Experimental Investigation on Performance and Emission Characteristics of Diesel Engine using Diesohol-Niger seed oil Biodiesel Blends

[1] Bharath Kumar S, [2] Shankar Nag G L, [3] Srikanth H V, [4] Sharnappa Godiganur

[1]Research Scholar, Sri Siddhartha institute of technology, Tumkur, India.
[2]Asst.prof Sri Siddhartha institute of technology, Tumkur, India.
[3]Asst.prof, Department of Aeronautical Engineering, NMIT, Bangalore, India.
[4]Professor & Head, Department of Mechanical Engineering, REVA ITM, India.

***Abstract*- The depletion of world petroleum reserves and the increased environmental concern has invoked the search of alternative fuel which is to be environment friendly. Transesterified vegetable and animal fat are identified and proved as promising alternative fuel for CI engines. In the same way ethanol a low cost oxygenated compound with high oxygen content has been used as a fuel for diesel engines since 19th century. Investigations has proved that biodiesel and diesel blends can be effectively used as fuel in CI engines without any modifications in engine hardware . In these days the diesohol and biodiesel blends is becoming popular because of good burning and less harmful emission characteristics. In the present work, the experimental investigations of diesel-biodiesel-ethanol blends as potential C I engine fuel was evaluated in terms of performance and emission characteristics. The Ethanol was added in the proportion of 7.5% by volume to diesel-biodiesel blends. Experimental results found that when the engine operates with diesel-biodiesel with Ethanol as an additive there was an increase in brake thermal efficiency with blends (D72.5, B20, E7.5); (D52.5, B40,E7.5) and (D32.5,B60,E7.5) of diesel-biodiesel-ethanol blends as compared to that of the conventional diesel fuel over the entire range of the load. Carbon Monoxide (CO) emission reduced significantly while Nitrogen Oxides (NO_x) emissions increased marginally as compared to the convection fossil diesel fuel.**

Keywords: Transesterification, Vegetable oil, Animal fat, Diesohol, Ethanol, Blends

I. INTRODUCTION

The current energy scenario has stimulated an active research interest in non-petroleum, renewable, and non-polluting fuels due to the factor that the world reserves of primary energy and raw materials are obviously, limited. The excessive usage of fossil fuels may leads to depletion of fossil fuels and environmental degradation like global warming. So, the present researchers have been focused on the Biofuels as environment friendly energy source to reduce dependence on fossil fuels and to reduce environmental degradation.

From the past few decades, a vigorous research has been carried out in field of Bio-fuel to reduce the too much dependence on the fossil fuels. Amongst the proposed alternative fuels, biodiesel and Diesohol have received much attention in recent years for diesel engines due to their advantage as the renewable energy resources.

However, ethanol and diesel fuel are inherently immiscible because of their difference in chemical structures and characteristics, and therefore need an effective emulsification technique for being an Emulsion. These two liquid fuels can be efficiently emulsified into a heterogeneous mixture of one micro-particle liquid phase dispersed into another liquid phase by mechanical blending in cooperation with suitable emulsifiers. Biodiesel which acts as emulsifiers can be produced from vegetable oils via transesterification process. Nevertheless, biodiesel has been employed not only as an alternative to the fossil derived fuels, but also as an additive for diesohol blending of ethanol with conventional diesel.

Since, Ethanol is similar to methanol, but it is considerably cleaner, less toxic and less corrosive and also It gives greater engine efficiency [1]. Ethanol is made from renewable resources like biomass from locally grown crops and even waste products such as waste paper, grass and tree trimmings etc. Alcohol is an alternative transportation fuel since it has properties, which would allow its use in existing engines with minor hardware modifications [2] Alcohol burns cleaner than regular gasoline and produce lesser carbon monoxide, HC and oxides of Nitrogen [3].

Kraipat Cheenkachorn, et al [4] has suggested that, suitable emulsifier for ethanol and diesel fuel is to contain both lipophilic part and hydrophilic part, in order to obtain an emulsion of diesel and alcohol. Such chemical structures can be found in Biodiesel.

The large Cetane number of the biodiesel offsets the reduction of Cetane number from addition of ethanol to diesel, thus improving the engine ignition. The addition of biodiesel increases the oxygen level in the blend. Also biodiesel have lubricating properties that benefit the engine, and are obtained from renewable energy sources such as vegetable oils and animal fats. Similar to ethanol, biodiesel have a great potential for reducing emissions, especially particulate materials.

E. A. Ajav et al [5] studied the fuel properties of local ethanol blended with diesel with different ethanol percent by volume and the fuel properties were experimentally determined to establish their suitability for use in compression ignition engines. And some of the properties like relative density, viscosity, cloud and pour point, flash point and calorific value were determined. They found that, the blends with 5, 10, 15 and 20 percent ethanol content were found to have acceptable fuel properties for use as supplementary fuel in diesel engines.

Antoni Jankowski et al [6] investigated the Biofuels application in viewpoint of exhaust emissions are presented in this paper. The Biofuels can be applied as blends or sole fuels. Ethanol can be used for fueling spark ignition engines and compression ignition engines but vegetable oil esters can be used in compression ignition engines only. The paper describes an increase of CO_2 content in atmospheric air and advantages and concerns from using of biofuels.

G. Venkata Subbaiah et al [7] investigated the Effect of Biodiesel and Bioethanol Blended Diesel Fuel on the Performance and Emission Characteristics of a Direct Injection Diesel Engine using The rice bran oil as biodiesel and studied the performance and emission characteristics of a direct injection (DI) diesel engine when fuelled with conventional diesel fuel, pure biodiesel, a blend of diesel and biodiesel and three blends of dieselbiodiesel-ethanol were studied over the entire range of load on the engine. The experimental results showed that the highest brake thermal efficiency was observed with 30% ethanol in diesel-biodiesel-ethanol blends. The exhaust gas temperature and noise reduced with the increase of ethanol percentage in diesel-biodiesel ethanol blends. The Carbon monoxide, smoke, exhaust gas temperature and sound reduced with the increase of ethanol percentage in diesel-biodiesel-ethanol blends.

Gerdes K Ret al [8] carried another work to study the phase bhevaiour and miscisibility of ethanol intyo dieseal, which concluded that aromatic contents and intermediate distillate temperatures had a significant impact on miscibility limits of blending of fuels.

Mayur D. Bawankure et al [9] has carried out an comprehensive study on the ethanol as an alternative fuel with Palm Stearin Methyl-Ester oil as additive**.** In this study, the diesel engine was tested using diesel blended with ethanol at certain mixing ratio of 90:10, 80:20, 70:30 and 60:40 of diesel to ethanol respectively. The results shows that the brake thermal efficiency of the engine increases for B40 blend for medium load capacity. It also shows that the exhaust gas temperature for B10 ratio is near the diesel fuel. The exhaust temperature for diesel fuel was higher compared to any mixing of the blended fuel. Brake specific fuel consumption of all ethanol Methyl-ester, diesel blends are lower compared with diesel at full load.

Srikanth et al [10] investigated the effect of addition of fish oil biodiesel for diesel and ethanol blends on a single cylinder four stroke diesel engine, the result shows that the maximum brake thermal efficiency of 13.32% higher than diesel fuel and 10.11% higher than fish oil biodiesel was observed with the blend DE15B10. And also the CO emissions reduced by 50% than the conventional diesel with the blend of DE15B10 at full load of engine.

The above studies reveal that the diesel-ethanol-biodiesel blends can be used as alternative fuels for diesel engines. In the present investigation the performance and emission characteristics of a diesel engine were studied with 20%, 40%, 60%, 80% and 100% volume of Niger seed oil biodiesel and a constant volume of alcohol (say 7.5%) is added as an additive in the diesel-biodiesel blends and compared with that of the diesel fuel.

Niger seed (Guizotia abyssinica) is native to Africa, from Ethiopia to Malawi, and was probably domesticated and cultivated in Ethiopia and India in rotation with cereals and pulses. The crop is widely adapted to all types of soil and is commonly grown in India on poor and acidic soils or hilly slopes that are low in fertility. It requires moderate rain fall and grows in temperature and tropical areas. Yield levels are reported to be 200-300 kg/ha with good management. The crop can be cultivated in rotation with wheat or maize [11]. The seed contains about 40% oil with fatty acid composition of 75-80% linolenic acid, 7-8% palmitic and stearic acids, and 5-8% oleic acid. The Indian types contain 25% oleic and 55% linoleic acids [12].

II. MATERIAL AND METHODS

After extracting the oil from Niger seed, oil is filtered through filter paper of 10 microns to remove the impurities like uncrushed seed cake and other particles from Niger. These oils were dried to remove moisture about 1 hour at 100˚C and then cooled to room temperature and stored in a container. The vegetable oils are composed of triglycerides and free fatty acids; FFA plays a vital role during the production of biodiesel. The FFA more than 2% decreases the yield of the final product. Therefore the Total acid number (TAN) of oils was measured, which essential to determine Free Fatty Acids (FFA) content generally the percentage is half the acid number. Acid number is defined as the number of milligrams of KOH required to neutralize 1gm of oil. This is determined by the standard titrometry. By the titration we came to know that acid number of Niger seed oil is 12.6 mg KOH/g oil, and having FFA around 6.3%. Since the Niger seed oil contains more than 2% of FFA, the two stage transesterification process is adopted ie., acid catalyzed followed by base catalyzed transesterification.

TABLE 1
PROPERTIES OF NIGER SEED METHYL ESTER AND BIO-ETHANOL

Properties	***Niger seed methyl ester***	***Bio-Ethanol***
Description	Yellow colored viscous liquid.	Color less liquid
Density at 15°C (g/cm^3)	0.910	0.78
Viscosity , mm^2/sec. at 40^0 c	3.752	1.35
Calorific value KJ/kg	40,197	27000
Flash point ^{0}c.	142	13.5
Fire point^{0}c.	152	22

The experimental setup is shown in figure 1 with accessories and measuring instruments.

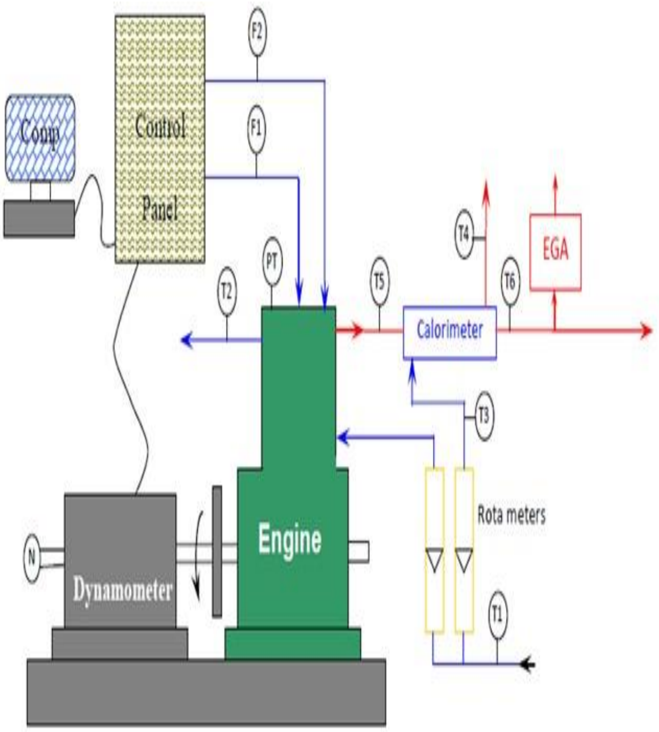

Fig.1 Diesel Engine Test Rig

Where,T1,T3=Inlet Water Temperature,T2=Outlet Engine Jacket Water Temperature,T4=Outlet Calorimeter Water Temperature,T5=Exhaust Gas Temperature before Calorimeter,T6=Exhaust Gas Temperature after Calorimeter,F1=Fuel Flow DP (Differential Pressure) unit,F2=Air Intake DP unit,PT=Pressure Transducer, Wt = Load, N=RPM Decoder,EGA = Exhaust Gas Analyzer.

Kirloskar make single cylinder four stroke, naturally aspirated, direct injection, water-cooled diesel engine test rig of 3.72 kW (5BHP) with 1500 RPM, is directly coupled to an eddy current dynamometer. The engine and the dynamometer are interfaced to a control panel, which is connected to computer for automatic recording the experimental observations such as fuel flow rate, temperatures, air flow rate, loads, water flow rate, etc., are measured. An exhaust gas analyzer is attached to record the exhaust emissions. A detailed engine specification is given in Table 3.

TABLE 3
THE ENGINE SPECIFICATION

Sl no.	Parameters	Specifications
1.	Type	TV 1 (kirloskar made)
2.	Nozzle opening pressure	200 to 225 bar
3.	Governor type	Mechanical centrifugal type
4.	Number of cylinder	Single cylinder
5.	Number of strokes	Four stroke
6.	fuel	Diesel
7.	Compression ratio	16.5:1
8.	Cylinder diameter (Bore)	80mm
9.	Stroke length	110mm
10.	rated power @ 1500 rpm	37.5 k W
Eddy Current Dynamometer		
11	Type	Foot mounted, continuous rating
12.	Alternator rating	3KVA
13.	Speed	2800-3000RPM
14.	Voltage	220 AC

III. EXPERIMENTAL WORK

The engine was first operated on diesel fuel with no load for few minutes at rated speed of 1500 rpm until the cooling water and lubricating oil temperatures reaches to 85$_0$ C. The same temperatures were maintained throughout the experiment with all the fuel modes. The required readings pertaining to diesel fuel were taken down for different load conditions. The diesel fuel was replaced with the niger seed oil biodiesel (B100). After the niger seed oil biodiesel, four diesel- biodiesel-ethanol blends were prepared consisting of 72.5 diesel, 20% biodiesel and 7.5% ethanol (*D72.5,B20,E7.5*), 52.5% diesel, 40% biodiesel and 7.5% ethanol (*D52.5,B40,E7.5*), 32.5% diesel, 60% biodiesel and 7.5% ethanol (*D32.5,B60,E7.5*) and 12.5% of diesel, 80% of biodiesel and 7.5% of ethanol (*D12.5,B80,E7.5*).

The performance of the engine is evaluated in terms of Brake thermal efficiency, Brake specific energy consumption, Exhaust gas temperature and emission of the engine is analyzed by AVL smoke analyzer five gas analyzer was used to measure the concentration of gaseous emissions (HC, CO, CO_2, O_2 and NO_x).The results were compared with diesel fuel at rated speed of 1500 rpm.

IV. RESULTS AND DISCUSSIONS

A. *Performance Characteristics*

The engine performance and emission characteristics were discussed and different graphs showing the performance and emission characteristics were drawn and those graphs were analyzed in detailed.

Brake Thermal Efficiency

The variation of brake thermal efficiency with load for diesel fuel, biodiesel and diesel-biodiesel-ethanol blends *(D72.5,B20,E7.5); (D52.5,B40,E7.5); (D32.5,B60,E7.5) and (D12.5,B80,E7.5)* are obtained. The brake thermal efficiency increased with load for all fuel modes. The brake thermal efficiency of diesel-biodiesel-ethanol blends is as shown in figure 2 shown in the graph.

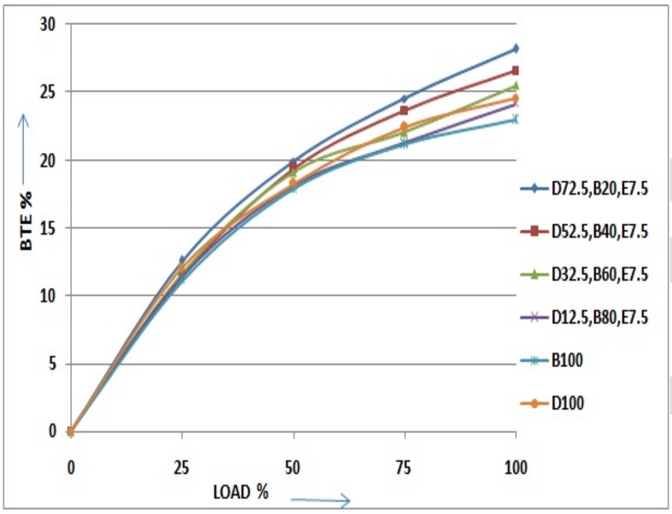

Fig.2 Variation of BTE with Load

The brake thermal efficiency of diesel-biodiesel-ethanol blends is as shown in the graph. The brake thermal efficiency increased with load for all fuel modes. The brake thermal efficiencies of (D72.5,B20,E7.5); (D52.5,B40,E7.5) and (D32.5,B60,E7.5) blends of diesel-biodiesel-ethanol were higher than that of the conventional diesel fuel over the entire range of the load. The blend (D12.5,B80, E7.5) was having lower brake thermal efficiency than that of the conventional diesel fuel over the entire range of the load. The reason for higher brake thermal efficiency is due to the extended ignition delay and the leaner combustion of biodiesel, resulting in a larger amount of fuel burned in the premixed mode of the ethanol blends. The maximum brake thermal efficiency was observed with the blend D72.5, B20, E7.5 at all the loading conditions of the diesel engine and it was 13.04% and 18.43% higher than that of diesel fuel and B100 respectively at full load of the engine. It may be due to the reduction in the density and viscosity of the fuel by the addition of ethanol.

Brake Specific Fuel Consumption

The variation of brake specific fuel consumption (BSFC) with load for different fuels is as shown in Fig.3

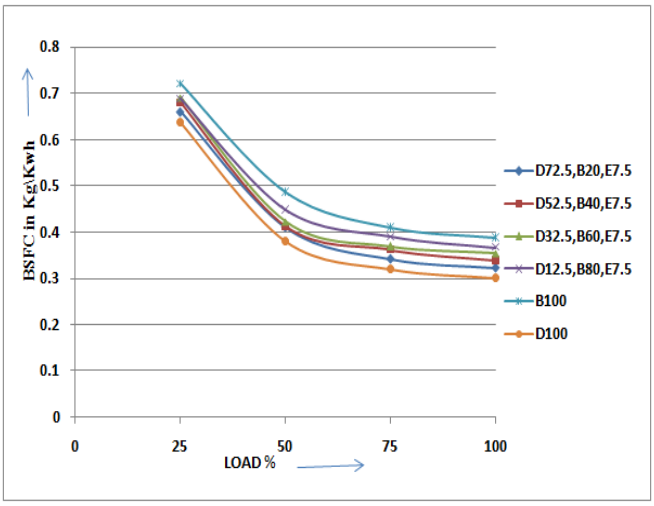

Fig 3: variation of BSFC with load

.The BSFC was reduced with diesel-biodiesel-ethanol blends at all loading conditions of the engine for all the fuel modes. The BSFC of B100 is 22.68% higher than that of the diesel fuel at maximum load of the engine. The BSFC increased by 6.86%, 11.50%, 15.25 % and 18.18 respectively with the blends D72.5, B20, E7.5; D52.5, B40, E7.5; D32.5, B60, E7.5 and D12.5,B80,E7.5 compared with diesel. It is due to the lower heating values of biodiesel and ethanol compared with diesel fuel. The oxygenated ethanol blending leads to leaner combustion resulting in higher BSFC.

Brake Specific Energy Consumption

BSFC decreased sharply with increase in percentage of load for all fuels. The variation is observed from fig 4.

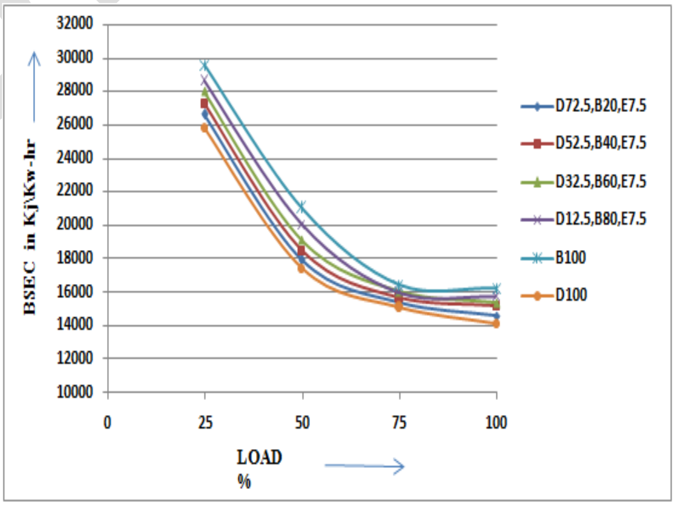

Fig.4 Variation of BSEC with Load

The main reason for this could be that the percent increase in fuel required to operate the engine is less than the percent increase in brake power, because relatively less portion of the heat is lost at higher loads.

The BSEC for all blends was higher than that of diesel. This trend was observed due to lower calorific value, with increase in biodiesel percentage in blends. The BSEC of (D72.5, B20, E7.5); (D52.5, B40, E7.5); (D32.5, B60, E7.5) and (D12.5,B80, E7.5) are 3.55%, 7.08% , 8.323% and 13.30% more respectively, when compared with diesel at maximum load.

Exhaust Gas Temperature

The variation of exhaust gas temperature with load for diesel fuel, biodiesel and diesel-biodiesel-ethanol blends (D72.5, B20, E7.5); (D52.5, B40, E7.5); (D32.5, B60, E7.5) and (D12.5,B80,E7.5) is as shown in the Fig. 5.

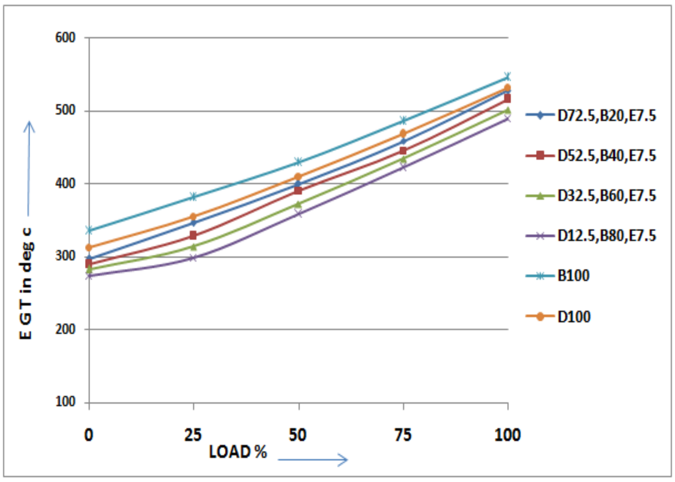

Fig.5 Variation of EGT with Load

The exhaust gas temperature increased with the load for all the fuel blends. The exhaust gas temperature of the blend B100 was 2.74% higher than that of diesel fuel. The addition of ethanol in the diesel-biodiesel-ethanol blends reduced the exhaust gas temperature. The reduction was 3.40%, 5.80%, 8.96% and 11.63% in blends (D72.5,B20,E7.5); (D52.5,B40,E7.5); (D32.5,B60, E7.5) and (D12.5,B80,E7.5) respectively as compared with B100. The decrease in exhaust temperatures with addition of ethanol is due to the high evaporative heat and low heating values of ethanol, which takes off the heat from combustion space.

B. Emission Characteristics Carbon-dioxide emission

The variation of carbon dioxide emission with load for diesel fuel, biodiesel and diesel-biodiesel-ethanol blends (D72.5, B20, E7.5); (D52.5, B40, E7.5); (D32.5, B60, E7.5) and (D12.5,B80,E7.5) is as shown in the Fig 6.

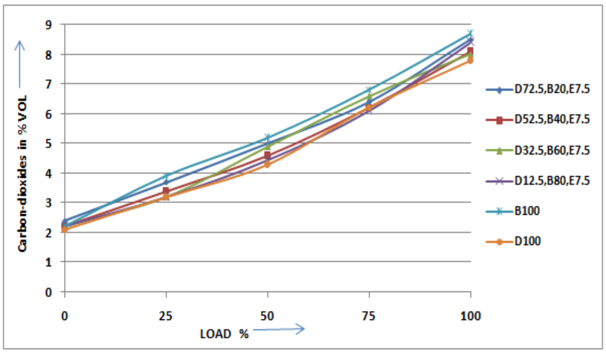

Fig.6 Variation of CO_2 with Load

The CO_2 emissions increased with load for all the fuel modes. The CO_2 emissions of B100 were slightly higher than those of diesel fuel at maximum load and it was increased by 2.29% than that of fossil diesel.CO_2 emission was increased by 8.23% , 3.70%, 2.5% and 7.142% for (D72.5,B20,E7.5); (D52.5,B40,E7.5); (D32.5,B60,E7.5) and (D12.5,B80,E7.5) respectively of diesel-biodiesel-ethanol blends compared with diesel at maximum load condition.

Hydro-Carbon emissions

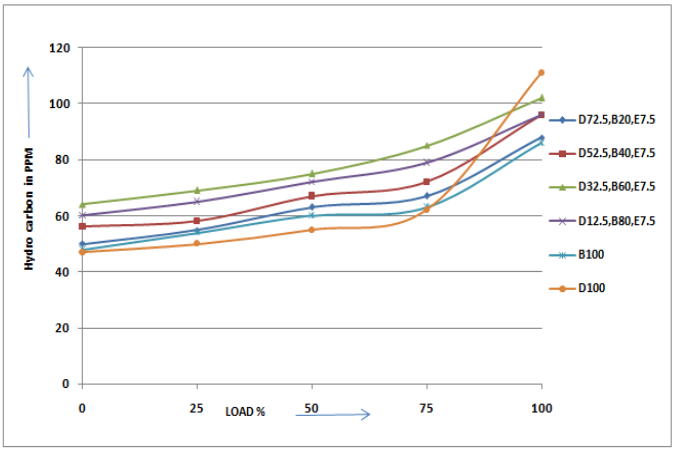

Fig.7 Variation of H C with Load

The variation of hydro-carbon emissions with load for diesel, biodiesel and diesel-biodiesel-ethanol blends is as shown in figure 7. The HC emissions of the pure biodiesel and diesel-biodiesel-ethanol blends were higher at low and medium loads and significantly decreased at higher loads than those of diesel fuel. It is due to the better combustion achieved at a medium speed and with a medium sized load. The HC emissions increased with addition of ethanol in the diesel-biodiesel blends. Higher HC emission is due to unburned ethanol emitted in the exhaust due to the larger ethanol dispersion region in the combustion chamber. The HC emissions were 20.7%, 13.51%, 8.10% and13.5% lesser than those of diesel fuel at full load of the engine. Also 22.52% lesser HC emissions are observed than those of fossil diesel when compared with B100 at full loading conditions.

Oxides of nitrogen emission

The variation of oxide of nitrogen with load for diesel fuel blends (D72.5,B20,E7.5);(D52.5,B40,E7.5);(D32.5,B60,E7.5) and (D12.5,B80,E7.5) is as shown in the Fig.8.

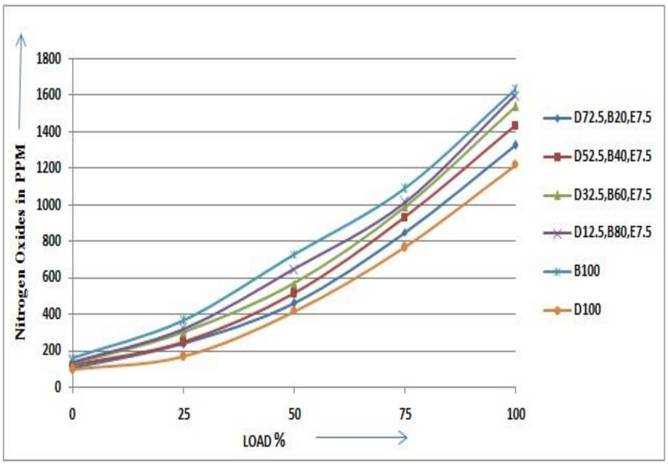

Fig 8 Variation of NO_x with load

The NO_x emissions of biodiesel, and diesel-biodiesel-ethanol blends goes on increasing and it is more at medium and high loads than those of diesel fuel..

It is due to the higher oxygen content and combustion temperature of the biodiesel and the ethanol at medium and high loads. The NO_X emissions increased with the Addition of ethanol in blends. The NO_x emissions of (D72.5,B20,E7.5);(D52.5,B40,E7.5);(D32.5,B60,E7.5) and (D12.5,B80,E7.5) were 18.79%, 12.29%, 5.752% and 2.019% lesser than B100 respectively at full loading conditions.

Carbon-monoxide emission

The variation of CO with load for diesel fuel blends (D72.5,B20,E7.5);(D52.5,B40,E7.5);(D32.5,B60,E7.5) and (D12.5,B80,E7.5) is as shown in the Fig.9.

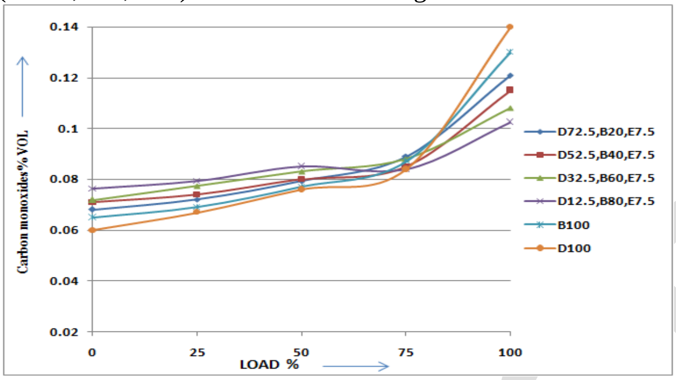

Fig 9 Variation of CO with load

The CO emissions slightly increased at low and medium loads and increased significantly at higher loads with all the fuel modes. The CO emissions of the diesel-biodiesel-ethanol blends were not much deviates from that of conventional diesel at low and medium loads. However, the CO emissions of these blends decreased significantly, when compared with those of conventional diesel at full load of the engine. This is due to the higher amount of oxygen with the ethanol and biodiesel addition, which will promote the further oxidation of CO during the engine exhaust process. The results showed that the CO emissions reduced with addition of ethanol percentage in the diesel-biodiesel-ethanol blend. The CO emissions reduced by 13.57%, 17.857%, 22.85% and 26.785% than the conventional diesel with blending composition of (D72.5, B20,E7.5) ; (D52.5,B40,E7.5) ; (D32.5,B60,E7.5) and (D12.5,B80,E7.5) diesel-biodiesel-ethanol blends respectively at maximum load condition.

Unused oxygen emission

The variation of Unused Oxygen (O_2) emissions with load for diesel fuel, biodiesel and diesel biodiesel-ethanol blends (D72.5,B20,E7.5);(D52.5,B40,E7.5);(D32.5,B60,E7.5) and (D12.5,B80,E7.5) is as shown in the Fig.9.The unused oxygen emissions reduced with load for all the fuel modes. The unused O_2 emissions of biodiesel are 11.14% lower than those of diesel fuel. The O_2 Emissions reduced by 3.34% with the addition of ethanol for the blend (D72.5,B20,E7.5) and increased by 0.55% for (D52.5,B40,E7.5) blend and the trend of increasing unused oxygen is observed for the rest of the blends (D32.5,B60,E7.5) and (D12.5,B80,E7.5) with 4.98% and 6.274% respectively at maximum load.

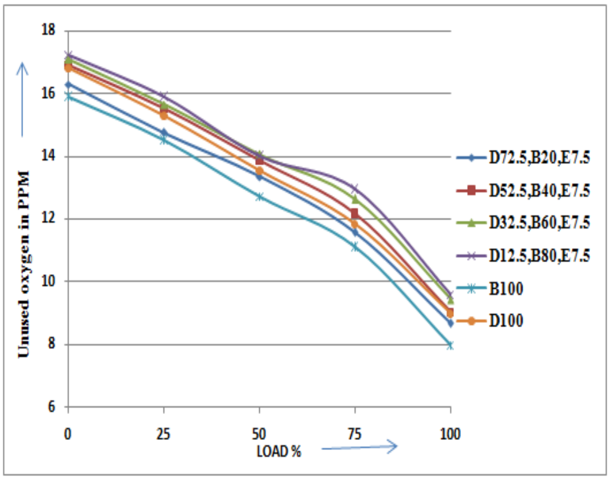

Fig.10 Variation of unused oxygen with Load.

CONCLUSIONS

The performance and emission characteristics of conventional diesel niger seed oil biodiesel, and diesel-biodiesel-ethanol blends were investigated on a single cylinder diesel engine. The conclusions of this investigation are as follows.

- The brake thermal efficiencies of all diesel-biodiesel-ethanol blends were higher than that of the conventional diesel fuel over the entire range of the load. The maximum brake thermal efficiency was observed with (D72.5, B20, E7.5) at all the loading conditions of the diesel engine and it was 13.04% and 18.43% higher than that of diesel fuel and B100 respectively at full load of the engine.

- The BSFC increased by with the blends respectively as compared with fossil diesel.

- The addition of ethanol in the diesel-biodiesel-ethanol blends reduced the exhaust gas temperature as compared with B100.
- The HC emissions were lesser than those of diesel fuel at full load of the engine. Also 22.52% lesser HC Emissions are observed than those of fossil diesel when compared with B100 at full loading conditions.
- The NO_X emissions were increased in all blends. But it was lesser than B100 respectively at full loading conditions and the fossil diesel fuel has still has lesser NO_x emission and it was accounted as 25.39% lesser NO_x than B100 at full load.
- The results showed that the CO emissions were reduced in the diesel-biodiesel-ethanol blend than the conventional diesel at maximum load conditions.
- The unused O_2 emissions of biodiesel are lower than those of diesel fuel for (D72.5,B20,E7.5) blend.

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