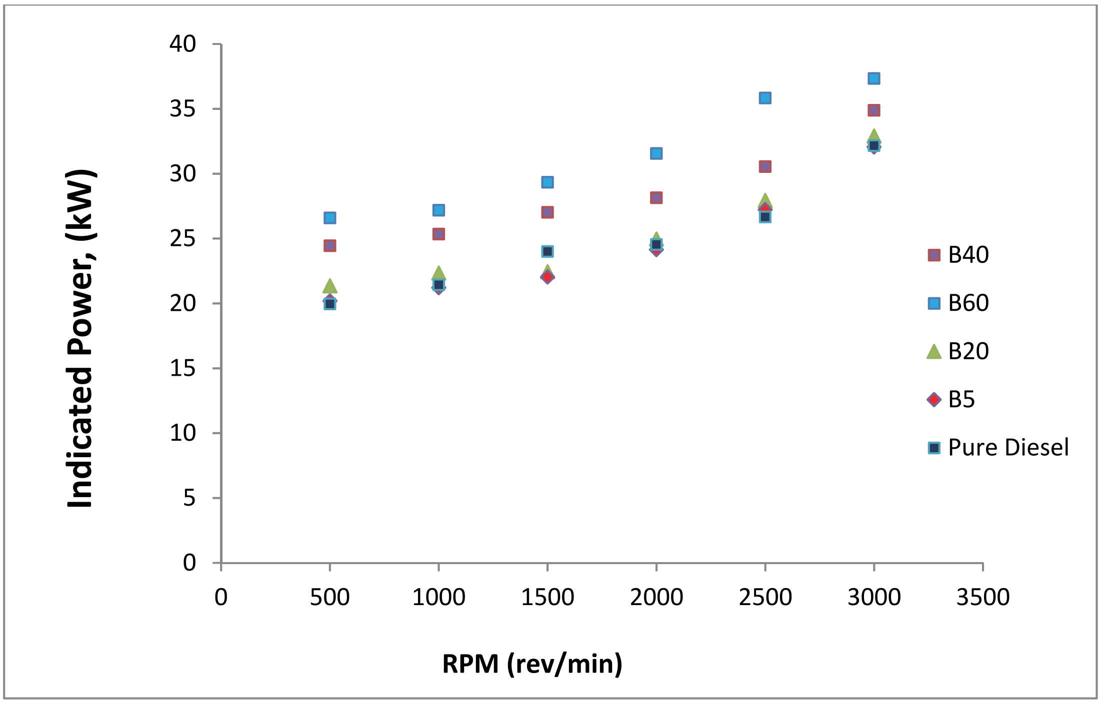

Fig-2: RPM Vs INDICATED POWER

Fig 1 shows that the brake power increases with increase in speed for all the fuel. As expected the frictional power increases with increase in RPM. At very high speeds the frictional power is further more. Although the brake power decreases after a peak value the indicated power increases considerably. We know that the indicated power is brake power plus the frictional power. So the indicated power increases with increase in speed of the engine.

Engine efficiencies thermal efficiency& mechanical efficiency for different rpm on application of petroleum diesel and different blends are shown below.

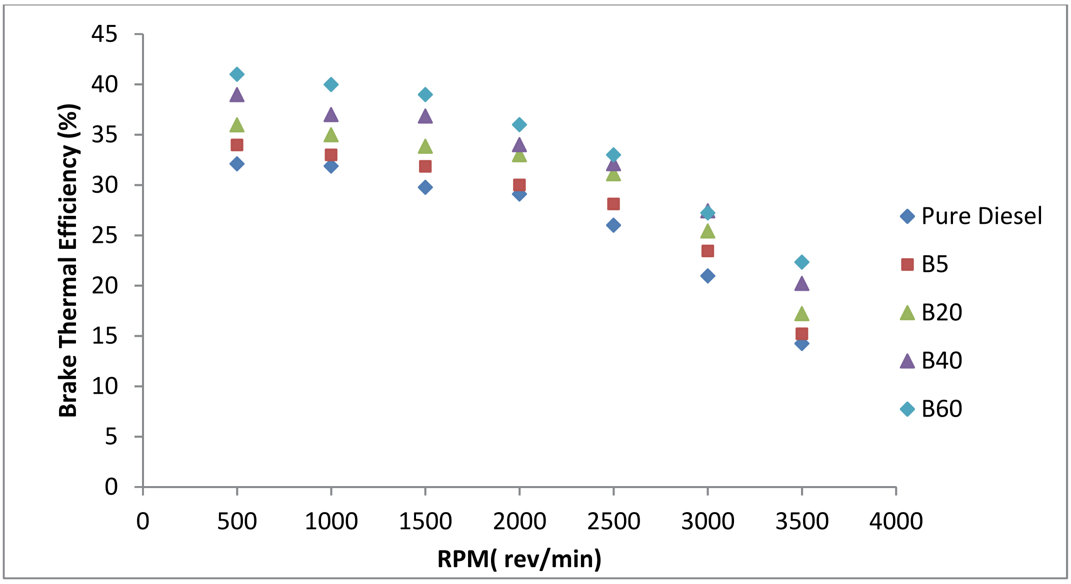

Fig-3: RPM Vs BRAKE THERMAL EFFICIENCY

Thermal efficiency is nothing but the ratio between the output power to the fuel energy provided through fuel injection. The fuel injection is directly proportional to the mass flow per second. Hence, the inverse of thermal efficiency is often referred to as brake-specific energy consumption. The total input power is also proportional to the calorific value of the fuel. The blends we have used has very lower calorific value compared to that of diesel. From the above plot it is clear that the Brake thermal efficiency decreases with speed for all the fuels. The blends B5,B20, B40 and B60 present an increase in brake thermal efficiency compared to diesel ..Therefore there is an increase in brake power and lesser fuel energy consumption for the biodiesel blends. The blend B60 gives the maximum thermal efficiency with a peak value of 41at RPM 500and a minimum value of 23.22 at RPM 3500. Thus we see the thermal efficiency decreases with the engine speed

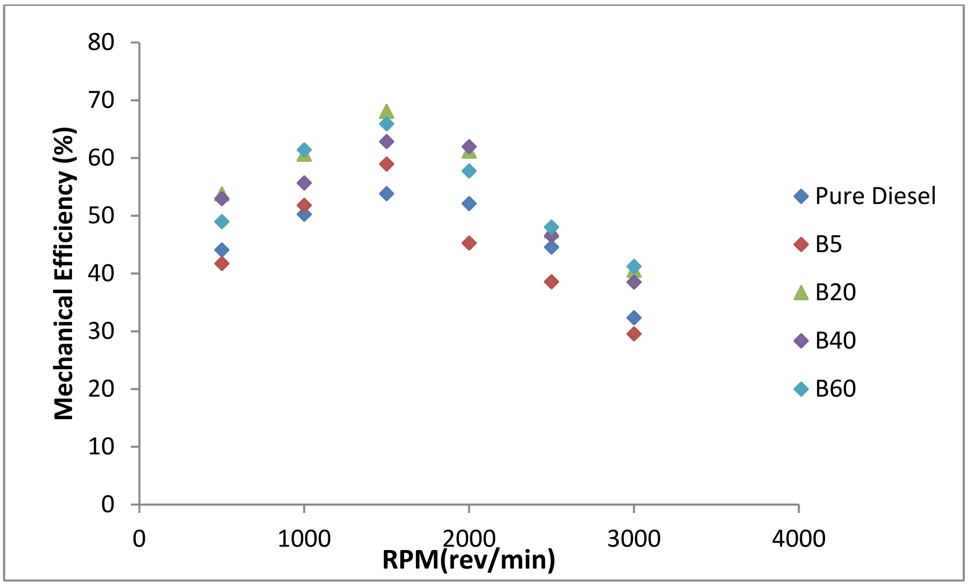

Fig-4: RPM Vs MECHANICAL EFFICIENCY

It is clear from the plot that the mechanical efficiency which is directly proportional to brake power and inversely proportional to the indicated power, shows an increasing trend initially but gives a gradual decreasing trend for all the blends at higher RPM. The peak value of nearly 69% and is obtained for blend B20 at an intermediate RPM of 1500. The mechanical efficiency of diesel and blend B5 are not very high. The peak value for diesel is 55% and peak value of blend B5 is 58.11.

Various engine parameters like brake specific fuel consumption (BSFC), of diesel engine for different rpm and load conditions on application of 'petroleum diesel' and the different blends are shown below.

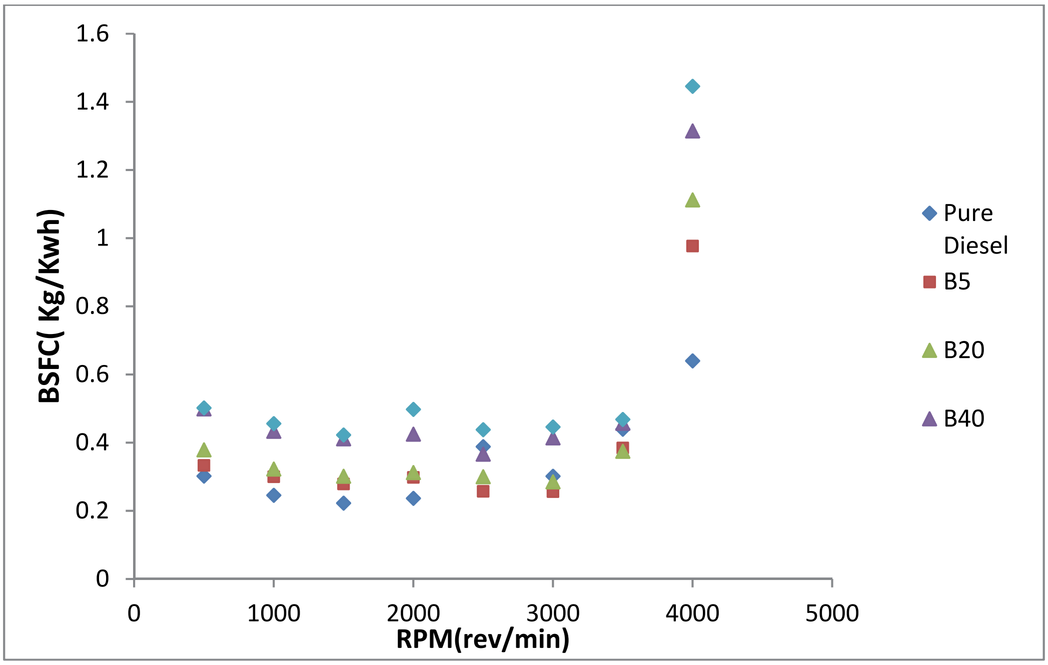

Fig-5: RPM Vs BSFC

The brake specific fuel consumption is inversely proportional to the thermal efficiency**.** Diesel has the lowest brake specific fuel consumption at a given RPM. It is because of its lower mass consumption and higher calorific value. Similarly B60 gives a high value of brake specific fuel consumption with a peak value of 1.445 at RPM 4000. We can see from the plot that at very low RPM the fuel consumption is high and it decreases up to an intermediate speed but it sharply increases at very high speeds. At 1500 RPM diesel consumes the least fuel with a brake specific fuel consumption value of 0.223

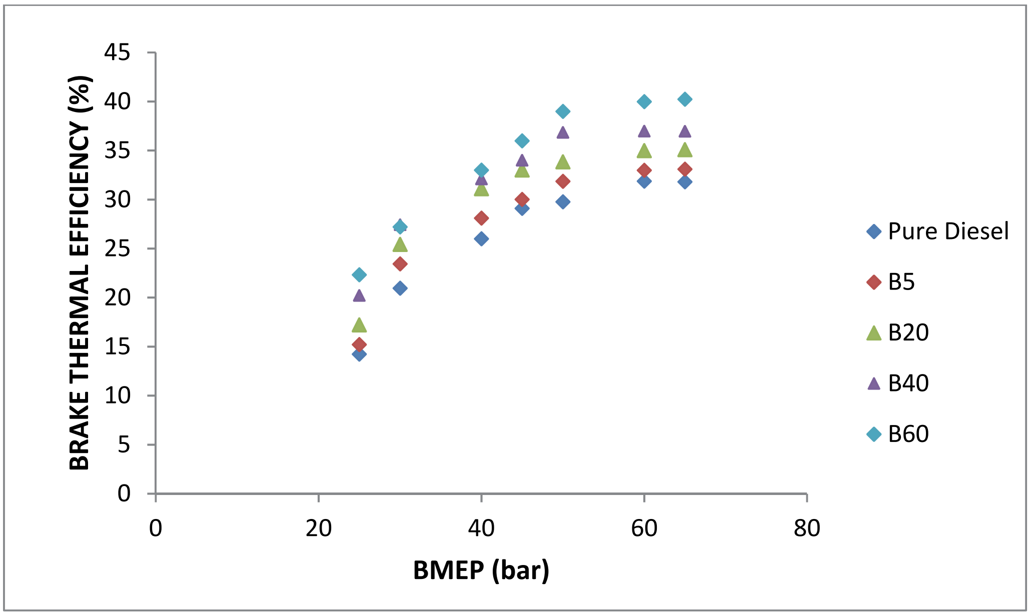

Fig-6: BRAKE THERMAL EFFICIENCY Vs BMEP

The brake thermal efficiency shows an increasing trend when plotted against brake mean effective pressure. At higher pressure the fuel combustion is better and thus results in a lesser fuel consumption. At very low pressure the fuel doesn't burn completely. Blend B60 gives higher thermal efficiency at a particular pressure. The peak value is nearly 41% at a brake mean effective pressure of 70 bar. But diesel fuel has thermal efficiency of nearly 32% only at the same pressure. Similarly the least value, i.e. 22.2 for blend B60 and 14.32 for diesel is at 25 bar. At lower pressure the combustion of fuel is not proper and thus gives a lower thermal efficiency. Also, the excess amount of oxygen present in the fuel containing bio diesel which facilitates in giving a better output power compared to diesel.. The increase in thermal efficiency with Brake mean effective pressure is quite sharp initially but gradually it attains a flat curve at higher pressure value and tends to decrease at higher pressure**.** The same pattern is followed for all the blends.

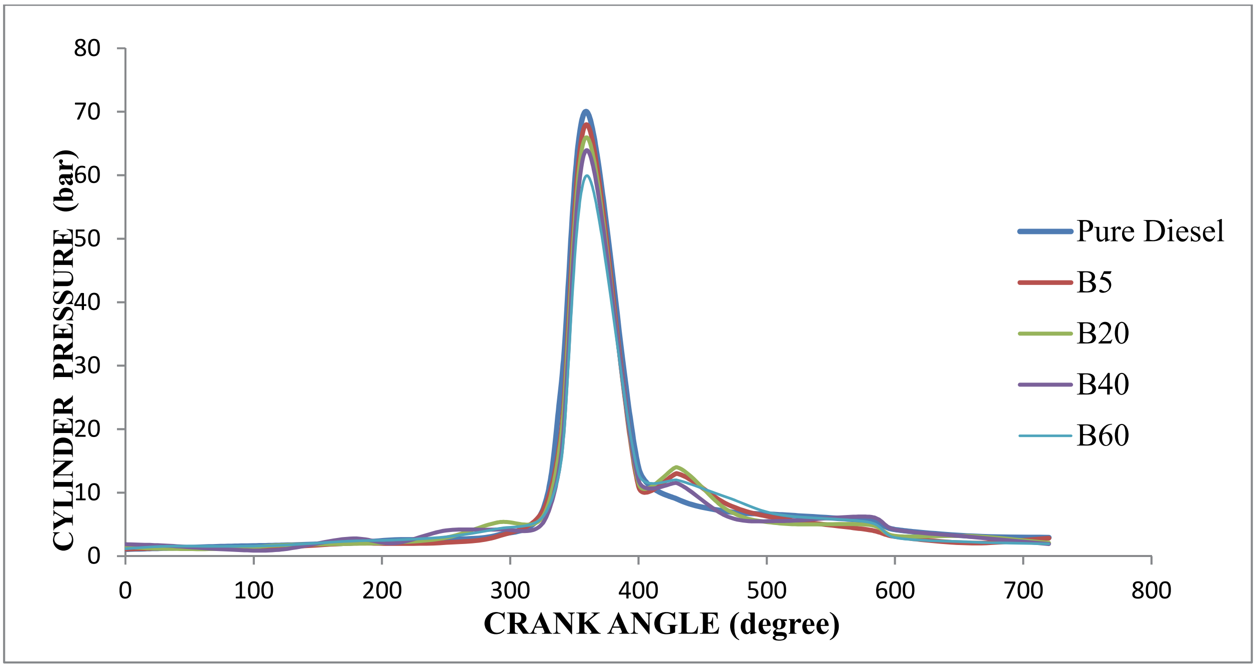

Fig-6: CYLINDER PRESSURE Vs CRANK ANGLE

In the Fig variation of Cylinder Pressure in the engine for different fuel samples at various crank angles are shown. The trends of curves are almost similar. At about 0^0 crank angle, the piston of the cylinder is at TDC at initial pressure. From 0^0 crank angle suction starts in the cylinder and piston moves to BDC at about 180^0 crank angle, from 180^0 compression starts and piston moves to TDC at about 360^0 crank angle. In the Fig fuel starts to inject at about 340^0 crank angle, ignition occurs between 340^0& 360^0 crank angles and pressure is increase sharply up to maximum pressure point. The maximum pressure obtained are nearly 70 bar, 68 bar,66 bar,64 bar and 60 bar for petroleum diesel,B5,B20,B40 and B60 respectively. That is the peak pressure for diesel is almost 14% higher than that of B60 and nearly 0.03% higher than that of B5.The cylinder pressure increases with load for all the blends because more amount of fuel is burnt at higher pressure. It is because at higher pressure the temperature increases inside the cylinder leading to a greater evaporation and better fuel mixing. After 360^0 power stroke takes place in the cylinder, pressure is decreased and piston moves to BDC at about 540^0 crank angle. Then from 540^0 exhaust of combustion gas takes place and piston moves to TDC at 720^0 crank angle and pressure goes almost to the initial level. In the figure there is an abrupt change in the curves in between 400^0 to 440^0 crank angle, which may be due to knocking (violent gas vibration due to very high pressure) and rough engine operation. It occurs mainly because of poor atomization and delay in ignition in case the blends considered.

5. CONCLUSION:

From the experiment it is cleared that the density as well as viscosity of pure biodiesel is higher.

As the Calorific value of of pure biodiesel is lower than petroleum diesel, therefore pure biodiesel have tendency to produce less power in the engine & tends to burn inefficiently thus causing lots of exhaust and air pollution. It is found that Cloud point & Pour point of pure biodiesel is lower than petroleum diesel. Therefore pure biodiesel is not suitable for use in low temperature environments. But petroleum diesel is suitable for low temperature environments also. Flash point of pure biodiesel is higher than petroleum diesel. So pure biodiesel may cause carbon deposit in the combustion chamber and cause high ignition delay. Also, oxidation stability of pure biodiesel is much lower than petroleum diesel. So, pure biodiesel is not suitable for diesel engine applications, so it is blended with petroleum diesel in different proportions to improve its fuel properties and to make suitable for engine application. The greatest benefits of the lower blends are that they don't require a substantial modification of the present engine, and from the experiment it is evident that the fuel properties of B5 and B20 are comparable to petroleum diesel. Also, because of the large concentration of oxygen in the molecules bio diesel blends, better combustion is facilitated. Petroleum diesel, B5, B20, B40, B60 are tested in the diesel engine of the above mentioned specifications. Various plots are obtained as shown in Fig 1 to Fig 7. From the performance test we have found that the Brake power (BP) and Indicated power increases with RPM for the blends as well as for petroleum diesel whereas the brake thermal efficiency decreases with RPM. The mechanical efficiency is low at very low RPM but increases to a peak value at an intermediate RPM of nearly 1500. But at very high speed the mechanical efficiency gives a decreasing trend. The BSFC decreases up to an intermediate RPM (nearly 1500) but when the RMP is very high (nearly 4000), the BSFC sharply increases. The brake thermal efficiency shows an increasing trend with increase in pressure. In case of B5 and B20, in the Cylinder Pressure Vs Crank angle curve, there is an abrupt change in the curves in between 400^0 to 440^0 crank angle as shown, which may be due to knocking, but the actual reason behind this needs further investigation. From the performance point of view, B5 and B20 show comparable behaviour with petroleum diesel.

The study reveals that Karanja (*Pongamiapinatta*) is a promising alternative fuel which could be blended with petroleum diesel and can be used in diesel engines. But the appropriate blend necessary to get the optimal output from the engine basically depends on the nature of the feedstock. In the present study we have found that the blends B5 and B20 show fuel properties and performance characteristics similar to that of pure diesel. They could be the potential alternatives. The blends B60 and B40 have greater viscosity and lower calorific values. Also, most of the other properties significantly vary from diesel oil. Considering all the factors it is summarized that the greater variation from diesel reduces the effectiveness of B40 and B60 as a fuel to be used in an engine. Therefore, B5 and B40 are considered to be the potential alternative fuels. Further, the optimal mix of the blends is a future scope of the present work.

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