# PERFORMANCE & EMISSION CHARACTERISTICS OF METHYL ESTER FROM RUBBER SEED OIL IN A CI ENGINE

[1]P.L.Navaneethakrishnan, [2]T.Mukesh, [3]K.Hariprakasham

Asst. Professor, Dept. of mechanical engineering, Adithya Institute of Technology, Coimbatore, India, **navanee.607@gmail.com**

PG Scholar, School of Energy, PSG College of Technology, Coimbatore, India, **mukeshmyst@outlook.com**

PG Scholar, School of Energy, PSG College of Technology, Coimbatore, India, **nba.live.hari@gmail.com**

***Abstract*** - *Increase in demand for fossil fuels and environmental threats, has forced the world to concentrate on a number of renewable sources of energy. In this paper an attempt is made to assess the suitability of Rubber seed oil for diesel engine operation, without any modifications in its existing construction. One of the important factors which influence the performance and emission of diesel engine is fuel injection pressure. In the present investigation biodiesel from Rubber seed oil has been investigated in a constant speed CI diesel engine with varied fuel injection pressures (160, 180 and 200 bar). The main objective of this study is to investigate the effect of injection pressures on performance and emissions characteristics of the engine. The performance and emission characteristics were presented and concluded that brake thermal efficiency increases with increase in injection pressure; Specific Fuel Consumption decreases with increase in injection pressure and reduces smoke emissions significantly.*

***Keywords*** **-** Diesel engine, Rubber seed oil, Fuel, Performance, Emission.

--------------------------------------------------------------------- *** ---------------------------------------------------------------------

## 1. INTRODUCTION

Biodiesel is an alternative fuel similar to conventional or fossil diesel. Biodiesel can be produced directly from Edible oil and waste cooking oil. Such Bio-diesel is being used in USA and Europe to reduce air pollution with reduced dependence on fossil fuel, whose recourses are limited. In USA and Europe, surplus edible oil like soybean oil, sunflower oil and rapeseed oil are being used as feedstock for the production of biodiesel, since India is the net importer of vegetable oils, therefore these oils cannot be used for the production of biodiesel and sourced from non edible oils like Jatropha Cucas, Pongamia Pinnata and Madhuca Indica. The process used to convert these oils to biodiesel is called transesterification. The findings of the project were overwhelming in terms of the potential and research were to develop biofuel in the region and in order to decrease the hazardous emissions of the engines and to improve the combustion and thermal efficiency. Rubber seed oil has been chosen as biodiesel.

Conversion of rubber seed oil into bio-fuel by transesterification process and selection of suitable biodiesel blend for replacing diesel. Investigation of fuel properties like calorific value, flash point, viscosity, density were done for Esterified Rubber seed oil, diesel and Rubber seed oil .The experiments were conducted at 0% 25% 50% 75% and full load condition(100%) for various blends of bio diesel and diesel will be carried. Investigation of the performance parameters and emission characteristics with blends of Esterified rubber seed oil of B-5, B-10, B-20, B-30, B-40, B-50 and D100 were recorded for three different injection pressures 160bar, 180bar and 200bar.

## 2. EXTRACTION OF RUBBER SEED OIL

India is one among the top ten rubber producing countries in the World and State of Kerala is the leading in rubber plantations. It originally belongs to Amazon basin (Africa) and later in the 19th century introduced to other countries in the tropical belts of Asia. The Para rubber tree (Hevea Brasiliensis), belongs to the family Euphrobiaceae and the most economical member of the genus Heavea. The tree is deciduous in nature having trifoliate leaves with long stalks (fig-1).Rubber plantation is of great economic value because of its sap-like extract, known as latex collected on the daily basis from its bark which is the primary source of natural rubber. The main yield of rubber plantation is latex. However, the rubber tree also produces large volumes of seed, which is underutilized. In India alone,there are around

2 lakh hectares of rubber plantations. On an average 160 kg of rubber seed is produced per hectare of rubber plantation. The estimated availability of rubber seeds in India is about 30,000 tons per annum, which can yield oil to the tune of about 5000 tons per annum. The oil content in the rubber seed is roughly around 30–40 wt.%. The seeds are lobed, each holding seeds, looks like castor seed in appearance but much larger in size (fig-1). Rubber seeds are ellipsoidal in size varying from 25 to 30 mm long, mottled brown in color, lustrous in look, weighing 2–4 g each. Rubber seeds are collected and kernels are separated by breaking them. These kernels are crushed and oil is extracted by screw pressing and then filtered.

**Fig-1: Photograph of rubber plantation in Kerala along with rubber seed (inside picture)**

## 3. ESTERIFICATION OF RUBBER SEED OIL

This section deals with steps involved in the preparation of biodiesel from untreated rubber seed oil (fig-2). After extraction of oil from seeds and filtering of oil, maintain the raw rubber seed oil up to a temperature of 60°C, stirring of mixture is continued for few minutes, about 7grams of NaOH catalyst are dissolved in 125ml menthol to prepare alkoxide, which is required to activate the alcohol. The alcohol-catalyst (NaOH) mixture is transferred to the reactor containing 350ml; stirring of mixture is continued for three hours at temperature 60°C. Provision is made to condense the evaporating methyl alcohol by fixing the condenser on the top of the reactor. Then remove the condensate and stirring is done for half an hour to remove the excess methyl alcohol. After a period of three hours, the mixture is taken out and poured into the separating funnel, soon the glycerol component of the mixture starts settling at the bottom. The mixture is allowed to settle by gravity in a separating funnel overnight. It is observed that there are two distinct layers formed; one is wine red color at the top & the other being dark brown at the bottom, without disturbing the funnel the bottom layer separated out, which is glycerol, the layer which is retained in the funnel is methyl ester of rubber seed oil. The upper layer is pure methyl ester that is biodiesel ready to use in diesel engine.

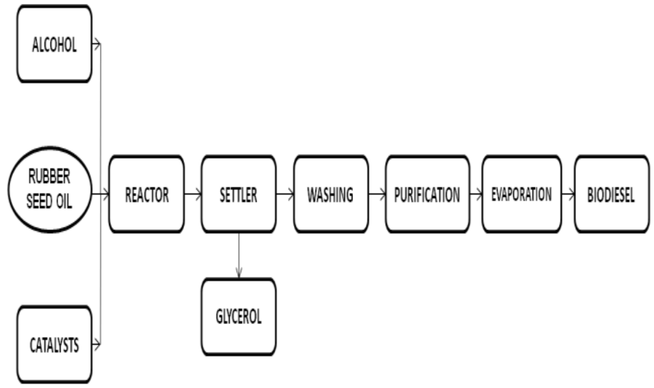


**Fig-2: Process of Transesterification**

## 4. CHARACTERIZATION OF BIODIESEL

Biodiesel produced from used Rubber seed oil was characterized for its fuel properties like flash point, kinematic viscosity, density, calorific value these fuel properties were compared with diesel. Flash point was higher than diesel and this confirms the safety of biodiesel storage. Kinematic viscosity and density were found to be higher than diesel which may result in improper spray characteristics. The fuel properties of biodiesel are shown in table 1.

**Table-1: Comparison of properties of raw rubber seed oil, its esterified and conventional diesel fuel**

| Properties | Diesel | Esterified Rubber seed oil | Rubber seed oil |
|---|---|---|---|
| Density(kg/m3) | 0.824 | 0.860 | 0.895 |
| Viscosity(centi stokes) | 3.55 | 5.81 | 66.5 |
| Calorific value(kJ/kg) | 45350 | 38830 | 36550 |
| Flash point(°C) | 55 | 72 | 195 |

## 5. EXPERIMENTAL SETUP

**Fig-3: Engine test rig**

The test were conducted on a single cylinder four stroke, naturally aspirated ,direct injection and water cooled diesel engine test setup (fig-3).and engine specification is given in table 2. The engine develops a rated power of 3.8kW.Engine was started by hand cranking with diesel fuel supply and allowed to run at steady state for 10 minutes. The whole set of experiment was conducted at the constant engine speed of 1500 rpm at the designed injection pressure of 160bar for 0% 25% 50% 75% and full load condition (100%) with diesel and blends of esterified rubber seed oil viz.., B10, B20, B30, B40, B50 and diesel. Similar experiments were conducted at different injection pressure viz.., 160,180 & 200bar and performance parameters and emissions characteristics were recorded. Smoke density was measured using Diesel Smoke meter in terms of hartridge smoke units. CO, $CO_2$, Oxygen, NOX and hydro carbon emissions were measured by AVL di-gas analyzer.

**TABLE-2: Engine Specification**

| SL NO | PARAMETER | SPECIFICATION |
|---|---|---|
| 1 | TYPE | TV1 KIRLOSKAR MAKE |
| 2 | NO. OF CYLINDERS | SINGLE CYLINDER |
| 3 | NO. OF STROKES | FOUR |
| 4 | RATED BHP | 5 |
| 5 | RATEDD kW | 3.8 |
| 6 | BORE/STROKE | 80mm/110mm |
| 7 | RATED RPM | 1500 |
| 8 | COMPRESSION RATIO | 16.5:1 |
| 9 | TYPE OF IGNITION | COMPRESSION IGNITION |
| 10 | METHOD OF LOADING | EDDY CURRENT DYNAMOMETER |
| 11 | METHOD OF STARTING | MANUAL CRANK START |
| 12 | METHOD OF COOLING | WATER |
| AVL FIVE GAS ANALYZER: | | |
| 13 | TYPE | DIGAS 444 |
| 14 | CAPACITY | |
| 15 | CO | 0-10%VOL |
| 16 | HC | 0-20000 PPM VOL |
| 17 | CO2 | 0-20%VOL |
| 18 | O2 | 0-22%VOL |
| 19 | NO | 0-5000 PPM VOL |
| EDDY CURRENT DYNAMOMETER: | | |
| 20 | MAKE | SAJ TEST PLANT PRIVATE LIMITED |
| 21 | MAXIMUM POWER | 80KW |
| 22 | MAXIMUM SPEED | 10000 rpm |

## 6. RESULT AND DISCUSSIONS

The tests were conducted with esterified rubber seed oil and its blends for 0% to 100% load condition at three different injection pressures 160 bar,180 bar and 200bar.For comparison the tests were also conducted with diesel at above mentioned pressures.

### 6.1. Specific Fuel Consumption(SFC)

The variation of specific fuel consumption with injection pressure for biodiesel and diesel shown in the fig-4.It is observed that the specific fuel consumption has decreased with increase in injection pressure till 180bar and increases when pressure is increased. However for diesel the trend is opposite. The lowest SFC was recorded for B10 at 180 bar injection pressure. The SFC for B10 blend is 0.2158 kg/kWh. Increase in injection pressure from 160 to 200bar leads to reduction in SFC and at 200 bar injection pressure SFC has increased. It can be concluded that, 180 bar is the optimum injection pressure. At higher injection pressure, the reduction in SFC may be due to improved atomization resulting in better combustion .

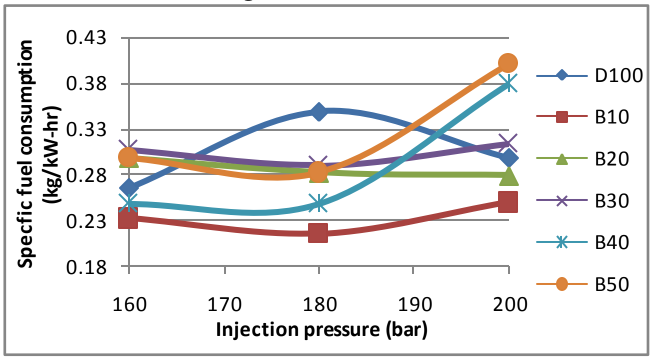


**Fig-4: Variation of Brake Thermal Efficiency with Injection pressure**

## 6.2. Brake Thermal Efficiency

The variation of brake thermal efficiency with load at three injection pressures for five blends of B10, B20, B30, B40, and B50 are shown in fig-5. It is observed that the maximum efficiency obtained for B10 blend at 180bar injection pressure. At this pressure the maximum efficiency is obtained as 37.49% at full load condition.. It is observed that brake thermal efficiency of B10 blend at 160bar is 33.01%, with increase in injection pressure to 180bar, the brake thermal efficiency for above said blend is improved by 4.4%. This may be attributed to better spray characteristics with B10 blend in the combustion chamber which leads to effective utilization of air resulting in more complete combustion.

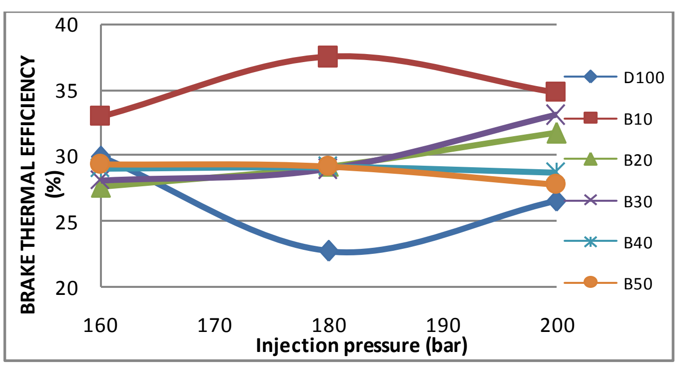


**Fig-5: Variation of Brake Thermal Efficiency with Injection pressure**

## 6.3. Mechanical Efficiency

The variation of Mechanical efficiency with injection pressure for biodiesel and diesel are shown in the fig-6. Mechanical Efficiency of B 50 and other biodiesel blends are less than diesel. This can be attributed to the increase of viscosity and thereby resulting in increase of friction power.

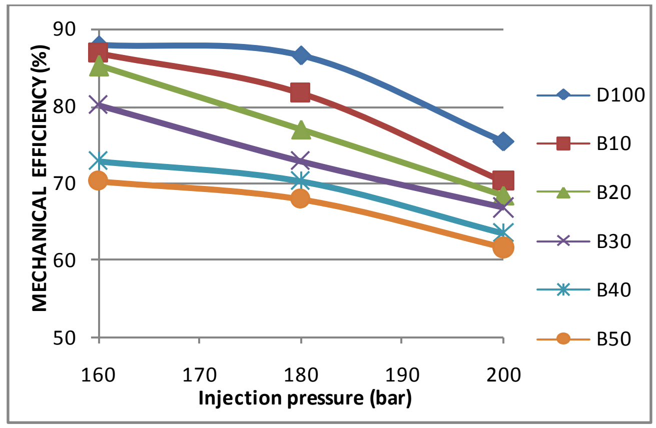


**Fig-6: Variation of Mechanical Efficiency with Injection pressure**

## 6.4. Oxides of Nitrogen (NO)

It is seen that for all blends of rubber seed oil at injection pressure of 180 bar, NO emission was lower, A lower emission of NO at this injection pressure due to decrease in the engine exhaust temperature. The higher NO at injection pressure other than 180bar is result of higher exhaust temperature. The NO measurement at full load for B10, B20, B30, B40, B50 blends shown in fig-7. NO emissions are higher for B50 than that for other blends. This due to the higher temperature in the combustion chamber resulting due to combustion of the blend at the later part of the expansion stroke.

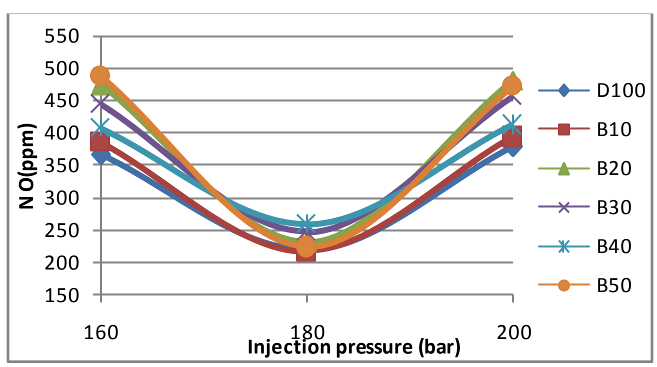

**Fig-7: Variation in Oxides of Nitrogen (NO) with Injection pressure**

## 6.5. Carbon dioxide (CO2)

The variation of carbon dioxide with respect to injection pressure is shown if fig-8. It is seen that for all blends of rubber seed oil at injection pressure of 180 bar was lower. The lower percentage of biodiesel blends emits very low amount of $CO_2$ in comparison with diesel. B10 emits very low level of $CO_2$ but with higher concentration of biodiesel in blend.

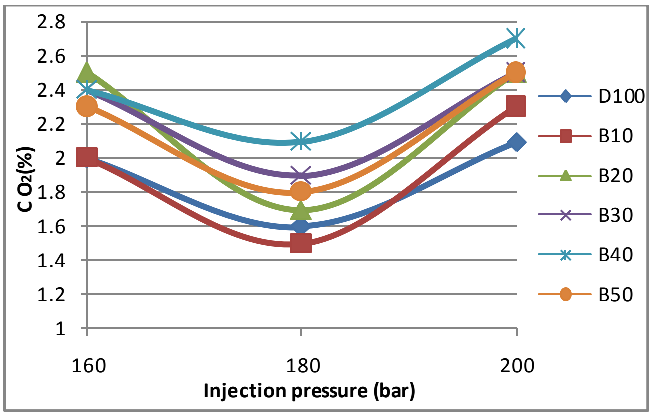


**Fig-8: Variation in Carbon dioxide (CO2) with Injection pressure**

## 6.6. Oxygen (O2)

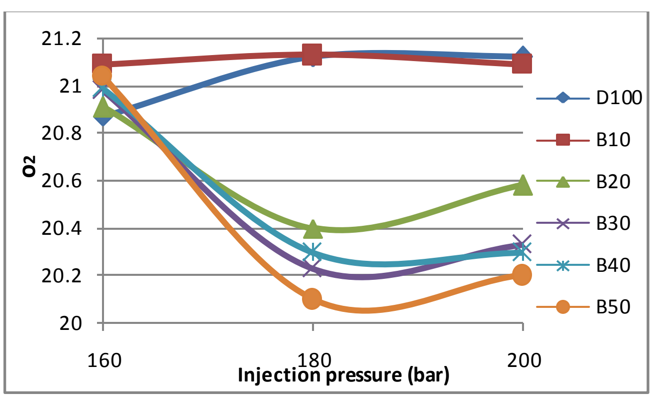


**Fig-9: Variation in Oxygen (O2) with Injection pressure**

## 6.7. Opacity (%)

The fig-9 indicates that variations of smoke opacity with load for the five blends for three different pressures. It can be observed that the higher opacity was recorded at higher injection pressure (200 bar).The presence of oxygen in the blend in addition to good atomization at higher pressure may be the reason for lower opacity.

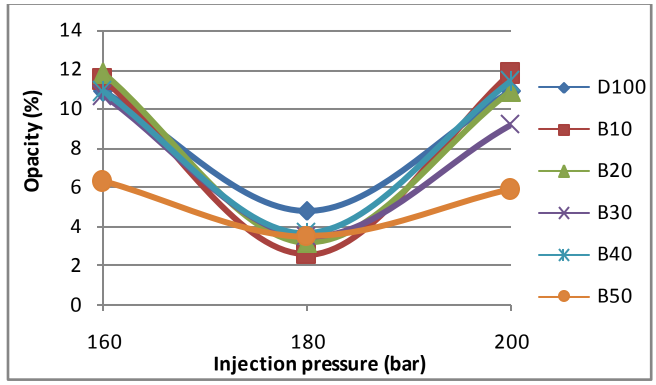


**Fig-10: Variation in Opacity with Injection pressure**

From the above results it can be summarized that B10 blend of methyl ester of rubber seed is the optimum blend with respect to both the performance and emission. It was observed that the brake thermal efficiency was better than for the other blends and diesel and also the specific fuel consumption was better than other blends and diesel. At 180 bar injection pressure, B10 blend has less smoke opacity, NO emission, oxygen and Carbon dioxide emissions, than diesel fuel. Hence, B10 blend can be considered as optimum blend with an optimum injection pressure of 180bar.

## 7. CONCLUSION

Based on the results and the investigations, it may summarized as follows.

1. Transesterification of Esterified rubber seed oil, decreases kinematic viscosity, Density, Flash point and Calorific value is increases.
2. The diesel engine performed satisfactorily on biodiesel, so that the rubber seed oil and diesel blend can be used as an alternative fuel in existing diesel engine without any modification in the system.
3. 10% biodiesel blend from the rubber seed oil was found to be the optimum, which improved the brake thermal efficiency of the engine by 4.4%.

4. SFC for B10 blend is less than other blends for all operating conditions and less than diesel fuel at 180 bar injection pressure.
5. Emission such as NO, smoke density and $CO_2$ were reduced for B10 fuel at 180 bar injection pressure.

Based on the exhaustive engine tests, it can be concluded that the blends of esterfied rubber seed oil with diesel fuel up to 50% by volume could replace the diesel for running the existing diesel engine without modification and 10% blend of rubber seed oil with diesel was found to be the best blend with regards to performance and emission characteristics when compared to all blends. Also it could be concluded that the biodiesel reduces the environment impacts of transportation, reduce the dependence on crude oil impacts and offer business possibilities to agricultural enterprises for periods of excess agricultural production. Finally it could be concluded that the blends of esterfied rubber seed oil with diesel are found to be a potential alternative fuel to diesel. since its physical properties are close to that of diesel.

## REFERENCES

[1]. Ramadhas A.S.., Jayaraj s. and Muraleedharan C., 2004,"Use of vegetable oils as I.C engine fuels - A review", Renewable Energy,Vol.29,pp 727-742.

[2]. Stalin N and Prabhu H.J,2007."Performance Test of I.C Engine Using Karanja Biodiesel Blending with Diesel",Engineering and Applied Science,Vol.2,pp.32-34.

[3]. Sukumar Puhan N.., Vedaraman and Sankaranarayan G..,2005,"performance and Emission study of Mahua oil ethyl ester in a 4-stroke natural aspirated direct injection diesel engine", Renewable Energy,Vol.30,pp1269-1278.

[4]. Meher L C..,Vidhya sagar D,Naik S.N..,2006,"Technical aspects of biodiesel production by transesterfication -a review", Renewable and Sustainable Energy reviews,Vol.10,pp.248-268.

[5]. Nwafor.O.MI 2004,"Emission charactertics of diesel engine operating on rapeseed methyl ester", Renewable Energy,Vol29,pp.119-129.

[6]. Lakshmi Narayan Rao G..,Sampath S and Rajagopal K..,2007,"Experimental studies on the Combustion and emission Characterics of a diesel engine fuelled with Used Cooked Oil Methyl ester and its Diesel Blends", applied Science, Engineering and Technology,vol.4,pp 66-70

[7]. Barnel B.K and Sharma M.P.,2005,"Prospectsof biodiesel production from vegetable oils in India", Renewable and Sustainable Energy reviews,Vol.9,pp.363-378.

[8]. John Van Gerpen,2005,"Biodiesel Processing and production", Fuel Processing Technology,vol.86,pp.1097-1107

[9]. Ganesan V.,2007,"Internal Combustion Engines", Tata Mc Graw Hill Publisher, New Delhi

[10]. John B Heywood.,2000." Internal Combustion Engines", Mc Graw Hill Publisher, New Delhi.

## BIOGRAPHIES

**P.L.Navaneethakrishnan,** received his M.E. from PSG College of Technology, India in 2013. He is currently working as Asst. professor in Adithya Institute of Technology, Coimbatore, India.

**T.Mukesh,** completed his B.E. in Velammal engineering college, India. He is currently doing his M.E. in PSG college of Technology, India.

**K.Hariprakasham,** completed his B.Tech. in Karunya university, India. He is currently doing his M.E. in PSG college of Technology, India.