Performance, Combustion and Emission Characteristics on Single Cylinder Diesel Engine using Calophyllum Inophyllum (Surahonne) Oil

[1]Ravi. S. D
M.Tech Scholar, Department of Mechanical Engineering, PDA College of Engineering Gulbarga, Karnataka(INDIA)

[2]S. R. Hotti
Professor Department of Mechanical Engineering, PDA College of Engineering Gulbarga, karnataka(INDIA)

[3]Dr. O. D. Hebbal
Professor Department of Mechanical Engineering, PDA College of Engineering Gulbarga, Karnataka(INDIA)

***Abstract* -Inflation in fuel prices and unprecedented shortage of its supply has promoted the interest in development of the alternative sources for petroleum fuels. In this present work, investigations were carried out to study the performance, emission and combustion characteristics of Calophyllum Inophyllum (Surahonne) oil. The results were compared with diesel fuel, and the selected Calophyllum Inophyllum (Surahonne) oil fuel blends (10%, 20%, and 100%). For this experiment a single cylinder, four stroke, water cooled diesel engine was used. Initially the engine was run with diesel fuel and the readings were recorded. Then the engine was run with the Calophyllum Inophyllum (Surahonne) oil (B10, B, B20 and B100) added by volume basis and the readings were taken. Tests were carried out over entire range of engine operation at varying conditions of load. The engine performance parameters such as specific fuel consumption, brake thermal efficiency, exhaust gas temperature and exhaust emission (CO, CO_2, HC, O_2 and NO_x) were recorded. The lower blends of biodiesel increases the brake thermal efficiency and reduces the specific fuel consumption. The exhaust gas emissions are reduced with increase in biodiesel concentration. The experimental results proved that the use of biodiesel in compression ignition engine is a viable alternative to diesel.**

Keywords: Diesel engine, Biodiesel, Performance, Emission, Calophyllum Inophyllum (Surahonne) oil

1. INTRODUCTION

Due to excess use of the petroleum based fuels for industry and automobile application in present time, the world is facing severe problems like energy crisis, environmental pollution and global warming. Therefore global consciousness has started to grow to prevent the fuel crisis by developing alternative fuel sources for engine application. Many research programs are going on to replace diesel fuel with a suitable alternative fuel like biodiesel. Non-edible sources like mahua oil, karanja oil, neem oil, jatropha oil, simarouba oil etc. are being investigated for biodiesel production. Fatty acids like stearic, palmitic, oleic,linoleic and linolenic acid are commonly found in non-edible oils . Vegetable oils blended with diesel in various proportions have been experimentally tested by a number of researchers in several countries. In developing countries like India, it is easily possible to grow these non-edible vegetable oils but not economically feasible to convert them to methyl esters undergoing different types of chemical process. Therefore, preheated oils blended with diesel are used and tested as alternative fuels in engines. There is no single solution to global warming, which is primarily a problem of too much heat-trapping carbon dioxide (CO_2), methane and nitrous oxide in the atmosphere. The technologies and approaches outlined below are all needed to bring down the emissions of these gases by at least 80 percent by mid-century. Biodiesel is a clean burning alternative fuel produced from domestic, renewable resources such as plant oils, animal fats, used cooking oil and even from algae.

Biodiesel contains no petroleum, but can be blended at any level with petroleum diesel to create a biodiesel blend. Biodiesel blends can be used in compression ignition engines with little or no modifications. Among the vegetable oils edible and non-edible oils are used to produce biodiesel. The use of edible is a great concern with food materials. So it is justified to use non edible for the production of biodiesel. Non edible trees can grow in inhospitable condition of heat, low water, rocky and sandy soils. So non-edible oil plants like karanja, jatropha, mahua, neem will be the best choice for the source of biodiesel production. This experimental work describes the findings of experiments conducted on a diesel engine to investigate about its performance and emission parameters with a number of test fuels prepared from Calophyllum Inophyllum (Surahonne) Biodiesel.[1]

2. EXPERIMENTAION

A. Transesterification

It is most commonly used and important method to reduce the viscosity of vegetable oils. In this process triglyceride reacts with three molecules of alcohol in the presence of a catalyst producing a mixture of fatty acids, alkyl ester and glycerol. The process of removal of all the glycerol and the fatty acids from the vegetable oil in the presence of a catalyst is called esterification. This esterifies vegetable oil is called bio-diesel. Biodiesel properties are similar to diesel fuel. It is renewable, non-toxic, bio-degradable and environment friendly transportation fuel. After esterification of the vegetable oil its density, viscosity, cetane number, calorific value, atomization and vaporization rate, molecular weight, and fuel spray penetration distance are improved more. So these improved properties give good performance in CI engine. The Fig 1 shows the transesterification process

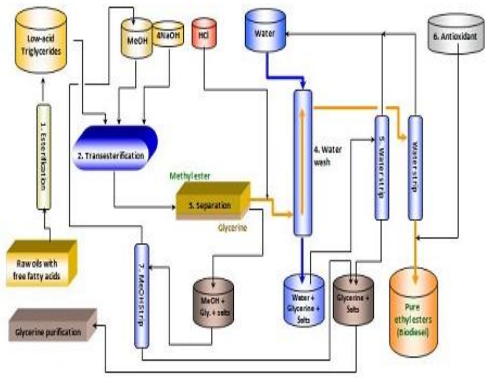

Fig 2.1: Shows the transesterification process

The Fig -2 shows the separation of glycerin from the bio- diesel. After reaction the oil is kept in a settling funnel for the process of separation. In which biodiesel, glycerin and catalyst are separated

B. *Separation of glycerol from bio- diesel*

Fig 2.2: Seperation of glycerin

3. EXPERIMENTAL SET-UP

Experiments were performed in the internal combustion engine laboratory, Department of mechanical engineering, PDA College of engineering, Gulbarga. The experimental setup consists of single cylinder, four strokes, diesel engine connected to eddy current dynamometer for variable loading. The set as stand- alone type independent panel box consisting of air box, fuel tank, manometer etc. The set up enables study of engine for brake power, BMEP, brake thermal efficiency, mechanical efficiency, specific fuel consumption, volumetric efficiency, A/F ratio, and emission characteristics like CO, CO2, HC and NO_X.

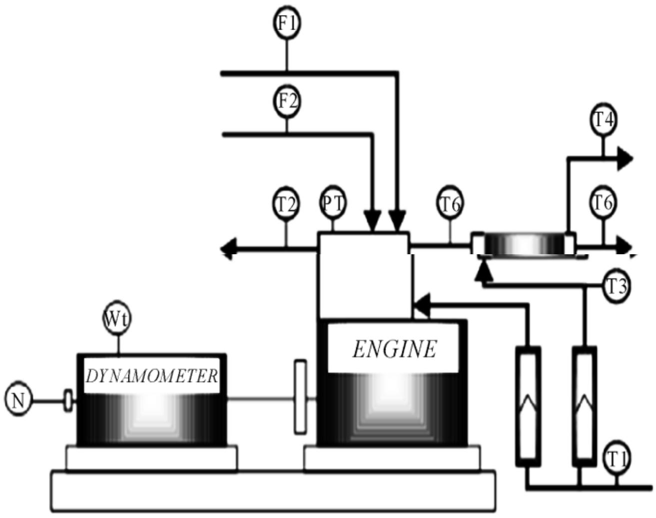

Fig 3.1: Experimental setup

The various components of experimental set up are described. Fig.2 shows line diagram and fig.3.shows the photograph of the experimental set up. The important components of the system are,

- The engine
- Dynamometer
- Exhaust emission testing machine
- Calorimeter
- Fuel measuring unit
- Pressure sensor
- Temperature sensor
- Rotameter
- Software

Table 3.1: Technical specifications of the engine

Manufacturer	Kirloskar Oil Engines Ltd., India
Model	TV–SR II, naturally Aspirated
Engine	Single cylinder, DI, 4 strokes
Bore/stroke	87.5mm/110mm
Compression ratio	17.5:1
Speed	1500 r/min, constant
Rated power	5.2 kW
Injection pressure	240 bar/23° BTDC
Type of sensor	Piezo electric
Crank angle sensor	1-degree crank angle

Properties	Dies el	BD 10	BD 20	BD 100	Equipment	BIS Specific ation
Calorific value (KJ/Kg)	4200 0	4122 0	4044 0	3420 0	Bomb calorimeter	-
Kinematics viscosity at 40^{0}C (Cst)	2.54	2.85	3.20	6.0	Red wood viscometer	2.5 – 6.0
Density (kg/m^3)	830	835	840	880	Hydrometer	860-900
Flash Point (^{0}C)	54	65	76	165	Pensky marten's	≤ 120
Fire Point (^{0}C)	64	75	88	175	Pensky marten's	-

Fig 3.2: Photograph of experimental setup

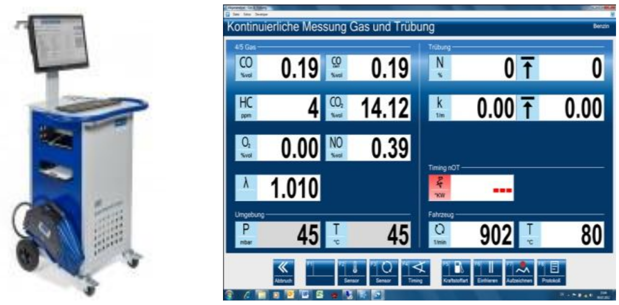

Fig 3.3: Emission testing machine

The emissions test is are done with AVL DITEST MDS 350 Exhaust Gas Analyzer. It is designed with sophisticated measurement modules. The product has additional features to save a vehicle and customer database, radio-connected diesel measuring chamber up to the option of designing the protocols individually. Due to the robustness and intuitive application of the device, the tester can be used to get sophisticated and accurate emission measurements. This provides for motivation and satisfaction. Fig.4 shows the emission testing machine.

4. RESULTS AND DISCUSSION

A. Fuel properties and characteristics

The proprieties of the desert date biodiesel, diesel fuel and blends were determined and the results are shown in Table: 2
Table 2 Properties of diesel and desert date biodiesel blends

B. Performance characteristics

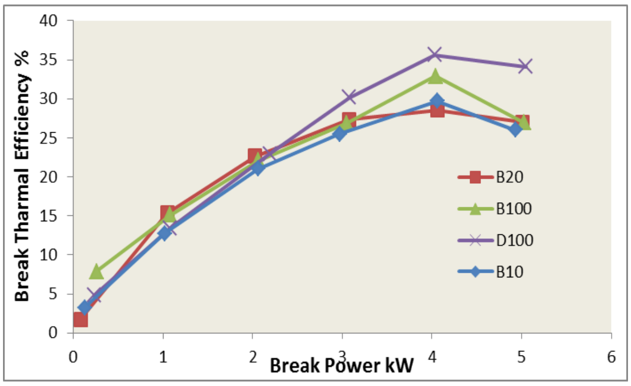

Fig 4.1: Variation of brake thermal efficiency with brake power

The variation of brake thermal efficiency with brake power for diesel, Calophyllum Inophyllum (Surahonne) biodiesel oil and their blends are shown in Fig 4.1. Brake thermal efficiency is increasing with increasing brake power for all multi-blends of biodiesel and diesel. It may be due to reduction in heat loss and increase in power with increase in load. The decrase in brake thermal efficiency for higher blends may be due to the combined effect of its lower heating value and increase in fuel consumption. Brake thermal efficiency of 100% biodiesel is very close to diesel for entire range of operation. Maximum brake thermal efficiency of 100% blend is 32.89% against, 35.60% of diesel oil, which is lower by 2.71%. We can say that brake thermal efficiency of 100% biodiesel is very well comparable with diesel. The maximum brake thermal efficiency of 10% and 20% blends are 29.69% and 28.56% against 35.60% of diesel.

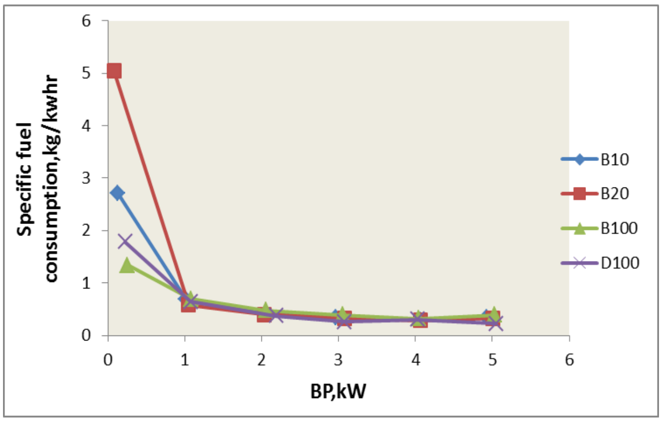

Fig 4.2: Variation of specific fuel consumption with brake power

The variation of specific fuel consumption with brake power shown in fig 6 as the power developed increases the specific fuel consumption decreases for all the tested fuels. The specific fuel consumption of blends is more than that of diesel, this is due to lower calorific value of the fuel, and engine consumes more amount of the fuel in order to produce the same out-put power. Brake thermal efficiency for B20 fuel is very close to that of diesel. At full load, the maximum Brake thermal efficiency for diesel is 0.31 kg/kW-h for B20 the value is 0.33 kg/kW-h, B10 is 0.35 kg/kW-h, and B100 is 0.391 kg/kW-h

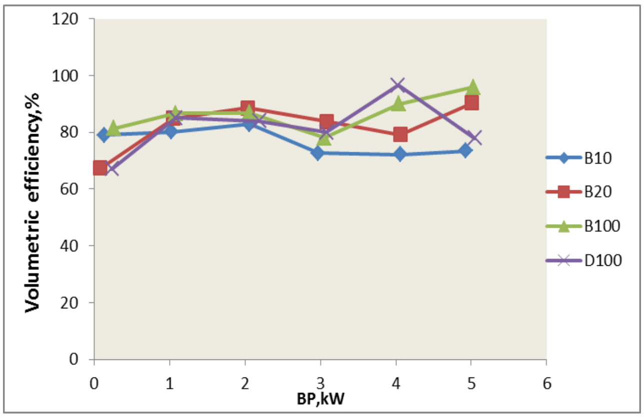

Fig 4.3: Variation of volumetric efficiency with brake power

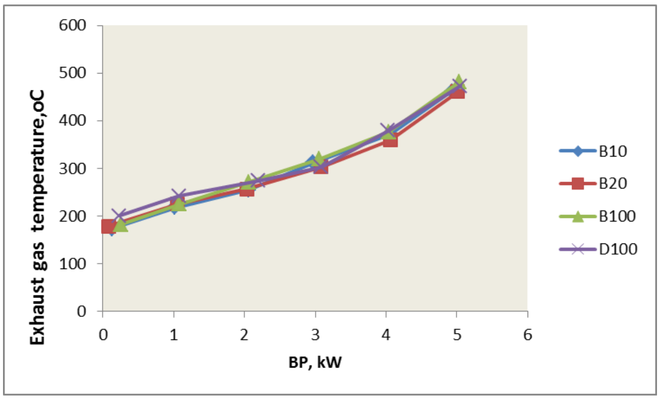

Fig 4.4: Variation of exhaust gas temperature with brake power

Fig 7: The variation of volumetric efficiency with brake power is shown in fig 7 from graph diesel has higher volumetric efficiency compare to blends .the graph for different blends are in zigzag in nature because of breathing ability of engine for the particular combinations .i.e. ,ratio of the air actually induced at ambient conditions to the swept volume of the engine.

Fig 8. The variation of exhaust gas temperature with brake power for different blends shown in fig 8. It is evident from the graph that exhaust gas temperature is increased along with the increase in load for all fuels. The increase in exhaust gas temperature with load is obvious from the fact that more fuel is required to take additional load. The exhaust gas temperature was found to increase with increasing concentration of biodiesel in the blends. This could be due to lower heat transfer rate in case of biodiesel which in evident from trends of thermal efficiency. From analysis point , The exhaust temperature of 10% blend of Calophyllum Inophyllum Biodiesel has lower values compared with all other blends and is well comparable with diesel, The 10% blend of Calophyllum Inophyllum Biodiesel has higher performance than other blends due to reduction in exhaust loss.

C .Combustion Characteristics

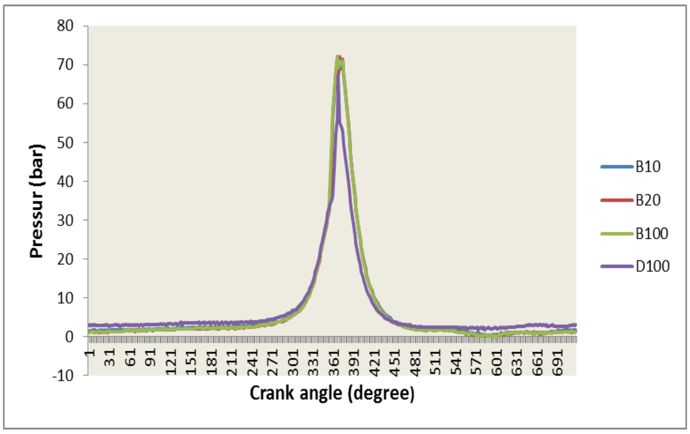

Fig 4.5: Variation of pressure with crank angle

The variation of pressure with crank angle for diesel, Calophyllum Inophyllum biodiesel and their blends are shown in Fig 9. In a CI engine the cylinder pressure is depends on fuel burning rate during the premixed burning phase, which in turn leads better combustion and heat release. It can be seen from Fig 4.5 the maximum pressure is for diesel 67.32bars and for biodiesel B10, B20 and B100 are 72.1bar, 72bar, and 72bar respectively.

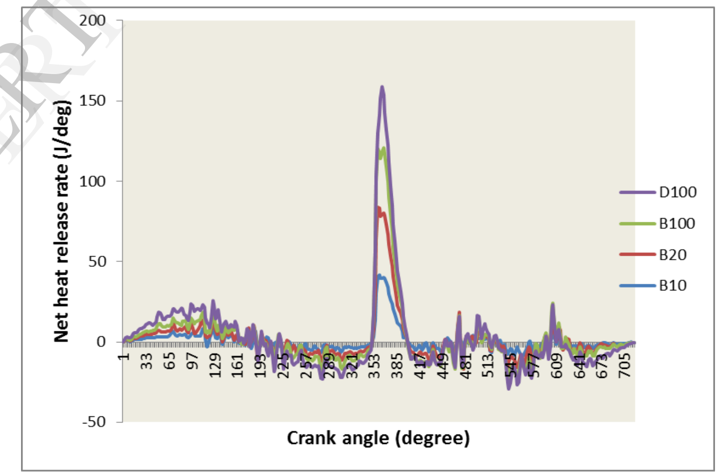

Fig 4.6: Variation of Net HRR with crank angle

The variation of heat release rate with crank angle is shown in figure 10. The heat release rate for all other tested fuel was slightly less than that of diesel this may be attributed to low vaporization, high viscosity and low peak pressure of blends as compared to that of diesel.It can be observed that heat release rate is high for diesel. This is due to premixed and uncontrolled combustion phase. The value of heat release rate is 167.07 J/degree for diesel and heat release rate is for B10, B20 and B100 are 123 J/degree, 78 J/degree, and 46 J/degree respectively.

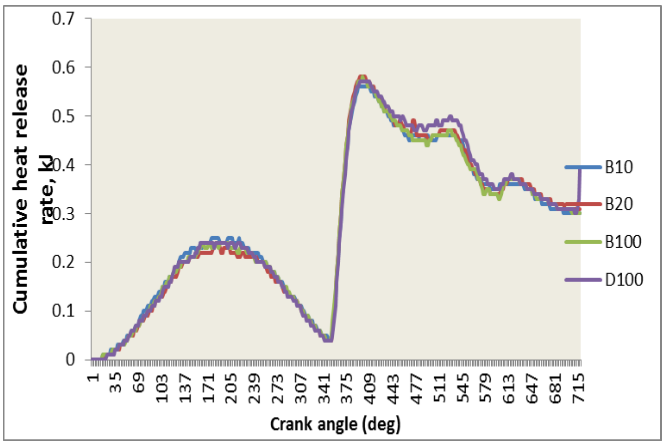

Fig 4.7: Variation of cumulative heat release rate with

The variation of cumulative heat release rate with crank angle is shown in fig 11.The diesel and blend values are same in all loads. 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.

D. *Emission characteristics*

The CO emission depends solely depends upon the strength of the mixture, availability of oxygen and viscosity of fuel. From fig 12 it is observed that the CO emission initially decreases at lower loads sharply increases for all test fuels. This is due to incomplete combustion at very high loads which results in higher CO emissions. CO emission is found highest for B20 if we compare with diesel. Lowest for pure biodiesel B100 at all loads. From the figure it is revealed that B100 shows lowest carbon monoxide emission compared to all other test fuels are B10, B20, D100 and then increases due to incomplete combustion.

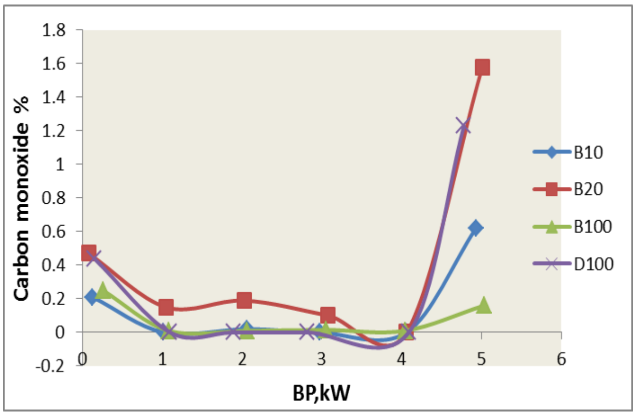

Fig 4.8: Variation of carbon monoxide with brake power

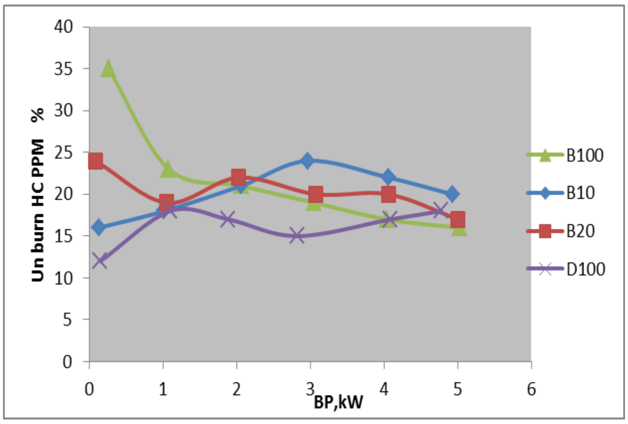

Fig 4.9: Variation of hydrocarbon with brake power

Fig 13 shows the variation of emission of hydrocarbon with brake power for different blends of Calophyllum Inophyllum Biodiesel and pure diesel. The emission of HC is decreasing with increase of loads. HC of pure biodiesel (B100) has lower emission compared with all other blends followed by 20% blend. The minimum value of HC at pure biodiesel is 16 ppm against 18 ppm of diesel. For B10 HC value is 20ppm it is higher than the diesel fuel (D100) that is 18 ppm from the above observation it is clear that the engine operates at lower performance and higher smoke, CO and unborn HC emission compared with diesel. This could be due to low volatility, which effects the spray formation in combustion chamber and thus leads to slow formation.

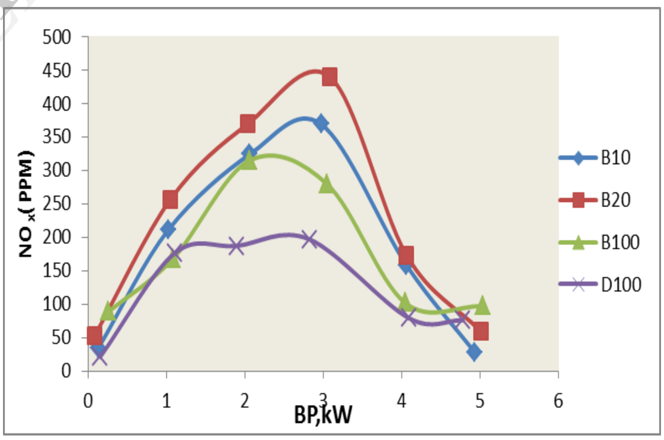

Fig 4.10: Variation of NO_x with brake power

The NO_x emission depends upon the oxidation of nitrogen at high temperature. The results obtained in Fig. 14 show that NO_x emission increases with engine load for all test fuels. It is found highest for pure biodiesel and lowest for diesel at all loads. Higher NO_x emission in case of biodiesel is due to the fact that it contains higher oxygen which results in higher combustion temperature. Results also show decrease in NO_x emission for B10, comparing with diesel D100. From the figure it is revealed that B10 shows lower nitrogen oxide emission compared to other blends such as B20, B100.

E. *Comparison of Calophyllum Inophyllum (Surahonne) biodiesel performance and emission characteristics with karanja biodiesel and mahuam oil*

To ascertain the validity of result obtained, Calophyllum Inophyllum (Surahonne) performance and emission characteristics is compared with the similar experimental work of Pro.S.R.Hotti, Pro.O.D.Hebbal, from PDA Engineering College Gulbarga and Pro.Haiter Lenin from PET Engineering College, Vallioor. Pro.S.R.Hotti, and Pro.O.D.Hebbal conducted the variable load performance test with karanja Oil. Then the performance of engine is evaluated in terms of brake thermal efficiency, BSFC, and exhaust temperature. Pro.Haiter Lenin also conducted the variable load test with Mahua Oil Then the performance of engine is evaluated in terms of brake thermal efficiency, unburnt HC, CO emission and exhaust temperature. Though the performance result are available for blends, for convenience only the result of neat vegetable oils are used for comparison. The results are plotted with trend lines for easy understanding. For the purpose of comparison Karanja oil used by Pro.S.R.Hotti,and Pro.O.D.Hebbal is labeled as K100 and Mahua oil used by . Pro.Haiter Lenin is labeled as H100.

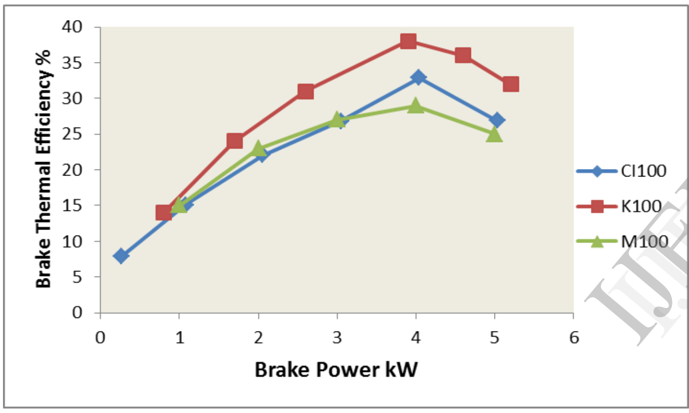

Fig 4.11: Variation of brake thermal efficiency with brake power

Fig 15: Variation of brake thermal efficiency with brake power. The brake thermal efficiency of Calophyllum Inophyllum (Surahonne) biodiesel is lesser than the Karanja Biodiesel and higher than that of mahua oil. The maximum thermal efficiency Calophyllum Inophyllum (Surahonne) is (CI100) 32.05% and K100 and H100 is 38.01% and 28.01% respectively.

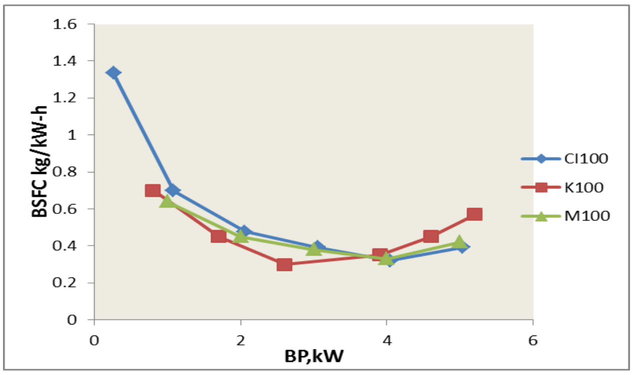

Fig 4.12: Variation of specific fuel consumption with brake power

The variation of specific fuel consumption with brake power shows in fig 16. The BSFC of Calophyllum Inophyllum oil and Mahua oil are minimum specific fuel consumption than that of Karanja biodiesel, the minimum BSFC of Calophyllum Inophyllum oil and Mahua oil is 0.42 kg/kW-h and 0.47 kg/kW-h respectively. Fig 17 shows the variation of exhaust temperature with brake power. Exhaust temperature of the Calophyllum Inophyllum biodiesel (CI100) is lower than the karanja oi(K100). The maximum Exhaust temperature of CI100, K100 and M100 are 4804^{o}C,4904^{o}C, and 330 4^{o}C respectively

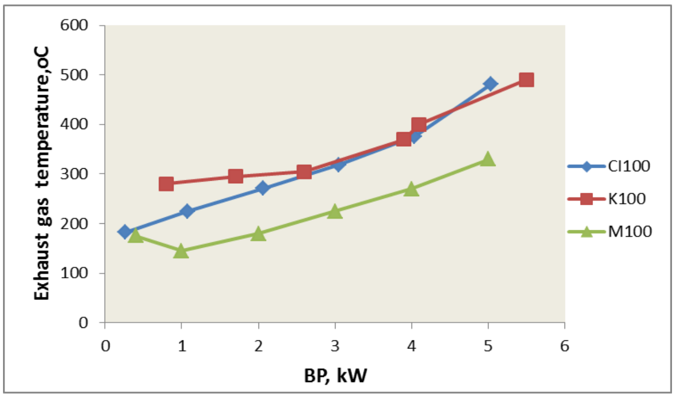

Fig 4.13: Variation of exhaust gas temperature with brake power

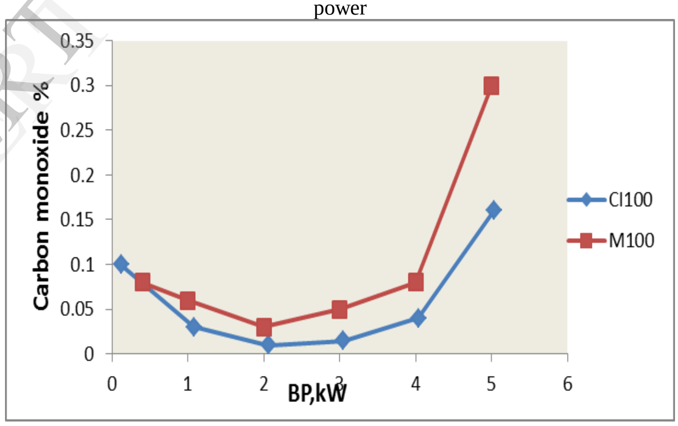

Fig 4.14: Variation of carbon monoxide with brake power

The variation of carbon monoxide with brake power is shown in fig 18. The CO value for value for Calophyllum Inophyllum oil is lower than the other biodiesel. The maximum CO value for Calophyllum Inophyllum oil, CI100 and M100 is 0.16%, 0.3% respectively.

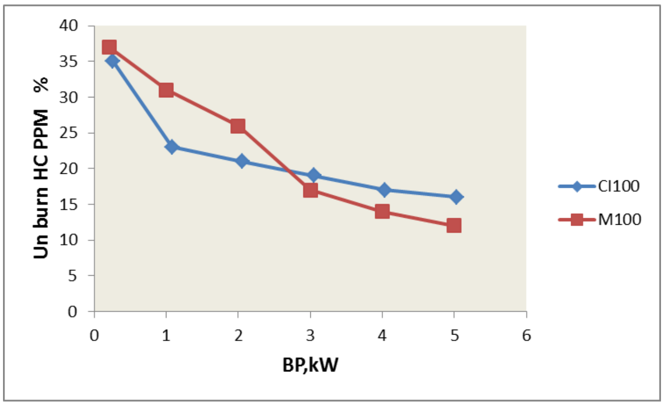

Fig 4.15: Variation of hydrocarbon with brake power

The variation of unburnt HC with brake power is shown in fig 4.15. The values of HC for CI100 and M100 are increases with the increases of load, but in case of Calophyllum Inophyllum oil is a decrease with the increases of load.

5. CONCLUSIONS

The experimental work carried out on a single cylinder diesel engine using biodiesel derived from Calophyllum Inophyllum Biodiesel as an alternate fuel. The performance, combustion and emission characteristics of blends are evaluated and compared with diesel. No difficulty was faced at the time of starting the engine and the engine ran smoothly over the range of engine speed. From the above investigation, the following conclusions are drawn.

- The properties viz; density, viscosity, flash point and fire point of Calophyllum Inophyllum biodiesel is higher and calorific value is 40 kg/m^3 higher than that of diesel.
- Performance, combustion and emission characteristics of 20% blend are better than other blends, followed by B100. And efficiency of B100 is well compare with the diesel. The maximum brake thermal efficiency of B100, B10 and B20 are respectively 32.89%, 29.69% and 28.56% against, 35.66% of diesel.
- The maximum brake thermal efficiency of Calophyllum Inophyllum biodiesel is 32.89% against 35.66% of diesel.
- The minimum BSFC of Calophyllum Inophyllum biodiesel (B100) is 0.037 kg/kW-h higher compared with diesel.
- Unburnt HC, CO and NO_x emissions at maximum load for Calophyllum Inophyllum biodiesel compared with diesel are higher by 21ppm, 18.01 vol%, and 02ppm, respectively.
- After comparison of Calophyllum Inophyllum biodiesel with Karanja and Mahua oil it is concluded that, the brake thermal efficiency of Calophyllum Inophyllum biodiesel is lesser than that of Karanja oil and higher than the Mahua oil .
- The maximum brake thermal efficiency of Calophyllum Inophyllum biodiesel (CI100), K100 and M100 26.01%, 32% and 25% respectively.
- The CO emission and unburnt HC of Calophyllum Inophyllum Biodiesel is lower than D100 and H100.this could be the reason for higher efficiency of Calophyllum Inophyllum Biodiesel. The maximum value of CO for Calophyllum Inophyllum Biodiesel, DH100 and H100 are 0.05%, 0.17% and 0.37% respectively.
- The CO value for value for Calophyllum Inophyllum oil is lower than the other biodiesel. The maximum CO value for Calophyllum Inophyllum oil, CI100 and M100 is 0.16%, 0.3% respectively.

The values of HC for CI100 and M100 are increases with the increases of load, but in case of Calophyllum Inophyllum oil is a decrease with the increases of load.

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