EFFECT OF INJECTION OPENING PRESSURE (IOP), INJECTION TIMING (IT) AND EGR ON THE PERFORMANCE AND EMISSION CHARACTERISTICS OF DIESEL ENGINE OPERATED WITH TALLOW OIL METHYL ESTER (TOME)

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Abstract: As the fuel price and crisis for fuel is goes on increasing day by day, it is very much necessary to use renewable source of energy for meeting our requirements. The use of internal combustion engine for various applications such as power generation, Marine, Transportation etc, always exposes for searching a new alternative fuel which is most economical as well renewable so that dependency on the fossil fuel for engine applications will be reduces. In that context 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 Tallow oil methyl ester (TOME) Biodiesel and diesel blends with and without EGR and performance and emission characteristics, from the results obtained, for blend B40D60 (without EGR) at 260bar Injection opening pressure (IOP) and Injection Timing (IT) 19°bTDC it's having higher Break Thermal Efficiency (BTE) of 29.7% as compared with other blends B10, B20 and B30. For blend B40D66 its having less emission of CO (0.03%), CO_2 (1.49%), HC (41ppm) and Smoke density (32.01HSU) as compared with other blends and diesel for the same load condition. For the blend B40D60 (with EGR 20%) increased in BTE (30.81%) and decrease in the emissions of CO (0.023%), CO_2 (1.24%), HC (34ppm) and Smoke density (31.1HSU), compared the optimized blend result with diesel results.

***Index Terms* - Biodiesel, TOME, EGR, Injection Opening Pressure, Injection Timing.**

I. INTRODUCTION

The internal combustion engine is an energy conversion device in which 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. Internal combustion engine is used for many applications so the research towards the innovation of alternative fuel for IC engines for improved efficiency and less emissions. In that contrary many researches are carried out on this area some of them are *V.K.Shahir et.al* [1], Author has concluded that our society is highly dependent on petroleum for its activity. However, petroleum is a finite source and causes several environmental problems such as rising carbon dioxide levels in the atmosphere. About 90% of petroleum produced is used as an energy source for transportation, heat and electricity generation, and the remaining sources used as feed stocks in the chemical industry. As demands for energy is increasing and fossil fuels are limited, research is directed towards alternate renewable fuels. Alternate fuels for compression ignition (CI) engines have become the need of the hour due to rapid depletion and predicted scarcity of conventional petroleum resources. Biodiesel is becoming a common propulsion fuel. Various countries around the world blend it to mineral diesel, usually in low percentages. Large scale biodiesel production by using low cost abundant feedstock of waste animal fat is becoming more important. Experiments were carried out with different blends of biodiesel from animal fat mixed with mineral diesel in the concentrations of 10%, 20%, 30%, 40% and 50% to examine the effect of emissions and performance of a CRDI engine. The collected data were analyzed for various parameters such as, brake specific fuel consumption (BSFC), thermal efficiency, CO, CO2, NOX, O2 and HC emissions. Of all the animal fat biodiesel blends, the 30% blend concentrations were found to be at par with mineral diesel, regarding the performance and emission parameters of the CRDI engine. These were, however, observed to be marginally inferior for higher and lower blend concentrations. *D.John Panneer Selvam et.al* [2], Author has concluded that using methyl esters from animal fat as an alternative fuel for diesel. Biodiesel is an alternative fuel produced from different kinds of vegetable oils and animal fats. It has an oxygenated, non toxic, sulphur free, biodegradable and renewable fuel that can be used in diesel engines without any significant modification. Performance and exhaust emissions of direct injection diesel engine have been experimentally investigated with methyl ester of beef tallow as neat biodiesel (B100) and its blends (B5, B25, B50 and B75) with diesel fuel. Engine performance parameters namely brake power, brake specific fuel consumption, brake thermal efficiency and exhaust emissions of CO, NOx, HC were determined for different loading conditions and constant engine speed of 1500rpm. The test result indicates that there is slight decrease in brake thermal efficiency values for its B5, B25, B50 and B75 blends are 49.28, 48.45, 47.85, 46.07, 44.85 and 43.25% respectively which is lower than diesel fuel at full load of the engine and increase specific fuel consumption for all blended fuels when compared to that of diesel fuel the BSFC values for biodiesel B5, B25, B50 and B75 blends are 187, 198, 213, 221, 235 and 248g/kw-hr respectively. The drastic reduction in carbon monoxide (24.7%), unburned hydrocarbon (32.5%) were recorded for all the blended fuels as well as neat biodiesel. However, in case of NOx (6.35%), there is slight increase for all the blended fuels and with neat biodiesel when compared to diesel fuel. On the whole, methyl esters of beef tallow and its blends with diesel fuel can be used as an alternative fuel for diesel in direct injection diesel engine without any significant engine modification. *G.R.K Sastry et.al* [3], Author has concluded that Biodiesel with additives is generally preferred for improvement of performance and emission characteristics of diesel engines. Higher fuel injection pressure is effective in improving the performance and reducing emissions. In the present work, Isobutanol and ethanol as additives to the diesel-biodiesel blends was investigated experimentally in a direct injection diesel engine. Isobutanol (A1) and Ethanol (A2) were added 5%-10% by volume to diesel-biodiesel blends and the performance and emissions characteristics at different injection pressures viz. 200, 225, 250 and 275 bars were studied. From the results, it was found that nozzle opening injection pressure could be increased up to 250bar, as a result of which brake thermal efficiency and fuel economy of the engine were improved. Further, Carbon Monoxide (CO) emissions opacity was reduced significantly. However, Nitrogen Oxide (NOx) emissions decrease in some blends marginally. *Nitin M. Sakhare et.al* [4], Author has studied the effect of EGR and cottonseed B20 biodiesel on engine performance, emission and combustion characteristics of a single cylinder diesel engine with power rating of 3kW and at constant speed of 1500 rpm are studied. It is observed that ignition delay is shorter with cottonseed B20 biodiesel as compare to base diesel due to biodiesel is having higher cetane number and oxygenated fuel. It is decreased from 9.5 ºCA with base diesel to 8.5 ºCA with cottonseed B20 biodiesel. Premixed combustion phase is increased with cottonseed B20 biodiesel as compared base diesel whereas diffusion combustion phase is decreased. The higher premixed combustion phase is responsible for higher NOx emission. Utilization of exhaust gas recirculation (EGR) 4 % and 6 % by volume shows deterioration in performance of the diesel engine. This was the main reason to use small quantity (4 % and 6 % by volume) of EGR only to reduce NOx. NOx emission increased with cottonseed B20 biodiesel whereas the emission decreased with exhaust gas recirculation. CO and HC emission decreased with cottonseed B20 biodiesel due to zero aromatic, oxygenated fuel results in clean burning of fuel. However, CO and HC emissions slightly increased with exhaust gas recirculation.*Mohamed F. Al Dawody et.al* [5], Author has studied in this work experimental and theoretical investigations were carried out on a single cylinder, direct injection diesel engine operating on different blends of a soybean methyl ester (SME) with diesel fuel. The effect of blending on the cylinder pressure, heat release rate, carbon monoxide (CO), unburned hydrocarbon (UHC), nitrogen oxides (NOx), and smoke opacity were measured. The results indicate that the use of biodiesel produces lower smoke opacity up to 48.23% with 14.65% higher brake specific fuel consumption (BSFC) compared to diesel fuel. The measured CO emissions of B20% SME and B100% SME were found to be 11.36% and 41.7% lower than that of diesel fuel respectively. All blends of SME were found to emit significantly lower UHC concentration compared to that of diesel over the entire load. NOx emissions are observed to be higher for all blends of SME. The experimental results are compared with the results of Diesel-rk software and a good agreement between them is noticed.

II. PROPERTIES OF FUEL

The properties of TOME biodiesel and diesel were determined and given in the table.

A. Tallow Oil Methyl Ester (TOME)

Tallow is rendered from animal fat, Tallow oil methyl ester is extracted from the raw tallow by Transesterification process.

Fig 1.Crude Tallow **Fig 2**. Esterified Tallow oil

Table 1.Properties of TOME

Properties	Values	Instruments Used
Flash point	127 ^{0}C	Cleveland Apparatus
Fire point	151 ^{0}C	Cleveland Apparatus
Density	786.0 kg/m^3	Redwood viscometer
Kinematic Viscosity	5.0 mm^2/s @ 50^0 C	Redwood viscometer
Calorific value	38350 KJ/Kg	Bomb calorimeter

It is found that properties of TOME for flash point, fire point, kinematic viscosity having higher value than the diesel and for density and calorific value it's lower than the diesel, these properties are find out in laboratory condition. The effect of IOP, IT and EGR on performance and emission on diesel engine fueled with this TOME.

III. EXPERIMENTAL SET UP

Experiments conducted on the Kirloskar TV1 type, 4- Stroke, Single cylinder, water cooled diesel engine test rig fueled with TOME. Figure 4.shows the test rig used. In this study different types of TOME and diesel blends are used for operating conditions of IOP, IT and EGR and blends like B10D90, B20D80, B30D70 and B40D60.

Fig 3. Biodiesel Blends

Fig 4. Experimental set up

Performance and Emission characteristics are were studied for each blend, the optimized blend combination with EGR of 10% and 20% and again noted performance and emission so that optimized blend with EGR and without EGR were suggested. The variation of Break Thermal Efficiency with reference to the performance characteristics and CO, CO_2, HC and smoke density with reference to the Emission characteristics.

The specification of test rig used in the study mentioned in the table 2.

Table 2.Specifications of test rig used

Engine (Kirloskar TV1)	**Specifications**
No. of cylinders	1
No. of strokes	4
Fuel	H.S.Diesel
RPM	1500
Rated power	3.5 kW
Cylinder dia.	80 mm
Stroke length	110mm
Connecting rod length	234mm
Compression ratio very	17.5:1
Orifice dia.	20mm
Dynamometer arm length	185mm
Type of loading	Mechanical Type
Cooling	Water cooled engine

IV. RESULTS AND DISCUSSIONS

4.1 Variation of Break Thermal Efficiency with Load for Blend B40D60-5 hole (without EGR)

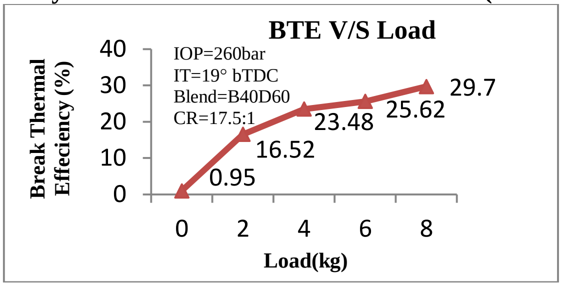


Fig 5. Varation of Break thermal efficiency with Load

The above fig 5.depicts that the variation of brake thermal efficiency with load, for a blend of B40D60 with 5 hole injector having orifice diameter 0.30mm hence it is observed that the brake thermal efficiency go on increasing as the load on the engine increases this is because at higher pressure atomization of the fuel takes place which exposes more surface area of the fuel for complete combustion of fuel to takes place. The efficiency is increased for the blend of B40D60 (29.7%) as compared to other blends B30 (28.1%), B20 (27.8%) and B10 (27.5%) to some extent.

4.2 Variation of Brake Thermal Efficiency with Load for blend B40D60 and Diesel – 5 holes (without EGR)

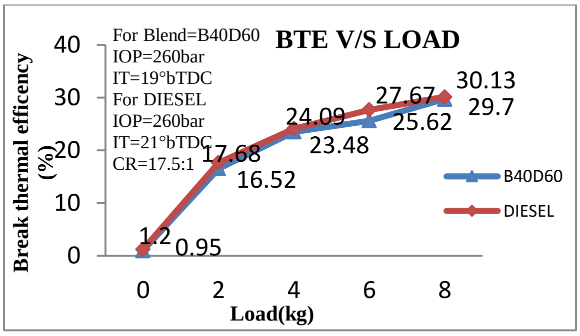
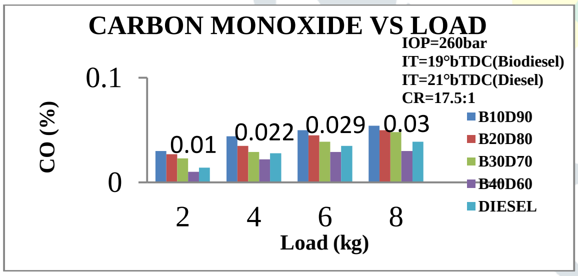


Fig.6 Variation of Brake Thermal Efficiency with Load

The above fig 6.illustrates comparison of Diesel with B40D60 blend, variation of brake thermal efficiency with load, Diesel (30.13%) is having slightly higher BTE that of B40D60 (29.7%) at similar load condition.

Emission characteristics for Diesel and TOME blends (without EGR)

4.3 Variation of Carbon monoxide with Load- 5 hole and Variation of Carbon dioxide with Load- 5 hole



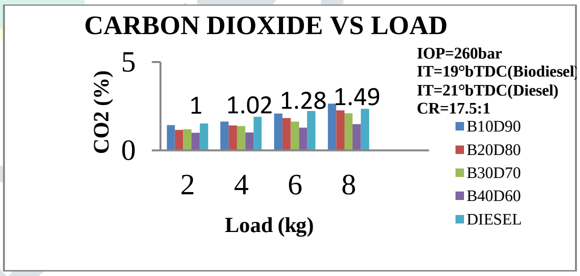
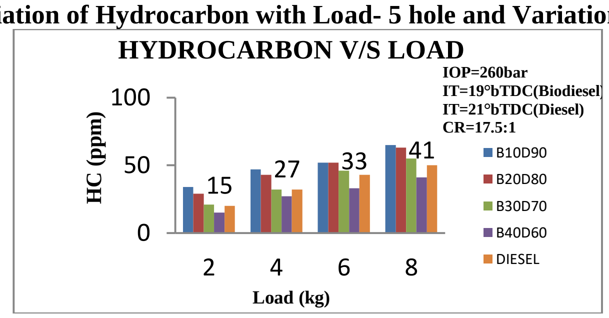


Fig 7. Variation of Carbon monoxide with load **Fig 8.**Variation of Carbon dioxide with load

The above fig 7.illustrates variation of carbon monoxide with load, for blend B40D60 (0.03%) having less emission of CO as compare with other blends B10 (0.054%), B20 (0.05%), B30 (0.048%) and Diesel (0.039%).

The above fig 8.illustrates variation of carbon dioxide with load, for blend B40D60 (1.49%) having less emission of CO_2 as compare with other blends B10, B20, B30 and Diesel.

4.4 Variation of Hydrocarbon with Load- 5 hole and Variation of Smoke density with Load- 5 hole



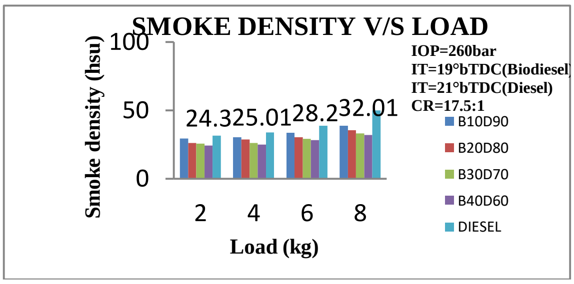


Fig 9. Variation of Hydrocarbon with load **Fig 10.**Variation of Smoke density with load

The above fig 9.illustrates variation of Hydrocarbon (HC) with load, for blend B40D60 (41ppm) having less emission of HC as compare with other blends B10, B20, B30 and Diesel.

The above fig 10.illustrates variation of Smoke density with load, for B40D60 (32.01HSU) less emission of Smoke as compare with other blends B10, B20, B30 and Diesel.

Comparison of Diesel with B40D60 blend (with EGR)

4.5 Variation of Brake Thermal Efficiency with Load – EGR 20%

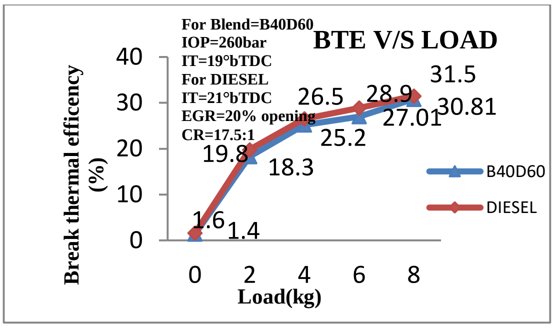


Fig 11.Variation of Brake Thermal Efficiency with Load

The above fig 11.illustrates comparison of Diesel with B40D60 blend, variation of brake thermal efficiency with load, Diesel is having slightly higher BTE that of B40D60 at similar load condition and for 20% EGR.

Emission characteristics for blend B40D60 (with EGR)

4.6 Variation of Carbon monoxide with Load-EGR 10% and 20% Opening

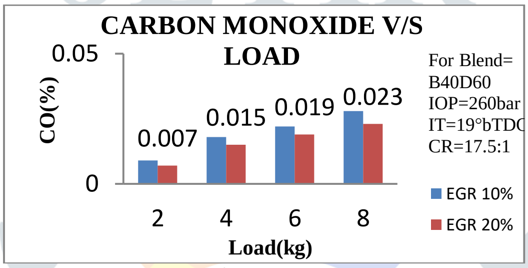


Fig 12. Variation of Carbon monoxide with Load

The above fig 12.illustrates variation of Carbon monoxide with load, for blend B40D60 with EGR of 10% and 20%, for 20% EGR having less emission of Carbon monoxide as compare with 10% EGR.

4.7 Variation of Carbon dioxide with Load-EGR 10% and 20% Opening

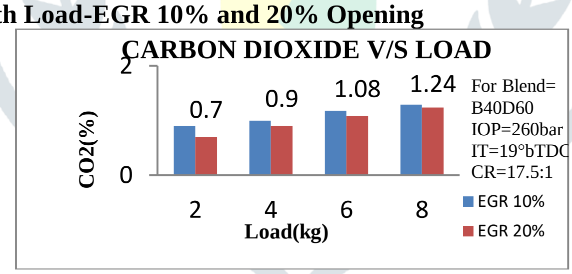


Fig 13.Variation of Carbon dioxide with Load

The above fig 13.illustrates variation of Carbon dioxide with load, for blend B40D60 with EGR of 10% and 20%, for 20% EGR having less emission of Carbon dioxide as compare with 10% EGR.

4.8 Variation of Hydrocarbon with Load-EGR 10% and 20% Opening

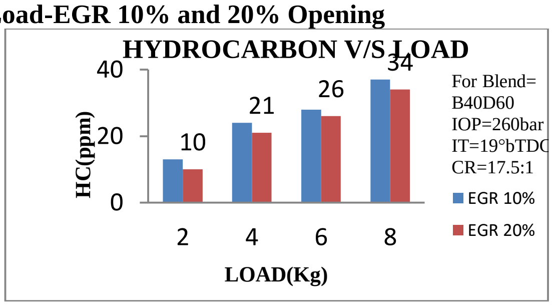


Fig 14.Variation of Hydrocarbon with Load

The above fig 14.illustrates variation of Hydrocarbon with load, for blend B40D60 with EGR of 10% and 20%, for 20% EGR having less emission of Hydrocarbon as compare with 10% EGR.

4.9 Variation of Smoke density with Load-EGR 10% and 20% Opening

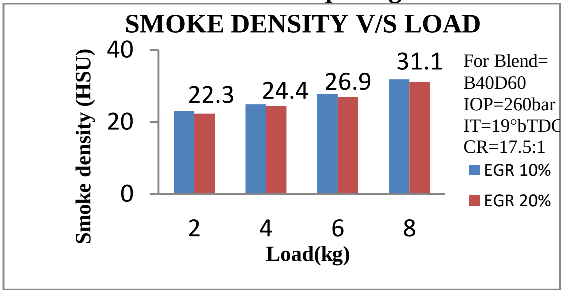


Fig 15.Variation of Smoke density with Load

The above fig 15.illustrates variation of Smoke density with load, for blend B40D60 with EGR of 10% and 20%, for 20% EGR having less emission of Smoke as compare with 10% EGR.

CONCLUSION

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

- The viscosity and density of the biodiesel is comparatively higher than the diesel and also the calorific value of the biodiesel is less that is 38350 KJ/Kg
- From the exhaustive study it is observed that for 260bar the blend B40D60 gives good results having break thermal efficiency of 29.7% than the other blends, this is because of complete combustion of fuel takes place with biodiesel.
- From the study as compared with diesel BTE 30.13% for blend B40D60 it's having 29.7% and slightly decreases for blend B40D60 in BTE.
- From literature survey Injection timing for blends Biodiesel having 19°bTDC and for diesel 21°bTDC.
- From the study there is decrease in CO, CO_2, HC and smoke for blend B40D60 as compared with other blends B10, B20, B30 and diesel.
- For the blend with 20% EGR there is increased in the BTE and decrease in emission of CO, CO_2, HC and smoke.
- The use of TOME 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.
- At high injection pressure of about 260bar the atomization of the fuel takes place resulting in complete combustion of fuel takes place with less appreciable amounts of hydrocarbons exhausted to the atmosphere.

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