

Investigation on Performance and Emission Characteristics of a 4 Stroke Diesel Engine Fuelled with Polanga Biodiesel - Diesel Blends

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ABSTRACT: A remarkable growth is observed in the automobile as well as industrial sectors and accordingly the requirement for the fossil fuels is also increasing. As a result, the amount of fossil fuels available is decreasing drastically. It is well known that modern world depends mostly on energy produced from different energy sources, because of their various uses. Most of the energy sources are fossil fuels which are getting exhausted. Therefore, many scientists from different parts of the globe are carrying out research to find an alternative source in order to replace the existing one. Biodiesel can replace the present energy crisis and further help in reducing global warming. It is mainly produced from edible and non-edible oils. Non-edible oils when blended with diesel give rise to biofuels which have exhibited a remarkable growth in the automobile industries because of their environment friendly and lubricating nature. This paper depicts the production of the non-edible oil based mono esters like Polanga which are blended with diesel and were tested as an alternative fuels for diesel engines. This paper also investigates about the production of Calophyllum oil (polanga) and its applications in the single cylinder 4 stroke dual fuelled diesel engine practically. Several experiments were conducted with different blends of High speed diesel (HSD) and polanga oil methyl ester (POME) fuel like (B10, B20 and B30), their engine performance and emissions like NO_x, CO, HC, Smoke and CO₂ at varying loads (0%, 10%, 20%, 30%, 40%, 50%, 60%). The properties of the POME fuel were tested and the values were recorded accordingly. The results depict that biodiesel from polanga emits less greenhouse gas emission in comparison to diesel and is a potential source of non-edible oil to substitute petrodiesel for the modern diesel engines without any engine modifications.

KEYWORDS: Polanga biodiesel, Diesel engine, transesterification, performance, emission

I. INTRODUCTION

The word BIOFUEL is now making a prodigious importance in the field of Renewable sources of energy because of its properties and nature as it can be used as a source of alternate energy. The global awareness of energy crises and the environmental impacts has presented an examine which are linked with fossil fuels gives the idea of using alternative energy resources such as biodiesel which is defined as the fatty acids of long chain mono-alkyl esters that are derived from renewable lipids such as vegetable oils and animal fats and alcohol [1-6]. Biodiesel has special characteristics like it is renewable, biodegradable and toxic in nature. It is readily available in nature which can be portable having inherent lubricity with high flash point and cetane ignition rating along with lesser emission rates than the pure diesel. These advantages of Biodiesel made it an ideal fuel in the nature. The main reason why the biodiesel is used in worldwide is the wide range of its feedstocks which makes its promotion to the best alternative fuel [7]. Globally, there are more than 350 crops identified as feedstock for the biodiesel industry which alone represents 75% of the overall biodiesel production cost [1-14]. So, it is important to select a cheapest form of feedstock which leads for the low production cost of biodiesel. The main goal was to investigate the use of many alternative fuels which replaces normal petroleum supplies due to the increasing prices of oil in the forthcoming days.

At present, the world with economic growth, development in the socialism, human welfare and the improvement in the quality of life, all together depends on the energy for its running. With the trend of growing industrialization and modernization, the growth of energy demand is at a faster rate. Taking this condition into consideration, the idea of

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using biofuels in the diesel engines was given by the inventor of diesel engine “Rudolf diesel” at the World exhibition in Paris 1900 by the use of peanut oil as a fuel [15]. But due to more petroleum supply in those early days, the R&D has not paid much attention towards the usage of vegetable oils. As the petroleum is getting defunct day by day, there is an exigency for the use of environment friendly renewable substitutes. The use of vegetable oil directly results in some unfavourable conditions of the engine such as their physical properties like viscosity, ignition value etc. With higher viscosity, oil causes some depletion such as incomplete combustion, carbon deposition on the injectors and valve seats, poor fuel atomization which then results in very serious effect on engine fouling. When the engine runs directly with vegetable oil, injectors get choked up after few hours leading to poor fuel atomization, dilution of lubricating oil and less efficient combustion rate because of partial burning of vegetable oil. To overcome this problem a process was then applied that is blending of vegetable oil with diesel in proper proportion. Not only the blending but also the other method called transesterification of Oils to produce biodiesel was invented [16]. It was also proved that the transesterification process plays a vital role for the biodiesel production and the reduction of viscosity in the vegetable oils. There are some other factors that influence the transesterification process like temperatures, catalyst type, concentration ratio of alcohol to fuel and stirring speed rate to a greater extent. But these can be controlled if we have a brief study on the use of biodiesel from coconut oil (50/50 blend), that is named as “B50” in motor which shows that it gives almost negligible particulates emissions [17]. In order to decrease the diesel fuel shortage, we have to select an alternative fuel to suit the diesel engines which can be more economical and attractive in the small region than the modification of the diesel engine. For this purpose blending is required with diesel fuel as an alternative liquid fuel which should be low in their adequate and economic quantities but with little engine modifications [18]. But there will be no significant changes in the engine performance and durability. Hence there will be a great usage of biodiesel in the diesel engines. Because of some special characteristics of the Biodiesel such as it is being renewable, green fuel, biodegradable, helps to reduce the dependence on conventional or non-conventional fossil fuels in order to improve the environmental quality in metro, urban and rural areas with the reduction of ineffective dangerous automotive/ vehicular emissions [19].

II. RELATED WORK

In modern world Biodiesel has the potential of reducing the dependence of petrol and diesel. Many recent studies proved that the usage of biodiesel reduce the toxic level in the automobile emissions. The study reveals that it can increase the performance of the vehicle. In India many researches were going on the improvement of the biodiesel and their usage. Countries like U.S.A, Germany, U.K has already gone further in research of improving the biodiesel quality.

Many literature studies about biodiesel were drawn many facts about its being usage, advantages and disadvantages. Some of them states that biodiesel can be used as heating fluid or heating reagents in the Boilers or boiler drums of commercial and domestic type of industries which is being considered as one of the major advantages. Blending of standardized bio fuel with the heating oil is used in these industries, which is often known by a name called “Bioheat” that are available in various blends up to 20%.

Some recent studies and practical examinations proved that using biodiesel fuel existing many industrial basis furnaces without any adaptation is considered allowable. Biodiesel is not only limited to automobiles and industries but also some chemical laboratories were they elaborately do research and projects in increasing the use biodiesel fuel as an alternative source of energy in the coming years.

III. REASONS FOR PREFERRED NON-EDIBLE OILS OVER EDIBLE OILS

It was indicated earlier that the non-edible oils are getting worldwide attention to use because of their availability in many parts of the world. They can even eliminate competition for food, most efficient, economical and environment friendly. The by- products of these oils can also be used in many cases compared to edible oils. This is the main reason why we prefer non-edible oils to edible oils. Another point to be considered is that if we use edible oils as a fuel then

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there will be a time when there is a shortage of the food since it fulfils human's daily needs. The non-edible oils are represented as the 2nd generation biodiesel feedstocks. Examples of the non-edible oils are:- Calophyllum inophyllum, Croton megalocarpus, Castor oil (Ricinus communis L.), Neem (Azadirachta indica), Cerbera odollam (sea mango), Sapium sebiferum L., Yellow oleander (Thevetia peruviana Schum.), Madhuca indica (Mahua) and Madhuca longifolia, silk cotton tree (Ceiba pentandra), Hevea brasiliensis (Rubber) and Eruca sativa Gars, Jatropha curcas L., Milo (Thespesia populnea L.), Pongamia pinnata (Karanja), Moringa oleifera. Some recent experiments states that most of the non-edible oils contains high free fatty acid (FFA) values, which gives more amount of soap and are dangerous as it makes the separation of glycerol and ester more difficult while undergoing alkali based catalysed transesterification process. Thus, there will be no longer catalyst to give rise to the biodiesel forming reaction. In order to compensate this problem, high catalyst loading process is required and hence we use the acid catalysed transesterification process followed by base catalysed transesterification process. As its reaction rate is little less, it requires more reaction time and it is the best way to produce biodiesel from non-edible oils having high FFA. Calophyllum inophyllum being non-edible oil has some special characteristics like high potentiality to survive in nature upto a proactive nature of 50 years than edible oil [1-13].

IV. KNOWN FACTS ABOUT POLANGA SEED

The scientific name of the polanga is Calophyllum inophyllum which belongs to the family Clusiaceae. It is commonly known as the family of mangosteen. These plants have their origins all over the world with some important places like East Africa, India, South East Asia, Australia and the South Pacific [1, 20-25]. It has many names according to places all over the world shown in the table:-1[26]. The reason why polanga seed is having different names is due to its origin place or due to its climatic conditions or due to the region with different languages with different locality they named it as different names. Countries like India, South East Asia and Australia contains the major portion of the availability of the Calophyllum inophyllum. They grow in the areas where the annual rainfall is around 1000-5000 mm at altitudes ranging from 0 to 200 m. These trees are low branching and slow growing which have two different flowering times, one at late spring and the other at late autumn. But in few areas, it gives flowers throughout the year. Calophyllum inophyllum are better in growing sandy, well drained soils areas but it can tolerate to grow in clays, calcareous, and rocky soils. These trees are dense canopy of glossy, shine, elliptical and having tough leaves with fragrant flowers with white colour and contains large nuts which are round in shape and they have small yellow petals growing around the centre of the flower and some small branched fruit nuts are grown around outside the flower. These trees are of big and tall sizes and they spread its branches wide enough up to 3 metres long as shown in fig:1.. At the stage of maturity their sizes mostly ranged in between 8 and 20 m (25- 65 ft.) tall and sometimes reaching up to 35 m (115 ft.). Generally these trees have a growth rate of 1m (3.3ft.) in height per year. These trees leaves are heavy in weight and glossy in nature with 10-20 ac (4-8 in.) long and 6-9 cm (2.4 -3.6 in.) wide which are light green when they are young and dark green when they are grow older. The leaves of these trees are of some bitter in taste. These trees have fruits which are spherical drupes in shape and are arranged in a cluster manner around the tree as shown in fig:2. The colour of this fruit is likely to be pinkish-green at first, however when they are ripened it turns into bright green and later on it turns into dark grey-brown and wrinkled. This tree yields upto 100-200 fruits/kg in which each fruit contains one large brown seed of diameter 2-4 cm (0.8-1.6 in.) which is surrounded by a shell and a thin layer of pulp of 3-5 mm. The production of seeds from these trees is 3000-10,000 seeds/tree/season. This oil is dark green in colour. It is more often used as medicine, soap, lamp oil, hair grease, and cosmetics in different regions of the world. These trees are very sensitive to frost and inflammable in nature. These fruits can be consumed even they are slightly toxic in nature. In Indian climatic conditions, these trees can give flowers and bear fruits throughout the year. These flowers appear in March-April and fruits get ripened in May-June in Kerala, May-June and October-November in Odisha. These flowers usually appear in cold season and fruits get ripened in March in Tamil Nadu and Mysore. In Andaman Islands these trees give flowers during rainy season and ripening of fruits takes place in June – August [1].

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Table.1. Different names of Calophyllum inophyllum around the world [26].

Country	Vernacular (Dialectal) name
India	Poon, Polanga, Undi, Sultan, Champa
Bangladesh	Punnang
Cambodia	Kchyong, Khtung
Malaysia	Bintangor, Penanglout
Indonesia	Bintangur, Nyamplung
Guam	Da'ok, Da'og
Thailand	Naowakan, Krathing, Saraphee
Tahiti	Tamanu
Philippines	Bitag, Butalau, Palomaria



(a)



(b)

Fig. 1. Calophyllum inophyllum (a) Flower (b) Tree.



(a)



(b)

Fig. 2. Calophyllum inophyllum (a) Leaves (b) Fruit.

V. PRODUCTION OF BIODIESEL

In order to reduce viscosity of the oil, Trans-esterification is the process in which oil having long chains of triglycerides is transfigure into small chains of methyl esters [27]. After the extraction of the oil from the seeds of the Calophyllum inophyllum, the production of the biodiesel from the polanga oil is followed by the four stages.

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The methodology for the production of Bio diesel is stated in the form of a flow chart as shown in the fig.3.

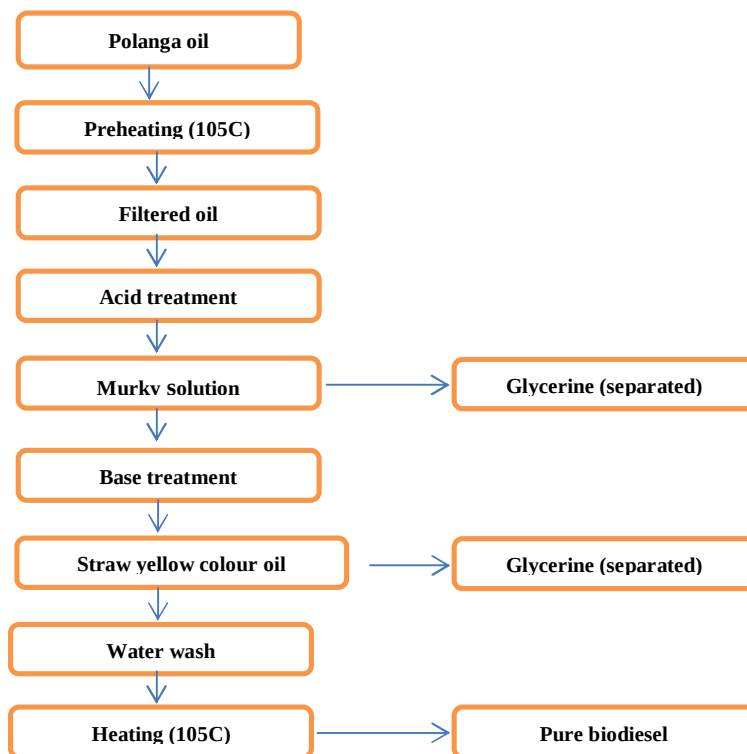


Fig.3.Methodology for the production of Biodiesel [29].

At last the pure Bio-oil is then blended with pure diesel in our required proportions Polanga Biodiesel10 (PBD10), Polanga Biodiesel20 (PBD20).

Pre-heating or Pre-treatment of oil:-

In this stage the extracted oil is heated more than 100°C for the removal of water particles and some impurities by homogeneous mixing using magnetic stirrer.

Acid catalysed Trans-esterification process:-

In this process, the heated oil is first allowed to cool down upto 50°C-55°C. The transesterification process for this stage is carried out in the presence of the acid catalyst (H_2SO_4). The mixing of oil with Methanol (generally methanol is used as it is cost effective) or Ethanol in presence of acid is done in between 50°C to 55°C of the temperature. This mixture has to be continuously stirred for 3 hours and has to be maintained in that temperature range and allow it to settle down for more than 24 hours enabling for the separation of glycerine.

Base catalysed Trans-esterification process:-

After the second stage process the oil is allowed to undergo Trans-esterification process in the presence of the base catalyst (either KOH or NaOH). The oil is then mixed and stirred with the Methanol or Ethanol in presence of base maintained within the same temperature range. This solution is now kept for settling down for more than 24 hours in order to obtain the by-product called glycerol.

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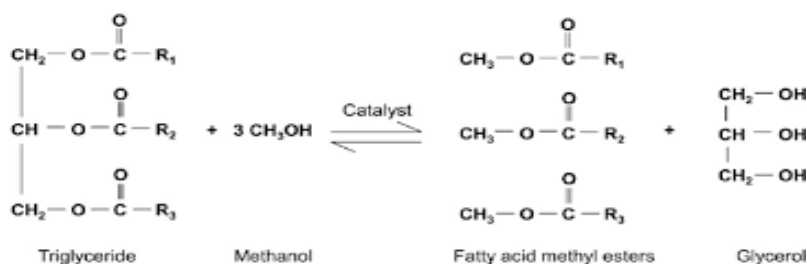


Fig.4. Trans-esterification process

The fig: 4 shows a chemical reaction of the trans-esterification process where the conversion of triglycerides (fat or oil) to esters and glycerol with the help of alcohol. Three long chains of fatty acids are attached to the base of a glycerine molecule in a triglyceride chemical. In the trans-esterification process, the triglyceride chemical has carbon molecules that tend to break their bond and is reacted with alcohol in the presence of a catalyst that makes a three similar methyl ester compound molecules and a single carbon bonded OH molecule known as glycerol.

Water wash:-

Once the solution gets settled down in the third stage, the upper layer of the solution i.e., oil undergoes the washing process. Mostly distilled water is used for washing of the oil as it is free from minerals. The distilled water used should be in the same proportion to the oil obtained in this stage. In addition to that 2 to 3 drops of the phenolphthalein indicator is used. This mixed solution undergoes bubbling for one hour and then allowed for the settling process for removal of soap particles as a by-product. After the settling process, the pure bio-oil is obtained on the upper layer and make sure that it is free from FFA and water particles. Again this oil is heated for 2-3 hours for removal of any further water particles [28].

VI. STUDY OF PERFORMANCE AND EMISSION CHARACTERISTICS

Experiment is conducted on 4 stroke single cylinder diesel engine fueled with PD and PBD10, PBD20 in order to determine and study the performance of the engine. Some of the performance characteristics like Brake thermal efficiency (BTE), Exhaust gas temperature (EGT) values were recorded during the engine running process against the Brake Power (BP) or load which is applied by electric dynamometer. By varying the brake power at different load, corresponding BTE and EGT values were noted down.

BTE (Brake thermal efficiency):

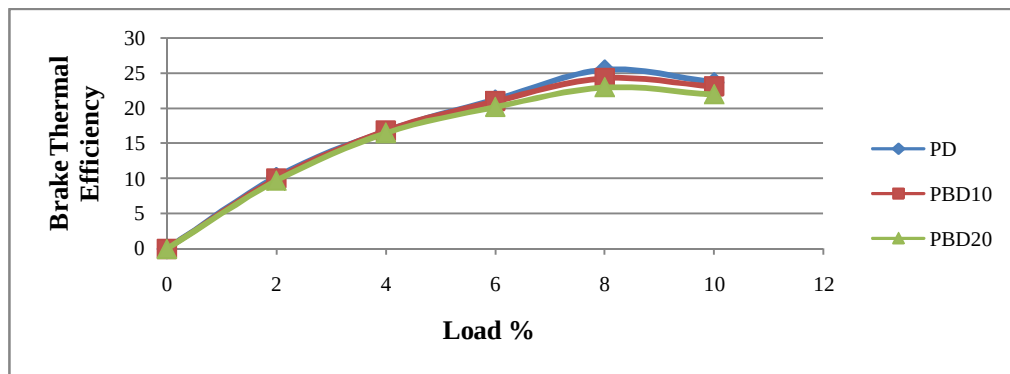
In the heat engine the brake power is a function of the thermal input or the amount of heat input from the fuel. BTE precisely gives the idea about that how good an engine converts the heat from the fuel combustion to the mechanical work [30]. The curves in the graph:1 depicts that the PD shows good BTE values than the blends. This is because of the presence of oxygen in the blends due to the increase of the fuel consumption in the chamber which reduces the combustion process. Therefore the BTE values of the PBD10, PBD20 were lower than the PD which shows that the biodiesel blends give almost same output power like PD.

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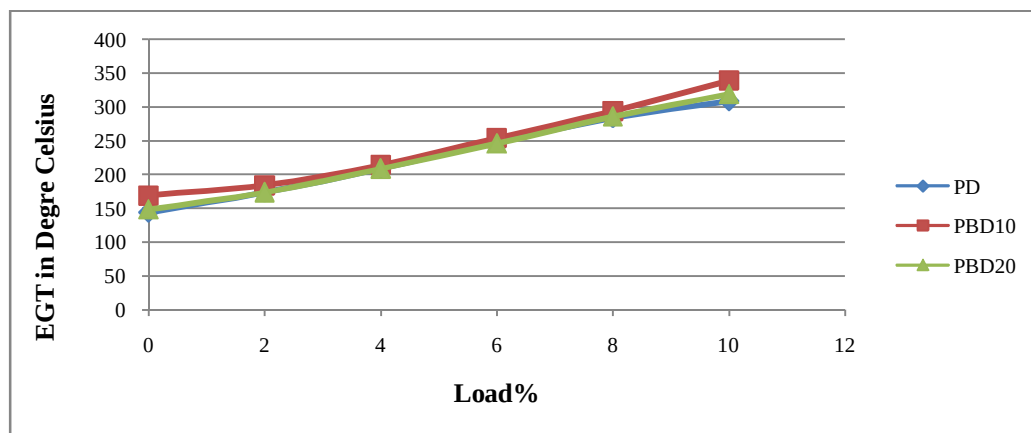
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Graph.1. Variation of Brake Thermal Efficiency with Load

EGT (Exhaust Gas Temperature):

EGT plays an important role in the study of the engine performance. The curves in the Graph:2 shows that PD gives the low EGT values under the different loads than the blends. This happens because of the amount of oxygen in the intake air fuel ratio is higher which results in the increase of the activation energy in the combustion chamber to complete the chemical reaction. Therefore the higher EGT values will give the more NO_x emissions because of the affect in the flame temperature [16]. Thus the PD is slightly good in EGT values than that of the blends of polanga. However the PBD20 gives almost similar performance characteristics to the PD.



Graph.2. Variation of Exhaust Gas Temperature with Load

The main characteristics that describe the nature of the fuel in the environmental effects are the Emission parameters. These are the engine exhaust emissions such as CO, CO₂, NO_x, Opacity, Hydro Carbon, etc. All these emissions parameters were recorded at different loads and graphs were plotted between these emission parameters and loads in order to study the nature of the Calophyllum blends.

NO_x Emissions:

Graph:3 shows the relationship between NO_x and different loads. NO_x are the oxides of nitrogen and these are directly proportional to the increasing load [31]. From the graph it can be stated that PBD20 gives less % of NO_x than the PD because when the load is increasing the temperature in the chamber also increases and as the EGT increase the NO_x

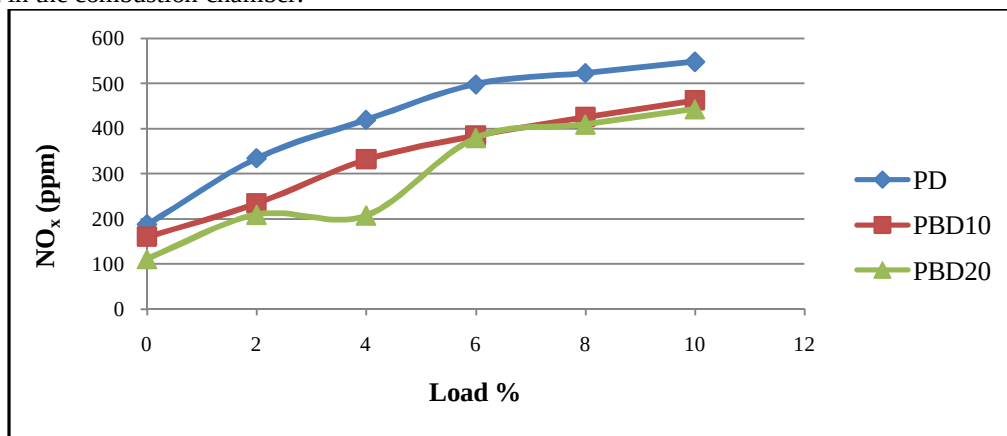
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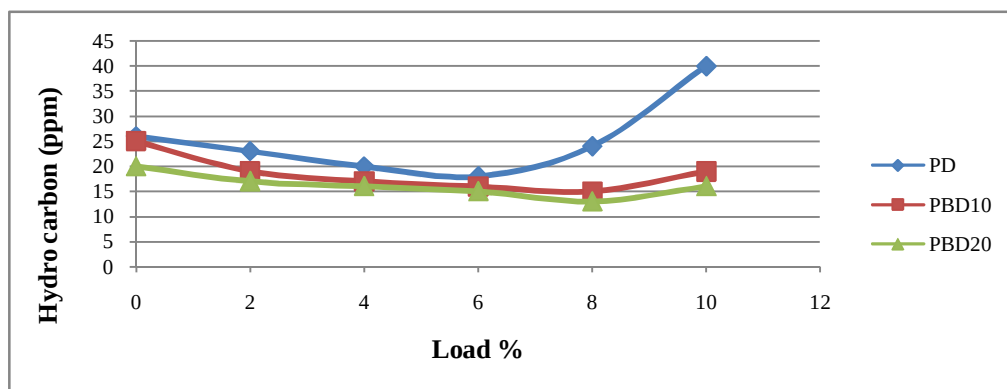
which, also increases due to its temperature dependent property. PBD20 gives less NO_x values because it has low temperature in the combustion chamber.



Graph.3. Variation of NO_x emissions in ppm with Load

HC Emissions:

Another effective parameter in the emission characteristics is Unburned Hydrocarbon. Graph:4 shows the relation between HC and loads, which shows that PD gives more HC than Blends. From graph it is clear that PBD20 gives the lower HC values because Biodiesel undergoes good combustion in the combustion chamber due to the presence of the oxygen in the Polanga blends [1,31].



Graph.4. Variation of Hydro Carbon emissions in ppm with Load

OPACITY (smoke) Emissions:

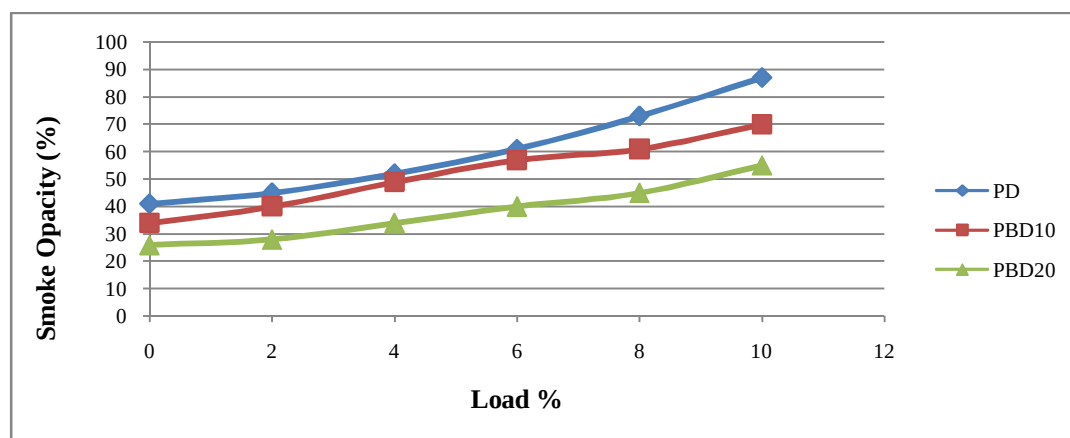
One of the major problems in the diesel engines is the smoke emissions. In this paper, smoke parameters were recorded for PD and Polanga blends and are shown in a graph: 5. From the graph it is clearly observed that PDB20 gives lower smoke % values than the PD. It is because of the remained unburnt Hydrocarbons and some particles of carbon in the combustion chamber. If there is more biodiesel blending then it reduces the carbon remains in the combustion chamber. So, PBD20 gives lesser smoke opacity and particulate matters during the emission.

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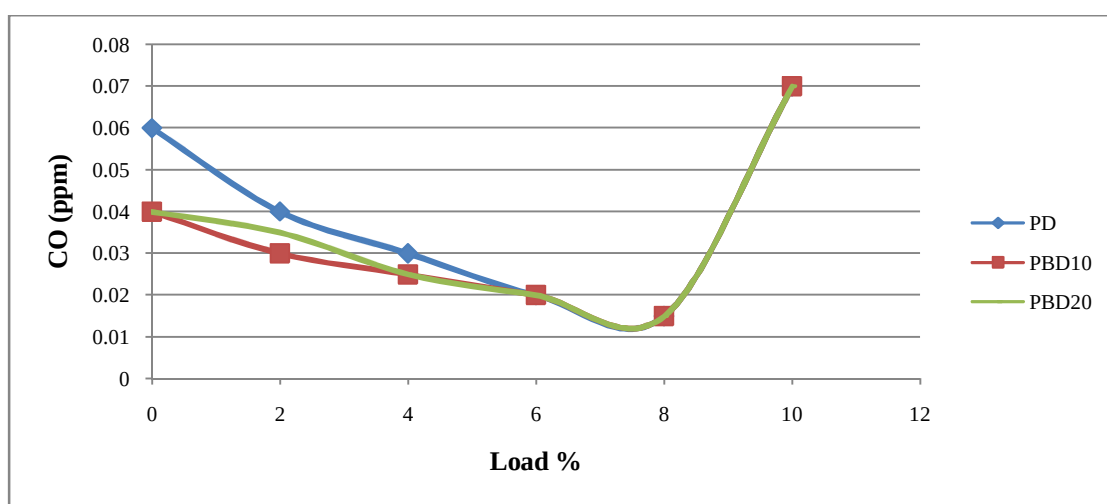
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Graph.5. Variation of Smoke opacity with Load

CO Emissions:

The Carbon Monoxide emissions values of PD and Polanga blends operated in the engine at different loads were plotted as shown in the graph: 6. From the graph it is observed that all the curves got merged, which indicates that PD, PBD10, PBD20 gives same amount of CO emissions. Even the CO emissions in Bio-diesel blends can be lowered if the viscosity of the blends is reduced [29]. But as the load is increased to the max level, the CO emission values were raised to small extent in both the PD and Polanga blends due to the rise in the exhaust gas temperature.



Graph.6. Variation of CO in ppm with Load

CO₂ Emissions:

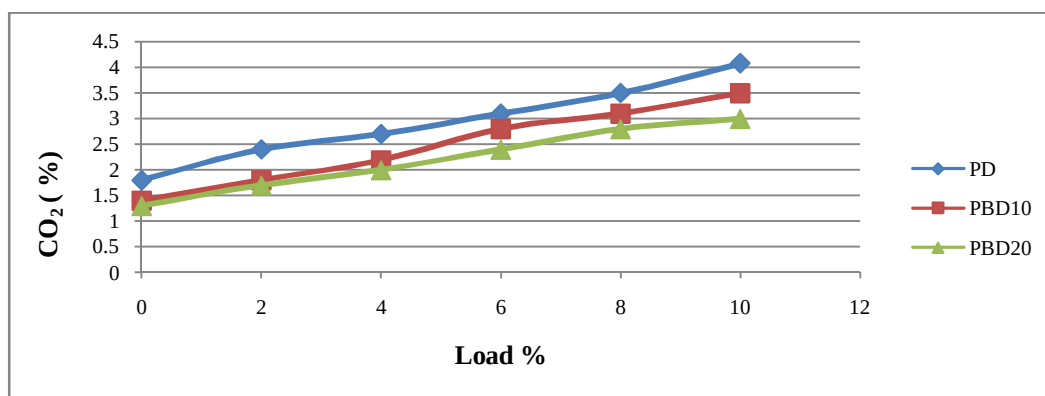
CO₂ is stated as the Greenhouse emission as it is responsible for the greenhouse effect. Graph:7 shows the bond plotted between CO₂ (carbon dioxide) emissions and load, which states that PDB20 gives lower CO₂ emissions than the PD. If the Biodiesel Blending ratio is increased then the emission of CO₂ will be decreased since the Biodiesel blending contains more oxygen content which in turn gives good combustion ratio. Thus PBD20 gives best Emissions performance when used in diesel engine.

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Graph.7. Variation of CO₂ emissions with Load

VII. CONCLUSION

This paper's main objective is to investigate the performance and emission characteristics of the Calophyllum inophyllum and its blends with the pure diesel. The production of biodiesel by the acid and base catalysed of transesterification process by which the FFA contents are reduced is illustrated in this paper. This process not only reduces the FFA but also improves some of the chemical properties.

From the section of performance characteristics, the brake thermal efficiency seems to be same for both the reference oil and blends with the increasing load. But in the case of exhaust gas temperature values, as the brake torque is increasing, PD gives some better results than those of the blends. Thus PD gives overall good performance of the engine rather than the Calophyllum inophyllum blends. PB20 gives satisfied results next to the PD.

From the emission characteristics, except in the case of CO emission the PB20 gives very low values of ppm in the case of emissions of NO_x, HC, CO₂ and smoke when there is an increase in the load of engine. This clearly depicts that by using PB20 the emissions are reduced to almost 20%-30% when compared to the pure diesel. So, we can say that PB20 is better than the PD in reducing emissions.

Thus, we can conclude that PB20 gives better and satisfactory results than the reference oil for the future operation on the engines.

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