# PERFORMANCE AND EMISSIONS ANALYSIS OF INTERNAL COMBUSTION (IC) ENGINE BY USING JULI FLORA OIL METHYL ESTER WITH HYDROGEN GAS.

**Bhanumurty karna**

PG Student,Mechanichal Engineering St' Anns College of Engineering, Chirala,Prakasam District, Andhra Pradesh, INDIA.

**Jawaharlal Dandu**

Associate professor,Mechanichal Engineering St' Anns College of Engineering, Chirala,Prakasam District, Andhra Pradesh, INDIA.

Dr. Lakshmi Tulasi Chavali

Professor ,Mechanichal Engineering St' Anns College of Engineering, Chirala,Prakasam District, Andhra Pradesh, INDIA.

Dr. K. Jagadeesh Babu

Professor, Eletronics and Communication Engineering, St' Anns College of Engineering, Chirala,Prakasam District, Andhra Pradesh, INDIA.

**Abstract**

The increasing industrialization and motorization there is a scarcity of petroleum products. So, there is a need for suitable alternative fuels for diesel engines. In the present study, Juli flora oil Methyl Ester with hydrogen were blended with Diesel (25% on volume basis) and various chemical and Added hydrogen in 4lpm(lpm: litre per minute) performance characteristics were evaluated on compression ignition engine and results compared with baseline data of Diesel. Finally results shown that there is the blend B25 of Juli flora oil shows lowest fuel consumption values than the diesel. Brake Specific Fuel Consumption is gradually decreasing for the B2 and Increase in “Brake thermal efficiency”, “Indicated thermal efficiency”, “Mechanical efficiency”, on comparing with the baseline data of diesel fuel. This Performance has been to justify the potentiality of Juli flora oil as alternative fuel for compression ignition engines.

**Key words:** JFME (Juli flora Oil Methyl Esters), B.P (Brake Power), I.P (Indicated Power), BTE (Brake Thermal Efficiency), BSFC (Brake Specific Fuel Consumption), Indicated thermal efficiency &Mechanical efficiency.

# 1. INTRODUCTION

Diesel engines are being used as one of the vital prime movers for generating power and electricity in many industrial and agricultural applications. Reports emanating from research studies on alternate or renewable fuels unanimously predict an unprecedented demand for petroleum fuels by 2030 and the repercussions of this have been already felt by the sudden surge in petroleum prices. In addition to this petroleum fuel demand, its use is also associated with increased environmental problems. Considering the future energy security, sustainability and environmental damage, the study on various alternate, clean and renewable sources of fuel has grabbed the interest and attention of many researchers. Among which, biodiesel is one of the most commonly used alternative fuel for diesel engine. Biodiesel is normally produced from vegetable oil or animal fats through Transesterification in the presence of catalyst at elevated temperature, while higher fatty acid oil even demands double stage Transesterification process. The conversion of triglycerides into methyl or ethyl esters, through the transesterification process, reduces the molecular weight to one-third that of the triglyceride and reduces the viscosity by a factor of about eight, with a marginal increase in volatility. Thus, after trans-esterification process, the properties of the biodiesel are so conducive for its use in diesel engine. Recent studies on engine performance using biodiesel have shown significant improvements when compared to that of diesel. Furthermore, emissions such as smoke, HC (hydrocarbon), CO (carbon monoxide) and CO2 (carbon dioxide) were also found to be reduced at the expense of slight increase in NOx (oxides of nitrogen). Nevertheless, the use of biodiesel has also shown several apprehensions due to its higher viscosity, lower calorific value, and lower horsepower output. Apart from bio diesel, researchers have conceived the idea of using alcohol and emulsion fuels in diesel engine as an alternative fuel. Experimental studies with micro emulsion fuel have reported a drastic reduction of NOx emission in diesel engine. However, the use of emulsion fuels has also shown significant increase in CO and HC emission levels and drop in BTE (brake thermal efficiency) at lower loads. Therefore, in order to address these shortcomings of emulsion fuels, recent research on novel emulsion fuel with the addition of nano particle additives has shown an increase in BTE and decrease in NOx emission than diesel. Furthermore, the application of ethanol in diesel engine has come to limelight in recent decades as it has the potential to reduce environmental emissions. Ethanol is an oxygen enriched fuel and when used in blends with diesel, the fuel viscosity is reduced, resulting in enhanced 2 combustion. Though ethanol is less viscous, the heating value is very low and suffers limited miscibility with diesel. Besides emulsion fuel and ethanol, there have been reports about using turpentine oil derived from resin of tree in diesel engine. The same report also suggests that there is an increase in BSFC (brake specific fuel consumption) and decrease in BTE for all the blends of turpentine with diesel. Similarly, another study pertaining to the use of turpentine in diesel engine claimed 60 to65% replacement of diesel with turpentine while operating the engine in dual fuel mode. The reported experiment was performed by inducting turpentine as main fuel through induction manifold and diesel was admitted into the engine through conventional fuel injector. Further, an increase in CO, HC and NOx emissions were noticed at high load condition when compared to diesel. Until now, ample studies on bio*fuel* haven't reported substantial improvement in performance and emission while using 100% biodiesel, ethanol, and emulsion fuel in diesel engine. It has been categorically reported that biodiesel can only be used in blends with diesel, where the recommended blend is B25 as the study conducted using oil biodiesel claims that biodiesel can be safely blended with diesel up to 20% for getting fairly accurate performance as that of diesel. Therefore, the present research has taken all the above-mentioned considerations in the selection of bio*fuel*. Further, we have attempted to use pure biofuel and its blend in diesel engine. In this study, we introduce oil bio*fuel*, which is in contrary to the regular use of trans-esterified biodiesel, for fuelling diesel engine. Not much attention has been paid to use oil in diesel engine and hence significant endeavours have been made to test the characteristics of diesel engine using oil. Oil, a renewable source, is synthesized from oleoresin which in turn is obtained from trees. The thermos physical properties of pure oil such as density, viscosity, calorific value, cetane index, sulphur content, flash point and boiling point have been evaluated by standard ASTM (American Society for Testing and Materials) methods and are listed. From the properties tested, it is comprehended that the total acidity of oil is very low and the oil is toxic free. The oil manifests itself as a light oil liquid biofuel, as its viscosity is too low and the measured properties are found to be suited for its use in diesel engine. For the current study, the oil being used has been procured from the commercial store and has been utilized as it is.

## 2. Materials And Methods

In this project we tried to investigate the potential use Spirulina Oil. Various experiments were conducted on Juli flora Oil and the results were recorded. We collected the results from various journals and research papers. The results of Juli flora were compared with conventional diesel. A brief introduction about the material used in this project is given below.

### 2.1. Juli Flora Oil (Methyl Ester)

Juli flora stems are collected from the southern part of Tamil Nadu , India and crushed into fine powder and dried in sunlight. The obtained dried biomass powder is used as a feedstock for pyrolysis. Coir fibers required for the preparation of composite laminates are purchased from Fiber region, Chennai, Tamil Nadu. Also, the epoxy resin, which is purchased from Huntsman, Chennai is used as such without further purification. Prosopis juli flora plays a fundamental role in an ecological organization, in the economy of arid and semi -arid environment, and in sustainable development. It can be used for different purposes. This species produces a good- quality wood used as fuel for producing high -quality food

Figure.1: Juli flora (Methyl Ester) oil, leaf

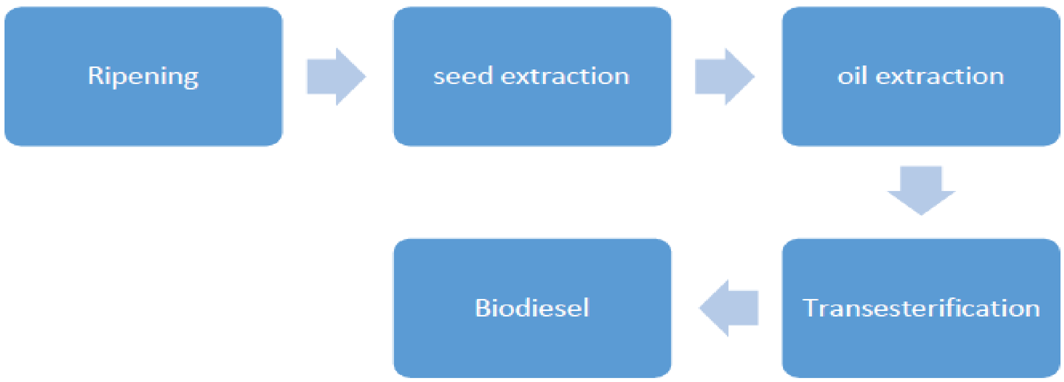


Fig.2. JULI FLORA OIL EXTRACTION PROCESS

## 2.2. JULI FLORA OIL EXTRACTION PROCESS

1. Transesterification.
2. Settling and Separation of esters and glycerin.
3. Washing of biofuel 4.Heating.

The most common derivatives of agricultural oil for fuels are methyl esters. These are formed by trans esterification of the oil with methanol in the presence of a catalyst (usually basic) to give methyl ester and glycerol. Sodium hydroxide (NaOH) is the most common catalyst, though others such as potassium hydroxide (KOH) can also be used. Contents used in trans etherification process are. Veg oil: Cotton seed oil, sunflower oil. Alcohol: Methanol.
Catalyst: Sodium hydroxide, Potassium hydroxide

## 2.3. Pretreatment and transesterification

The pretreatment of oil before transesterification includes two steps: acid esterification followed by alkaline transesterification. After the second pretreatment step, if we intend to get the value of free. atty acid (FFA) as 1 mg KOH/gm, then in the first step, value of 5 mg KOH/gm should be obtained13. When there was a gradual increase in the reaction in the reaction time and Methanol/oil molar ratio, there was the reduction in the acid value from 43.7 to 39 mg KOH/gm (3:1 molar ratio, 0.5 hrs) and further it was reduced to 18.5 mg KOH/gm (3:1,2 hrs). In the pretreatment steps, the acid value of the oil was reduced from 43.7 mg KOH/gm to 8.6 mg KOH/gm under the optimum reaction conditions of 9:1v/v methanol/oil ratio and a minimum reaction time of about 120 minutes. The end products got from acid catalyzed pretreatment process was used for alkali catalyzed transesterification process. A series of experiments were carried out at various molar ratios, different proportion of catalyst, reaction temperature and extent of reaction time. From the findings optimum conditions for oil extraction was noted down.

## 3. EXPERIMENTAL SETUP AND PROCEDURE

### 3.1. FLASH AND FIRE POINT TEST

A key property for determining the flammability of fuel is the flash point. The flash point is the lowest temperature at which an applied ignition source causes the vapours of sample to ignite. The fire point is sometimes used to designate the fuel temperature producing sufficient vapour to maintain a continuous flame. The fire point is the minimum temperature to which it must be heated so that vapours burn at least 5 seconds. The two parameters have a great importance while determining the fire hazards.

### 3.2. Mechanism

Every flammable liquid has a vapour pressure, which is a function of that liquid's temperature. As the temperature increases, the vapour pressure increases. As the vapour pressure increases, the concentration of evaporated flammable liquid in the air increases. Hence it is that temperature, which determines the concentration of evaporated flammable liquid in the air under equilibrium conditions. Different flammable liquids require different concentrations of the fuel in air to sustain combustion. The flash point is that minimum temperature at which there is a sufficient concentration of evaporated fuel in the air for combustion to propagate after an ignition source has been introduced.

### 3.3. Measuring Flashpoint

There are two basic types of flash point measurement-open cup and closed cup. In open cup devices the sample is contained in an open cup which is heated and at intervals a flame is brought over the surface. The measured flash point will vary with the height of the flame above the liquid surface, and at sufficient height the measured flash point temperature will coincide with the fire point. Closed cup testers, of which the Abl's closed cup is one example is one example, are sealed with a lid through which the ignition source can be introduced periodically.

The vapour above the liquid is assumed to be in reasonable equilibrium with the liquid. Closed cup testers give lower values for the flash point and are a better approximation to the temperature at which the vapour pressure reaches the lower flammable limit.

## 3.4. Description of the Apparatus

Penske Martin's closed cup apparatus consists of the following essential parts: 19

- **Oil cup:**

This is a cylindrical vessel made of brass, with a filling mark grooved inside near the top. The inside of the cup is of slightly larger diameter above the filling and oil.

- **Flame exposure device:** the lid is equipped with a brass shutter operating on the plane of the upper surface of the cover proper. The shutter is so shaped and mounted on the lid that, when it is in one position, the holes are completely closed and when in the other these orifices are completely opened.
- Flash and fire point are obtained by using pen sky test. The apparatus consists of a brass cup and cover fitted with shutter mechanism without shutter mechanism (open cup), test flame arrangement, hand stirrer (closed cup), thermometer socket, etc., heated with energy regulator, a thermometer socket made of copper.


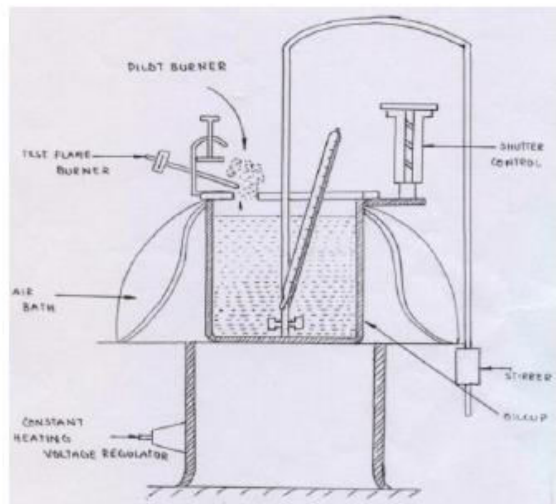


Fig.3. Penske Martin Apparatus

- **Experimental Observation**

1. Brake Power, **B.P** =[VIcosØ] **/** [ηtran x ηgenx 1000] kw

Where,

V = voltage, volts

A = current, amperes Cos Ø = Power factor = 1 ηtran = Transmission Efficiency = 0.98 ηgen = Generator Efficiency = 0.9

2. **T.F.C** = 10 x 0.85 x 3600**/** t x 1000Kg/h

Where,

T.F.C = Total Fuel Consumption, Kg/h Specific gravity of diesel = 0.88 t = Time taken for 10 c.c fuel, seconds

3. Brake Specific Fuel Consumption, **bsfc** = T.F.C/B.P Kg/kwh

4. Heat Input = T.F.C X C.V kW Where,

C.V = Calorific Value of Fuel, kJ/kg k
5. Frictional Power, F.P = kW (from graph by William's line method)

6. Indicated Power = B.P + F.P, Indicated Power = kW 7.Mechanical efficiency = B.P/I.P x 100 %

8. Brake thermal efficiency = B.P/Heat Input x 100 %

9. Indicated thermal efficiency = I.P/Heat Input x 100 %

## 4. EXPERIMENTAL RESULTS

**Table.1 Experimental Results using Diesel. (D100)**

| Load (Kg) | Time sec | Torque (Nm) | BP (kW) | FP (kW) | IP (kW) | T.F.C (Kg/H ) | BSFC Kg/kwh | BTHE (%) | ITHE (%) | Mech Eff. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.02 | 82.01 | 0.04 | 0.01 | 2.01 | 2.02 | 0.38 | 0 | 0.06 | 12.50 | 0.4 |
| 4.50 | 39.01 | 8.17 | 1.13 | 2.35 | 3.48 | 0.81 | 0.71 | 3.32 | 10.23 | 32.4 |
| 9.01 | 28.0 | 16.36 | 2.26 | 2.39 | 4.62 | 1.13 | 0.503 | 4.07 | 10.1 | 48.9 |
| 13.50 | 20.0 | 24.50 | 3.40 | 2.39 | 5.79 | 1.58 | 0.46 | 5.161 | 8.79 | 58.7 |
| 18.02 | 13.9 | 32.71 | 4.53 | 2.35 | 6.88 | 2.4 | 0.52 | 5.48 | 6.79 | 65.8 |

**Table .2 Experimental Emissions Results using Diesel. (D100)**

| Load kg | CO % | HC PPM | CO2 % | O2 % | NOX PPM | Opacity % |
|---|---|---|---|---|---|---|
| 0.02 | 0.082 | 50 | 1.74 | 16.96 | 85 | 16.6 |
| 4.50 | 0.11 | 55 | 4.24 | 13.41 | 584 | 29.3 |
| 9.01 | 0.25 | 65 | 5.86 | 11.9 | 1113 | 41.01 |
| 13.50 | 0.28 | 69 | 8.06 | 8.98 | 1586 | 58.47 |
| 18.02 | 0.6 | 98 | 10.6 | 5.2 | 1779 | 71.84 |

**Table .3 Experimental Results using Juli flora oil B25.**

| Load (Kg) | Time sec | Torque (Nm) | BP (kW) | FP (kW) | IP (kW) | T.F.C (Kg/H) | BSFC Kg/kwh | BTHE (%) | ITHE (%) | Mech Eff. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.02 | 90.20 | 0.04 | 0.01 | 2.01 | 2.02 | 0.33 | 0 | 0.07 | 14.92 | 0.30 |
| 4.50 | 43.26 | 8.17 | 1.30 | 2.35 | 3.65 | 0.69 | 0.53 | 4.57 | 13.16 | 35.64 |
| 9.01 | 32.16 | 16.36 | 2.54 | 2.39 | 4.93 | 0.94 | 0.37 | 6.58 | 12.78 | 51.48 |
| 13.50 | 24.85 | 24.50 | 3.75 | 2.39 | 6.15 | 1.21 | 0.34 | 7.55 | 12.3 | 61.04 |
| 18.02 | 19.15 | 32.71 | 4.94 | 2.35 | 7.29 | 1.57 | 0.31 | 7.67 | 11.31 | 67.79 |

**Table .4 Experimental Emission Results using Diesel. (B25)**

| Load kg | CO % | HC PPM | CO2 % | O2 % | NOX PPM | Opacity % |
|---|---|---|---|---|---|---|
| 0.02 | 0.102 | 55 | 1.63 | 18.35 | 113 | 14.7 |
| 4.50 | 0.074 | 59 | 4.16 | 14.8 | 711 | 26.9 |
| 9.01 | 0.06 | 59 | 5.78 | 12.44 | 1240 | 38.6 |
| 13.50 | 0.085 | 63 | 7.98 | 9.11 | 1714 | 56.3 |
| 18.02 | 0.407 | 94 | 10.5 | 5.67 | 1907 | 68.4 |

**Table .5Experimental Results using Diesel. (B25 H 4 lpm)**

| Load (Kg) | Time sec | T.F.C (Kg/H) | Torque (Nm) | BP (kW) | FP (kW) | IP (kW) | BSFC Kg/kwh | BTHE (%) | ITHE (%) | Mech Eff. (%) |
|---|---|---|---|---|---|---|---|---|---|---|
| 0.02 | 103.7 | 0.29 | 0.04 | 0.01 | 2.03 | 2.03 | 0 | 0.08 | 17.07 | 0.30 |
| 4.50 | 49.79 | 0.60 | 8.17 | 1.30 | 2.48 | 3.78 | 0.46 | 5.28 | 15.39 | 34.27 |
| 9.01 | 34.75 | 0.87 | 16.37 | 2.54 | 2.50 | 5.04 | 0.34 | 7.11 | 14.13 | 50.36 |
| 13.50 | 26.41 | 1.14 | 24.50 | 3.74 | 2.44 | 6.17 | 0.30 | 7.9 | 13.19 | 60.54 |
| 18.02 | 20.31 | 1.48 | 32.71 | 4.91 | 2.29 | 7.20 | 0.29 | 8.08 | 11.86 | 68.24 |

**Table .6 Experimental Emission Results using Diesel. (B25 H 4lpm)**

| Load kg | CO % | HC PPM | CO2 % | O2 % | NOX PPM | Opacity % |
|---|---|---|---|---|---|---|
| 0.02 | 0.080 | 67 | 1.5 | 18.12 | 91 | 12.8 |
| 4.50 | 0.059 | 59 | 3.59 | 14.89 | 578 | 23.7 |
| 9.01 | 0.049 | 62 | 5.22 | 12.72 | 1208 | 34.8 |
| 13.50 | 0.077 | 70 | 7.46 | 9.46 | 1839 | 55.2 |
| 18.02 | 0.3 | 91 | 9.96 | 5.68 | 2035 | 66.3 |

GRAPHS

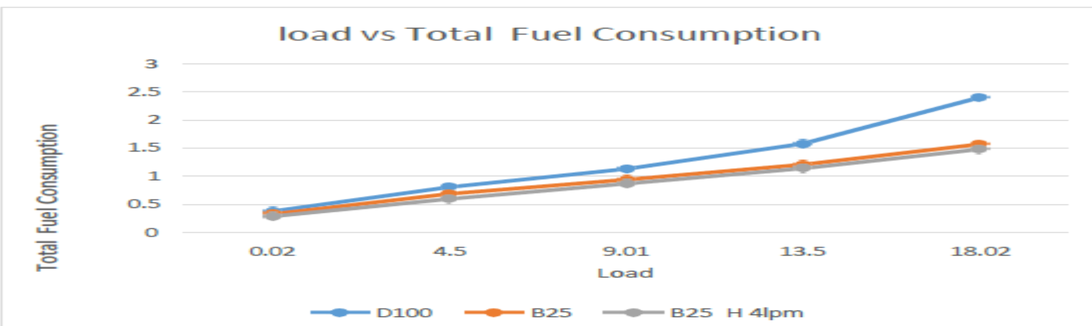


Fig.4. Graph between Load and Total Fuel Consumption

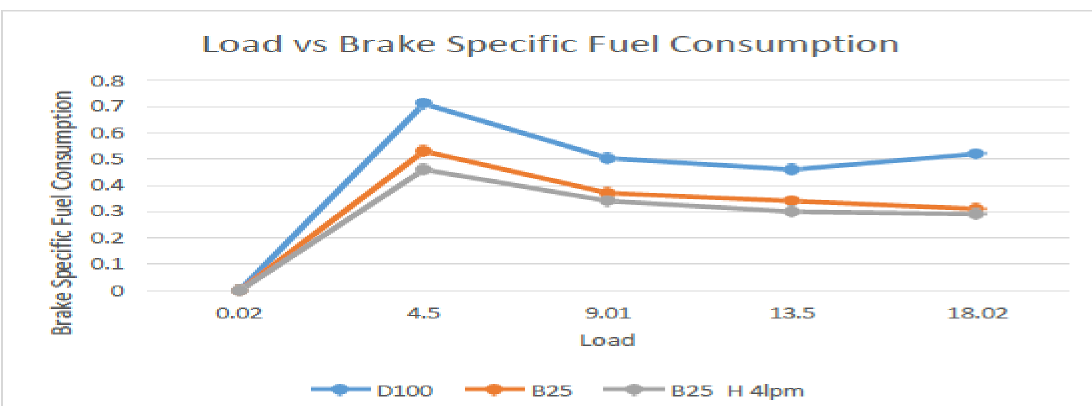


Fig.5.Graph between Load and Brake Specific Fuel Consumption

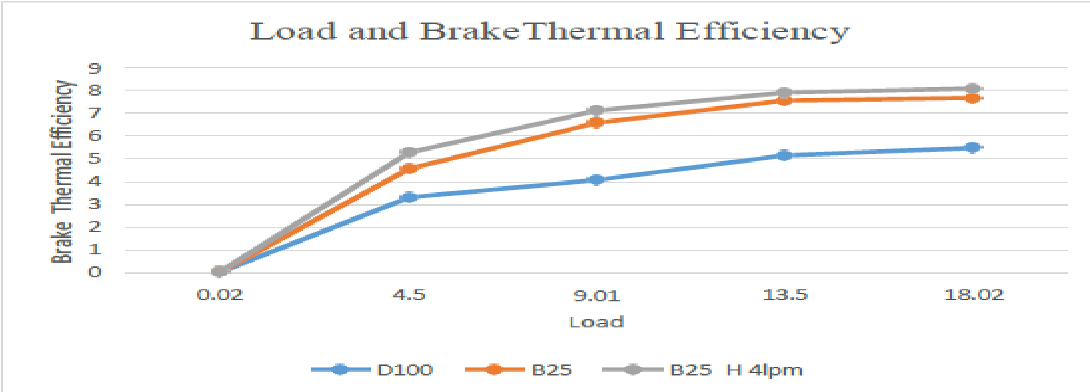


Fig. 6.Graph between Load and Brake Thermal Efficiency

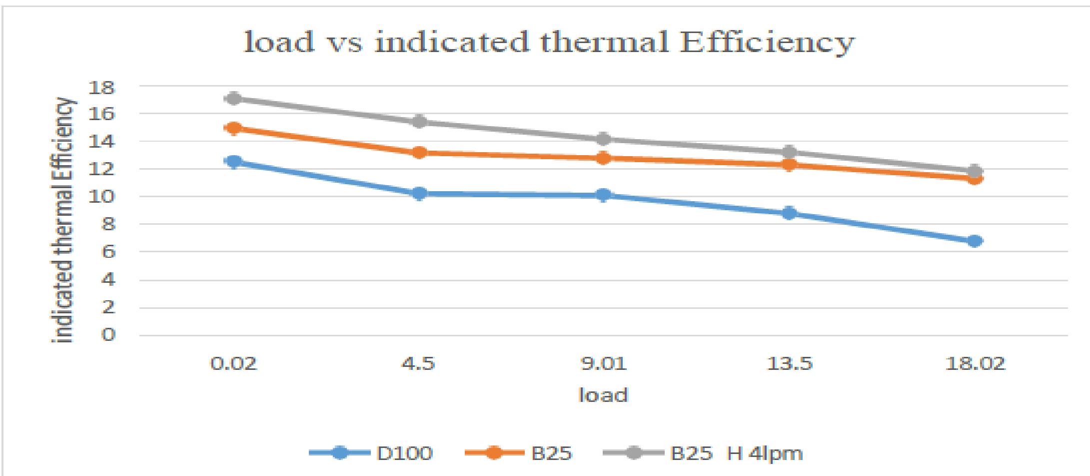


Fig. 7.Graph between Load and indicated thermal Efficiency.

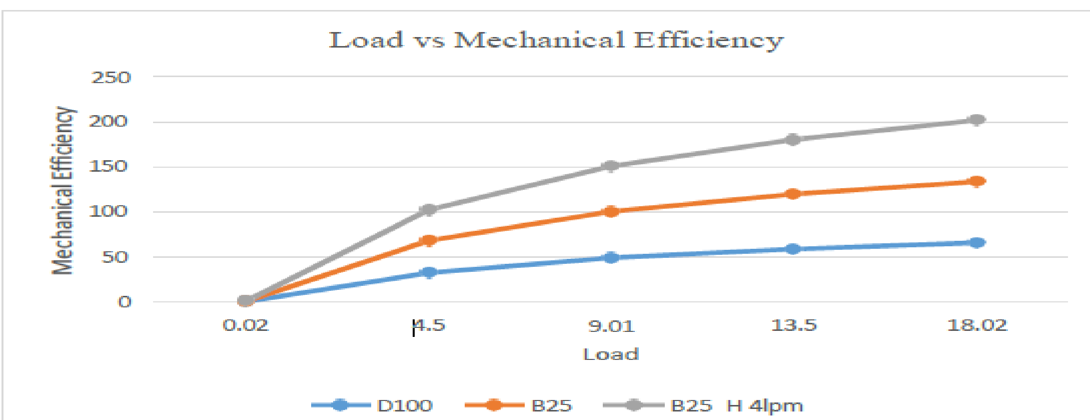


Fig.8. Graph between Load and Mechanical Efficiency

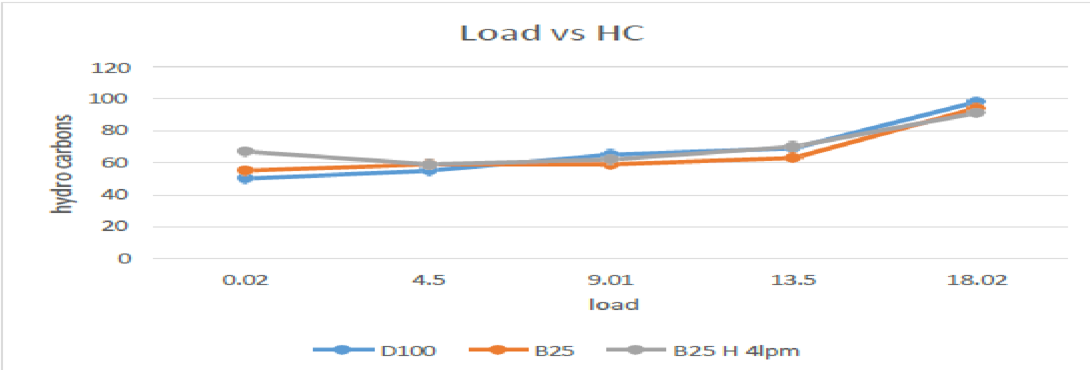


Fig. 9.Graph between Load and HC (Hydrocarbon)

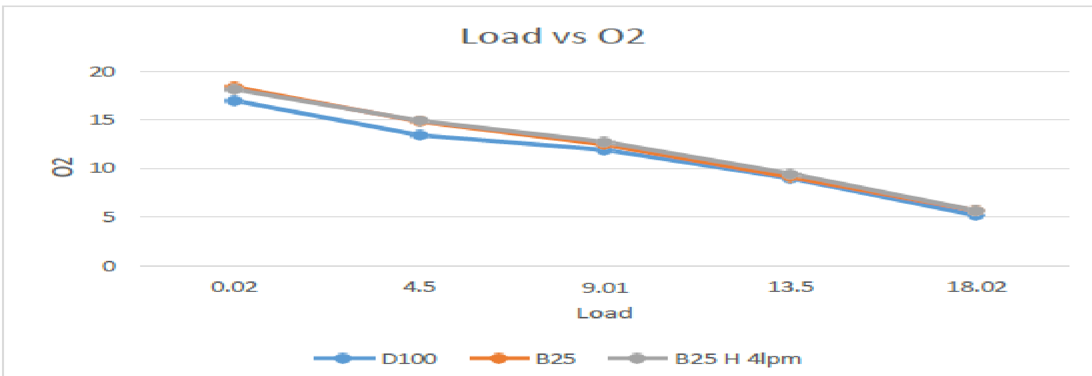


Fig.10. Graph between Load and O2(Oxygen)

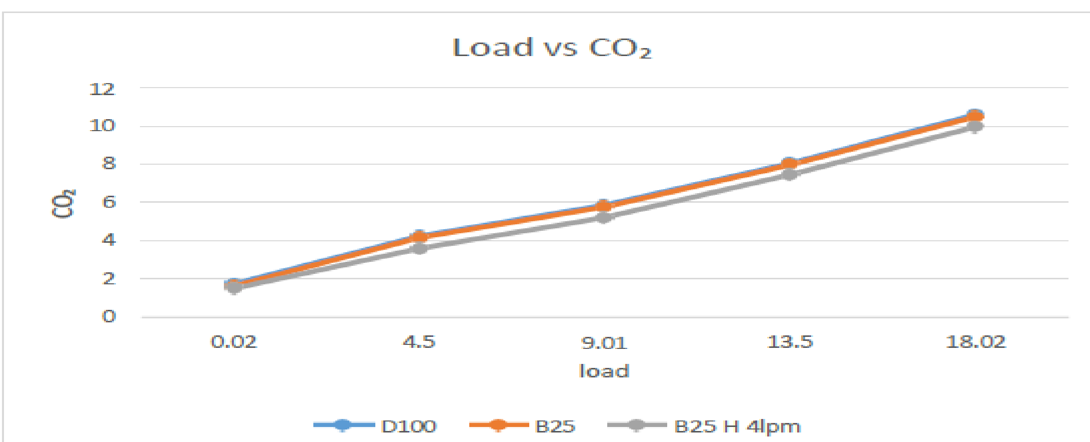


Fig. 11.Graph between Load and CO2 (Carbon dioxide)

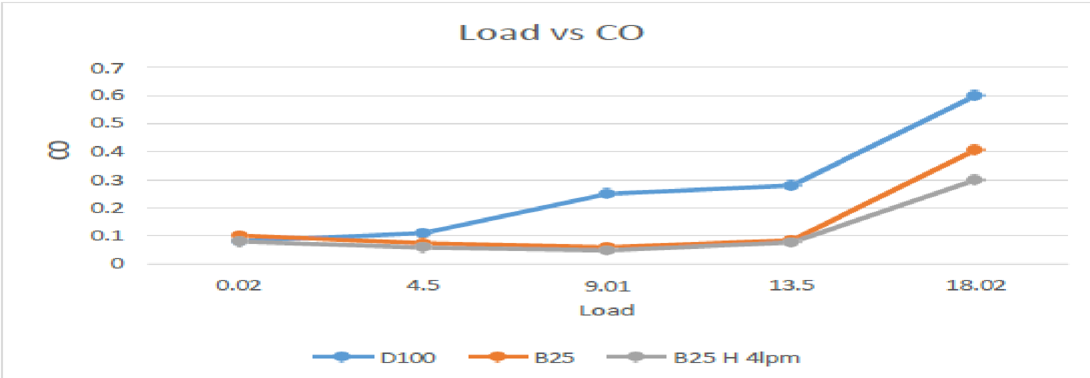


Fig.12. Graph between Load and CO (Carbon monoxide)

## 5. Results And Discussion

The performance parameters such as brake power, mass of fuel consumption, brake thermal efficiency, brake specific fuel consumption, volumetric efficiency, mechanical efficiency and indicated thermal efficiency, co emission, carbon dioxide, hydrocarbons were calculated from the observed parameters and shown in the graphs. The variation of performance parameters is discussed with respect to diesel fuel, biodiesel blends and obtained optimum blend are discussed in the article below.

### 5.1 Total Fuel Consumption

The result for the variations in the Total Fuel Consumption (TFC). For all the Fuels TFC increases with increasing load up to 18.5. can be shown that TFC is maximum for blend B20 and minimum blend B25H 4lpm for all the loads.

### 5.2. Brake Specific Fuel Consumption

The result for the variations in the Brake Specific Fuel Consumption (BSFC) is presented above. For all the Fuels BSFC falls with increasing load up to 18.5 kg. This indicates that the optimum value of TFC is at a load of 18.5. From Fig., It can be shown that TFC is maximum for blend B20 and minimum blend B25 H 4lpm for all the loads.

### 5.3. Brake Thermal Efficiency

The variation of brake thermal efficiency with respect to load for diesel and blends was shown in Fig:5.4 It can be observed that the brake thermal efficiency increases with load up to 18.5Kg. By observing all the values of blends D100, B25, B25 H 4lpm and diesel at 18.5kg load, among these B25 h 4lpm showing good result and considered as optimum blend and it gives the value of 8.08 at 18.5 kg load. 37

### 5.4. INDICATED THERMAL EFFICIENCY

The variation of indicated thermal efficiency with respect to load for diesel and blends was shown above. It can be observed that the indicated thermal efficiency falls with load up to 18.5kg. By observing all the values of blends B25, B25 H 4lpm and diesel at 18.5kg load, among these B25 H 4lpm showing good result and considered as optimum blend and it gives the value of 11.86 at B25 H 4lpm load.

### 5.5. MECHANICAL EFFICIENCY

The variation of mechanical efficiency with respect to load for diesel and blends was shown above. It can be observed that the mechanical efficiency increases with load up to 18.5kg. By observing all the values of blends B25, B25 H 4lpm and diesel at 18.5 load, among these B25 H 4lpm showing good result and considered as optimum blend and it gives the value of at B25 H 4lpm load.

### 5.6. HC (Hydrocarbon)

The variation of Hydrocarbon with respect to load for diesel and blends was shown above. It can be observed that the hydrocarbon decreases with load up to 18.5. By observing all the values of blends B25, B25 H 4lpm and diesel at 18.5 kg load, among these B25 H 4lpm showing good result and considered as optimum blend and it gives the value 90ppm at B25 H 4lpm load.

### 5.7. CO2 (Carbon dioxide)

The variation of carbon dioxide with respect to load for diesel and blends was shown above. It can be observed that the carbon dioxide decreases with load up to 18.5kg. By observing all the values of blends B25, B25 H 4lpm and diesel at 18.5 load, among these B25 H 4lpm showing good result and considered as optimum blend and it gives the value 9.96 %of at B25 H 4lpm load.

### 5.8. O2(Oxygen)

The variation of Oxygen with respect to load for diesel and blends was shown above. It can be observed that the Oxygen increases with load up to 18.5kg. By observing all the values of blends B25, B25 H 4lpm and diesel at 18.5 load, among these B25 H 4lpm showing good result and considered as optimum blend and it gives the value 5.68%of at B25 H 4lpm load. 38

### 5.8. NOX (Nitrogen Oxides)

The variation of NOX (Nitrogen Oxides) with respect to load for diesel and blends was shown above. It can be observed that the NOX (Nitrogen Oxides) NOx increases with load up to 18.5kg. By observing all the values of blends B25, B25 H 4lpm and diesel at 18.5 load, among these B25 H 4lpm showing good result and considered as optimum blend and it gives the value 2035 of at B25 H 4lpm load.

### 5.9. CO (Carbon monoxide)

The variation of CO (Carbon monoxide) with respect to load for diesel and blends was shown above. It can be observed that the CO (Carbon monoxide) decreases with load up to 18.5kg. By observing all the values of blends B25, B25 H 4lpm and diesel at 18.5 load, among these B25 H 4lpm showing good result and considered as optimum blend and it gives the value 2035 of at B25 H 4lpm load.

## 6. Conclusions

Following are the conclusions based on the experimental results obtained with full load conditions while operating computerized single cylinder air cooled diesel engine fuelled with diesel and rapeseed oil methyl ester with hydrogen.

- The total fuel consumption is decreased for blend B25 H 4lpm at full load. Compared with pure diesel, B25.
- The brake thermal efficiency is increased for blend B25 H 4lpm blend at full load compared to Diesel. Compared with pure diesel, B25.
- The indicated thermal efficiency of the tested diesel engine is 11.86 %varied when it is fuelled with B25 H 4lpm at full load loads. Compared with pure diesel, B25.
- The mechanical efficiency of the tested diesel engine is 68.24 %improved when it is fuelled with B25 H 4lpm blend at full load. Compared with pure diesel, B25.
- Carbon monoxide of the tested diesel engine is 9.96 decreased when fueled with B25 H 4lpm blend at full load. Compared with pure diesel, B25.
- The hydrocarbons of the tested diesel engine is 91 decreased when fueled with B25 H 4lpm blend at full load. Compared with pure diesel, B25.
- Carbon dioxide of the tested diesel engine is 0.3 decreases when fueled with B25 H 4lpm at full load. Compared with pure diesel, B25.
- The oxygen of the tested diesel engine is 5.68 increased when fueled with B25 H 4lpm at full load. Compared with pure diesel, B25.
- The NOX of the tested diesel engine is 2035 increased when fueled with B25 H 4lpm at full load. Compared with pure diesel, B25.

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