International Journal of Engineering Research & Technology (IJERT)
ISSN: 2278-0181
Vol. 3 Issue 8, August - 2014

Experimental Investigation on Performance, Emission and Combustion Characteristics of Single Cylinder LHR Diesel Engine using Tobacco Seed Biodiesel

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***Abstract* - In this present investigation tobacco oil biodiesel, a non-edible oil biodiesel is selected for the test on diesel engine and its suitability as alternative fuel is examined. The blends are prepared in 10/90%, 20/80%, 30/70% and 100/0% on volume basis, then analyzed and compared with diesel. Further blends are heated and effect of viscosity on temperature is studied. The performance and emission characteristics of blends are evaluated at variable loads of 0.1, 1.04, 2, 3.02, 4.01, 4.85 kW at constant rated speed of 1500 rpm and the results are compared with diesel. The brake thermal efficiency, brake specific fuel consumption, exhaust gas temperature, and air fuel ratio are well comparable with diesel. Emission characteristics HC higher and CO little lower than diesel fuel. For ascertaining the validity of results obtained tobacco biodiesel is compared with pongamia biodiesel for the similar work available in the literature and were well comparable. From the investigation it has been established that the tobacco biodiesel blends without heating can be substituted for the biodiesel without any engine modification**

Keywords: Tobacco seed biodiesel, BTE, Transesterification, BSFC

I. INTRODUCTION

With increasing trend of modernization and industrialization, the world energy demand is growing at a faster rate. Since their exploration, the petroleum fuels continued as major conventional energy source. On the other hand they are limited in reserve. Both the factors have contributed a sharp increase in the petroleum prices. Also, petroleum fuels are currently the dominant global source of CO_2 emission and their combustion is posing stronger threat to clean the environment. Sharp rise in the petroleum price and increase in the environment pollution jointly necessitated exploring some alternate to conventional fuels [1]. The continuous increasing demand for energy and the diminishing tendency of petroleum resources has led to the search for alternative renewable and sustainable fuel [2-8].

In 1895, Rudolf Diesel developed a new engine with the intention that it could use a variety of fuels, including vegetable oil. He ran his engine at the World Exhibition in Paris in 1900 by using peanut oil as a fuel. Due to higher viscosity, the straight vegetable oil causes poor fuel atomization, incomplete combustion and carbon deposition on the injector and valve seats resulting in serious engine fouling. It has been reported that when direct injection engines are run with neat vegetable oil as fuel, injectors get choked up after few hours and lead to poor fuel atomization, less efficient combustion and dilution of lubricating oil by partially burnt vegetable oil [10,11,12]. With the increased emphasis on the need for clean, renewable fuels, it is imperative to fully understand the operational characteristics of biodiesel. For many years, petroleum has been the primary source for diesel fuels. However, in recent years the supply of petroleum has slowed, while the need for petroleum fuels has substantially increased Tobacco seeds are a by-product of leaves production of tobacco (Nicotiana tabacum L., family Solanaceae). The seeds can give glyceride oil, which is raw material in the coating industry, for preparation of printing inks, dyes etc [13]. The content of oil in the seeds is about 300 g/kg. Present investigation provides the performance, emission and combustion characteristics of tobacco seed oil biodiesel.

The concept of LHR engine is to minimize heat loss to the coolant by providing thermal insulation in the path of the heat flow to the coolant. LHR engines were classified depending on degree of insulation as low grade LHR engines, medium grade LHR engines and high grade LHR engines. Low grade LHR engines consisted of thermal coatings on piston, liner and cylinder head with low thermal conductivity materials, medium grade LHR engines provide an air gap in the piston and other engine components with superni (an alloy of nickel), cast iron and mild steel etc., while high grade LHR engine was the combination of low and medium grade LHR engines.

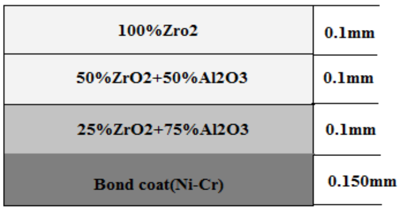


Fig 1.1 metal matrix thermal barrier coating composition and thickness of layers

Experiments were conducted on LHR engine [14] with cylinder head, valves and pistons of the engine coated with plasma spray zirconium with the thickness of 0.5 mm and it was reported that In comparison to CE, SFC was decreased by 6 %, and BTE was increased by 2%. The available exhaust gas energy of the LHR engine was 3–27% higher for the LHR engine compared to the standard (STD) Diesel engine.
Tests were performed [15,16] on a six cylinder, direct injection, turbocharged diesel engine whose pistons were coated with a 350 microns thickness of MgZrO3 over a 150 micron thickness of NiCrAl bond coat. CaZrO3 was employed as the coating material for the cylinder head and valves. The results showed that 1–8% reduction in BSFC could be achieved by the combined effect of the thermal barrier coating (TBC) and injection timing. On the other hand, NOx emissions were obtained below those of the base engine by 11% for 18obTDC injection timing [17]. It was explained that compared with CE, LHR engine with ceramic coating on piston crown and inner side of cylinder head with pure diesel operation, the engine power was increased by 2%, the engine torque was increased by 1.5–2.5 %, and SFC was decreased by 4.5–9 %.
In the present investigation, cylinder head coated with metal matrix composition using plasma spray coating is used for experimental work

II. PREPARATION OF BIODIESEL

1. Esterification

Esterification is the first process of making biodiesel from crude oil. This process consisting of removal of acid content in the crude oil. Sulphuric acid is used as acid removal agent in the esterification process.

Calculated amount of oil is taken in a three necked flask. Three necked flak consists of three necks. Middle neck is for addition of oil, the other two necks are for removal of oil and addition of catalytic solution. Mount the reflux condenser to the middle neck after pouring the oil into the flask. Care should be taken to see that there is continuous supply of fresh water to the condenser which is mounted on the three necked flask. Heat the oil in the flask to about 60℃ Well mixed solution of sulphuric (H_2SO_4) acid and methanol ($NaOCH_3$) is added to the heated oil at 60℃. Close the three necks with air tight seal and ensure that there are no foreign particles enters into the apparatus. The oil mixes well with the help of magnetic stirrer. Continue this process about to one and half hour. The oil mixture after the test hour is taken into the separator for about a half an hour. The oil mixture forms two layers, top one is esterified oil and take it again in a three necked flask for esterification

2. Transesterification

Transesterification is the second process of making biodiesel. It consists of removal of glycerin in the oil with help of catalyst sodium methoxide ($NaOCH_3$)
Prepare the solution with calculated amount of methanol (CH_3OH) and sodium methoxide ($NaOCH_3$). The oil which is esterified is taken again in the same three necked flask. Now the solution is prepared by mixing the calculated amount of sodium methoxide and methanol. Heat the esterified oil, with same experimental set up, to 60℃, add the solution to oil when oil reaches the temperature of about 60℃. Heat the mixture up to about one and half hour. Two layers forms in separator when the oil poured in to the separator.

III. PROPERTIES OF TOBACCO BIODIESEL

Table 1
Blend ratios of tobacco biodiesel

Bends	Diesel %	Tobacco biodiesel %
D100	100	0
B10	90	10
B20	80	20
B30	70	30
B100	0	100

Table 1 shows the blend ratios of tobacco biodiesel with diesel. The important physical and chemical properties of tobacco biodiesel are determined as per the Indian standard (IS) methods in the fuel and lubricant laboratory. Determination of density, viscosity, calorific value, flash point, fire point and carbon residue test are carried out using hydrometer, redwood viscometer, bomb calorimeter, Pensky-martien's apparatus [17-20] respectively. From the table 2 it is observed that viscosity, flash point, fire point and carbon residue is of the biodiesel is higher than diesel and calorific value and density is lower than diesel. From the table 2 it also observed the effect of dilution o viscosity, density, calorific value, carbon residue, flash point and fire point of biodiesel and diesel blends

Table 2
Comparison of tobacco biodiesel and its blends with diesel

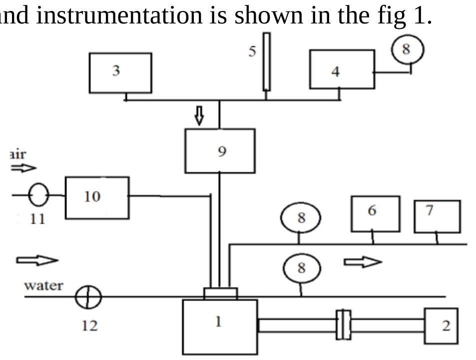
Properties	diesel	Tobacco blends			
		B10	B20	B30	B100
Density	0.831	0.828	0.836	0.842	0.891
Viscosity at 40℃ (cSt)	4.1	4.13	4.22	4.28	4.69
Calorific Value KJ/kg	42800	39195	38200	37283	36960
Flash point℃	51	56	60	64	142
Fire point ℃	57	70	72	76	162
Carbon residue (%)	0	0.11	0.119	0.139	0.2

IV. EXPERIMENTAL SET UP

Specifications of the engine

Manufacturer: Kirloskar, India
Model: TV_SR II, naturally aspirated
Engine: Single cylinder, DI diesel engine
Bore/stroke/compression
Ratio: 87.5 mm/110 mm/17.5:1
Power: 5.2 kW
Speed: 1500 rpm, constant
Injection pressure/advance: 200bar/23 degree before TDC

Experiments are conducted on a 5.2kW, TV1 Kirloskar make, naturally aspirated, direct injection (DI), single cylinder, water cooled, engine having 87.5 mm bore and 110mm stroke with 17.5:1 compression ratio. The engine can be used in agriculture sector, transport vehicle, form machinery, small and medium scale commercial purposes. The engine can withstand peak pressure encountered due to high compression ratio. Further the necessary modification on engine crown and piston head can be carried out easily. Hence engine is selected for the present research work. The engine is coupled with SAJ Froude AG series eddy current dynamometer, it is a bi-directional water cooled type the layout of experimental test rig and instrumentation is shown in the fig 1.



1. Diesel engine 2. Dynamometer 3. Diesel tank 4.biodiesel tank 5. Measuring burette 6. Smoke meter 7. HC & CO analyser 8. Digital thermocouple 9. Filter 10. Air tank 11. Orifice meter with manometer 12. Rotameter

Fig 1.2 Layout of experimental set up with insrtumentation

Experiments are conducted on a 5.2kW, TV1 Kirloskar make, naturally aspirated, direct injection (DI), single cylinder, water cooled, engine having 87.5 mm bore and 110mm stroke with 17.5:1 compression ratio. The engine can be used in agriculture sector, transport vehicle, form machinery, small and medium scale commercial purposes. The engine can withstand peak pressure encountered due to high compression ratio. Further the necessary modification on engine crown and piston head can be carried out easily. Hence engine is selected for the present research work. The engine is coupled with SAJ Froude AG series eddy current dynamometer, it is a bi-directional water cooled type the layout of experimental test rig and instrumentation is shown in the fig 1.2

Variable load tests are conducted for 0.1, 1.04, 2, 3.02, 4.01, 4.85 kW at constant speed of 1500 rpm, with fuel injection pressure of 200 bar. The engine was sufficiently wormed up and stabilized before take all readings. All the readings were replicated thrice to get a reasonable value. The performance characteristics of the engine are evaluated in terms of brake thermal efficiency, specific fuel consumption (BSFC) and air fuel ratio. Emission characteristics are evaluated in terms of unburned HC, CO, CO_2 and exhaust gas temperature. These characteristics of biodiesel are compared with diesel.

V. RESULT AND DISCUSSION

1. PERFORMANCE CHARACTERISTICS

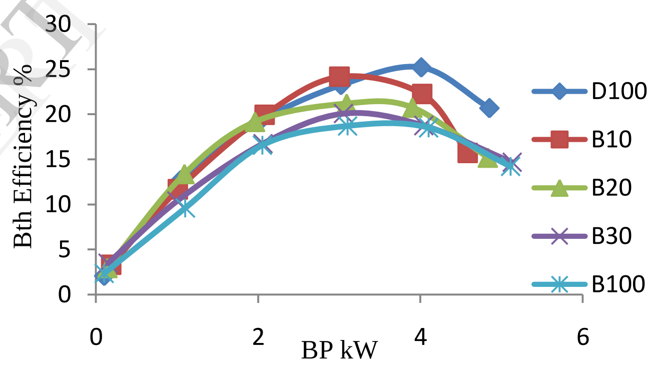


Fig 1.1 Variation of brake thermal efficiency with brake power.

The variation of brake thermal efficiency with brake power for diesel, and tobacco biodiesel and its blend is shown in figure 1.1. Max brake rhermal efficiecy is attained by diesel and it is 25.2%. Figure shows that brake thermal efficiencies of all the blends is lower at almost all load levels. Among the blends B10 is found to have the thermal efficiency of 24.15% at a brake power of 3 kW while for diesel it is 25.2%. The percentage decrease in the brake thermal efficiency against that of diesel is recorded as24.13%, 26.50%, 29.06%, 39.29%. The decrease in brake thermal efficiency with increase in tobacco biodiesel concentration is due to the poor atomization of the blends due to their high viscosity.

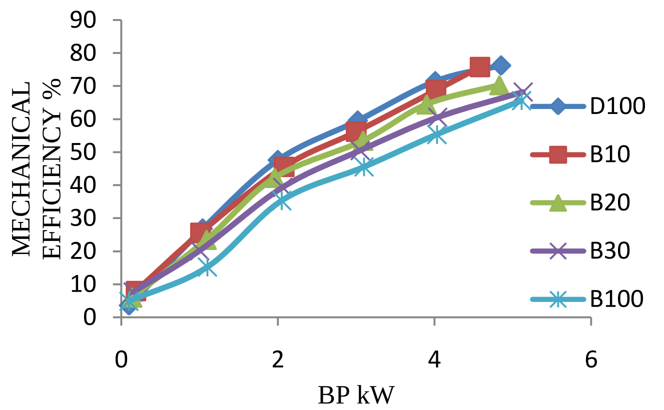


Fig 1.2 Variation of mechanical efficiency with brake power

The variation of mechanical efficiency with brake power for diesel and tobacco biodiesel blends is as shown in figure 1.2. The mechanical efficiency of diesel is slightly higher than the tobacco biodiesel blends and D100 and B10 are seen to be almost nearer to each other and also from the graph it is evident that with increase in the concentration of tobacco biodiesel in neat diesel decreases the mechanical efficiency.

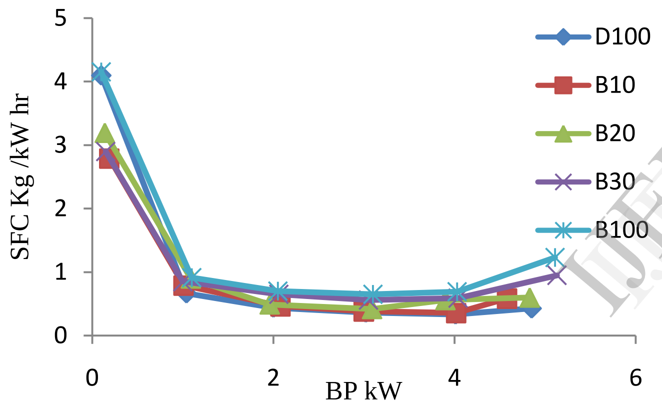


Fig 1.3 Variation of brake specific fuel consumption with brake power.

The variation of specific fuel consumption with brake power for diesel and tobacco biodiesel oil and its blend is shown in figure 1.3. Specific fuel consumption for tobacco 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.

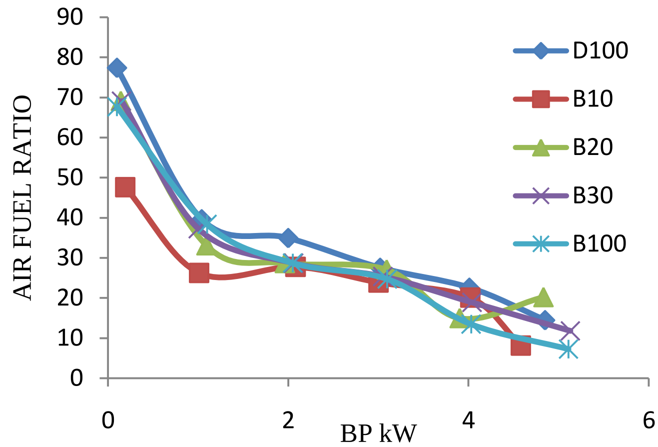


Fig 1.4 Variation of air fuel with brake power.

The variation of air fuel ratio with brake power for diesel and tobacco biodiesel blends is shown in figure 1.4. It can be observed that air fuel ratio of pure diesel is higher than other tobacco biodiesel and its blends, and we can also see that the air fuel ratio decreases as the load increases.

The variation of cylinder pressure with respect to crank angle for diesel and 10% blend of tobacco biodiesel is presented in figure 1.5. Peak pressures of 74.73 bar and 76.59 bar are found for pure diesel and B10 respectively. From the test results it is observed that the peak pressure variations are less Since the properties such as calorific value, viscosity and density are brought closer to diesel after transesterification of the tobacco oil, no major variation in the pressures are found. In a CI engine the cylinder pressure depends on the fuel burning rate during the premixed burning phase, which in turn leads better combustion. Peak pressure as compared to normal engine is higher due to complete combustion of fuel in LHR engine.

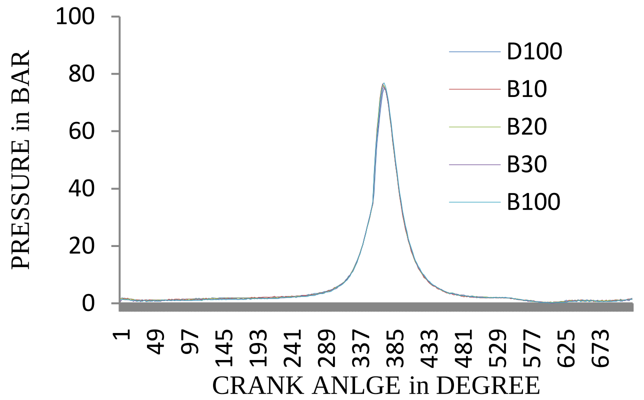


Fig 1.5 Variation of cylinder pressure with crank angle

2. COMBUSTION CHARACTERISTICS

Fig 2.1 shows the variation of net heat release rate with crank angle. From the figure it is evident that diesel fuel has high net heat release rate of 43.59KJ/m^3 deg at 369° CA (crank angle). Among the blends B30 has recorded high net heat release rate of 42.14 KJ/m^3 deg at 365° CA. Other blends B10, B20, B100 having net heat release rate of 39.35 KJ/m^3 deg , 38.4 KJ/m^3 deg and 41.56 KJ/m^3 deg at 365°, 365° and 367°, CA respectively.

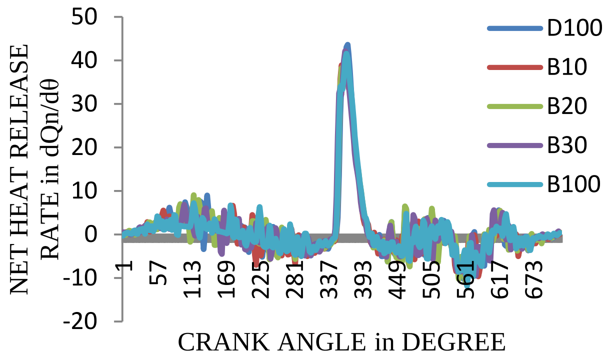


Fig 2.1 Variation of net heat release rate with crank angle

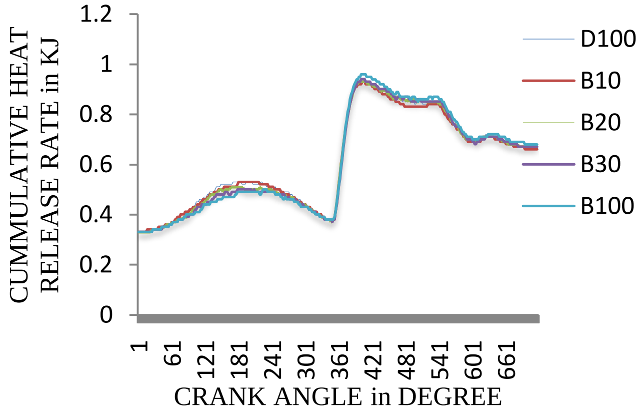


Fig 2.2 Variation of cumulative heat release rate with crank angle

Fig 2.2 shows the variation of cumulative heat release rate with crank angle. From the fig it is clear that high cumulative heat release occurs for the blend B100 and it is recorded as 0.93 KJ followed by the blend B30. Diesel, the tobacco blends B10 B20 have same cumulative heat release rate at 401° crank angle.

3. EMISSION CHARACTERISTICS

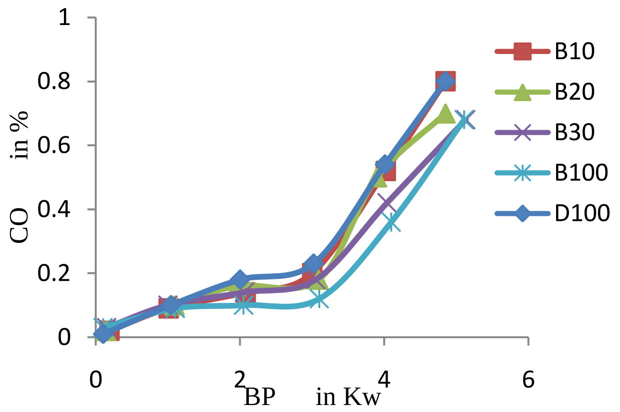


Fig 3.1 Variation of CO with brake power

From the figure 3.1, it is evident that carbon monoxide emissions of tobacco biodiesel blends B10, B20 are very nearer to the diesel fuel diesel (D100), B10, B20 emits high carbon monoxide. The remaining blends B30 and B100 have decreased carbon monoxide emission respectively with14.28%, 17.6%, by volume at full load condition. Carbon monoxide varies almost linearly with brake power. Fig 3.1 shows the variation of carbon monoxide with brake power.

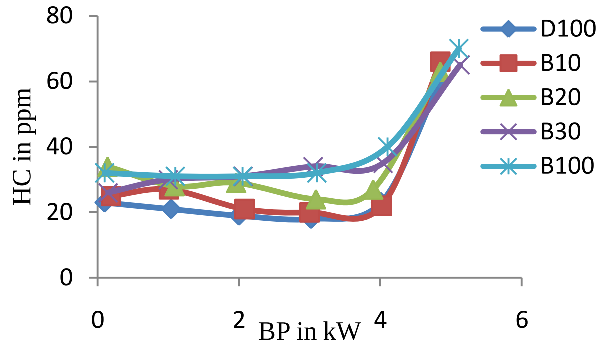


Fig 3.2 Variation of unburned hydrocarbon with brake power

Fig 3.2 shows the variation of hydrocarbons with the brake power and it is evident that biodiesel blend B100 have high emission characteristics of hydrocarbon. The blends B10, B20, B30 follow the blend B100 and have less emission of hydrocarbons. Diesel emits less HC compared to the blends Hydrocarbon emission varies almost constant and increases instantly. Maximum HC emission is by tobacco biodiesel is recorded as 70 ppm and minimum HC from diesel as 60 ppm.

Variation of carbon dioxide of tobacco blends and diesel with brake power is shown in the fig 3.3. From the fig it is clear that CO_2 emission varies linearly with brake power and diesel fuel has high CO_2 emission compared to tobacco biodiesel blends. Carbon monoxide of biodiesel blends decreases 1.9%, 7.7%, 9.7% and 12.1% by volume for blends B10, B20, B30, and B100 respectively against that of the diesel.

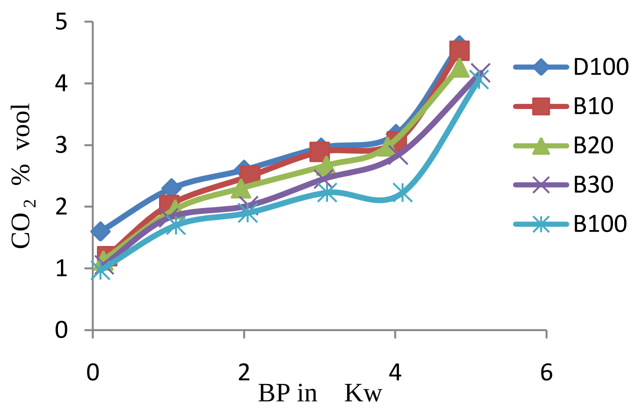


Fig 3.3 Variation of carbon dioxide with brake power

Variation of NO_X (oxides of nitrogen) with brake power is shown in the fig 3.4 and it is noted that diesel having high NO_X emission than biodiesel. At full load conditions, maximum NO_X emission by the diesel is recorded as 230 ppm where as tobacco biodiesel blends B10, B20, B30 and B100 are recorded as 230, 218, 208, 196 and 159 ppm respectively. Variation of oxides of nitrogen varies linearly with brake power.

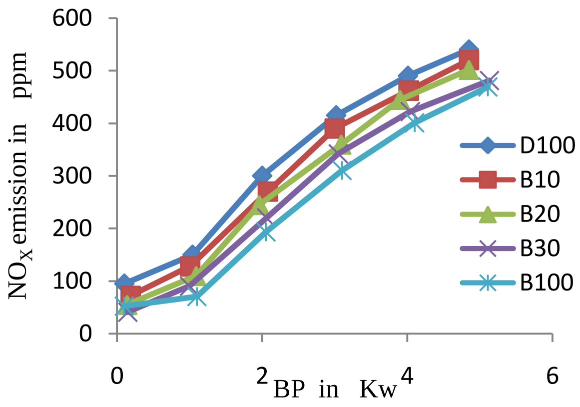


Fig 3.4 Variation of NO_X with brake power

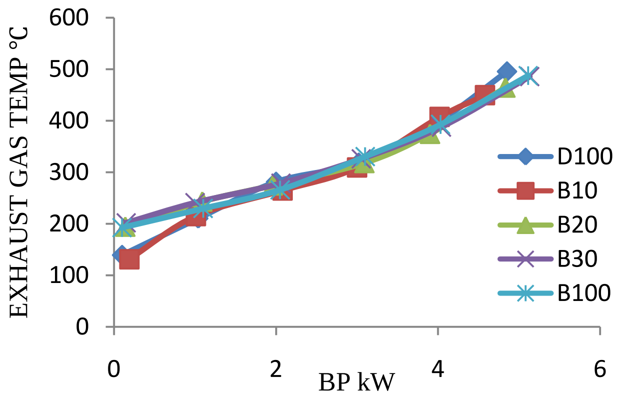


Fig 3.5 Variation of exhaust gas emission with brake power

The variation of exhaust emission gas temperature with brake power for diesel, and other blends of tobacco biodiesel is shown in figure.3.5, the exhaust emission temperature of all the biodiesel is higher than the diesel as it is evident from the graph. The exhaust gas temperatures for 100% diesel and 10%, 20%, 30%, 100% blends for varying loads can be observed and stated as they are slightly parallel to each other. The exhaust gas temperature of all the blends and 100% diesel increase as the load increases. It is observed that, at full load the exhaust gas temperature is maximum, this is because at full load the chemically correct ratio of air and fuel is used, due to chemically correct ratio of air and fuel, high heat is generated inside the cylinder

4. COMPARISON

To ascertain the validity of the result obtained, tobacco biodiesel performance is compared with result obtained from the similar experimental work [21,22] using pongamia (karanja) biodiesel. Mohamed Mustapha, et ai, [23]. Mohamed musthapha is in his experimental work reduced the viscosity of karanja biodiesel by diluting the biodiesel and further blends are heated to reduce the viscosity equivalent to that of diesel. They have also used the similar 5.2kW, 1500 rpm, CR of 17.5:1, naturally aspirated, Kirloskar make diesel engine, which further simplifies the comparison work. Mohamed musthafa conducted experiment on Rice bran methyl ester and pongamia bio diesel at fuel injection pressure of 220 bar. Then the performance of engine is evaluated in terms of brake thermal efficiency, HC emission exhaust gas temperature, and BSFC and NOx emission

Fig 4.1 shows the variation of brake thermal efficiency of diesel, pongamia biodiesel and tobacco biodiesel with brake power in single cylinder, four stroke, compression ignition, LHR engine. It evident from the fig that diesel has brake thermal efficiency of 25.2%, where as Pongamia has high BTE of 35.5% and tobacco biodiesel has BTE of 18.51%.

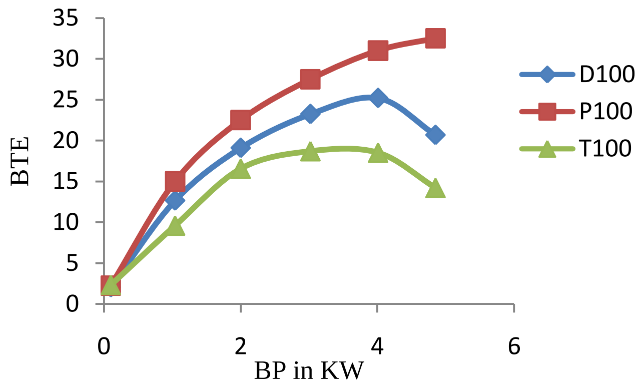


Fig 4.1 Variation of brake thermal efficiency with brake power

Variation of brake specific fuel consumption of pure diesel, pure pongamia biodiesel and pure tobacco biodiesel with brake power is shown in the fig 4.2. It is clear from the fig that high fuel consumption is required for the engine to start and attains constant once the engine starts. P100 and D100 have similar readings where as T100 having little high brake specific fuel consumption. BSFC of pongamia biodiesel and tobacco biodiesel is high because of lower calorific value and high density

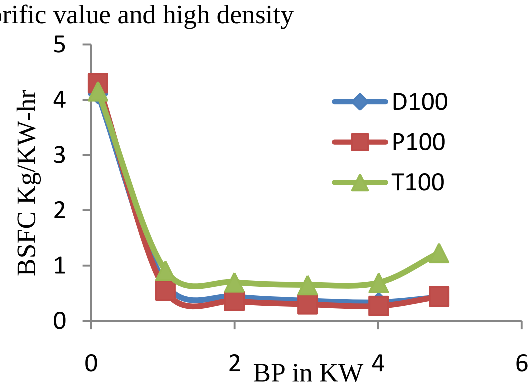


Fig 4.2 Variation of brake specific fuel consumption with brake power

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Fig 4.3 shows the variation of exhaust gas temperature with brake power. Form the fig it is evident that both diesel and tobacco biodiesel are having same exhaust temperature and higher than the pongamia biodiesel. Tobacco biodiesel and pongamia biodiesel gives the exhaust temperature of 487.42 °C and 300°C respectively against diesel exhaust temperature of 495.73°C.

Fig 4.4 shows the variation of unburned hydrocarbons with the brake power. It is evident from the fig that, tobacco biodiesel has high emission of HC. Maximum HC emission from tobacco biodiesel is 70 ppm where as pongamia and diesel fuel contributes70 and60 ppm respectively. HC emission of all the three fuels is near to constant and rises suddenly.

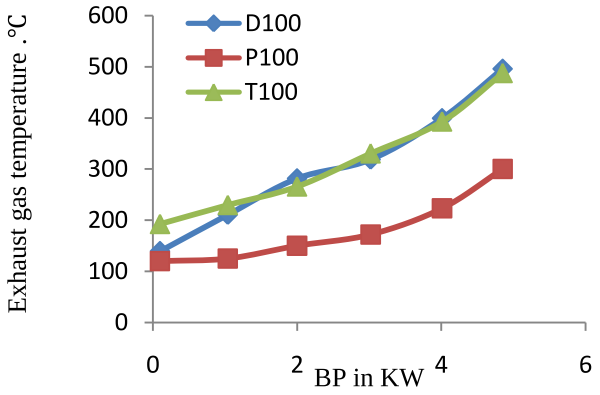

Fig 4.3 Variation of exhaust gas temperature with brake power

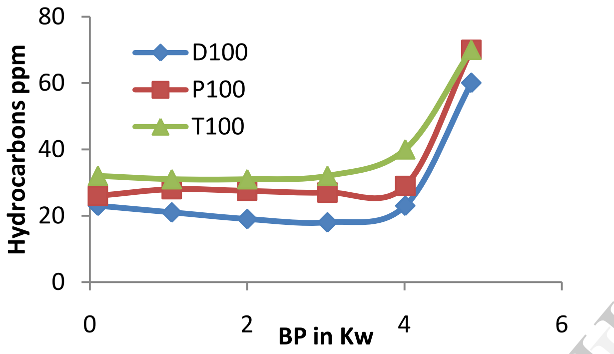

Fig 4.4 Variation of unburned hydrocarbons with brake power

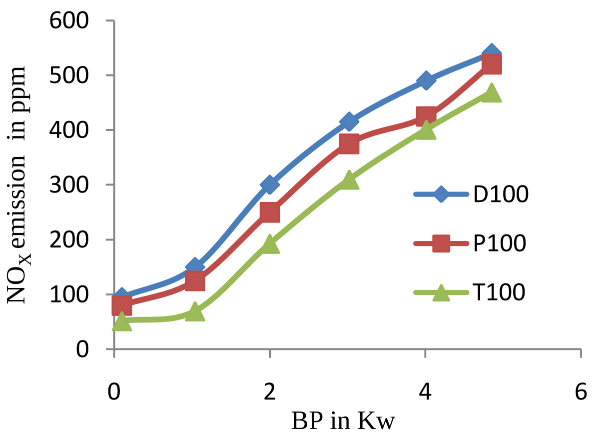

Fig 4.5 Variation of unburned hydrocarbons with brake power

Variation of NOx with brake power is as shown in the fig 4.5. It is clear from the fig that, NOx emission is directly proportional to brake power. Variation between these parameters is almost linear. Diesel fuel contributes high NOx followed by pongamia and tobacco biodiesel. Pongamia biodiesel and tobacco biodiesel gives NOx emission of 520 ppm 469 ppm respectively against diesel of 540 ppm.

5. CONCLUSION

Experimental investigations are carried out on a single cylinder DI diesel engine to examine the suitability of tobacco biodiesel as an alternative fuel. At the beginning effect of dilution with diesel and heating of blends on viscosity are studied. Then the performance and emission characteristics of blends are evaluated and compared with diesel and optimum blend is determined. Further for confirming its validity the results are compared with pongamia biodiesel available in literature for similar work. From the above investigations, the following conclusions are drawn.

- The properties viz; density, viscosity, flash point, fire point and carbon residue of tobacco biodiesel is higher and calorific value is 0.932 times that of diesel.
- Dilution of tobacco biodiesel reduces the viscosity considerably. The blends containing 90% 80% and 70% of diesel has viscosity 4.13 cSt, 4.22 cSt, 4.28 cSt and 4.69 cSt which is very close to viscosity of diesel 4.1 cSt at 40℃ and does not require any heating prior to injection into the combustion chamber. Blends containing 0% of diesel required preheating up to 80℃.
- Performance and emission characteristics of 90% (B10) and 80% (B20)are better than the other blends followed by 70% blend. The maximum efficiency of 90%and 80% blend is well comparable with diesel. However unburned HC emissions are increased up to 4.1kW load by 10%, 18.5%, 37.14% and 45% for 90%, 80%, 70% and 0% blends but HC is reduced by 16%, 18% and 24% for the blends B10, B20 and B30 respectively compared with diesel at full load condition. CO emission, CO_2 emissions reduced 1.9%, 7.7%, 9.7% and 12.1% for the blends B10, B20and B30 respectively when compared with diesel. 3.7%, 7%, 10.9% and 13.14% decrease in the NOx emission for the blends B10, B20 and B30 respectively when compared with diesel.
- Decrease in the brake thermal efficiency of tobacco biodiesel blends B10, B20, B30 and B100 are 24.13%, 26.50%, 29.06% and 31.29% respectively when compared with the diesel.
- Brake specific fuel consumption higher than diesel and BSFC for the blends B10, B20, B30 and B100 is respectively 1.3 times, 1.39 times, 2.21times, and 2.86 times the consumption of diesel
- Performance of tobacco biodiesel is validated as results are in well comparison with the results of pongamia biodiesel.
- Hence from the above conclusion it may be stated that, blends up to B100 can be substituted as fuel for diesel engine without any modification.

- Form the study of comparison of tobacco and pongamia biodiesels, it is concluded that pongamia biodiesel has high brake thermal efficiency of 35.5%, diesel has brake thermal efficiency of 25.2%, where as tobacco biodiesel has BTE of 18.51%. Pongamia biodiesel has 10.3% higher BTE than diesel and 16.99% higher BTE than tobacco biodiesel at full load condition.
- BSFC of diesel, pongamia and tobacco biodiesel is recorded as 0.44 kg/kW-h, 0.429 kg/kW-h and 1.23 kg/kW-h respectively. Tobacco biodiesel requires 65.12% higher than diesel and 2.5% higher than pongamia biodiesel at full load condition.
- Exhaust gas temperature of diesel, tobacco biodiesel and pongamia biodiesel is recorded as 495.73℃, 487.72℃ and 300℃ respectively. EGT of pongamia biodiesel is 65.24% and 62.47% lower than diesel and tobacco biodiesel at full load condition.
- Unburned hydrocarbon emission from diesel, tobacco biodiesel and pongamia biodiesel is respectively 60 ppm, 70 ppm and 70 ppm. HC emission from pongamia biodiesel and tobacco biodiesel is 14.25% higher than diesel at full load condition. Pongamia and tobacco biodiesels are equal in HC emission at full load conditions.
- NOx emission from diesel, tobacco biodiesel and pongamia biodiesel is 540 ppm, 469 ppm and 520 ppm respectively. NOx emission from pongamia biodiesel is 3.84% lower than diesel and 9.80% higher than tobacco biodiesel.

REFERENCES

[1] Dr. O.D. Hebbal[a,*], professor PDA college of engineering. Gulbarga K. Vijayakumar Reddy[b], K.Rajagopal[c] "Performance charectoristic of diesel engine with deccan hemp oil" fuel 85(2006)2187-2194.

[2] Jacob Powell "Engine performance and exhaust emissions of cottonseed oil biodiesel" January 8-11, 2008

[3] L. Ranganathan * Laxminarayana, S.Sampath "Experimental Investigation of a Diesel Engine Fuelled With Optimum Biodiesel Produced From Cotton Seed Oil" ISSN 1450-216X Vol.62 No.1 (2011), pp. 101-115

[4] P.N. Shrirao[1], Dr. A.N. Pawar[2] "Performance Evaluation of Single Cylinder Diesel Engine with Mullite as Thermal Barrier Coating and its Validation using Matlab" ISSN 2249-6149 Issue1, Vol. 3(November-2011)

[5] P. N. Shrirao1, A. N. Pawar2 "Evaluation of Performance and Emission characteristics of Turbocharged Diesel Engine with Mullite as Thermal Barrier Coating" IJRET Vol.3 (3), 2011, 256-262

[6] Siew Hwa Chan* "Performance and emissions characteristics of a partially insulated gasoline engine" Int. J. Therm. Sci. (2001) 40, 255–261

[7] Sagar P.Kadu [1*], R.H. Sarda [2] "Use of vegetable oils by transesterification method as c.i. engines fuels: A technical review" Journal of Engineering Research and Studies E-ISSN0976-7916

[8] K.Venkateswarlu "Effect of engine modifications on performance and emission characteristics of diesel engines with alternative fuels" IJEAS Vol.2, Issue 2(2010)69-78

[9] T. Ratna Reddy1, M. V. S. Murali Krishna2*, Ch. Kesava Reddy3 and P. V. K. Murthy4* "Performance Evaluation of aLow Heat Rejection Diesel Enginewith Mohr Oil Based Biodiesel" British Journal of Applied Science & Technology 2(2): 179-198, 2012

[10] Sanjaykumar DALVI[1*], Swati SONAWANE[2], and Raghunath POKHARKAR[2] "Preparation of Biodiesel of Undi seed with In-situ Transesterification" ISSN 1583-1078 Issue 20, January-June 2012 p. 175-182

[11] M. C. Navindgi, Maheswar Dutta, B. Sudheer Prem Kumar "Performance of a CI Engine with Different Blends of Mahua (Madhuca Longifolia) Biodiesel under Varying Operating Conditions" International Journal of Engineering and Technology Volume 2 No. 7, July, 2012

[12] N. Janardhan[1], M.V.S. Murali Krishna[2], P.Ushasri[3], and P.V.K. Murthy[4] "Performance Evaluation of a Low Heat Rejection Diesel Engine with Jatropha" ISSN: 2278-7461, www.ijeijournal.com Volume 1, Issue 2 (September 2012) PP: 23-35

[13] Baste S.V.[1], Bhonsale A.V.[2] and Chavan S.B.[3] "Emission Characteristics of Pongamia Pinnata (Karanja) Biodiesel and Its Blending up to 100% in a C.I. Engine" _ ISSN 2320-6063 Vol. 1(7), 1-5, August (2013)

[14] A.F. Sherwani 1, A. Sharma2, A.K. Yadav3 "Comparative Analysis of Performance and Emission Parameters of A C.I. Engine Fuelled With Different Blends Of Biodiesel Derived From Mahua Oil And Waste Cooking Oil" ISSN: 2319-8753 Vol. 2, Issue 9, September 2013

[15] M C Navindgi1, Dr. Maheswar Dutta2, Dr. B. Sudheer Prem Kumar3 "Comparative Experimental Investigation of Combustion, Performance and Emission in a Single Cylinder Thermal Barrier Coated Diesel Engine using Diesel and Neem Biodiesel" e-ISSN: 2278-067X, p-ISSN: 2278-800X, www.ijerd.com Volume 3, Issue 2 (August 2012), PP. 12-20

[16] 1Ch.Narasimha, 2M.Rajesh "Performance And Emissions Characteristics Of Diesel Engine Fuelled With Rice Bran Oil" (IJETT) – Volume 4 Issue 10 - Oct 2013

[17] Mohd. Yousuf Ali[1], S. N. Mehd[2], P. R. Reddy[3] "Performance and emission characteristics of a diesel engine with cottonseed oil plus diesel oil blends" International Journal of Engineering Vol. 18, No. 1, February 2005 -1

[18] Ch. Kesava Reddy,1 M. V. S. Murali Krishna,2 P. V. K. Murthy,3 and T. Ratna Reddy1 "Performance Evaluation of a Low-Grade Low-Heat-Rejection Diesel Engine with Crude Pongamiaoil" ISRN Renewable Energy Volume 2012, Article ID 489605.

[19] T. Venkateswara Rao a,*, G. Prabhakar Rao a, and K. Hema Chandra Reddy b "Experimental Investigation of Pongamia, Jatropha and Neem Methyl Esters as Biodiesel on C.I. Engine" Volume 2, Number 2, Jun. 2008 ISSN 1995-6665

[20] Naveen. P1, C.R. Rajashekhar2, C. Umashankar3& Vinayaka Rajashekhar Kiragi4 "Effect of Titanium Oxide Coating on Performance Characteristics of Bio-Diesel (Honge) Fuelled C.I.Engine" Vol.2, Issue.4, July-Aug 2012 pp-2825-2828ISSN:2249-6645

[21] 1B.Rajendra Prasath, 2P.Tamil Porai, 3Mohd.F.Shabir "An Experimental Comparison Of Combustion, Performance And Emission In A Single Cylinder Thermal Barrier Coated Diesel Engine Using Diesel And Biodiesel" Vol.10 Issue 4(Ver1.0),September 2010

[22] Hanbey hazar "Effect of biodiesel on a low heat loss diesel engine" H. Hazar / Renewable Energy 34 (2009) 1533–1537

[23] M. Mohamed Musthafa, S. P. Sivapirakasam, and M. Udayakumar "A comparative evaluation of Al2O3 coated low heat rejection diesel engine performance and emission characteristics using fuel as rice bran and pongamia methyl ester" 053105 (2010) American Institute of Physics