Effect of Di Ethyl Ether (DEE) Additive, Compression Ratio (CR) and EGR on the Performance and Emission of DI Diesel Engine Operated on Fish Oil Methyl Ester (FOME)

Nagaraj M Dandinavar[1] Nagaraj Barimarad[2] Anjaneya[3] B M Dodamani[4] Dr. B M Shrigiri[5]
[1,2,3]Student [4]Assistant Professor [5]Professor & Head
[1,2,3,4,5]Department of Mechanical Engineering
[1,2,3,4,5]Hirasugar Institute of Tech, Nidasoshi, Belagavi, Karnataka, India

Abstract— As all we know that the applications of IC engines increasing day by day and at the same time the use of fossil fuels for this purpose increased drastically for past decades. Hence it was given much more importance to alternative fuels in the field of engineering. Hence much more researchers are working on design as well as operating parameters of an IC engine so that we can expect improved efficiency with limited emissions parameters. This paper depicts the use of biodiesel as alternative fuel for IC engines. This experimental investigation were carried out on single cylinder 4-stroke diesel engine operated with Fish oil methyl ester (FOME) Biodiesel and diesel blends with and without EGR and performance and emission characteristics, with compression ratio 16.5:1 and 17.5:1 from the results obtained, for blend B40D40A20 (without EGR) with compression ratio 17.5:1 it's having higher Break Thermal Efficiency (BTE) of 29.5% as compared with other blends B10, B20 and B30. For blend B40D40A20 its having less emission of CO (0.04%), CO_2 (2.31%), HC (61ppm) and Smoke density (59HSU) as compared with other blends and diesel for the same load condition. For the blend B40D40A20 (with EGR 20% and compression ratio 17.5:1) increased in BTE (30.06%) and decrease in the emissions of CO (0.035%), CO_2 (2.19%), HC (51ppm) and Smoke density (54HSU), compared the optimized blend result with diesel results.

Keywords: Fish Oil, DEE, EGR, Biodiesel Engine, Emissions

I. INTRODUCTION

An internal combustion engine (ICE) is a heat engine where the combustion of a fuel occurs with an oxidizer (usually air) in a combustion chamber that is an integral part of the working fluid flow circuit. In an internal combustion engine, the expansion of the high-temperature and high-pressure gases produced by combustion applies direct force to some component of the engine. The force is applied typically to pistons, turbine blades, rotor or a nozzle. This force moves the component over a distance, transforming chemical energy into useful mechanical energy.

Biodiesel is an ester based oxygenated fuels consisting long chain fatty acids derived from vegetable oils (both edible and non-edible) or animal fats and it is non-explosive, biodegradable, non-flammable renewable, non-toxic. It can be used in diesel engine as alternative of diesel fuel without major modification of the engine with same or better performance in comparison to ordinary diesel fuel. Currently, the sources of biodiesel include soybean oil, sunflower oil, corn oil, used fried oil, olive oil, rapeseed oil, castor oil, lesquerella oil, milkweed (Asclepias) seed oil, Jatrophacurcas, Pongamiaglabra(karanja), Madhucaindica (Mahua), Salvadoraoleoides(Pilu), Calophylluminophyllum, palm oil, linseed oil, algae etc. However, the atomization of biodiesel is poor due to its higher viscosity (almost twice the diesel). Biodiesels can replace diesel fuel completely however it being less volatile needs to be blended with other low viscosity fuels such as diesel or ethanol to get better performance. The higher viscosity of biodiesel prompts it to be injected at higher IOP to improve the fuel injection and atomization characteristics thereby improving the combustion quality. In compression ignition (CI) engines, the peak cylinder pressure depends on the fraction of burned fuel during the premixed burning phase or uncontrolled combustion phase. The IOP characterizes the ability of the fuel to mix well with surrounding air and undergo complete combustion. It was reported that increased injection pressure caused increased NOx concentrations, while soot concentrations were decreased. CI engines when operated using different vegetable oils showed improved performance at higher compression ratio.

Fig. 1: Sample of waste fish oil

Waste Fish oil was used as raw material for biodiesel production. Two stage process, esterfication and trans esterfication were applied to convert waste fish oil to biodiesel. An acid catalyst (H2SO4) and alkaline catalyst were used for catalysts of the esterfication and trans esterfication, respectively. Fish oil, methanol or ethanol, and catalyst were reacted in a three-neck flask at temperature at 60 °C and time of 2 h. The effect of alcohol types on biodiesel conversion showed that the optimum condition (conversion of 66.09%) was obtained using methanol. The density, kinematic viscosity, heating value of fish oil biodiesel was 0.8822 g/mL, 4.741 mm2/s. 9713 Cal/g, respectively. The biodiesel was tested on diesel engines to determine the engine torque, power and Brake Specific Fuel Consumption as compared to diesel oil. At lower speed engine of 1200-1400 rpm, the engine torque of waste fish oil biodiesel and diesel oil was higher than that at higher speed engine of 1400-1500 rpm. Blending of waste fish oil had higher engine torque than that of diesel oil. Blends fuel of waste fish oil biodiesel had higher power engine as compared to that of diesel oil fuel at speed of 1200-1500 rpm. Blends waste fish oil biodiesel had lower BSFC (Brake Specific Fuel Consumption) as compared to that of pure diesel oil.

For our study, we are searched some research papers related to our study.

Amir Hossein Saeedi Dehaghani et.al [1] The authors study carried out to investigate the effect of four different additives on pour point and cloud point temperature of blends, this is measured using standard ASTM D2500 and ASTM D97-96a methods. They prepared different additives and diesel fuel mixture and they found that A 20% ethanol fuel mixture caused nearly 30 reduction in the fuel pour point temperature, and they concluded that higher the concentration of the additive in additive-fuel mixture the lower the pour point and cloud point temperature become. and toluene, xylene, n-heptane, and ethanol have the most to least effect on cloud point of the diesel fuel respectively.

PapullaBridjesh et.al [2] Experimental investigation is an endeavour to supplant diesel at least by 50% with waste plastic oil alongside 2-methoxy ethyl acetane(MEA) and diethyl ether(DEE) as additive. Test fuels considered in this studyare WPO, 50D50W(50%Diesel+50%WPO), 50D40W1 MEA(50%Diesel+40%WPO+10%MEA), 50D40W10DEE (50%Diesel+40%WPO+10%DEE). The test results are compared with diesel. An increase in brake thermal efficiency and abatement in brake specific fuel consumption are seen with 50D40W10MEA, As well as reduction in hydro carbon monoxide and smoke emission whereas 50D40W10DEE showed reduced NOx emission whereas 50D40W10MEA has almost no impact. After study they concluded that the physical and chemical properties of WPO, 50D50W, 50D40W10MEA and 50D40W10DEE are adequate and favourable to be used as fuels on diesel engine. BTE increased with load for all test fuels and with increased spray atomisation along with faster fuel vaporisation, BTE for 50D40W10MEA is little higher than diesel.

S. Imtenan et.al [3] Experimental investigation evaluates the comparative improvement of palm biodiesel-diesel blend (20%palm biodiesel-80%diesel) with the help of ethanol, n-butanol and diethyl ether as additive regarding emission and performance characteristics. The improved blends consisted 80% diesel, 15% palm biodiesel and 5% additive. Use of additive improved brake power, decreased BSFC and increased BTE. Diethyl ether showed highest 6.25% increment of brake power, 3.28% decrement of BSFC and about 4% increment of BTE than 20% palm biodiesel-diesel blend when used as additive.

K. Vamsi Krishna et.al [4] In this, study carried out the test case was semi adiabatic diesel engine (SADE) produced by thermal barrier 8 YSZ (Yatria stabilized zirconia) ceramic coated cylinder head and liner with bond coat NiCrAl as an intermediate layer and coupled with an EGR (Exhaust gas recirculation) of 10% constant rate. The test fuel injected directly into the combustion chamber is diesel blend A15B85 by vol. (Additive Diethyl ether 15% and Rubber seed biodiesel 85%). Throughout the experiment they maintain compression ratio as 18:1, fuel injection pressure is 190 bar and speed is 1800rpm. Load from 0% to 100% and start of injection (SOI) timing from 30^o BTDC to 35^o BTDC was varied to investigate performance. After investigation it found that injection timing improved all the investigated parameters except NOx emissions. Compared to ODE with diesel at any sp. Injection timing, the test case with blend fuel found to be favourable. After the study, they concluded that, In comparison to ODE fuelled by diesel, SADE with A15B85 shows higher improvement in all the investigated parameters and the optimum were BTE(7%), BSEC(9%), EGT(18.5%), Particulates(48.5%) and NOx(19.5%) at optimum SOI timing 33^o BTDC.

G.R.K. Sastry et.al [5] In this paper, they studied Biodiesel with additives is generally preferred for improvement of performance and emission characteristics of diesel engines. Higher the fuel injection pressure will improve the performance and reduce the emissions. Isobutanol and Ethanol as additives used in diesel engine. Isobutanol (A1) and Ethanol (A2) were added 5% to 10% by volume to diesel-biodiesel blends and performance & emission characteristics at different injection pressure viz. 200, 225, 250 & 275bars were studied. From the results it was found that nozzle opening injection pressure could be increased up to 250bar, as a result brake thermal efficiency (BTE) will improved. Further, emission like carbon monoxide (CO) significantly reduced. After the results they concluded that, brake specific fuel consumption (BSFC) increases by using biodiesel blends with Isobutanol and Ethanol as additives which however decreases with increase in injection pressure. Indicated thermal efficiency also increases. In case of volumetric efficiency for blend B20 A1(5%) A2(5%) D70 is more as compare to conventional diesel fuel. It may due to the presence of additives like Isobutanol and Ethanol.

Swarup Kumar Nayak et.al [6] The authors investigated that, in this paper the production of bio-diesel from neat mahua oil via base catalysed Transesterification and mixing of the biodiesel with a suitable additive (Dimethyl carbonate) in varying volume proporation in order to prepare a number of test fuels for engine application.The result investigation show increase in brake power and brake thermal efficiency with load for all prepared test fuels. It is also noticed that brake thermal efficiency increase with the percentage of additive in all the test fuels. The brake specific fuel consumption decrease with increase in additive percentage. CO and HC emission are highest for diesel and lowest for pure biodiesel because of higher oxygen content .It is also concluded that with increase in additive percentage in mahua oil methyl ester both CO and HC tends to decrease.

II. PROPERTIES OF FUEL

In this project, we have used Fish oil methyl ester (FOME) as a test fuel. Its characters such as flash point, fire point, density, viscosity and calorific values are found using different instruments.

Sl. No	Properties	Diesel	FOME biodiesel	Apparatus used
1)	Density (kg/m3)	825	898.3	Mass/Volume
2)	Kinematic viscosity (centistokes)	2.52	5.0	Redwood viscometer
3)	Calorific value (kJ/kg)	45843	40839	Bomb calorimeter
4)	Flash point (°C)	55	168	Cleveland apparatus
6)	Fire point (°C)	58	175	Cleveland apparatus

Table 1. Properties of Diesel and Fome

It is found that properties of FOME for flash point, fire point, kinematic viscosity having higher value than the diesel and for density and calorific value is lower than the diesel these properties are find out in laboratory condition.

III. EXPERIMENTAL METHODOLOGY

The below chapter depicts the experimental set up used to carry out the study with all the necessary components and the details are explained below

Fig. 2: Four stroke single cylinder diesel engine test rig

Engine	specifications
No. Of cylinders	1
No. Of strokes	4
Fuel	Diesel
Engine speed	1500rpm
Cylinder diameter(Bore)	87.5mm
Stroke length	110mm
Compression ratio	17.5:1 Variable from 12-18
Rated power	3.7Kw
Orifice dia.	0.15mm
Cylinder capacity	624cc
Type of cooling	Water cooling

Table 2: Engine specifications

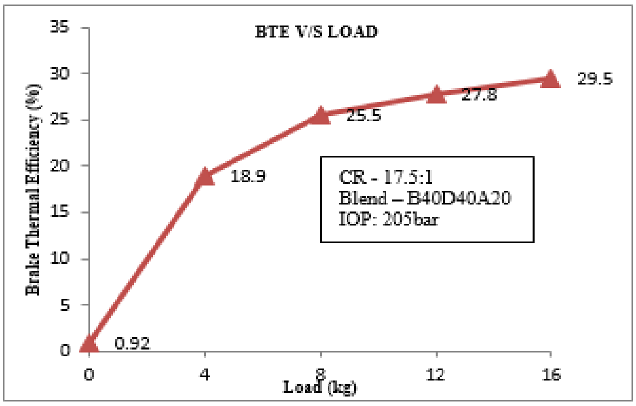

Fig. 3: Variation of Brake Thermal Efficiency with Load

The above fig 3. Depicts that the variation of load with brake thermal efficiency with a blend of B40D40A20 with compression ratio 17.5:1. Hence, it is observed that the brake thermal efficiency go on increasing as the load on the engine increases this is because more volume of oxygen is available for complete combustion of fuel to takes place In addition of diethyl ether as additive to boost up the combustion process. The B40D40A20 blend gives, at part load conditions 25.5% and at full load condition 29.5% of BTE will increase for compression ratio 17.5:1

A. Variation of Brake Thermal Efficiency with Load

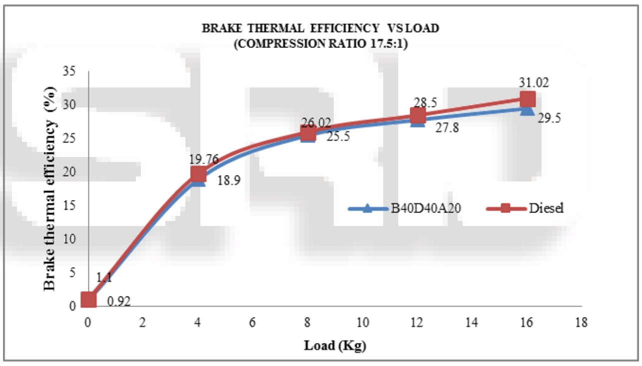

Fig. 4: Variation of Brake Thermal Efficiency with Load

The above graph 4 illustrates that, variation of brake thermal efficiency with different load for diesel and optimized biodiesel blend B40D40A20. The graph shows that, diesel gives slightly higher efficiency than B40D40A20 of FOME blend with varying at different load conditions for 17.5:1 compression ratio.

B. Emission characteristics for Diesel and FOME blends (without EGR) Comparison of CO with Load

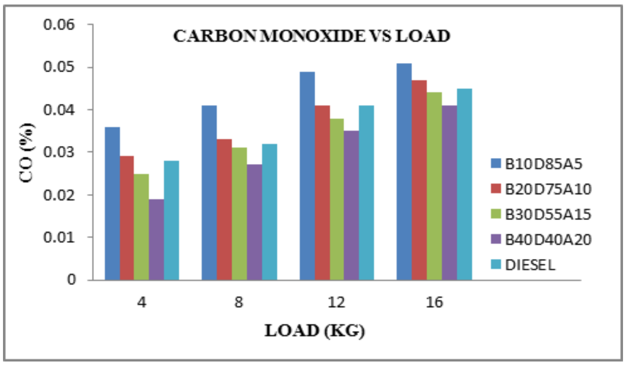

Fig. 5: Variation of CO with Load

The above fig 5: depicts that the variation of carbon monoxide (CO) emissions with varying the engine load as 4, 8, 12 and 16. It shows that, CO emissions of FOME blends and diesel. Compare to B10, B20, B30 blends, B40D40A20 produced lower CO emission than diesel. The B40 blend at part load conditions 0.027 % of emissions and at full load condition 0.041 % of CO emissions will produced for compression ratio 17.5:1.

C. Comparison of CO_2 with Load

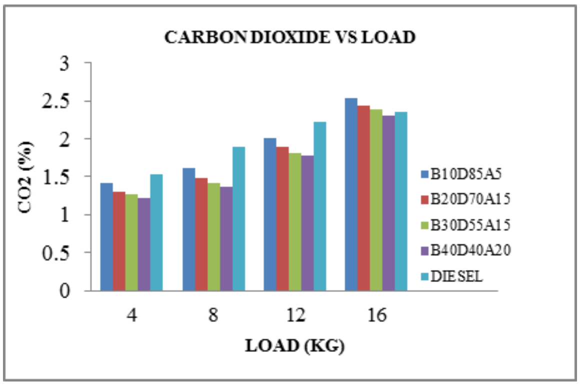

Fig. 6: Variation of CO_2 with Load

The above fig 6 depicts that the variation of carbon dioxide (CO2) emissions with varying the engine load as 4, 8, 12 and 16. It shows that, CO2 emissions of FOME blends are lower than that of diesel. Compare to B10, B20, B30 blends, B40D40A20 produced lower CO2 emission than diesel. The B40 blend at part load conditions 1.36 % of emissions and at full load condition 2.31 % of CO2 emissions will produced for compression ratio 17.5:1.

D. Comparison of HC with Load

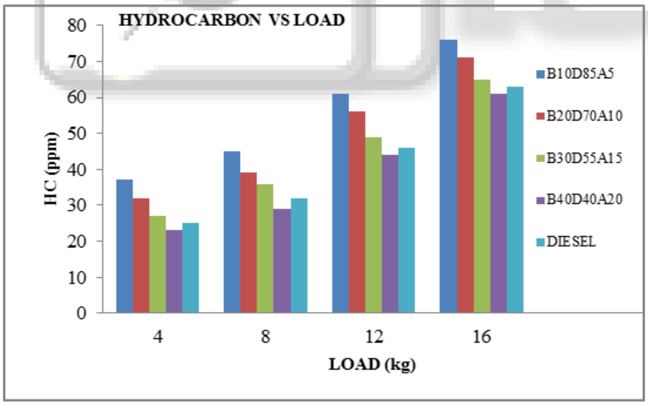

Fig. 7: Variation of HC with Load

The above fig 7 depicts that the variation of Hydrocarbons (HC) emissions with varying the engine load as 4, 8, 12 and 16. It shows that, HC emissions of FOME blends are higher than that of diesel. Compare to B10, B20, B30 blends, B40D40A20 produced lower HC emission than diesel. The B40 blend at part load conditions 29% of emissions and at full load condition 61% of HC emissions will produce for compression ratio 17.5:1

E. Comparison of Smoke with Load

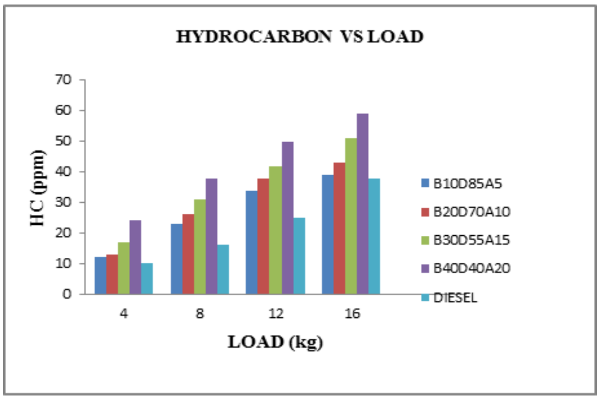

Fig. 8: Variation of Smoke with Load

The above fig 8 depicts that the variation of Smoke with varying the engine load as 4, 8, 12 and 16. It shows that, Smoke of FOME blends are higher than that of diesel. Compare to B10, B20, B30 blends, B40D40A20 produced higher smoke. The B40 blend at part load conditions 38 of HSU and at full load condition 59 of HSU smoke will produce for compression ratio 17.5:1.

F. Comparison of Diesel with B40D40A20 blend (with EGR) Variation of Brake Thermal Efficiency with Load – EGR 20%

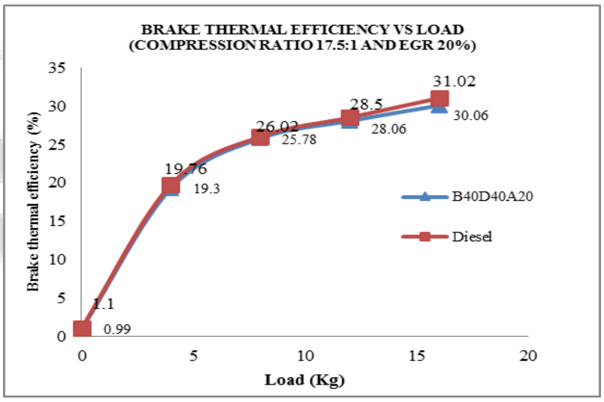

Fig. 9: Variation of Brake Thermal Efficiency with Load

The above graph 9 illustrates comparison of Diesel with B40D40A20 blend with EGR. It shows the variation of brake thermal efficiency with different load. For 20% EGR, Diesel is having slightly higher BTE that of B40D40A20 at similar load condition.

G. Emission characteristics for blend B40D40A20 (with EGR) Variation of Carbon monoxide with Load-EGR 10% and 20%

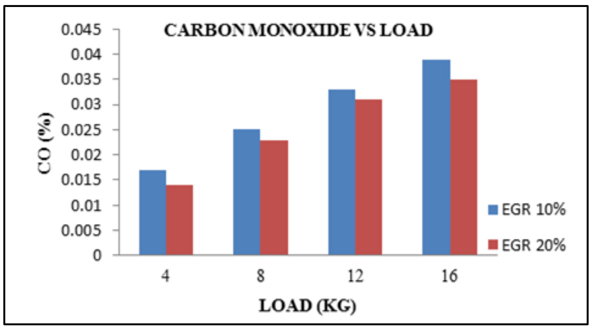

Fig. 10: Variation of Carbon monoxide with Load

The above graph 10 illustrates variation of Carbon monoxide with load, for blend B40D40A20 at 17.5:1 compression ratio with EGR of 10% and 20%. It shows that, for 20% EGR having less emission of Carbon monoxide as compared with 10% EGR.

H. Variation of Carbon dioxide with Load-EGR 10% and 20%

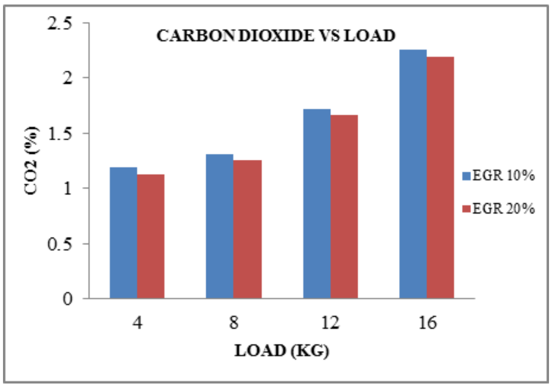

Fig. 11: Variation of Carbon dioxide with Load

The above graph 11 illustrates variation of Carbon dioxide with load, for blend B40D40A20 with EGR of 10% and 20%. It shows that, for 20% EGR having less emission of Carbon dioxide as compared with 10% EGR for 17.5:1 compression ratio.

I. Variation of Hydrocarbon with Load-EGR 10% and 20%

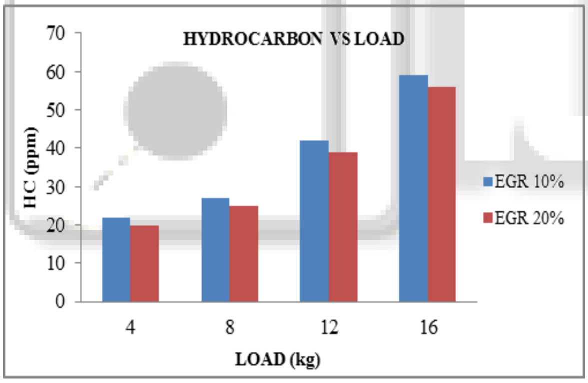

Fig. 12: Variation of Hydrocarbon with Load

The above graph 12 illustrates variation of Hydrocarbon with load, for blend B40D40A20 with EGR of 10% and 20%. It shows that, for 20% EGR having less emission of Hydrocarbon as compared with 10% EGR for 17.5:1 compression ratio.

J. Variation of Smoke density with Load-EGR 10% and 20%

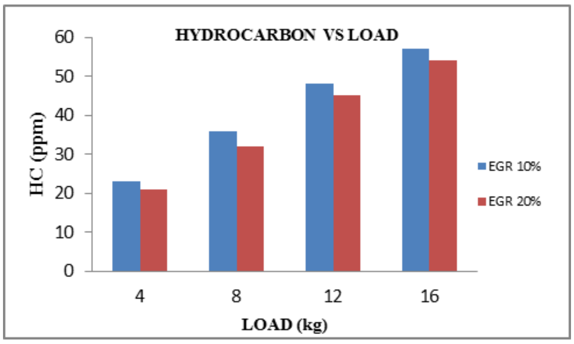

Fig. 13: Variation of Smoke density with Load

The above graph 13 illustrates variation of Smoke density with load, for blend B40D40A20 with EGR of 10% and 20%. It shows that, for 20% EGR having less emission of Smoke as compared with 10% EGR for 17.5:1 compression ratio.

IV. Conclusion

The diesel engine designed to run on bio-fuel has been tested with pure diesel and blend of FOME biodiesel.

- The viscosity and density of the biodiesel is comparatively higher than the diesel and also the calorific value of the biodiesel is comparatively less than diesel.
- Used 5%, 10%, 15%, 20% of Diethyl ether (DEE) as additive to increase the flame propagation speed or to boost up the combustion process. Among them 20% of DEE gives superior value.
- From the exhaustive study it is observed that the blend B40D40A20 gives good results than the other blends. This is because of complete combustion of fuel takes place with biodiesel.
- From the study, blend B40D40A20 having slightly increase in the BTE for 17.5:1 compression ratio as compared with 16.5:1 compression ratio.
- From the study there is decrease in CO, CO2, HC and smoke density for blend B40D40A20 as compared with other blends B10, B20, B30 and diesel
- The efficiency of the engine can be still improved by using exhaust gas recirculation system.
- For the blend with 20% EGR there is increased in the BTE and decrease in emission of CO, CO2, HC and smoke with 17.5:1 compression ratio as compared with 10% EGR.
- The use of FOME biodiesel in internal combustion engine needs no modification in the engine configuration
- The oxides of nitrogen from the emission of exhaust gas can be reduced with the help of EGR.

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