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Performance and Emission study of supercharged IDI diesel engine using Beef Tallow Methyl Ester with ethanol as an additive

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Abstract: ***Beef Tallow Methyl Ester (BTME) was tried in an Indirect Diesel Injection (IDI) engine with super charger and secondary injection of hydrated ethyl alcohol as an additive at the suction end. The additive was injected at 3bar in to the incoming air without affecting the breathing capacity of the engine. Alcohol injection is resorted to ensure low temperature combustion. The additive starting from 2% to 8% was injected in steps of 2% increase. For all these percentages of additive, the combustion pressures and tail pipe emissions were measured to compare the engine performance in these aspects with respect to diesel fuel. The experimentation revealed that the biodiesel with 2% hydrated ethyl alcohol proved to be befitting replacement to the diesel fuel.***

Keywords: Indirect Diesel Injection (IDI)**,** Beef tallow methyl ester (BTME), Performance and Emissions.

1. Introduction

Biodiesel application in internal combustion engines is increasing at a faster rate. There are many factors which influence the growth rate of biodiesel production some of them were biodiesel is an oxygenated fuel, it acts as a good lubricant, it can blend with any ratio with conventional diesel and the tail pipe emissions are much lower than the diesel fuel and so on. Raw oils can be directly used in diesel engines but due to their high viscosity leads to poor atomization of the fuel and result in incomplete combustion. To reduce the viscosity of the raw oils, Transesterification is widely used method [1]. Literature on the IDI engines reviles that. Poor quality fuels can be used in IDI engines. A Kolakoti & B V A Rao [2-3] conducted experiments on supercharged IDI engine with palm biodiesel and coconut biodiesel as an additive results envisage that 3% coconut in palm biodiesel gives better performance and reduction of NOx (44ppm), CO (Zero%) and CO_2(1.54%) emissions compared to diesel fuel. T Victor et al [4-6] examines experimentally the effect of rice bran methyl ester with isopropanol as an additive in IDI diesel engine. The main idea in introducing the additive isopropanol is to dilute the combustion and thereby to reduce the combustion temperatures to limit the NOx formation. K Prasada Rao & BVA Rao [7-8] conducted experiments on IDI diesel engine fuelled with mahua methyl ester along with methanol additive blends with an attempt to reduce NOx, HC, CO and smoke emissions. It was observed that at 3% additive in biodiesel performed better and could be a replacement for diesel fuel. SCVR Murty et al [9-10] conducted experiments on the performance and emissions characteristics of IDI engine fuelled with neat palm methyl ester along with 1,4-Dioxane as an additive. From the results engine emissions were decreased by 2ppm for HC, 40% for CO, 10.89% for CO_2 and 56ppm for NOx with 3% additive in biodiesel with respect to diesel fuel. John Panneer Selvam & Vadivel[11] conducted experiments on DI diesel engine fuelled with methyl esters of beef tallow and diesel blends. The results indicate that there is a slight decrease in break thermal efficiency and increase in specific fuel consumption for all blends fuels when compared to diesel fuel.

After a critical review of the work executed by several researchers in the field of IDI engines the author proposed to study the performance and emissions analysis of a supercharged IDI diesel engine using beef tallow methyl ester with a hydrated additive ethanol injected at the suction end.

2. Methods and Materials

2.1 Transesterification

In this study Beef tallow methyl ester (BTME) was used to examine the performance and emission aspects. For this purpose raw beef tallow was used as a feed stock. The biodiesel was prepared by esterification followed by transesterification method. In this reaction methanol and sodium hydroxide is used as a catalyst. By maintaining 65^0C temperature the mixture was kept stirring for 90 minutes. After the reaction period, the methyl ester was separated in a funnel and kept it for 7 to 9 hours. And then glycerin was separated from methyl ester finally methyl ester was washed with distil water until the separation of distil water and methyl ester appear. The obtain methyl ester was heated up to 110^0C and filtered. The properties of BTME in comparison with diesel fuel are tabulated in Table 1.

Table 1: Properties

Properties	*Diesel*	*BTME*	*Ethanol*
Density (kg/m^3)	850	883	789
Calorific Value (kJ/kg)	42800	38570	29700
Cetane Number	47	58	5-7
Flash point (^{o}C)	62	170	14
Pour point (^{o}C)	-14	-5 to 10	-
Cloud point (^{o}C)	-15 to -5	-3 to 15	-
Stoichiometric air to fuel ratio,wt/wt	15	12.67	9
Auto ignition temp. (^{o}C)	210	365	363
Oxygen content % weight	0	11	34.7

2.2 Experimentations

Experimentation was conducted on a single cylinder, 4-stroke super charged Indirect Diesel Injection (IDI) engine as shown

in schematic diagram Fig.1 and the technical specification of the engine was tabulated in Table 2. For supercharging the engine an air blower powered by an electric motor with a rating of 350Watt was used. In an attempt to improve the performance of the engine with neat biodiesel application, ethyl alcohol enriched with 5% water was used as an additive to control the combustion temperatures in both the chambers i.e pre and main chambers. Beef tallow methyl ester was injected through the pintel nozzle and the various percentage of additive (2%,4%,6% and 8%) was injected at 3bar pressure into the inducted air with a suitable electronically control electric injection system which is located exactly after the full opening of the inlet valve. The test was conducted at five discrete part load conditions (No load, 0.77kW, 1.54kW, 2.31kW and 2.92kW). Supercharging enabled the engine operation stable with 9% output power increase at a constant speed of 1500 rpm. This rated rpm and loads have been fixed arbitrarily in the absence of variable speed aspect to test the performance and emissions aspects with the new fuel samples.

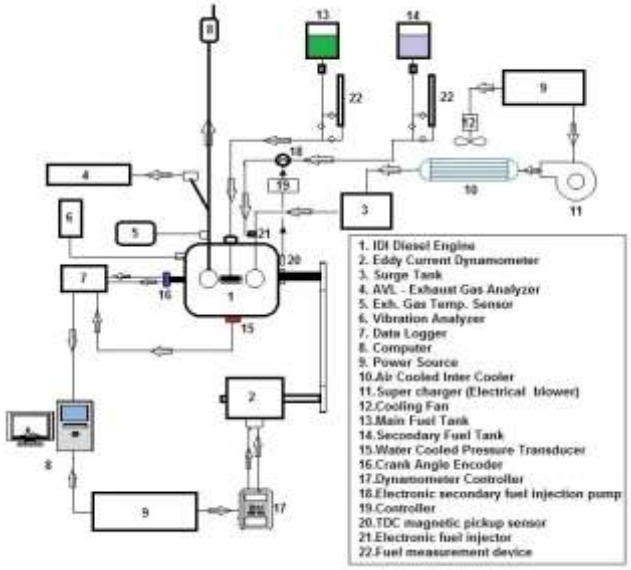

Figure 1: Indirect Diesel Injection Engine Test Rig

Table 2: Specifications of IDI Engine

Engine manufacturer	Bajaj RE Diesel Engine
Engine type	Four Stroke, forced air and oil cooled
No. of Cylinders	One
Bore	86.0 mm
Stroke	77.0 mm
Engine displacement	447.3 cm^3
Compression Ratio	24:1
Maximum net power	5.04 kW at 3000 rpm
Maximum net torque	18.7 Nm at 2200 rpm
Idling rpm	1250±150 rpm
Injection Timing	8.5^0 to 9.5^0 BTDC
Injector	Pintel type
Injector pressure	142 to 148 kg/cm^2
Fuel	Diesel
Starting	Electric Start

3 Results and Discussions

Methyl ester derived from beef tallow with ethyl alcohol enriched with 5% water is used as an additive. Water addition is meant to enhance the latent heat of ethyl alcohol to encourage low temperature combustion. Performance aspects like brake thermal efficiency (BTE), brake specific fuel consumption (BSFC) and equivalency ratio (EQR), the tail pipe emissions like HC, CO, CO_2, NOx and Smoke were also studied.

Figures 2 & 3 indicates the Cylinder pressure verse crank angle at maximum and $3/4^{th}$ maximum loads. There is leading pressure rise in the case of diesel combustion because of its higher heat value and remnant gas temperatures. All other fuels give belated combustion reaching peak pressures late in cylinder due to higher latent heat associated with alcohol combinations and higher self-ignition temperatures. There is sporadic spurt in combustion in the case of fuel combinations related to hydrated alcohol with biodiesel in the pressure spectrum after it reaches peak pressure and this can be acclaimed due to the presence of water in the biodiesel which is not a fuel.

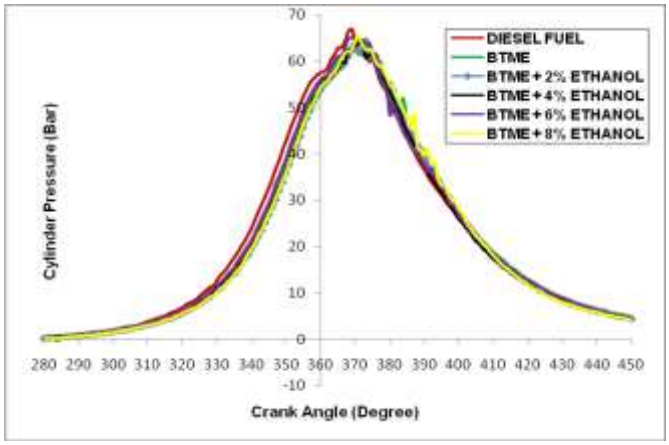

Figure.2 Pressure Verses Crank angle at maximum load

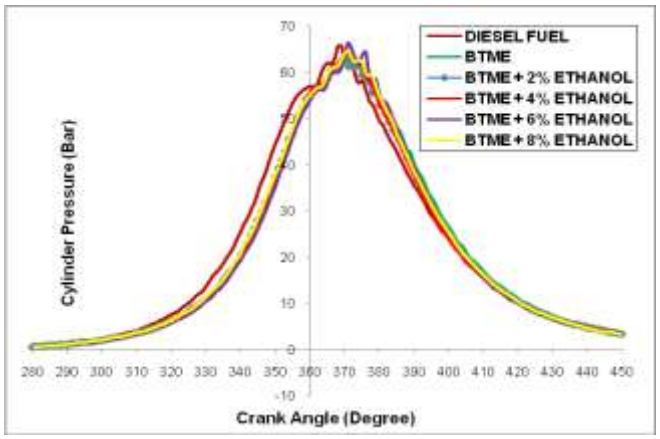

Figure 3: Pressure Verses Crank angle at $3/4^{th}$ maximum load

It is a fact that the lower calorific value of the diesel fuel is higher than BTME and BTME with additive mentioned in Table 1. Despite this reason brake specific fuel consumption (BSFC) of the renewable fuels is higher than the diesel fuel combustion with the fuels formulated are showing up in most of the parameters. In Fig.4 the BSFC of diesel fuel is lowest at all loads. For example, at maximum load and at next lower load, the diesel BSFC is reduced by 2.71% and 3.63% respectively comparing with the fuel containing 2% of the hydrated ethyl alcohol with the methyl ester of beef tallow.

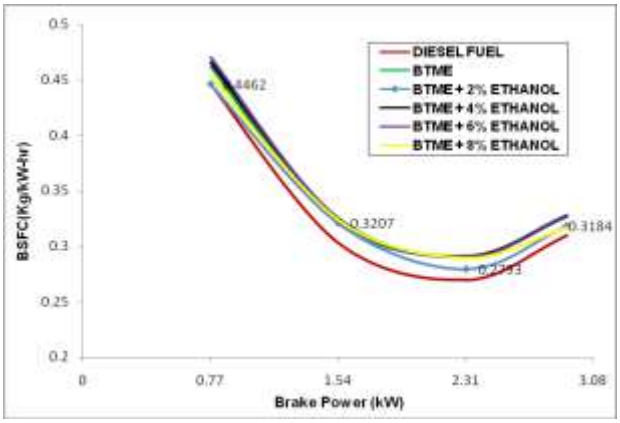

Figure 4: BSFC Verses Brake Power

BSFC verses the equivalence ratio exhibited the performance of the 2% additive with BTME in a lucid way with 2.72% & 3.71% increase in equivalence ratio at upper two loads and in the case of neat BTME the respective percentages are 6.02 and 8.26 as shown in Fig.5. In this aspect also 2% alcohol with BTME shown up beneficially when compared to neat diesel.

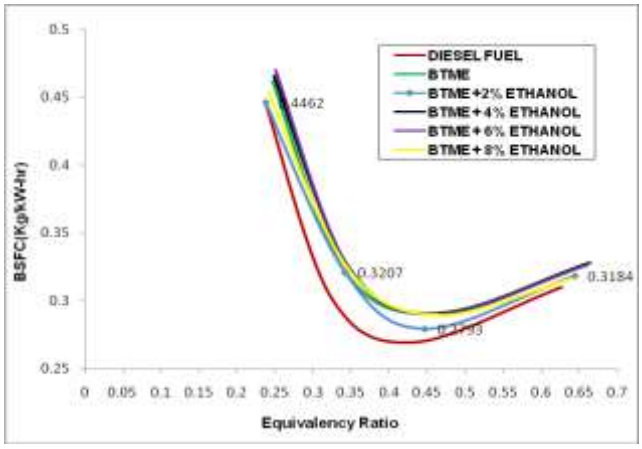

Figure 5: BSFC Verses Equivalency Ratio

The thermal efficiency as shown in Fig.6 increases by 9% & 8% respectively at the upper loads in the case of 2% additive in BTME. 5.15% & 2.96% are the hikes in thermal efficiencies when we compare the diesel and BTME fuels.

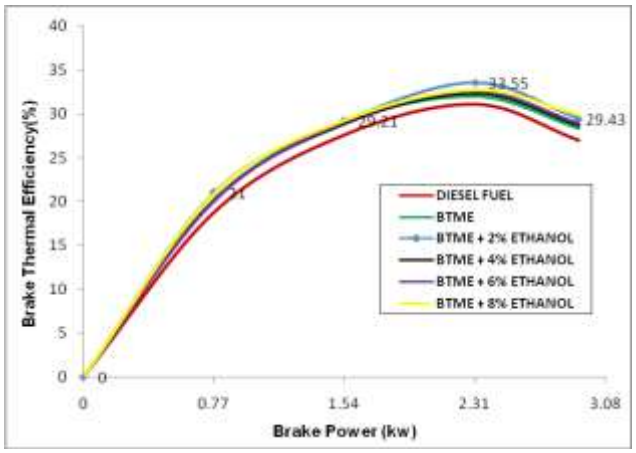

Figure 6: Brake Thermal efficiency Verses Brake Power

From the Fig.7, there was a 2.72% & 3.71% increase in equivalency ratio (EQR) for 2% additive with BTME and 6.02%& 8.26% EQR increase in the case of neat BTME. This is an indication of better combustion with 2% hydrated ethyl alcohol with BTME.

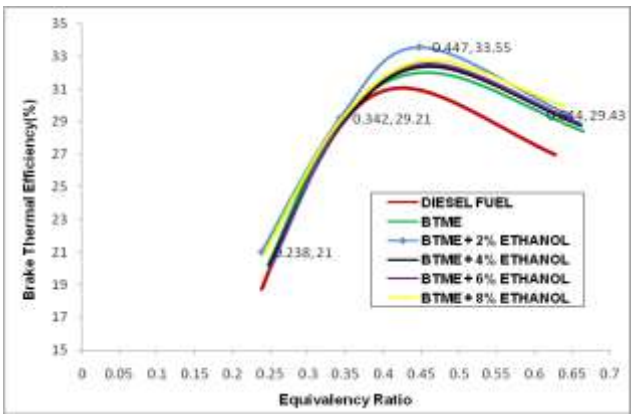

Figure 7: Brake Thermal efficiency Verses Equivalency Ratio

CO emission is totally zero in case of 8% alcohol in BTME as shown in Fig.8 but others shown marginal level with only one exception i.e. 4% ethanol injected with BTME at maximum load condition.8% alcohol in BTME could be able to fully utilize the molecular Oxygen. 4% alcohol in BTME is worst candidate in utilizing both the molecular Oxygen and free Oxygen in the suction air or molecular Oxygen in ethyl alcohol.

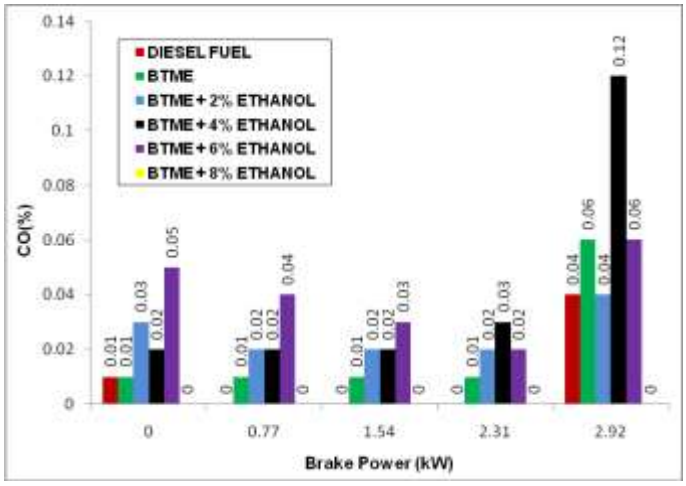

Figure 8: CO Verses Brake Power

CO_2 level is almost same for all fuels and again 8% alcohol with BTME has shown best performance in Fig.9

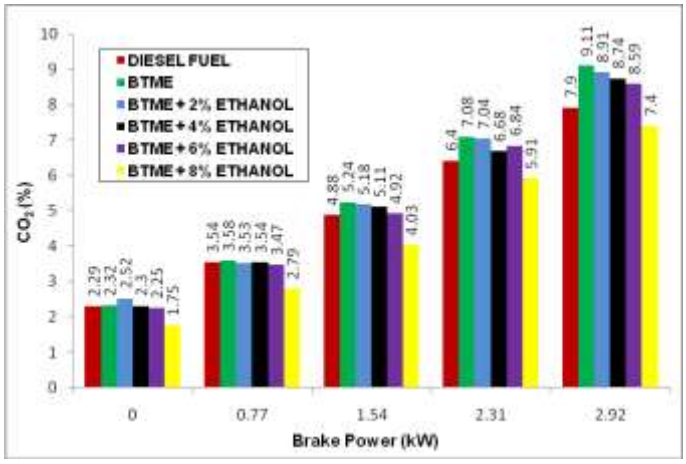

Figure 9: CO_2 Verses Brake power

HC emission in the case of BTME is the lowest because of its higher Cetane number Fig.10 HC emission is more for lower loads in the case of 8% alcohol. This may be one of the reasons for its best performance above, because of poor burning due to alcohol and water owing to reduced Cetane number with the reason of mixing with the BTME.

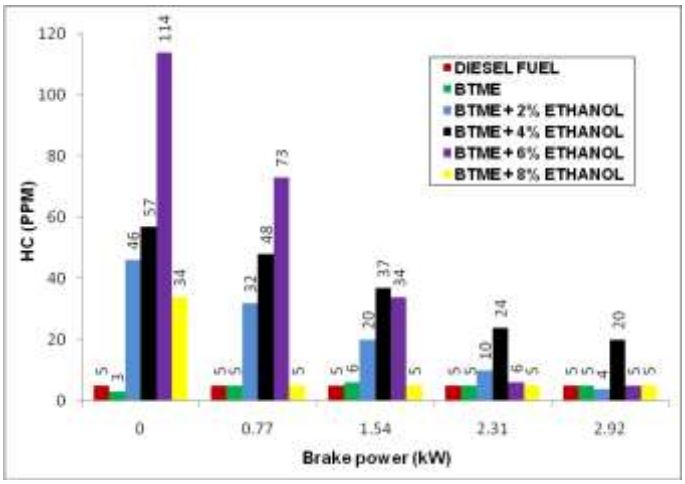

Figure 10: HC Verses Brake Power

NO_x is more in the case of diesel fuel and with all other fuels it is lesser because of low temperature combustion due to the alcohol and water along with BTME. Since diesel combustion is higher temperature combustion with more heat value, the NO_x formation is more as shown in Fig.11

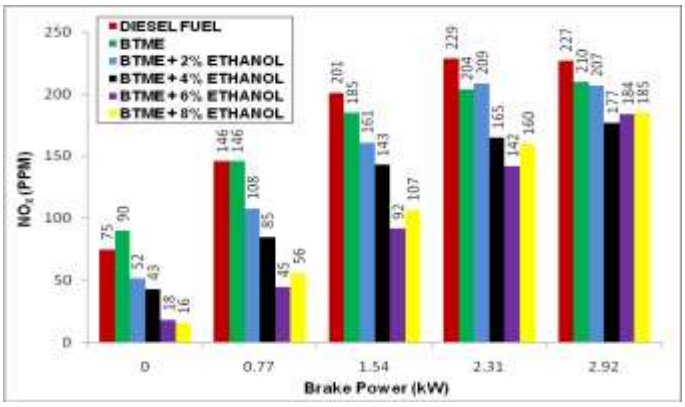

Figure 11: NOx Verses Brake Power

More than 50% smoke relief is there at higher loads with the new fuels as shown in Fig.12 Smoke emissions are almost same at lower loads. Benefit can be acclaimed because in practice the diesel engine operates at higher part loads only

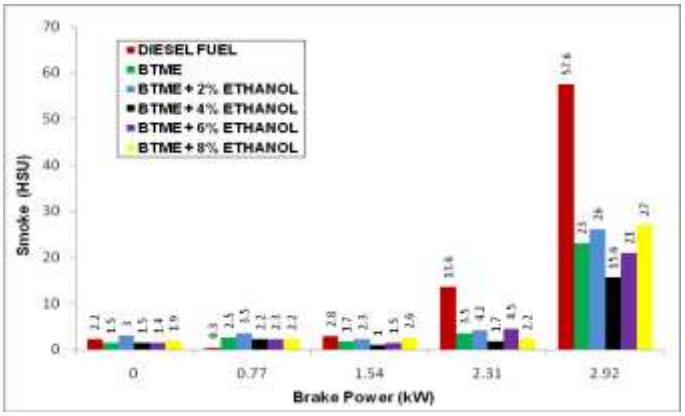

Figure 12: Smoke Verses Brake Power

Conclusions

This study examines the performance and emission characteristics of a supercharged IDI engine using BTME with different percentages of hydrated ethanol as an additive. It was observed that 2% additive in biodiesel gives better performance and reduced tail pipe emissions. The benefits are as follows

- The low temperature combustion associated with the new fuel samples delayed the maximum pressure raise point in the combustion duration because of the reason that the ethanol additive injected at suction end is hydrated. It is obvious that we are witnessing same trend of pressure curves at the next lower load also.
- The Brake Specific Fuel Consumption (BSFC) for the fuel sample consisting of various percent of ethanol as an additive along with BTME was observed to be marginally more because the reason that the Calorific Value of the new fuel samples are comparatively less then Diesel Fuel.
- In BSFC verses equivalence ratio plot the 2% ethanol with beef tallow methyl ester shown up beneficially when compared to neat diesel fuel.
- Brake thermal efficiency increased with the new additive of 2% ethanol with BTME compared to diesel fuel.
- 2% ethanol with BTME was considered to be reducing emissions in all respects which include smoke.

Hence it is to conclude that 2% hydrated ethanol with beef tallow methyl ester is suggested to be good replacement for the petro- diesel with the additional modifications by introducing the additive injection equipment at the suction side and a supercharger.

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