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Performance and Combustion Characteristics of Single Cylinder Diesel Engine Operating on Blends of Neem and Cotton Seed Biodiesel with Diesel

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Abstract: Continuous rise in the conventional fuel prices and shortage of its supply have increased the interest in the field of the alternative sources for petroleum fuels. Biodiesel is one such alternative source which provides advantage of pollution control. In the present work, experimentation is carried out to study the performance and combustion characteristics of Neem & Cotton seed biodiesel and diesel. In this experiment a single cylinder, four stroke, naturally aspired, direct injection, water cooled, eddy current dynamometer, CI engine is used at constant speed condition. Crude oil is converted into biodiesel and characterization has been done. The experiment is conducted at variable load condition. The engine performance parameters studied were brake power, brake specific fuel consumption, brake thermal efficiency. The combustion characteristics studied are cylinder pressure, net heat release rate. These results are compared to those of pure diesel. These results are again compared to the corresponding results of the diesel. From the graph it has been observed that, there is an improvement in combustion characteristics and performance characteristics compared to the diesel. The present experimental results show that Neem & Cotton seed biodiesel can be used as an alternative fuel in diesel engine.
Keywords: Biodiesel, Neem & Cotton seed biodiesel, Diesel, Alternate fuel, Transesterification, Performance, Combustion.

I. INTRODUCTION

With the socio-economic growth of the society, the energy requirement has increased multifold globally as the consumption pattern in a particular country depends upon the availability of energy resources. The various sectors that require energy from some sources are industry, transport, agriculture, domestic etc. Different energy sources are wood, coal, petroleum products, nuclear power, solar, wind etc. Out of these, the world surface transport depends primarily on petroleum fuels. The overbearing dependence on petroleum products and related economic and environmental problems have created disquieting situation. The known petroleum reserves are not only limited but also concentrated in certain regions of the world. Further- more, petroleum reserves are depleting at breakneck pace. The critical situation has stimulated scientists and industries to search for and evaluate alternative fuels for petrol and diesel engines. The diesel engine is frequently used in transportation, power generation and many miscellaneous applications including industrial and agricultural. The major pollutants from diesel engine are smoke, particulate matter(PM), carbonmonoxide(CO), Nitrogen oxides(NOx) and unburnthydrocarbon(UBHC). Among different pollutants, the most significant are smoke and nitrogen oxides. For achieving this goal, two methods have been followed; adaptation of the engine to the fuel and adaptation of the fuel to the engine. Considering the large numbers of existing engines, the second strategy seems to be more apropos. Hence, there is a need to explore aviable alternate fuel that can be used incompression ignition (CI) engines. Any such alternative should not only match the performance of diesel but also meet or exceed the current emission norms. Harvesting renewable energy has also become an important energy source worldwide. The alternate fuel must be readily available, technically feasible, economically viable and also meet the pollution norms. One of the possible alternatives to the fossil fuel is vegetable oil. The development of vegetable oil started about a century ago. Also during World WarII, vegetable oils were used as fuel in emergency situations. In principle, any vegetable or seed oil which essentially comprises triglycerides of long chain saturated and unsaturated fatty acid can be used in diesel engines. This fuel is biodegradable, non-toxic and above all, has emission profile comparable to diesel. The characteristics of vegetable oils fall with in a fairly narrow band and are quite close to those of diesel. However, the initial research to use vegetable oil as a fuel for diesel engine resulted in some negative impact on engine. It has been shown in previous work that utilization of vegetable oils in diesel engine leads to problem in pumping, atomization, gumming, injector fouling, piston ring sticking and contamination of lubricating oil in the long run operation. It is due to high viscosity, density, iodine value and poor non-volatility. Hence, it is essential to reduce the viscosity for better combustion of the vegetable oils by using methods such as preheating, thermal cracking and transesterification. Transesterification is primarily used to convert vegetable oil to a form that can be used in diesel engines and is called biodiesel. Biodiesel can be defined as mono-alkyl esters of long chain fatty acids derived from vegetable oils or animal fats which conform to the ASTM (American Society for Testing and Materials) specification for use in diesel engine. It is considered a clean fuel as it has almost no sulfur, no aromatics and has about 10% built-in oxygen, which helps it to burn completely and also gives it a high cetane number. Biodiesel may be easier to commercialize than other alternative fuels, and hence numerous vegetable oils have been tested as biodiesel. surveyed 364 different plant seed oils as promising fuel for diesel engine, both in the pure oil form as well as in the form of fatty acid methyl esters,. In general, biodiesel feedstock can be divided into four categories:

1) *Edible vegetable oil*: Sunflower, Rapeseed, Rice bran, Soybean, Coconut, Corn, Palm, Olive, Pistachia Palestine, Sesame seed, Peanut, Opium Poppy, Safflower oil etc.
2) *Non-edible vegetable oil*: Jatropha, Karanja or Pongamia, Neem, Jojoba, Cottonseed, Linseed, Mahua, Deccan hemp, Kusum, Orange, Rubberseed, Sea Mango, Algae and Halophytes etc.
3) Waste or recycled oil.
4) *Animal fats*: Tallow, yellow grease, chicken fat and by- products from fish oil etc.

The production and utilization of biodiesel as diesel fuel has been well tested and evaluated in several countries. Also, due to its properties similar to those of diesel, it can be used as a viable substitute without any significant modification in existing diesel engine, as well as fuel storage and distribution infrastructure. The goal of the present study is to evaluate the performance and emission of the diesel engine operating on biodiesel in relation to the effects of fatty acid composition.

II. LITERATURE REVIEW

India has rich and abundant forest resources with wide range of plants and oil seeds. The potential of tree borne oil seeds (TBO) is not fully explored. According to an economic survey of Government of India about 175 million hectors of land is classified as waste or barren land. Wild crops cultivated in waste land also form a source of biodiesel. Besides, some species of plants yielding non edible oils, like karanja also called honge (Pongamia pinnata) and neem (Azadirachta indica) may play significant role in providing resources. Country like India in tropical Asia is the primary habitat for neem and karanja crops. It is estimated that India alone has theoretical potential to produce 350,000 tons of neem oil per annum

1) *Saikiran*, V. Sakthimurugan Performance and Emission Analysis on C.I Engine with Neem Oil Bio Diesel at Different Load Conditions* Journal of Chemical and Pharmaceutical Sciences ISSN: 0974-2115.

The Blends are 15%, 20% and 25% of neem oil are used. Smoke test and viscosity experiment are made for all these bio diesel combinations and performance test was carried out. Because the results are observed and compare all of the graphs and discovered that the break thermal and mechanical effective for B20 is ready 30.29% and 92.34% that are larger B20 has bigger effective combo and grate cooling influence, when in comparison with different mixtures. Smoke test proved that the B20 blend has the mine to the pure diesel which has 30.2%. The increasing industrialization and motorization of the arena has led to a steep rise for the demand of petroleum products. Accordingly, it is vital to seem for replacement fuels, which may also be comprised of substances available within the nation. In this paper, biodiesel performance checking out is completed in C.I. Engine. Biodiesel has been ready from NEEM oil via mechanical stirring process and evaluation additionally has been made with diesel. The performances of this biodiesels had been confirmed by means of the efficiency parameters like torque, brake vigour, brake thermal effective and brake designated fuel consumption, brake specific power consumption, exhaust gas temperature, air gas ratio and emission characteristics like smoke opacity.

III.METHODOLOGY

A lot of research works have been carried out to use vegetable oil both in its neat and modified form. Studies have shown that the usage of vegetable oils in neat form is possible but not preferable. The high viscosity of vegetable oils and the low volatility affects the atomization and spray pattern of fuel, leading to incomplete combustion and severe carbon deposits, injector choking and piston ring sticking.

The methods used to reduce the viscosity are:

1) Blending with diesel
2) Emulsification
3) Pyrolysis
4) Transesterification

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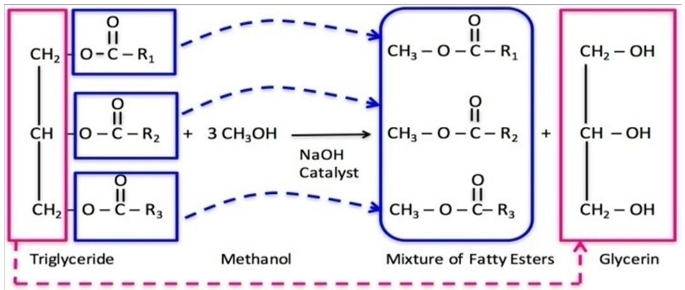
Among these, the transesterification is the commonly used commercial process to produce clean and environmental friendly fuel. However, this adds extra cost of processing, because of the transesterification reaction involving chemical and process heat inputs.

A. Transesterification Process

The conversion of oil into its methyl ester can be accomplished by the transesterification process. Transesterification involves reaction of the triglycerides of oil with methyl alcohol in the presence of a catalyst Sodium Hydroxide (NaOH) to produce glycerol and fatty acid ester.



B. Biodiesel Preparation

Free fatty acid (FFA) percentage in neem & cotton seed oil is to be determined. There are many methods to find out the free fatty acid percentage content in oil. Simple titration with the NaOH is a simple method.

Percentage of free fatty acid (FFA) in neem oil is 3.5% & cotton seed oil 2.5%. It is less than 4% so we can go for directly alkaline esterification (Single stage process) using methanol as reagent and NaOH as catalysts for base reactions was followed to produce biodiesel from crude neem & cotton seed oil.

C. Base catalyst process (Single stage process) :

The production of biodiesel by transesterification of the oil generally occurs using the following steps:

1) *Mixing of alcohol and catalyst:* For this process, a specified amount of 250 ml methanol and 6 gm Sodium hydroxide (NaOH) was mixed in a round bottom flask.
2) *Reaction:* The alcohol/catalyst mix is then charged into a 3 neck flask and 1000 ml oil is added. Excess alcohol is normally used to ensure total conversion of the fat or oil to its esters. The contents were stirred till ester formation began. The mixture was heated to 65^{o}C and held at that temperature with constant speed stirring for 2 hours and then it was allowed to cool overnight without stirring.
3) *Separation of glycerol and biodiesel:* Once the reaction complete, two major products exist; glycerol and biodiesel. The bottom layer consisted of glycerol and top layer was the ester. With the help of separating funnel the mixture is separated.
4) *Methyl Ester Wash:* The most important aspects of biodiesel production to ensure trouble free operation in diesel engines are complete reaction, removal of glycerine, removal of catalyst, removal of alcohol and absence of free fatty acids.

Thus formed biodiesel is taken up for washing process, where biodiesel is transferred in washing funnel specially assembled for this purpose along with 300ml of warm water (40^{o}C)slowly without any agitation. Now washed biodiesel is taken up for drying purpose into a beaker. Add magnetic pellet and heat the biodiesel to a temperature of 100oC at lower speed. Allow the biodiesel to cool gradually and is ready to use.

Fig 1: Processing of biodiesel from raw oil

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Fig 2: Separation of biodiesel

Fig 3: Washing of biodiesel

Fig 4: Blends of biodiesel

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D. Properties of fuels used

Table 1 shows the values of different properties such as density, kinematic viscosity, flash point, fire point and calorific value of diesel and neat rice bran biodiesel.

Properties	Ref. Std. (ASTM 6751)	Diesel	NOME	CSOME
Density (kg/m^3)	D 1448-1972	830	875	875
Kinematic viscosity (cSt)	D0445	2.72	4.38	4.3
Calorific value (kJ/kg)	D 6751	42500	38500	40860
Flash point (^oC)	D 93	46	152	138
Fire point (^oC)	D 93	53	180	167

Table 2: Properties of blends of biodiesel

Properties	B10	B20	B30
Density (kg/m3)	825	827	830
Kinematic viscosit(cSt)	3.76	4.08	4.41
Calorific value (kJ/kg)	41290.22	39942.07	39251.25
Flash point (^oC)	46	56	58
Fire point (^oC)	55	65	67

1) *Density:* Fig. 5 shows the hydrometer setup. Density is defined as the ratio of the mass of fluid to its volume. It is denoted by the symbol (rho). The SI unit is given by kg/m3. Density of diesel is 831 kg/m^3 **.** Neem & Cotton seed biodiesel is slightly heavier than the mineral diesel fuel. Density of Neem and Cotton seed biodiesel was found to be 875 (kg/m^3) while that of Diesel was 830 (kg/m^3). This allows use of splash blending by adding biodiesel on top of diesel fuel for making bio-diesel blends. While blending bio-diesel should always be blended at top of diesel fuel. If bio-diesel is first put at the bottom and then diesel. It was seen that for lower blends like B10 and B20 the results of densities of Neem & Cotton seed biodiesel are quiet comparable with diesel fuel.

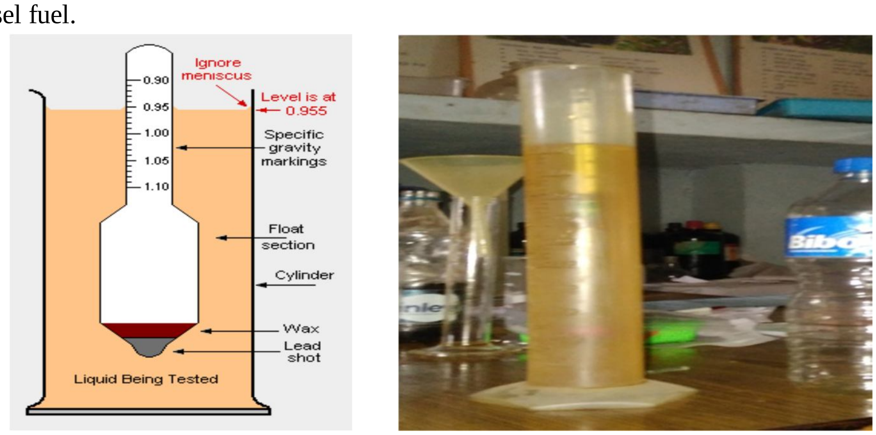


Fig5: Hydrometer

2) *Calorific vale:* The calorific value of a substance is the amount of energy released when the substance is burned completely to a final state and has released all of its energy. The gross calorific value of Neem and Cotton seed biodiesel by test method IS: 1448P:06 were found to be 38500kJ/kg & 40860kJ/kg respectively, which was approximately 90% that of the diesel fuel, which makes its use to be more viable in diesel engines. This could be due to the difference in their chemical composition from that of diesel or the difference in the percentage of carbon and hydrogen content, or the presence of oxygen molecule in the molecular structure of oil and biodiesel. It was observed that calorific value decreasing with the increasing in blend ratio.
3) *Kinematic viscosity:* The resistance offered to flow of a fluid under gravity. The kinematic viscosity is a basic design specification for the fuel injectors used in diesel engines. The kinematic viscosity of crude Neem oil was found to be near 44 cSt, which is twenty times more than that of diesel and it reduced to 4.38 cSt after transesterification. The kinematic viscosity values are decreased with increase in temperature. It was observed that viscosity of Neem and Cotton seed oil decreases remarkably with increasing temperature and it becomes close to diesel at temperature above 90 ^{o}C.

Fig 6: Redwood viscometer.

4) *Flash & Fire Point*

Flash point of the fuel is defined as the temperature at which fuel gives off vapour to just ignite in air. Fire point of the fuel is defined as the temperature at which fuel will ignite continuously when exposed to a flame or spark.

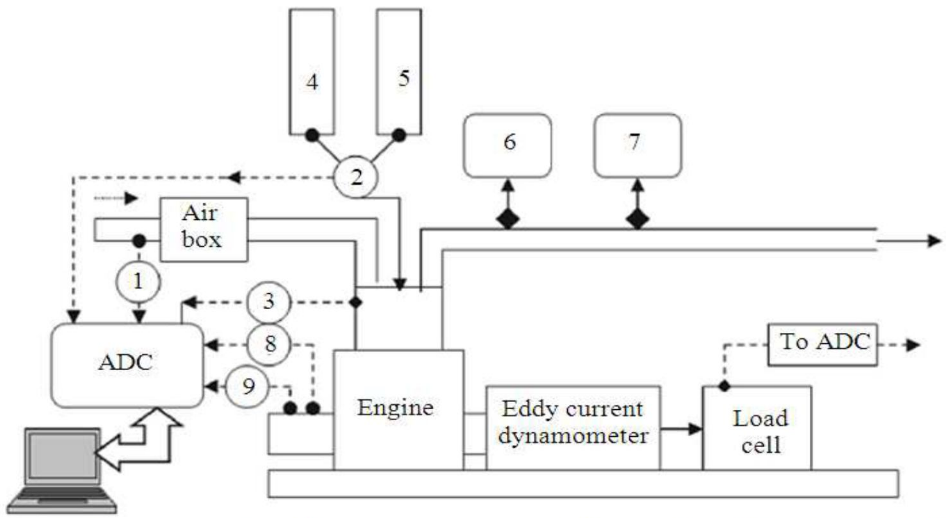
Fig 7: Abel's flash point apparatus

The flash point of biodiesel is higher than the petroleum based fuel. Flash point of biodiesel blends is dependent on the flash point of the base diesel fuel used and increase with percentage of biodiesel in the blend. Thus in storage, biodiesel and its blends are safer than conventional diesel. Determined by the instrument called Able's flash and fire point apparatus as shown in Fig .

Flash points of Neem and Cotton seed biodiesel was found to be 152^{o}C and 138^{o}C, respectively and were quite high compared to 46^{0}C for the diesel. Fire points of Neem and Cotton seed biodiesel were determined to be 128^{o}C and 167^{o}C, respectively and were quite high compared to 54^{0}C for the diesel.

E. Experimental setup

1) *Engine:* A Kirloskar make, single cylinder, air cooled, direct injection, DAF 8 model diesel engine (Product 240PE) was selected for the present research work, which is primarily used for agricultural activities and household electricity generations. It was a single cylinder, naturally aspirated, vertical, air-cooled engine. The detailed technical specifications of the engine are given in Table 3. The schematic diagram of the experimental setup along with all instrumentation is shown in Fig. 8. The engine trial was conducted as specified by IS: 10,000. The main parameters desired from the engine were power produced by the engines, engine speed (rpm), fuel consumption, exhaust gas analysis, crank angle measurement by crankshaft encoder, in-cylinder gas pressure measurement and heat release rate by using pressure transducers. The transducer and thermocouples were fitted at the suitable positions to measure the readings at different engine loadings. The fuel injection system was a traditional system consisting of a single hole pintle nozzle which inject the fuel at 200-205 bar.



1-Air flow sensor, 2-Fuel flow sensor, 3-Pressure sensor, 4-Diesel tank, 5-Biodiesel tank, 6-Five gas analyzer, 7-Smoke meter, 8-Speed sensor, 9-Crank angle encoder

Fig 8: Schematic view of the experimental setup

Engine performance study includes brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, Air fuel ratio, heat balance and combustion analysis. Lab view based Engine Performance Analysis software package **Engine soft** is provided for on line performance evaluation.

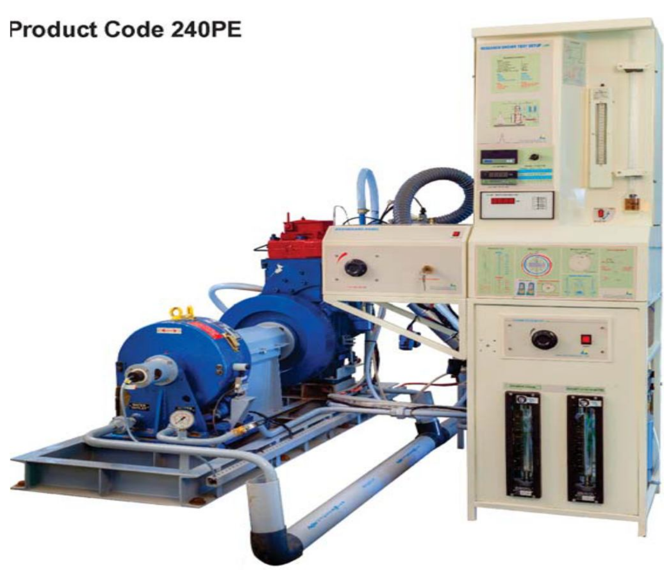


Fig 9: Test engine

Table 3: Specifications of test engine

Particulars	Specifications
Make	Kirloskar Oil Engines, India
Type	Vertical, water cooled engine
No. Of cylinder	One
Bore Diameter	87.5mm
Stroke Length	110mm
Compression Ratio	18:1
Speed	1500rpm
Rated power	3.5kW @1500rpm
Dynamometer	Type eddy current, water cooled with load unit
Starting	Self starting with electric motor

IV. RESULTS AND DISCUSSION

Worldwide, biodiesel is largely produced by methyl transesterification of oils. The recovery of ester as well as its kinematic viscosity is affected by the transesterification process parameters such as catalyst concentration, reaction temperature and reaction time. The above parameters were standardized to obtain methyl esters of neem oil and cotton seed oil with lowest possible kinematic viscosity and highest level of recovery. The engine performance parameters, combustion and exhaust gas emission characteristics of B10, B20, B30 and diesel were compared.

A. Performance Analysis

1) *Engine brake Power:* The variation of the engine brake power with the increase in load acting on the engine for diesel and blends of CSOME-NOME is as shown in the fig 11. The brake power for diesel is more than that of B10 & B30 blends of CSOME NOME at full load. This is due to the fact that biodiesel has lower heating value compared to diesel, so more biodiesel is needed to maintain constant power output. The brake power for B20 is almost equal to that of diesel at full load.

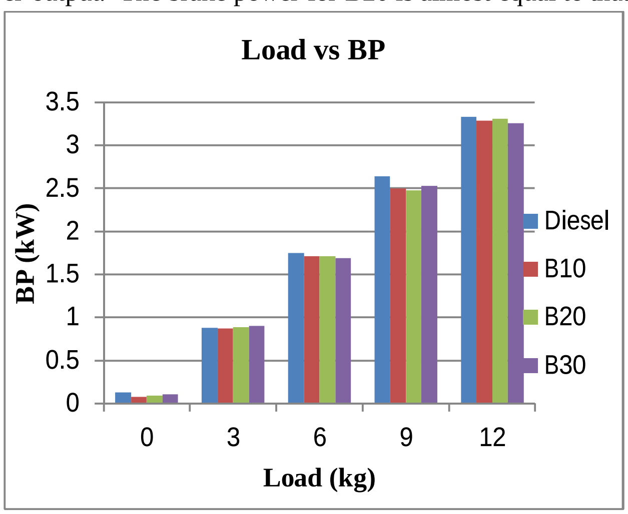


Fig 11: Variation in BP for different fuel.

2) *Brake thermal efficiency:* Thermal efficiency is the ratio of thermal power available in the fuel to the power the engine delivers to the crank shaft. It was observed that the brake thermal efficiency increased with the increase in load. This is due to the reduction in heat loss and increase in power with the increase in load.

The brake thermal efficiency obtained for the variable loads of the blends B10, B20, B30 and the diesel were compared and represented graphically as shown in the fig. 12. The brake thermal efficiency of B30 at full load is less than that of diesel whereas the BTE of B10 and B20 at full load are higher than that of the diesel. It shows that the BTE is found to be decreasing with the increase in the percentage of blends.

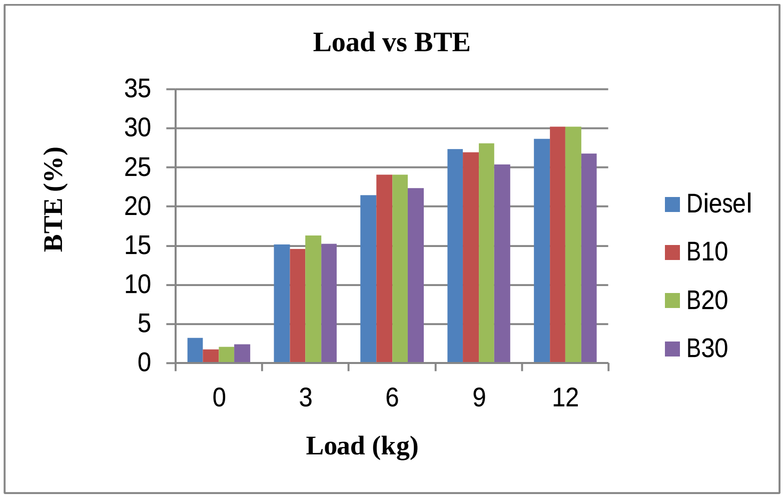


Fig 12:Variation of BTE for different fuels

3) *Brake specific fuel consumption*

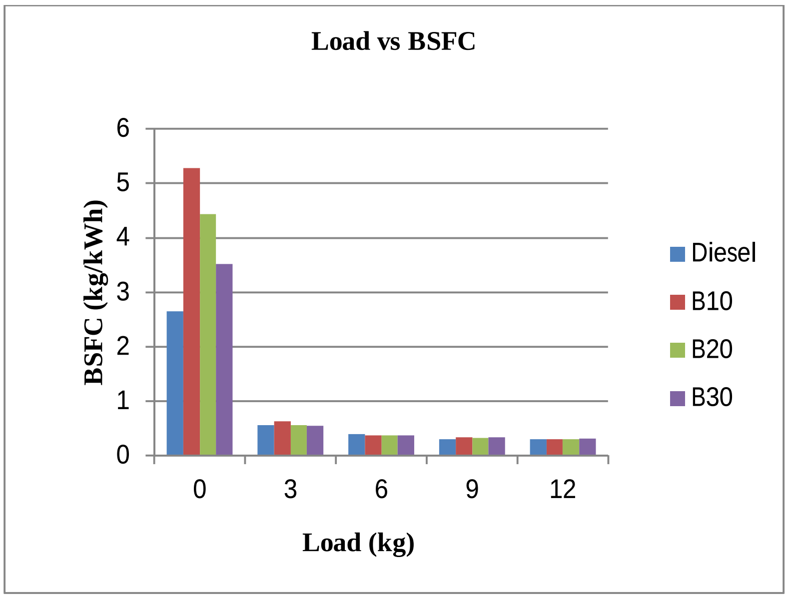


Fig 13: Variation of BTE for different fuels

It is defined as the fuel flow rate per unit power output. It is the measure of the efficiency of the engine in using the fuel supplied to produce work. The variation of BSFC for different fuels shows decline with increase in load. It is desirable to obtain a lower value of BSFC meaning that the engine used less fuel to produce the same amount of work. This is one of the most important parameters to compare when testing various fuels. The BSFC obtained at full load for the blends B10 and B20 is same as that of diesel and as shown in the fig. 13.

B. Combustion characteristics

1) *Cylinder pressure :* The variation of cylinder pressure with crank angle at different loads for different fuels is as shown in the fig. 14. In a CI engine, the cylinder pressure characterizes the ability of fuel to mix well with air and burn. It is clear that the combustion starts earlier for B20 due to shorter ignition delay. It is observed that B20 as higher peak pressure than diesel & other blends. It may be due to more fuel is accumulated in the combustion chamber which leads to higher peak pressure at the time of premixed combustion stage. The higher peak pressure for B20 as compared to diesel may also be due dynamic injection advance, which results in initiation of combustion before TDC at the pressure rises quickly. The peak pressure for B20 is 68.6 bar, while in the case of diesel, it is 67 bar at full load.

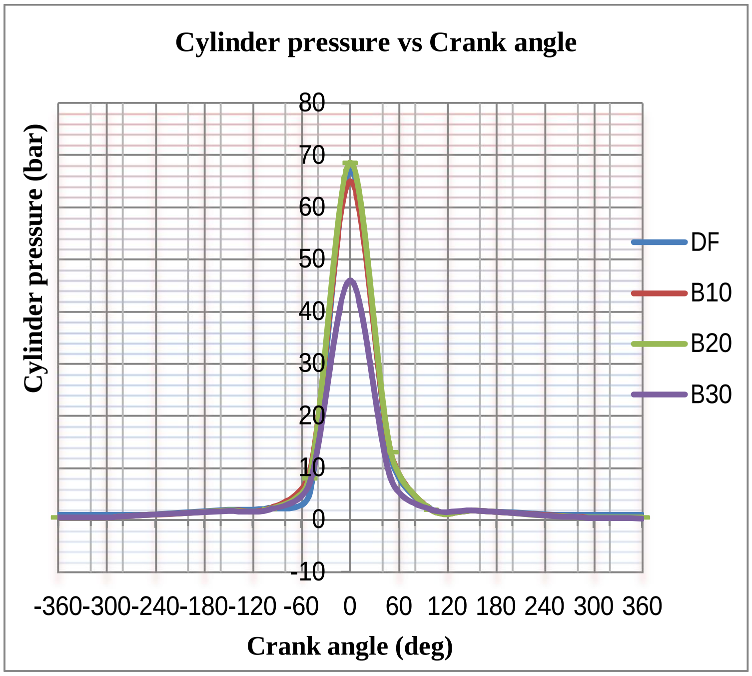


Fig 14: Variation of cylinder pressure with crank angle for different fuels

2) *Heat release rate:* The variation of heat release rate with crank angle at different loads for different fuels is as shown in fig. 15. It is observed that the heat release rate is higher for diesel than other blends at full loads. This may be due higher volatility and better mixing of diesel with air. Another reason may be, as a consequence of the longer ignition delay, the intensity of premixed combustion phase for diesel is more. On the other hand, the peak heat release rate is lower for B30 compared to B20 and diesel. This may be due to lower volatility and higher viscosity of B30, it leads to a reduction in air entrainment and fuel-air mixing rates, resulting in lesser amount of fuel being prepared for premixed combustion stage during ignition delay.

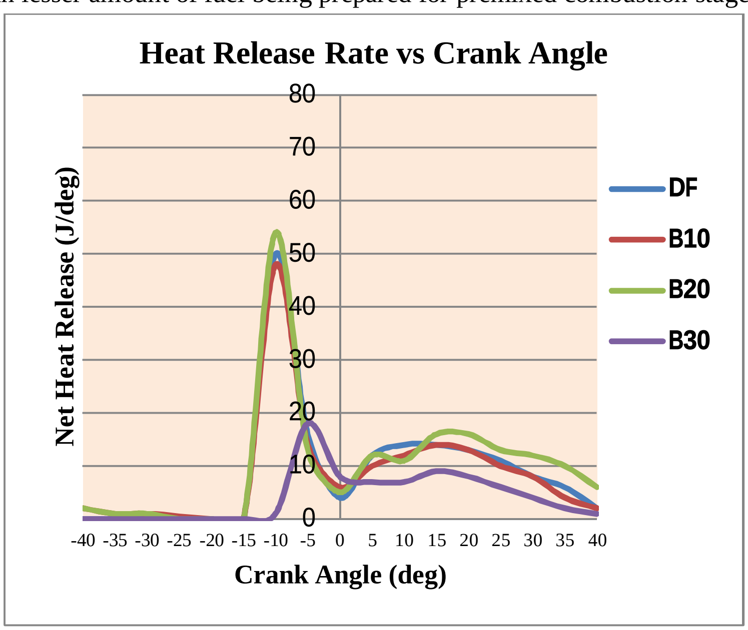


Fig 15: Variation of Heat release rate with crank angle for different fuels.

V. CONCLUSIONS

The present study was about technical feasibility of blends of biodiesels of neem and cotton seed with diesel fuel in the compression ignition engine without any modification. The engine performance and combustion characteristics were analyzed. The characteristics were briefly discussed in the previous chapter through which we can make following conclusions.

A. Performance Of The Engine

1) The brake thermal efficiency for B20 at full load was found to be higher than that of diesel and other blends.
2) The brake power for diesel is more than that of B10, B20, B30 blends of biodiesel of neem and cotton seed with diesel at full load. This is due to the fact that biodiesel has lower heating value compared to diesel, so more biodiesel is needed to maintain constant power output.
3) Torque increases with increasing load on the engine. The torque generated at full load using blends of biodiesel is nearly equal to that of the diesel. At lower loads the values of torque using blends of biodiesels are lower compared to that of diesel.
4) The BSFC obtained at full load for the blends B10 and B20 is same as that of diesel. It is observed that as the load increases the BSFC for diesel and other blends of biodiesel decreases and is almost same for all the fuels.

B. Combustion Characteristics

1) The peak cylinder pressure for B20 is closer to diesel fuel and it is slightly higher than B30 at full load
2) It is observed that the heat release rate is higher for diesel than other blends at full loads This may be due higher volatility and better mixing of diesel with air. Another reason may be, as a consequence of the longer ignition delay, the intensity of premixed combustion phase for diesel is more.

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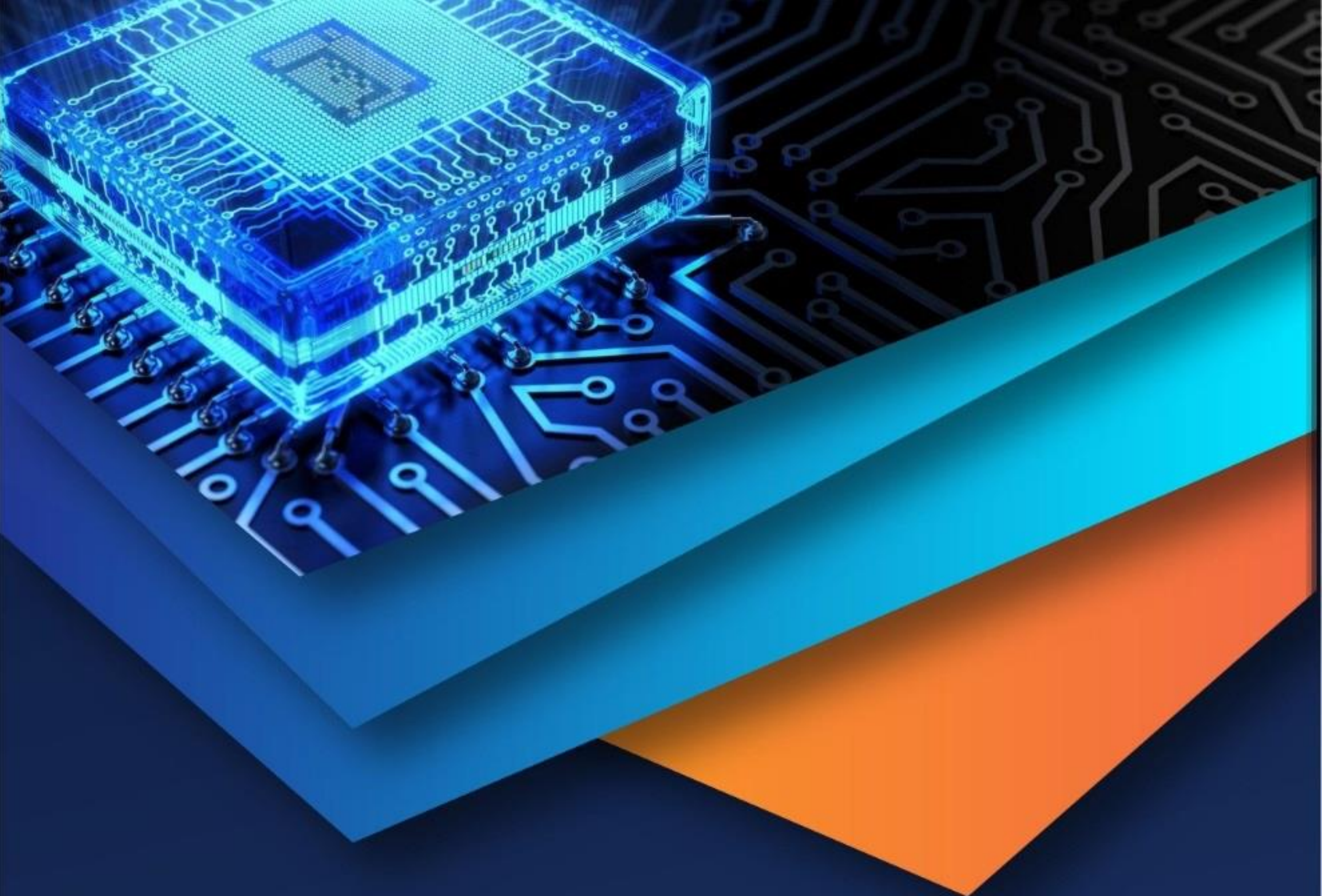

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