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Experimental Investigation on Performance of a Diesel Engine using Garcinia Indica (Kokam) and Rice Bran Oil based Biodiesels as Fuels

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Abstract: *On the face of upcoming energy crisis and increasing pollution, huge efforts have being made throughout the world to find out environment friendly as well as cost-effective fuels as an alternative to petroleum derived fuels. Fatty acid methyl esters also called as biodiesels derived from edible as well as non edible vegetable oils by transesterification process have come up as promising alternative to substitute diesel fuels due to their biodegradability and better-quality exhaust gas emissions. The scope of the present study is to investigate the performance and emission characteristics of multi-cylinder diesel engine using Garcinia Indica (Kokam) oil and Rice bran oil methyl esters as fuels. Different blends of biodiesel with petroleum based diesel were studied. The results show an appreciable reduction in emission level when compared with petroleum based diesel and also concluded that biodiesels obtained from Kokam oil and Rice bran oil could be used effectively as an alternative fuels in existing diesel engines without any engine hardware modifications.*
Keywords: *Biodiesel, Diesel Engine, Garcinia Indica, Rice bran oil.*

I. Introduction

Fossil fuels are one of the major sources of energy in the world today. Their popularity can be accounted to their easy usability, availability and cost effectiveness. The alarming increase in worldwide demand of these fuels having limited reserves is of great worry owing to their rapid depletion. A developing country like India depends mainly on imported fuels due to lack of fossil fuel reserves and it has a great impact on economy. Also the combustion of fossil fuels in internal combustion engines gives out various harmful emissions like carbon dioxide (CO_2), carbon monoxide (CO), nitrogen oxide (NO_X), unburned HCs etc which have detrimental effect on entire environment. The above reasons urge search for alternative fuels that are inexpensive, abundant and environmentally friendly which can be used in existing engines without any or with minor modifications. Country like India having vast vegetation and land availability, biodiesel have come up as a promising alternative fuel. Many feedstocks for biodiesel viz. edible as well as non edible vegetable oils such as rapeseed, soybean, palm, sunflower, coconut, linseed, etc. have been exploited for use as alternate fuel for diesel engine [1]. Implementation of biodiesel in India will lead to many advantages like green cover to wasteland, support to agriculture and rural economy and reduction in dependence on imported crude oil and reduction in air pollution [2].With the use of biodiesels it becomes essential to know the performance of the diesel engine for various proportions of blends, injection pressures and compression ratios. This requirement can be met by performing comprehensive tests for investigating performance and emissions of the diesel engine operating on the alternative fuels.

The present work investigates the suitability of Garcinia Indica (Kokam) oil and rice bran oil methyl esters (biodiesel) as alternate fuels by evaluating the effect of their use in a multi cylinder diesel engine in terms of performance and exhaust emissions.

II. Review Of Literature

A.E. Atabani et.al. [3] have laid emphasis on various aspects associated to non-edible oil feedstocks like Jatropha curcas, Calophyllum inaphyllum, Pongamia pinnata, Madhuca indica, Sterculia feotida, Rubberseed etc. for the biodiesel production. They have reviewed various facets such as non-edible oil resources, advantages of non- edible oils, problems in exploitation of non-edible oils, fatty acid composition profiles of various non-edible oils, oil extraction techniques, technologies of biodiesel production, properties and characteristic of non-edible biodiesel and finally the engine performance and emission characteristics. The authors indicated that there is a huge chance to produce biodiesel from non-edible sources in the future. Lin Lin et.al. [4] have reported successful production of biodiesel by transesterification of crude Rice bran oil (RBO). Later according to ASTM D6751-02 and DIN V51606 standards for biodiesel the properties of prepared RBO biodiesel were studied and compared which affirmed that the properties of RBO biodiesel agreed well within the parameters imposed. 30% and 100% RBO biodiesel when used in diesel engines during engine testing demonstrated that the power output was almost the same when compared with regular diesel but with fairly lower efficiency ,CO, HC and soot emissions but increased NO_X emission. Anand Kumar Pandey and M R Nandgaonkar [5] concluded that Karanja biodiesel fuel could be used as a potential alternative to diesel fuel by investigating the effects of its use on performance, emission and wear of 118kW, 06 cylinders, CIDI engine in comparison with the petroleum based diesel. They affirmed 35% lower wear of metal parts as compared to petroleum diesel by subjecting the engine to 100 hours long term endurance test with both test fuels during which the samples of lubricating oil were drawn from the engine after interval of 20 hours when engine is operated on biodiesel. They observed slight decrease in brake power but considerable decrease in CO and UHC emissions of the engine along with increase in NO_x emission when the same was fueled with biodiesel. Jasanpreet Singha et.al. [6] investigated the performance and emission characteristics of a diesel engine fuelled with Rice bran oil and its blends (5%, 10% and 15%) along with di-ethyl ether (DEE)at different load conditions. It was noticed that the brake power increased with the amount of Rice bran oil and blend due to presence of additional constituent oxygen in fuel which improves the combustion process. It was also observed that at full load condition, the RBO, 5%, 10% and 15% blends produce 6.2%, 8.7%, 11.6% and 10.6% higher brake thermal efficiency respectively than petroleum based diesel. The un-burnt hydrocarbon and carbon monoxide emissions decreased with the increase in DEE percentage in the blend. A noteworthy reduction in smoke emissions could be observed with RBO-DEE blend. Thus from the results of the experimental investigation it was concluded by the authors that the RBO-DEE blend could be used efficiently in diesel engine without much change in the engine hardware. G. Venkata Subbaiah et.al. [7] concluded that the Rice bran oil biodiesel could be used as an additive in diesel-ethanol blends by investigating the performance and exhaust emission characteristics of a single cylinder diesel engine when operating on petroleum diesel fuel, Rice bran oil biodiesel, a blend of diesel and Rice bran oil biodiesel and three blends of diesel-biodiesel-ethanol over the complete range of load on the engine. The experimental results demonstrated that the highest brake thermal efficiency of 28.2 % was observed with 15% ethanol in diesel-biodiesel-ethanol blends (B10E15). The carbon monoxide and smoke emissions lessened while the HCs and CO_2 emissions increased significantly with higher percentage of ethanol in diesel-biodiesel-ethanol blends. Lalit Prasad et.al. [8] developed an oil expeller having efficiency of more than 85% of total oil content. They examined the physio-chemical properties of jatropha oil methyl ester (JOME) and karanja oil methyl ester (JOME) as per Bureau of Indian Standards test methods (IS-1448).Later an experimental investigation of JOME (B15) and KOME (B15) in comparison with diesel was made on a Kirloskar make single cylinder, 4-stroke, water cooled diesel engine. They found the value of brake thermal efficiency of engine using JOME and KOME to be marginally lower as compared to base diesel. HC & CO emissions and smoke for both the test blends were lower while O_2 and NO_x emissions were found to be increased for both the test blends were lower compared to the base diesel.

From the above literature review it can be observed that Kokam oil biodiesel is unexplored as fuel for use in diesel engine and only few of the blends of rice bran biodiesel have been investigated.

III. Properties Of Kokam Oil And Rice Bran Oil Based Biodiesels

Base catalyzed transesterification process was selected for the production of Garcinia Indica (Kokam) oil and rice bran oil methyl esters (biodiesel) since it has been established as the most favorable process [9]. Before applying for a use as a commercial fuel, the prepared biodiesel must be analyzed using sophisticated analytical equipment to ensure it meets ASTM specifications. The properties of the tested biodiesel are given in TABLE 1 and TABLE 2 as follows. The examination of values of various important properties of Kokam oil biodiesel and Rice bran oil biodiesels reveal that their properties conform to ASTM 6751 standards and thus could be used in diesel engine effectively without making any changes in its hardware.

Table 1. Properties of Kokam oil biodiesel (KB100) and Rice-Bran oil biodiesel (RB100)

Sr. No.	Test Description	Ref. Std. ASTM 6751	Reference		Biodiesels	
			Unit	Limit	KB100	RB100
1	Density	D1448-1972	kg/m^3	850-900	862	880
2	Acid Number	D664	mg KOH/gm	-	0.3	0.031
3	Calorific Value	D6751	MJ/kg	34-45	39.12	35.60
4	Viscosity	D445	mm^2/s	3-6	5.80	5.56
5	Cloud Point	D57	^{0}C	-	12	7
6	Pour point	D57	^{0}C	-	9.5	NA
7	Flash point	D93	^{0}C	130 min	135	170

Table 2. Properties of different tested fuels

Tested Fuels	Calorific Value (MJ/kg)	Density (kg/m^3)
B0	42.50	830
RB20	41.50	841
RB100	35.60	880
KB20	41.52	836
KB100	39.12	862

IV. Experimental Study

An experimental test rig viz. three cylinder naturally aspirated diesel engine with 110 mm bore and 116 mm stroke length available at Vishwakarma Institute of Technology, Pune, Maharashtra, India is utilized for this study. The experimental test rig is suitably developed to conduct various test runs on the diesel engine under different working conditions to evaluate the its thermal performance and emission constituents when operated using biodiesel in comparison with that of a conventional diesel. Fig. 1 shows the schematic representation of diesel engine testing facility available for studying the engine performance and emission characteristics. The engine has compression ratio of 18:1 and was loaded by hydraulic (water brake) dynamometer. The value of exhaust gas temperature is measured using K type thermocouple during the experiments. Engine speed was measured with an optical speed sensor. The values of engine speed and exhaust gas temperature could be observed at the display panel.A special fuel system was designed so as to run the engine on diesel fuel as well as the biodiesel and its blends such that the fuel consumption could be measured with the help of digital weighing machines. The exhaust gas emission was tested with AVL 444 five gas analyzer while smoke from engine was measured with AVL 437 smoke-meter.

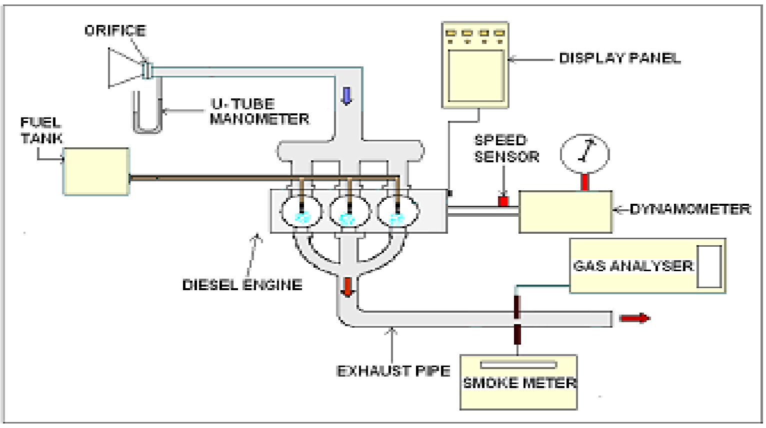

Fig. 1 Schematic of diesel engine test rig

V. Results And Discussions

The performance and emission characteristics of diesel engines operating on diesel oil blended with 20% and 100% biodiesel on volume basis is analyzed and compared with that of engine operating on pure diesel (B0) at various brake power of 0, 5.4, 10.79, 16.19 and 21.58kW at constant speed of 1500 rpm.

1. Brake Thermal Efficiency (BTE):

The Fig. 2 represents the comparison of variation of brake thermal efficiency (%) with brake power (kW) for Kokam oil biodiesel, Rice bran oil biodiesel and their blends. It can be observed that the brake thermal efficiency decreases with the increase in proportion of biodiesel in the blends. This trend has resulted due to the fact that with the increase in proportion of biodiesel in the blends the calorific value of the fuel decreases resulting into more fuel consumption and also the higher viscosity of blends results into poorer atomization and thus combustion. The maximum brake thermal efficiency is observed for diesel while least brake thermal efficiency is observed for RB100.

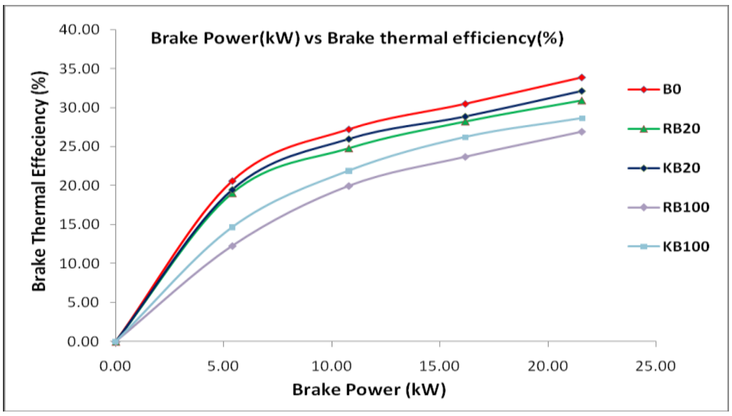

Fig. 2 Comparison of variation of brake thermal efficiency with brake power

2. Air fuel Ratio (AFR):

The Fig. 3 represents the comparison of variation of Air fuel ratio with brake power (kW) for Kokam oil biodiesel, Rice bran oil biodiesel and their blends. The trend shows that the AFR decreases with increase in concentration of biodiesel in blends with diesel fuel. This has resulted due to the fact that with the increase in load, the engine operating on biodiesel consumes more fuel for producing same level of power output in comparison with diesel but the air consumption remains same irrespective of the load because of the same maintained speed of 1500rpm.

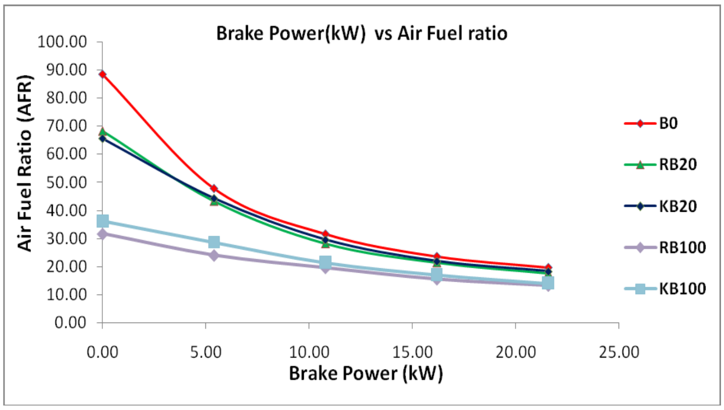

Fig. 3 Comparison of variation of air-fuel ratio with brake power

3. Smoke:

The Fig. 4 shows the variations of the smoke of exhaust gases with brake power for different blends. From the trend it can be observed that the smoke emitted increase with increase in the brake power for both the diesel and the biodiesel blends. This is attributed to the fact that as load on the engine increases richer mixture is utilized leading to more soot formation and thus more smoke. It is found that the smoke opacity for most of the biodiesel blends is less as compared to the same for diesel engine which is attributed to the fact that biodiesel has more oxygen content as compared to the mineral diesel which leads to the added complete burning of soot.

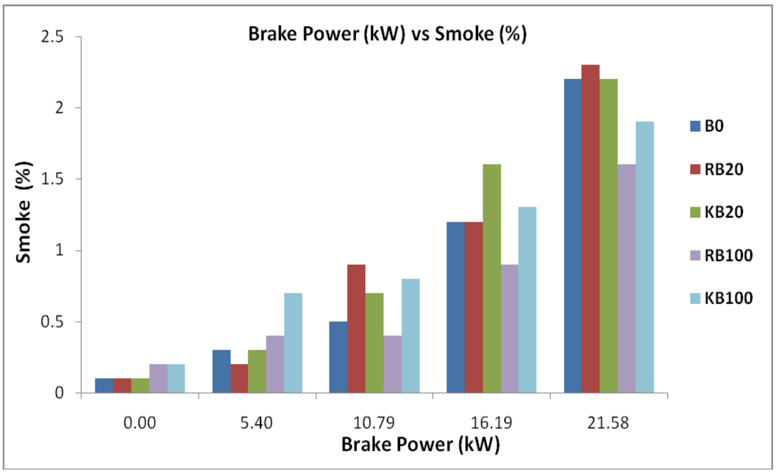

Fig. 4 Comparison of variation of Smoke (%) with brake power

4. Carbon Monoxide (CO):

The Fig. 5 shows the variations of the emission of CO (%) with brake power for different blends. It can be observed that CO emission for diesel decreases with the increase in load. The lower CO emission observed in case of biodiesel as compared to that of diesel is due to the presence of constituent oxygen in biodiesel which helps in complete oxidation of fuel.

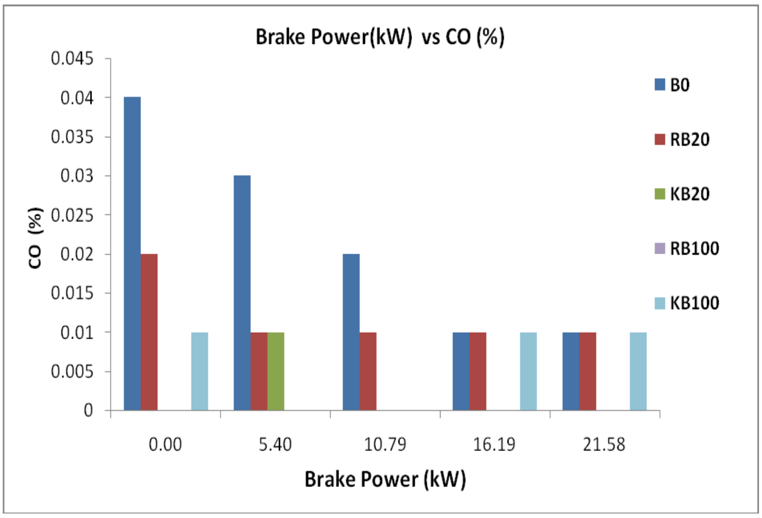

Fig. 5 Comparison of variation of CO (%) with brake power

5. Hydro carbons (HC):

The Fig. 6 shows the variations of the emission of un-burnt hydrocarbon (ppm) with brake power for different blends. Hydrocarbons in exhaust are due to incomplete combustion of carbon compounds in the blends. It can be observed that the values of HC emission are comparatively very low to that of diesel fuel. The possible reasons for decrease in un-burnt HC may be higher cetane number, presence of constituent oxygen molecules and increased gas temperature. The higher cetane number of biodiesel results decrease in HC emission due to shorter ignition delay. Increased temperature of burnt gases in biodiesel fuel helps in preventing condensation of higher hydrocarbon thus reducing un-burnt HC emissions while the presence of constituent oxygen in biodiesel which helps in complete combustion of fuel.

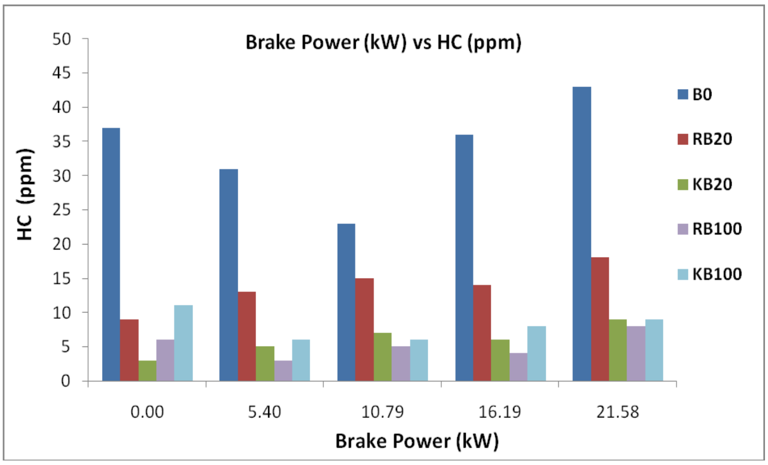

Fig. 6 Comparison of variation of HC (ppm) with brake power

6. Carbon Dioxides (CO_2):

The Fig. 7 shows the variations of carbon dioxide emission with brake power for different blends. This graph shows that the carbon dioxide emission increases with increase in the brake power for all fuels tested. It can be also observed that with the increase in the concentration of the biodiesel in the blend the CO_2 emission increases. The increase in CO_2 emission emissions with increase in blend proportion is due to the fact that at a particular load the air fuel ratio in case of biodiesel decreases resulting into richer fuel being inducted. This leads to presence of more carbon in the combustion chamber which gets oxidized to CO_2 by the oxygen present in the aspirated air as well as in the biodiesel.

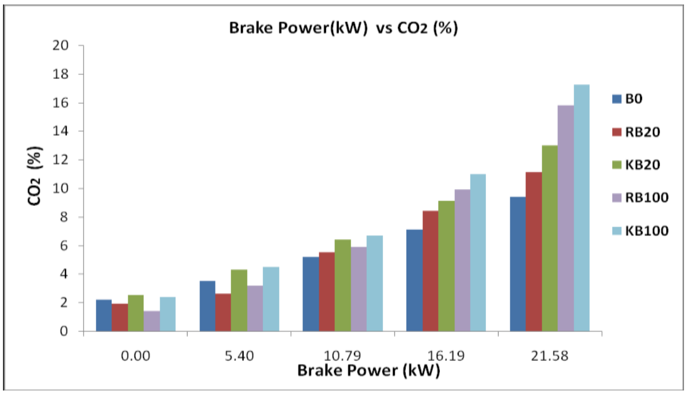

Fig. 7 Comparison of variation of CO_2 (%) with brake power

7. Oxygen (O_2):

The Fig. 8 shows the variations of oxygen content in exhaust with brake power for different blends. This graph shows that the oxygen content in exhaust decreases with increase in the brake power for all fuels tested. This is due to the more utilization of oxygen by the additional fuel injected with load. It can be also observed that the discharge of oxygen in exhaust is higher for the biodiesel blends as compared to diesel, which is due to the inherent oxygen content in biodiesel and also due to their higher viscosity leading to poor atomization resulting poor combustion and thus less utilization of oxygen.

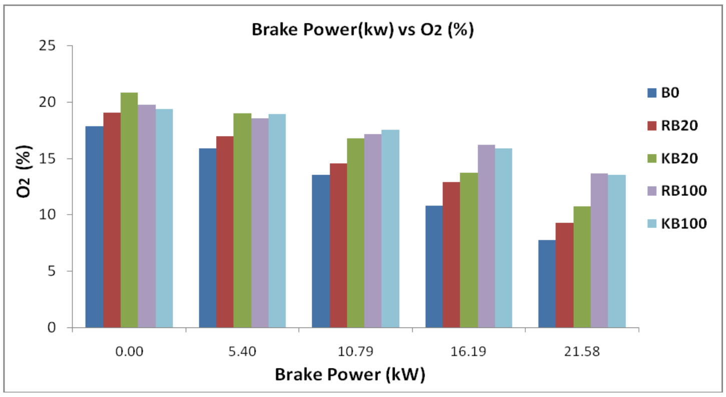

Fig. 8 Comparison of variation of O_2 (%) with brake power

8. Nitric Oxide (NO):

The Fig. 9 shows the variations of NO emission with brake power for different blends. The graph shows increase in emission of NO as there is increase in brake power. The most significant factor that causes NOx formation is high combustion temperature. The trend is attributed to the fact that as load on the engine increases there in increase in combustion temperature leading to higher NO emission. It is also observed that NO emission is higher for biodiesel and its bends. The reason for this is due to the higher oxygen content in biodiesels and their blends. During combustion additional oxygen available from biodiesel along with oxygen of aspirated air readily react with nitrogen from air at higher cylinder temperatures to form compounds like NO_2 and NO which constitutes NOx.

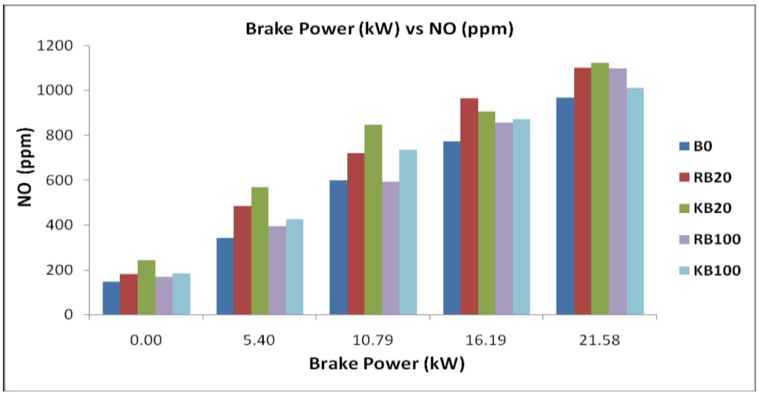

Fig. 9 Comparison of variation of NO (ppm) with brake power

VI. Conclusions

In present investigation, the inspection of values of various important properties of Kokam oil biodiesel and Rice bran oil biodiesel reveal that their properties conform to ASTM 6751standards.The results of tests performed on multi-cylinder diesel engine operating on diesel fuel and blends of Kokam oil and Rice bran oil biodiesel were found to be very comparable for RB20 and KB20 from the aspect of thermal performance. The maximum thermal efficiency obtained using diesel as fuel was 33.85%. By adding 20% of Kokam oil methyl ester and Rice bran oil methyl ester by volume in petroleum based diesel, it was noticed that the thermal efficiency reduced by 4 to 5% and 7 to 8% respectively as load varied. From emissions point of view, as compared to all other blends the NO_x emission was comparable to that of engine operating on diesel when the same was operated on RB20 and KB20. Also as compared to all other blends smoke emission was least in case of RB100 at almost all the loads. At maximum load use of RB100 in engine as fuel resulted in decrease in smoke emission by 27.3% while use of KB100 resulted in decrease in smoke emission by 13.6%.From the above results it could be concluded that Kokam oil biodiesel and Rice bran oil biodiesel could be used as an alternative fuel for diesel engine without any making any modification in diesel engine.

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