Optimization of Mango seed biodiesel blends for CI engines

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Abstract - *An abstract summarizes, Biodiesel is a low-emissions diesel substitute fuel made from renewable resources like vegetable oils. India is not self-sufficient in petroleum and has to import about two third of its requirements to introduce one of the solutions to the current oil crisis and toward off any future energy and economic crunch is to explore the feasibility of substitution of diesel with an alternative fuel which can be produced in the country on a massive scale to commercial utilization. Hence it has become imperative to find alternative fuels to replace the conventional fossil fuels. This report outlines the studies done to find the optimal method for converting Mango seed oil to usable biodiesel and using this biodiesel to run the four stroke diesel engine. The amount of alkaline catalyst and ratio of methanol to fresh oil for the greatest conversion of fatty acid methyl esters are reported. In addition, the optimal reaction was established. Finding the most efficient way to convert Mango seed oil to biodiesel would allow for this biodiesel to be produced as economically as possible. The performance test was conducted on a 4 stroke diesel engine in our EC laboratory. The pollution levels came down drastically and performance was better with various blends of Mango seed biodiesel and diesel.*

Key Words: *Biodiesel, Extraction, Mangifera Indica, Pretreatment, Transesterification.*

1. INTRODUCTION

In IC engine, the thermal energy is released by burning the fuel in the engine cylinder. The combustion of fuel in IC engine is quite fast but the time needed to get a proper air/fuel mixture depends mainly on the nature of fuel and the method of its introduction into the combustion chamber. The combustion process in the cylinder should take as little time as possible with the release of maximum heat energy during the period of operation. Longer operation results in the formation of deposits which in combination with other combustion products may cause excessive wear and corrosion of cylinder, piston and piston rings. The combustion product should not be toxic when exhausted to the atmosphere. These requirements can be satisfied using a number of liquid and gaseous fuels. The biodiesel from non edible sources like Jatropha, Mango, Mahua, Neem etc meets the above engine performance requirement and therefore can offer perfect viable alternative to diesel oil in India. The experiment on the diesel engine are performed and found out that it increase the BSFC using various blends of biodiesel from various resources including diesel. The finding indicates that there is increase in the BSFC when using biodiesel as compared to diesel for the same power output. This is because that the heating value of biodiesel is less as compared to diesel [1]. It is found that there is no significant change in the thermal efficiency while using biodiesel up to B20 but there is a slight decrease in thermal efficiency when B100 was used which is due to the lower energy content of biodiesel [2].

Oil has become increasingly important to the world economy due to its employment to energize the transportation industry. As the world population grows exponentially, so does the demand for oil. Since oil wells have depleted in the United States, it has forced the U.S. to import oil making them dependent on other countries to meet the demand. To solve this problem the U.S. has invested in alternative technologies research like Gasoline Hybrid, Full electric, Hydrogen, Ethanol, and many others.

For the past decades, oil has become important to the world economy due to its use to energize the world, specially the transportation sector as stated above. It is projected that the consumption of liquid fuels will increase from 84 million barrels per day in 2005 to 113 million barrels in 2030. The transportation sector accounts for a 74 percent increase from 2005 to 2030, since the new building are design with the purpose of energy efficiencies and sustainability.

Another study done by the EIA projects the amount of energy consumed worldwide by fuel type. It is expected that world oil price will remain high, the liquid fuels, are the slowest growing source of energy; liquid consumption increases at an average annual rate of 1.2 percent from 2005 to 2030. A trend is notice as the vehicle ownership increases, also does the change in liquid consumption for transportation energy from 2005 to 2030, especially in North America.

India was the fourth largest consumer of oil and petroleum products after the United States, China, and Japan in 2013, and it was also the fourth-largest net importer of crude oil and petroleum products. The gap between India's oil demand and supply is widening, as demand reached nearly 3.7 million barrels per day (bbl/d) in 2013 compared to less than 1 million bbl/d of total liquids production. EIA projects India's demands will more than doubleton 8.2 million bbl/d by 2040, while domestic production will remain relatively flat, hovering around 1 million bbl/d. The high degree of dependence on imported crude oil has led Indian energy companies to diversify their supply sources. To this end, Indian national oil companies (NOCs) have purchased equity stakes in overseas oil and gas fields in South America, Africa, Southeast Asia, and the Caspian Sea region to acquire reserves and production capability. However, the majority of imports continue to come from the Middle East, where Indian companies have little direct access to investment.

India's crude oil imports reached nearly 3.9 million bbl/d in 2013, according to Global Trade Atlas. Saudi Arabia is India's largest oil supplier, with a 20% share of crude oil imports. In total, approximately 62% of India's imported crude oil came from middle east countries. The second biggest source of imports is the Western Hemisphere (19%), with the majority of that crude oil coming from Venezuela. Africa contributed 16% of India's crude oil imports. supply disruptions in several countries, including Iran, Libya, Sudan, and Nigeria, in tandem with India's growing dependence on imported crude oil, have compelled India to diversify its crude oil import slate. Iran accounted for 5.5% of India's crude imports in 2013, down from 8.3% in 2011-12 as a result of the U.S. and European sanctions imposed on Iranian oil exports. Also, Indian refiners are trying to reduce crude oil import costs by purchasing less expensive crude oil. prices of middle eastern crude oil grades in the past year have been high relative to prices of oil from the Western Hemisphere, prompting Indian companies to import more crude oil from Latin America, primarily from Venezuela, Colombia, and Mexico. [3]

2. Characteristics of CI engine fuels

Mango seed oil is native to a number of countries including India, Malaysia, Indonesia, Taiwan, Bangladesh, Sri Lanka and Myanmar. It has also been naturalized in parts of eastern Africa, northern Australia and Florida. Mango seed oil has a varied habitat distribution and can grow in a wide range of conditions. Mango oil, a.k.a. mango kernel fat,[1] or, mango butter, is an oil fraction obtained during the processing of mango butter. Mango oil is a seed oil extracted from the stone of the fruit of the Mangifera indica. The oil is semi-solid at room temperatures, but melts on contact with skin, making it appealing for baby creams, suncare balms, hair products, and other moisturizing products. The oil is a soft yellow color with a melting point of 32-42 °C. A large green tree, valued mainly for its fruits, both green and ripe. It can grow up to 15–30 metres (49–98 ft) tall. The tree grows best in well-drained sandy loam; it does not grow well in heavy wet soils. The optimal pH of the soil should be between 5.2 and 7.5.

The following are the important factors, which influence the choice of fuel:

- Viscosity of the fuel
- Density
- Calorific value
- Fire point and flash point
- Water and sediment present
- Ash content of fuel
- Boiling range of fuel
- Ignition quality of fuel
- Fuel viscosity of fuel injection
- Storage facilities
- Materials compatibility issues

2.1 The Properties of Diesel fuel and Mango seed biodiesel

The different properties of diesel fuel and Mango seed biodiesel are determined and shown in table.3.2. After transesterification process the fuel properties like kinematic viscosity, calorific value, density, flash and fire point get improved in case of biodiesel. The calorific value of mango seed biodiesel is lower than that of diesel because of oxygen content. The flash and fire point temperature of biodiesel is higher than the pure diesel fuel this is beneficial by safety considerations which can be stored and transported without any risk.

Table -1: Fuel properties

Fuel Properties	Diesel	Mango seed biodiesel	Apparatus used
Fuel density in $\frac{kg}{m^3}$	830	865	Hydrometer
Calorific value (kJ/kg)	43000	40794	Bomb calorimeter
Flash point in °C	56	160	Pensky-martien's apparatus
Fire point in °C	65	170	Pensky-martien's apparatus
Kinematic viscosity at 40°C in cst	3.9	5.63	Redwood viscometer

3. Experimentation

3.1 Engine components

The various components of experimental set up are given below. Fig.3.8 shows the photograph of the experimental set up and Fig.3.9 shows the line diagram. The important components of the system are

- The engine
- Dynamometer
- Smoke meter
- Exhaust gas analyzer

Fig -1: Photograph of experimental setup

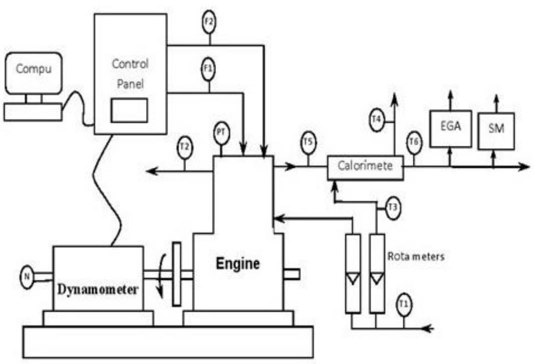

Fig -2: Experimental set up

Table -1: Engine Specifications

Sl No	Parameters	Specification
01	Manufacturer	Kirloskar oil engines Ltd. India
02	Model	TV-SR, naturally aspirated
03	Engine	Single cylinder, DI
04	Bore/stroke	87.5mm/110mm
05	C.R.	16.5:1
06	Speed	1500 RPM, constant
07	Rated power	5.2KW
08	Working cycle	Four stroke
09	Response time	4 micro seconds
10	Type of sensor	Piezo electric
11	Crank angle sensor	1-degree crank angle
12	Injection pressure	200bar/23 def TDC
13	Resolution of 1 deg	360 deg with a resolution of

4. RESULTS AND DISCUSSIONS

4.1 Introduction

This chapter consists of three types of experimental analysis, first one is performance characteristics like brake thermal efficiency, specific fuel consumption, exhaust gas temperature, against brake power, second one is combustion characteristics like pressure, and heat release rate, against crank angle, and finally third one is emission characteristics like carbon monoxide (co) carbon dioxide (co2), unburned hydrocarbon(HC) , NOx against brake power.

4.2 Performance characteristics of diesel, blends of Mango seed biodiesel on diesel engine

4.2.1 Brake Thermal Efficiency

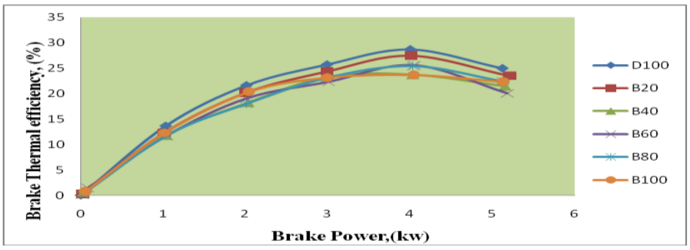

Fig -3: Variation of brake thermal efficiency with brake power

The variation of brake thermal efficiency with brake power for diesel and blends of Mango seed biodiesel are shown in fig.3. As the load on the engine increases, brake thermal efficiency increases because brake thermal efficiency is the function of brake power and brake power increases as the load on the engine increases. The maximum value of brake thermal efficiency for diesel & pure diesel is at 27 % and 32 %. The brake thermal efficiency is almost constant between range of 25 % to 30 %, brake thermal efficiency of all the blends are lower than that of diesel, this is attributed to more amount of fuel consumption for blends as compare to diesel. At full load conditions, the brake thermal efficiency of diesel is more than all blends. Brake thermal efficiency of B20 blend is very close to diesel for entire range of operation.

4.2.2 Specific fuel consumption

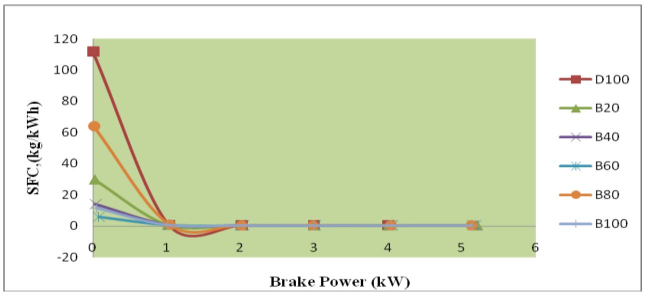

Fig -4: Variation of specific fuel consumption with brake power

The variation of specific fuel consumption with brake power for diesel and blends mango seed biodiesel are shown in figure 4, as the power developed increses the specific fuel consumption decreses for all the tested fuels. The specific fuel consumption of mamgo seed biodiesel blends are higher than diesel because of lower calorific value and high density of biodiesel. From the graph it is clear that the specific fuel consumption is more for initial loads and further it is almost constant for remaining loads

4.2.3 Exhaust Gas Temperature

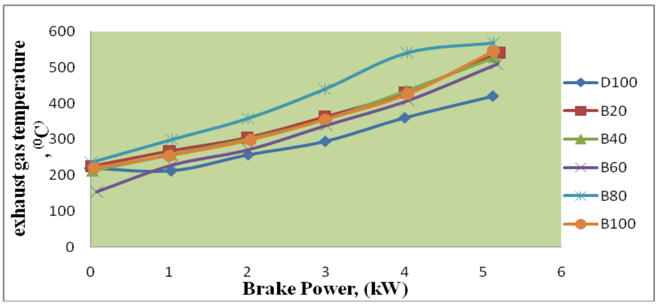

Fig -5: Variation of exhaust gas temperature with brake power

The variation of exhaust gas temperature for different blends with respect to the brake power is indicated in Figure 5. The exhaust gas temperature for all the fuels tested increases with increase in the brake power. Exhaust gas temperature is an indicative of the quality of combustion in the combustion chamber. At all loads, diesel was found to have the highest temperature and the temperatures for the different blends showed a downward trend with increasing concentration of mango seed biodiesel in the blends.

4.3 Emission characteristics

4.3.1 Carbon monoxide

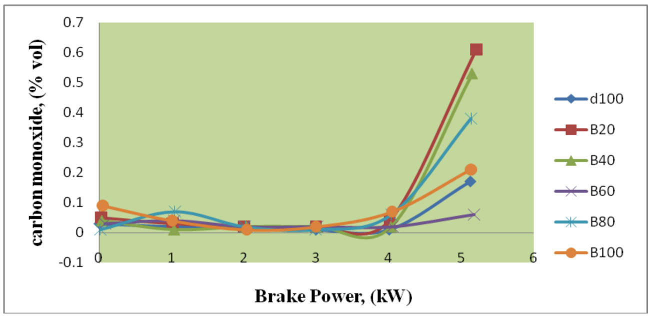

Fig -6: Variation of carbon monoxide with brake power

Fig.6 shows the variation of carbon monoxide emission with brake power for diesel and blends of mango seed biodiesel in the test engine are shown in figure 6. The CO emission depends upon the strength of the mixture, availability of oxygen and viscosity of fuel. CO emission of all blends is higher than that of diesel, except the blend B40 has a lower CO emission that of diesel. CO emission of B40 blends at maximum load is 0.02% volume against 0.03% volume of diesel. CO emission of neat mango seed biodiesel is nearer to the diesel and B20 is higher than all other blends. This due to incomplete combustion at higher loads which results in higher CO emissions.

4.3.2 Hydrocarbon

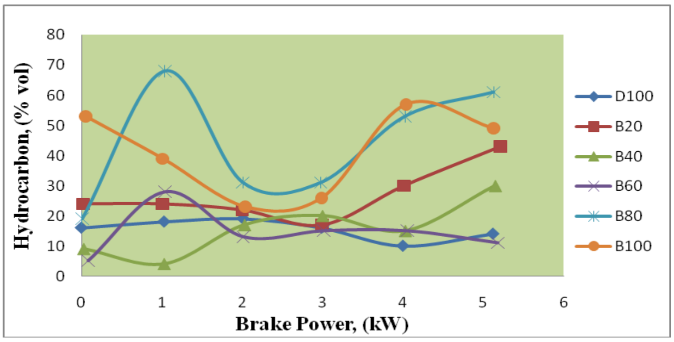

Fig -7: Variation of hydrocarbon with brake power

Fig.7. shows the variation in the quantity of unburnt hydrocarbons with change in brake power. It is observed from the figure that for B40 biodiesel blends the emission of

HC is less than that of the diesel. Unburnt hydrocarbon emission is the direct result of incomplete combustion. A reason for the reduction of HC emissions with biodiesel is the oxygen content in the biodiesel molecule, which leads to more complete and cleaner combustion.

4.3.3 Carbon Dioxide

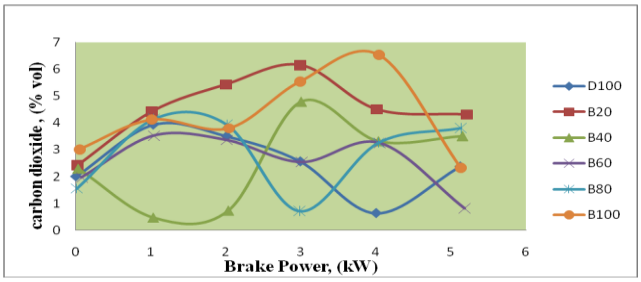

Fig -8: Variation of carbon dioxide with brake power

The variation of carbon dioxide with brake power for diesel and blends of mango seed biodiesel are shown in figure 8. CO_2 emission increased with increase in load for all blends. The lower percentage of blends emits less amount of CO_2 in comparison with diesel. Blends B40 emit very low emissions. This is due to the fact that biodiesel in general is a low carbon fuel and has a lower elemental carbon to hydrogen ratio than diesel fuel. In general biodiesels themselves are considered carbon neutral because, all the CO_2 released during combustion had been sequestered from the atmosphere for the growth of the vegetable oil crops

4.3.4 NO_X

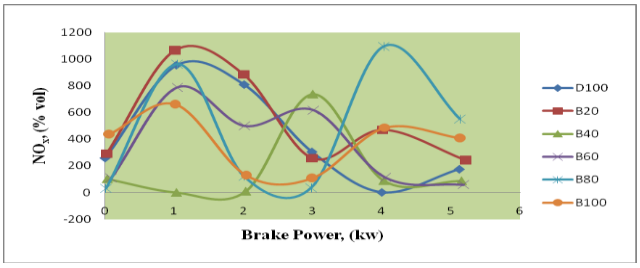

Fig -9: Variation of NOx with brake power

Fig. 9 shows the variation of nitrogen oxides emission with brake power output for diesel and mango seed biodiesel blends in the test engine are shown in figure 9. The NO_x emission for B20 and B80 are higher than that of diesel. The B40, B60 and B80 blends have less NO_x emission compared to diesel and B20 and B80 are high NO_x emission compare to diesel.

4.4 Combustion characteristics

4.4.1 Cylinder pressure with Crank angle

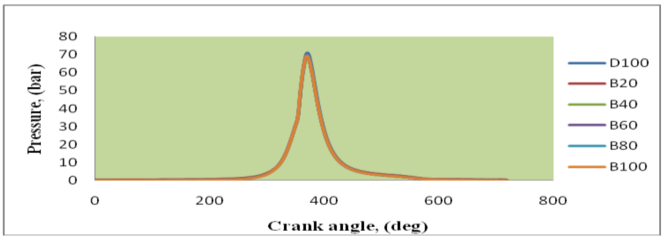

Fig -10: Variation of cylinder pressure with crank angle

In a CI engine the cylinder pressure is depends on the fuel burning rate during the premixed burning phase, which in turn leads better combustion and heat release. The variation of cylinder pressure with respect to crank angle for diesel and different blends of mango seed biodiesel are presented in fig10. Peak pressure of neat mango seed biodiesel and blends are greater than diesel. Peak pressure and crank angle is 73.71bars and 371Deg at100% pure biodiesel and diesel oil is 63.54 bars and 374Deg.

4.4.2 Heat Release Rate with Crank Angle

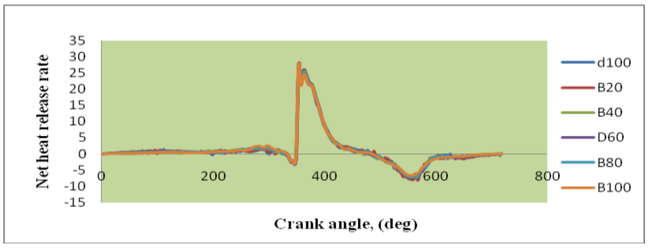

Fig -11: Variation of heat release rate with crank angle

The variation of cylinder net heat release rate with respect to crank angle for diesel and different blends of mango seed biodiesel are shown in fig.11. The heat release rate for all the tested fuel was less than that of diesel this may be attributed to low vaporization, high viscosity. Diesel has high net heat release rate of 34J at 370 degree CA compared to biodiesel of 30J at 365 degree CA.

4.4.3 Commulative Heat Release Rate with Crank Angle

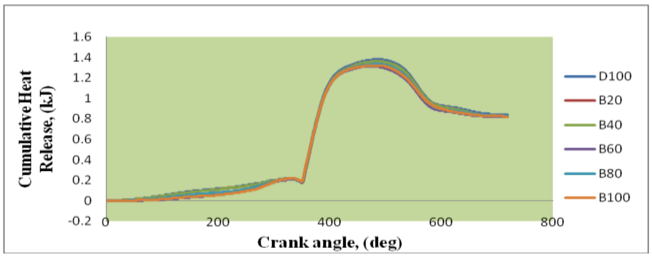

Fig -12: Variation of commulative heat release rate with crank angle

The variation of commulative heat release rate with crank angle is shown in fig.12. The neat mango seed biodiesel values are similar to diesel. The two main phases of the combustion process, premixed and diffusion, are clearly seen in the rate of heat release curve. If all heat losses (due to heat transfer from the gases to the cylinder walls, dissociation, incomplete combustion, gas leakage) are added to the apparent heat release characteristics, the fuel burn characteristics are obtained.

5. CONCLUSIONS

Experimental investigations are carried out on a single cylinder diesel engine to examine the suitability of mango seed biodiesel as an alternative fuel. The performance, emission and combustion characteristics of blends are evaluated and compared with diesel and optimum blend is determined. From the above investigations, the following conclusions are drawn.

- The fuel properties of neat mango seed biodiesel and its blends, density, viscosity, flash point and fire point were found to be higher than that of diesel and calorific value is lower than that of diesel.
- A study of performance of the engine with the Mango seed biodiesel and its blends at higher temperature can be carried out. Higher temperature results in lower viscosity of the fuel; hence an improvement in the performance of the engine can be expected.
- CO emission of all blends is higher than that of diesel, except the blend B40 has a lower CO emission that of diesel. CO emission of B40 blends at maximum load is 0.02% volume against 0.03% volume of diesel.
- The HC emission of B40 biodiesel blends the emission of HC is less than that of the diesel. Unburnt hydrocarbon emission is the direct result of incomplete combustion and other blends, is about 35% and 37% respectively.
- The CO_2 emission of mango seed biodiesel is less in comparison with diesel. Blends B40 emit very low emission compared to all other blends. And B40, B60 and B80 blends have less NO_x emission compared to diesel and B20 and B80 are high NO_x emission compare to diesel.
- The engine performance characteristics with mango seed biodiesel blends such as, brake thermal efficiency is lower than diesel, break specific fuel consumption is lower than diesel, and the exhaust gas temperature is higher than diesel.
- The heat release rate for all the tested fuel was less than that of diesel this may be attributed to low vaporization, high viscosity.

The above comparative study clearly reveals the possibility of using mango seed biodiesel in a diesel engine. We observed that the mango seed blend B40 gives optimum performance, combustion and emission characteristics than diesel. Thus, B40 is found to be an optimum blend.

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