International Journal of Thermal Technologies
E-ISSN 2277 – 4114
Available at http://inpressco.com/category/ijtt/

Review Article

Diesel Engine Performance Improvement with Biodiesels- A Review

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Accepted 25 April 2015, Available online 01 June 2015, **Vol.5, No.2 (June 2015)**

Abstract

As a renewable and alternative fuel for compression ignition engines, biodiesel instead of diesel has been increasingly fuelled. In the recent 10 years many researchers investigated the effects on engine performances and emissions which are the harmful in diesel engine. Around the world researched are devoted to reduce such emissions with different ways like fuel modification, combustion chamber design and treating the exhaust gas, etc., In this connection the hunt for the suitable alternative fuels for diesel engine initiated. In this study the performance and emission characteristics of the direct injection diesel engine fuelled with different biodiesel published in high rated journals are to be analyzed and compared. The performance parameters includes thermal efficiency & specific fuel consumption and the exhaust emissions includes unburnt hydrocarbons (HC), carbon monoxide (CO), carbon dioxide(CO_2), and nitrogen oxides(NO_x). A report will be framed indicating the increase and decrease in the performance and emission characteristics and the reasons for the change will be identified. The best combinations which will give reducing the emissions and increasing the performance characteristics are tabulated.

Keywords: *Alternative fuel, Combustion Chamber, Emission characteristics, Performance, Exhaust gas recirculation, Cetane improver.*

1. Introduction

[1]The resources of petroleum as fuel are dwindling (diminishing) day by day and increasing demand of fuels, as well as increasingly stringent regulations, pose a challenge to science and technology. With the commercialization of bioenergy, it has provided an effective way to fight against the problem of petroleum scarce and the influence on environment.

Biodiesel, as an alternative fuel of diesel, is described as fatty acid methyl or ethyl esters from vegetable oils or animal fats. It is renewable, biodegradable and oxygenated. Although many researches pointed out that it might help to reduce greenhouse gas emissions, there still exist some resistances for using it. The primary cause is a lack of new knowledge about the influence of biodiesel on diesel engines. For example, the reduce of engine power for biodiesel, as well as the increase of fuel consumption, is not as much as anticipated; the early research conclusions have been kept in many people's mind, that is, it is more having a tendency to oxidation for biodiesel which may result in insoluble gums and sediments that can plug fuel filter, and thus it will affect engine durability. Research has shown that the shape of the cooling curve measured by thermal couple mounted in the thermal analysis sample cup reflects the solidification process of iron melt in the cup (Zhu and Smith, 1995) .Measuring the shape of the cooling curve will give comprehensive information about the melting and treatments quality thereby the properties and microstructure could be predicted (Labrecque and Gagne, 1998), (Chisamera, *et al*, 2009), (Riposan, *et al* 2003).

Thermal analysis can be used to determine inoculants performance, apart from the traditional usage of thermal analysis to determine the percentage of carbon equivalent liquids, carbon and silicon levels, it can also be used to monitor metallurgical processes and identify potential problems areas such as low nodule count, under-cooled graphite and carbide/chill propensity (Udroiu, 2002), (Corneli, *et al*, 2004), (Seidu, 2008). It can be used to predict iron shrinkage tendency and help the foundry to control scrap.

2. Literature survey

(As per M. K. Duraisamy 2011) the biodiesel and EGR both can be employed in CI engines to obtain simultaneous reduction of NOx and smoke. Other emissions such as HC and CO are also found to have decreased. Here biodiesel with different percentages of EGR like 5%, 10%, 15%, and 20% are used. (M. Prabhakar *et al* 2012) conducted an experiment on

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diesel engine fuelled with diesel and 100% Pongamia methyl ester as fuel at different injection pressure at varying loads. The injection pressures are varying from 180 bar to 220 bar.

The brake thermal efficiency is increased about 1.5% for 100% PME at 220 bar injection pressure. The BSFC, CO and Smoke were decreased in 100% PME at 220 bar compared to 180 bar injection pressure. The nitrogen oxide emission (NO) was increased about 10% for 100% PME with 220 bar injection pressure. However pure Pongamia methyl ester can be used at higher injection pressure safely in a CI engine without any engine modification that could help in controlling air pollution. (R.B.V.Murali *et al*. 2013) have chosen a pre heating process that means before entering into the combustion chamber the fuel should be heated. In this paper Pre-heating set up is maintained at constant temperature of 55oC water bath and the blends entering into the combustion chamber is at 45oC. This is maintained at all the load conditions and for all the blends. This Pre-Heated set up is having Thermostat in order to regulate the temperature. The authors inferred that the palm sterin oil (which is obtained upon the trans-esterification of pure palmsterin oil) is suitable for running compression ignition engines. The performance of the methyl ester of palm sterin oil is on the same lines as that of diesel. (P.Ramesh Babu and B.V.Appa Rao 2012) examined on blend of Mahua methyl ester and diethyl ether as cetane improver. In this case the cetane number of the additive is more than125. The blend with the biodiesel may not increase the overall cetane number as per the previous works. In their work observed better diffused combustion with the increase in the DEE percentage because faster is the blend reaching auto ignition temperature. 15% DEE blend exhibited better combustion performance. Additives are used in order to get amend results so (K. Prasada Rao *et al*. 2013) gone through an indirect diesel injection with mahua methyl ester blended with small quantities of methanol used as an additive. They concluded that the fuel containing 3% additive in biodiesel performed maximum as replacement to the diesel fuel. Parameters related to diesel engine gives good results at 3% additive along the increase in co_2 emission. (R. Raghu, G. Ramadoss 2011) investigated on an injection timing (170,190,210,230C bTDC) and injection pressure (200,210,220,230,240, and 250 bar) of a DI diesel engine fueled with preheated rice bran oil. The optimum injection timing and injection pressure were concluded as 21°C bTDC and 230 bar respectively.

3. Properties of biodiesels

The Table 1 shows that whatever the biodiesels' considered in the comparison process their different properties.

Table 1 Properties of Biodiesels

Fuel	Calorific Value (kj/kg)	Kinematic viscosity (cSt)	Cetane number	Density (kg/m3)
Diesel	43200	3.9	49	833
Jatropha BD	40462	4.2	47	880
Rice bran	38552	4.8	63.8	884
Mahuva	38800	4.38	50	880
DEE	33892	0.2230	>125	713
DME	28882	1.84	-	197
Ethanol	26855	0.76	8	783.2
Methanol	21489	0.59	4	790

4. Different possible methods for increasing the engine performances

Generally, the direct usage biodiesel in the diesel engine may not give better performance than compare to the diesel thus it require some processes like

1. Exhaust gas recirculation (EGR)
2. Additives
3. Preheating process
4. Fuel injection system: fuel pressure and fuel timing
5. Cetane improver
6. Carburetion

4.1 Exhaust gas recirculation (EGR)

Exhaust gas recirculation (EGR) is a nitrogen oxide (NOx) emissions reduction technique used in petrol/gasoline and diesel engines. EGR works by recirculating a portion of an engine's exhaust gas back to the engine cylinders. In a gasoline engine, this inert exhaust displaces the amount of combustible matter in the cylinder. In a diesel engine, the exhaust gas replaces some of the excess oxygen in the pre-combustion mixture. Because NOx forms primarily when a mixture of nitrogen and oxygen is subjected to high temperature, the lower combustion chamber temperatures caused by EGR reduces the amount of NOx the combustion generates (though at some loss of engine efficiency). Gasses re-introduced from EGR systems will also contain near equilibrium concentrations of NOx and CO, most modern engines now require exhaust gas recirculation to meet emissions standards. By using this recirculation process increase the thermal efficiency of the direct injection diesel engine. Jatropha Biodiesel and EGR (M. K. Duraisamy 2011) *et al*. both can be employed together in CI engines by using this combination the NOx emission reduced and other emissions such as HC and CO are also decreased. At biodiesel 100% and 15% EGR is found to be optimum, which improves the thermal efficiency, reduces the exhaust emissions and the BSFC.

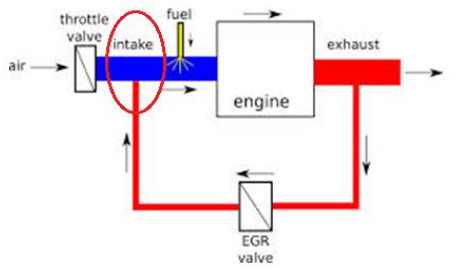

Fig.1 Simple DIG of exhaust gas recirculation

4.2 Additives

In order to achieve a better performance in diesel engines by using biodiesel as a fuel .In some cases the direct use of fuels may not give better results because of that we go for additives. Many engine researchers are hunting suitable alternative fuels for diesel engine. Among different alternative fuels, oxygenated fuel (M. Nurun Nabi1*et al* 2009) is a kind of alternative fuel. Diethylene glycol dimethyl ether (DGM), dimethoxy methane (DMM), dimethyl ether (DME), diethyl ether (DEE), methyl tertiary butyl ether (MTBE), dibutyl ether (DBE), dimethyl carbonate (DMC), methanol and ethanol have played their role to reduce diesel emissions. These fuels can either be used as a blend with conventional diesel fuel or as a neat fuel. The presence of oxygen in the fuel molecular structure plays an important role to reduce PM and other harmful emissions from diesel engine. Oxygenated additives (B. V. Appa Rao *et al* 2012) have been considered for reducing the ignition temperature of particulates. However, the reduction of particulate emissions through the introduction of oxygenated compounds depends on the molecular structure and oxygen content of the fuel and also depends on the local oxygen concentration in the fuel plume.

4.3 Preheating process

Preheating is process in order to obtain the closer diesel properties the bio fuels are heated before the process. Basically bio fuels are having higher viscosity than the diesel with the help of this preheating process we can reduce the property values.

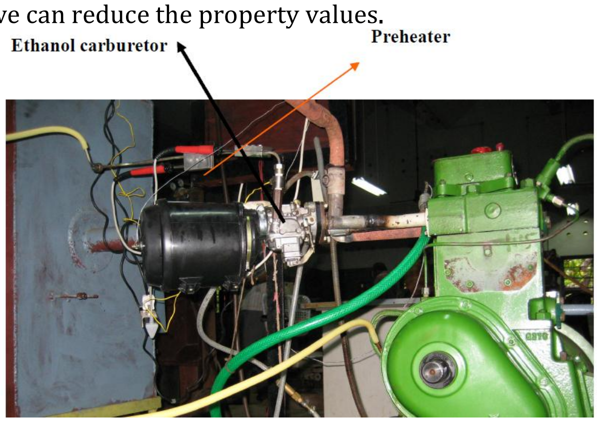

Fig.2 Diagram of both carburetion and preheating process

For example Cottonseed oil methyl ester COME (Shyam Kumar Ranganathan *et al*. 2012) was produced by means of trans-esterification process the viscosity of COME was reduced by preheating it before supplied to the test engine. Preheating of the COME caused a considerable decrease in its kinematic Viscosity thus causing them to approach the values of diesel fuel. A higher BTE was found with the preheated COME due to improved combustion compared to diesel fuel. Particularly COME 90 gives improvement in the BTE Compared to diesel fuel, brake specific fuel consumption for preheated COME90 7.8% is found higher.

4.4 Fuel injection system

The fuel injection system (Rosli Abu Bakar *et al* 2008) in a direct injection diesel engine is to achieve a high degree of atomization. The fuel injection system must be able to meter the desired amount of fuel, depending on engine speed and load, and to inject that fuel at the correct time and with the desired rate. Further depending on the particular combustion chamber, the appropriate spray shape and structure must be produced. Pressures between 100 and 200 MPa generated. The high pressures injection pump carries the fuel through high-pressure pipes to the injection nozzles in the cylinder head. Excess fuel transported back into the fuel tank.

Injection timing is an important engine parameter, which significantly affects the emissions. If injection starts earlier, the initial air temperature and pressure are lower so the ignition delay would increase. If injection starts later, the temperature and pressure are initially slightly higher but then rapidly decrease as the ignition delay proceeds. In the very early injection where the cylinder pressure is lower, the fuel penetration is strong and the wall-adherence (The spray is forced to flow tangentially along the wall) is increased and due to lower cylinder temperature, the evaporation of adhered fuel on the walls becomes slow. Therefore, there is a possibility that much adhered fuel goes out unburnt at early injection timing.

Injection pressure has a significant effect on spray formation and on air-fuel mixing. Basically, fuel under higher injection pressure leaves the nozzle holes with higher velocity and momentum. The higher velocity induces higher level of dispersion, and consequently better atomization and air-fuel mixing occur. Furthermore, there are good evaporations of small fuel droplets. As a result, fine mixing of smaller fuel droplets with entrained air can be expected causing high temperature of in-cylinder gases at high injection pressure. Faster mixing with the high-temperature in-cylinder gases at high injection pressure shortens the ignition delay. Due to the better evaporation and shorter ignition delay, there is a possibility of less wall-adherence. Moreover, the mixture with lower local equivalence ratio and smaller over-rich regions can be expected, but there is a possibility of local over leaning

Table2 Exhaust gas recirculation technique comparisons

S.No	Composition	Engine Emissions				Performance	
		HC (ppm)	CO_2 (%)	CO (%)	NO_X (ppm)	$\eta_{br.th}$ (%)	Sfc(Kg/Kwhr)
1.	**Mahuva+ 15% EGR**	**70**	**9.3**	**0.15**	**1004**	**26**	**0.39**
2.	**Jatropha+ 15%EGR**	**22**	**2.7**	**0.057**	**270**	**27**	**0.3**
3.	20%MME+ 20%EGR	32	-	0.20	460	30	-
4.	20%Jatropha+15%EGR	-	16	3.5	410	31	2.2

Table3 Carburetion technique comparison

S.No	Composition	Engine Emissions				Performance	
		HC (ppm)	CO_2 (%)	CO (%)	NO_X (ppm)	$\eta_{br.th}$ (%)	Sfc(Kg/Kwhr)
1.	MME+ Methanol	81	10.2	1.8	1150	25	0.78
2.	**RBME+ Ethanol**	**37**	**5.6**	**0.04**	**1211**	**28.4**	**0.42**

of the mixture at excessively high injection pressures. The injection pressure was varied from 20 MPa to 120 MPa.

4.5 Cetane Improver

Cetane number (CN) (P.V.Appa Rao 2011) is a prime indicator of the quality of fuel used in CI engines. It is a dimensionless descriptor. It is related to ignition delay (ID) time, i.e., the time that passes between injection of the fuel and onset of ignition. A shorter ID corresponds to a higher CN and vice versa. Biodiesel with high amounts of saturates will have a higher CN while the biodiesel with high amounts of unsaturated will have a low CN. The straight-chain, saturated hydrocarbons have higher CNs than branched-chain or aromatic compounds of similar molecular weight and number of carbon atoms. The longer the fatty acid carbon chains and the more saturated the molecules, the higher the CN. Branching and chain length influence CN. The CN is smaller with decreasing chain length and increasing branching. Too high or too low a CN can cause operational problems. If a CN is too high, combustion can occur before the fuel and air is properly mixed, resulting in incomplete combustion and smoke. If CN is too low, engine roughness, misfiring, higher air temperatures, slower engine warm-up, and also incomplete combustion occur.

4.6 Carburetion

Earlier researchers used heating of air with the carburetion technique, but Rambabu and Appa Rao *et al*, implemented on line heating of the fuel ethanol before carburetion at the suction end, this was attempted to make the volumetric efficiency of the engine safer. The diesel fuel is replaced with neat Rice bran methyl ester (RBME) and heated Ethyl alcohol is carbureted at the suction end through a bifurcated suction arrangement. This attempt is made after surveying the previous work done on alcohol carburetion. Different mass flow rates are used in that 70.17 mg/sec is give better results compare to remaining.

5. Review on Performance and Emission Analysis

Analyzing the literate survey on different techniques to improve the performance of the DI diesel engine fuelled with different biodiesels. Each technique with various fuels is discussed below.

5.1 Method Wise Analysis

5.1.1 Exhaust Gas Recirculation Technique

From the **Table 2** four combinations of different biodiesels, MME with EGR and Jatropha with EGR combination are neglected because these are the proportionate blends with diesel. Mahuva +15 % EGR and Jatropha +15 % EGR are the best optimal conditions in the all proportions. Comparing the parameters of the two biodiesels, Jatropha with 15% EGR is the best optimal combination because decrease in all engine emission parameters is seen. The reason for fewer emissions in Jatropha biodiesel is because of EGR technique.

5.1.2 Carburetion Technique

In this technique Mahuva Methyl Ester with methanol carburetion and Rice Bran Methyl Ester with ethanol carburetion are only considered. In between these two combinations rice bran methyl ester is good in performance with a small increase in NO_x emission as shown in the Table 3. Ethanol is having less viscosity and it is easily mix with Rice Bran and also reasonable calorific value of ethanol will increase diffusivity and leads to complete combustion of the fuel. This could be the reason to lesser emissions and high Brake Thermal Efficiency.

5.1.3 Preheating Technique

By considering the preheating process the density of Jatropha biodiesel 4.2 and Rice bran oil is 4.8 which higher the Jatropha , and both the biodiesels are having higher densities then Diesel Fuel. So by preheating process the viscosity of biodiesel is reduced and made

Table4 Preheating technique comparisons

S.No	Composition	Engine Emissions				Performance	
		HC (ppm)	CO_2 (%)	CO (%)	NO_x (ppm)	$\eta_{br.th}$ (%)	Sfc(Kg/Kwhr)
1.	**Jatropha**	**28**	**1.4**	**28**	**1080**	**28**	**0.32**
2.	Rice bran oil	25	5.4	32	1700	27	0.35

Table5 Additives technique comparisons

S.No	Composition	Engine Emissions				Performance	
		HC (ppm)	**CO_2 (%)**	**CO (%)**	**NO_x (ppm)**	**$\eta_{br.th}$ (%)**	**Sfc(Kg/Kwhr)**
1	**Jatropa+DME**	**25**	**8**	**0.02**	**480**	**22**	**0.4**
2	RBME+DEE	50	9	0.15	2400	15	0.41
3	20%MME+ 20%EGR	76	7	0.40	420	27	0.37
4	20%Jatropha+15%EGR	65	-	0.18	-	24	0.52
5	Jatropa+ DEE 15%	25	-	0.02	450	24	0.70
6	**RB+ Ethanol 35%**	**32**	**5.6**	**0.37**	**610**	**27**	**0.36**

comparable equal to diesel fuel which leads to proper flow of the fuel from tank to fuel injector.

By having lesser density due to preheating of the fuel proper atomization of fuel takes place and reduces detonation and has better combustion inside the engine. Through which an enhancement in performance of the engine will take place. So, Jatropha having lesser viscosity than rice bran gives small increase in performance and low emissions.

5.1.4 Additives Technique

In spite of marginal density difference, blending is not difficult as there is no separation observed with all combinations of additive blends. From the **Table 5** comparing the six different compositions using additives, four are neglected. The reasons are RBME with DEE gives more nitric oxide emissions because DEE is an Oxygenated additive. Rice bran and Jatropha with 15% DEE have more NOx emissions not much significance reductions in engine emissions. The Jatropha with DME and Rice brain with Ethanol blend shows some better emissions and comparably good percentage of performance, this is due to less density.

5.2 Graph Wise Analysis

The following graphs give the clear picture about engine emissions and performance of diesel engine which is fuelled with various bio-diesels in different combinations.

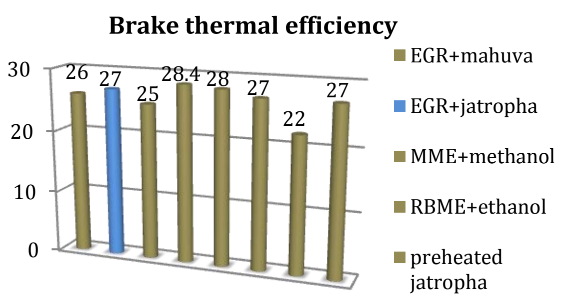

Fig.3 Brake thermal η with various biodiesels

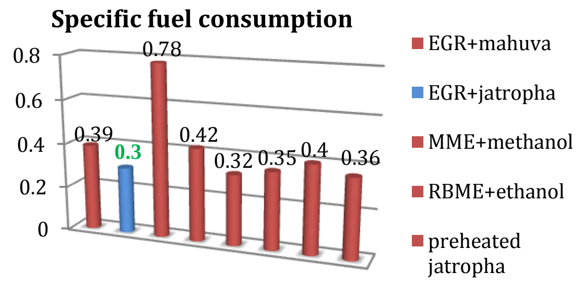

Fig.4 Specific fuel consumption with various biodiesels

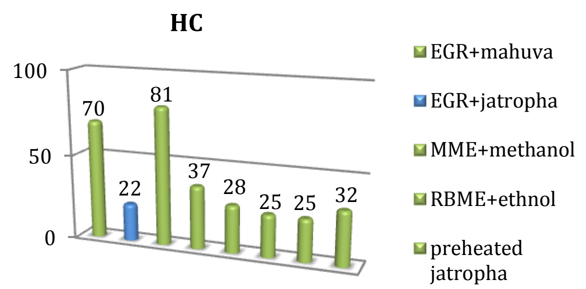

Fig.5 HC emissions with various biodiesels

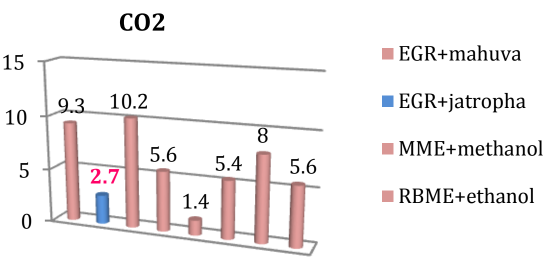

Fig.6 CO_2 emissions with various biodiesels

Comparing the above four graphs and by analysis, identified and concluded EGR+ Jatropha is the best combination biodiesel fuel, because it's having lesser specific fuel consumption, better brake thermal efficiency and lower emissions.

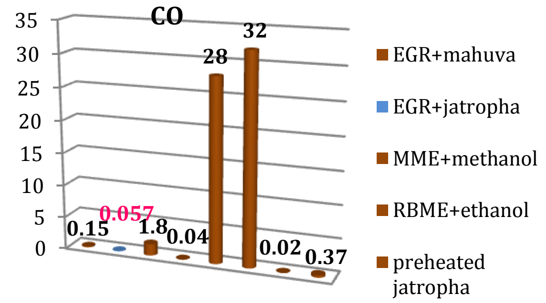

Fig.7 CO emissions with various biodiesels

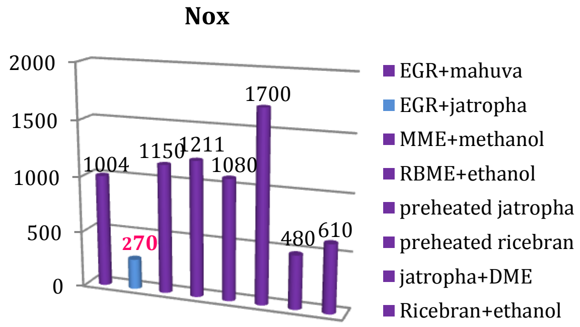

Fig.8 NOx emissions with various biodiesels

Conclusions

By comparing all the methods with different biodiesels following are the conclusions.

1) In EGR technique jatropha with 15% EGR gives better break thermal efficiency and low NO_x emission.
2) In Carburetion technique RBME with Ethanol gives the high performance with increase in NO_x emission similarly in preheating process the jatropha bio diesel obtain good break thermal efficiency.
3) In the same manner the additives technique shows good results in jatropha along with DME.
4) The best combination by comparing each method considering graphical analysis is Jatropha with exhaust gas recirculation technique and at the same time it is the most optimal method of a DI diesel engine. It gives high performance and low emissions.

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