Asian Review of Mechanical Engineering
ISSN: 2249 - 6289 Vol. 3 No. 1, 2014, pp. 12-17

A Review on Performance & Emission Characteristics of Diesel Engine Using Different Types of Biodiesel Blends as Alternate Fuel

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(Received on 08 March 2013 and accepted on 18 June 2014)

Abstract – **As a renewable, sustainable and alternative fuel for compression ignition engine, biodiesel instead of diesel has been increasingly fuelled to study its effects on engine performances and emissions in the recent 15 years. Bio-diesel is an alternative to petroleum-based fuels derived from vegetable oils, animal fats, and used waste cooking oil including triglycerides. Bio-diesel production is a very modern and technological area for researchers due to the relevance that it is winning everyday because of the increase in the petroleum price and the environmental advantages. Trans esterification is the most common method and leads to monoalkyl esters of vegetable oils and fats, now called bio-diesel when used for fuel purposes. In spite of having some other applications, recently it is being considered as one of the most promising alternative fuels in internal combustion engine. Also on the other hand increasing stringent emission regulation will make the use diesel very difficult in the coming days. Regarding the health and environment there is an alternate of diesel called biodiesel. This review paper collects experimentally investigated records and results of engine performance & emission characteristics of compression engine with biodiesel and compared it with conventional diesel. From the review it is found that the use of biodiesel leads to the substantial reduction in PM, HC and CO emissions accompanying with the imperceptible power loss, the increase in fuel consumption and the increase in NOx emission on conventional diesel engine.**

Keywords: **Diesel engines; Biodiesel; Transesterification, Performance parameters.**

I. Introduction

The availability of energy resource plays a critical role in the progress of a nation. A almost all the human energy needs are currently met from the fast depleting fossil fuels associated with serious environmental consequences. After energy crisis in the mid of 1970s, every country has tried to find a new energy that can replace petroleum by using their district energy; especially vegetable oil, the most promising alternate fuel. Vegetable oils cannot be used directly in diesel engine because of the problem associated with it of the using pure vegetable oils as a fuel in diesel engine. This could be the right time for alternates to deploy all over the world's fuel pump. Biodiesel is the good alternate which is renewable in nature made from biomass like vegetable oil, animal fat and their derivatives. Biodiesel is come in this category of bio-fuel. Biodiesel is a renewable and eco- friendly alternative diesel fuel for diesel engine. Recently considerable attention in developing countries such as Malaysia, Indonesia and Thailand has been drawn to the production of bio-fuels from domestic, renewable resources. Bio-fuels are currently being considered from multidimensional perspectives i.e. depleting fossil fuels, resources, environmental health, energy security and agricultural economy. Biodiesel can be obtained from a number of edible and non edible oil resources and major thrust is given for the utilization of non edible seed plant. The oil from these plants can be transesterified by suitable method depending on its FFA content for the production of biodiesel that can be used to operate a CI engine. Biodiesel is an oxygenate, sulphur-free and biodegradable fuel and its content of oxygen helps to improve its combustion efficiency therefore fewer green house gases such carbon dioxide are released into the atmosphere.

Biodiesel is a fatty acid composed of saturated and unsaturated chain of monoalkyl ester. Combustion behavior of biodiesel also depends on the percentage of saturated and unsaturated chain. Biodiesel is the alternate which has property enough same as conventional diesel. Biodiesel have high incompressibility, density, viscosity, pour point, flash point and cetane number. There are some differences in injection, combustion, performance and emission characteristics with biodiesel compare to conventional diesel.

II. Indian Energy Scenario

As per 2009/10, estimates, the crude oil production in India stood at 33.67 MT which is approximately the same as compared to the previous year's production of 33.51 MT (2008-09). Since the Indian economy is growing at the rate of 6% or more and the energy demand is therefore, expected to rise to 166MT by 2019 and 622MT by 2047. [1] The demand of crude oil in the country is met through indigenous supplies as well as through imports. The dependency on imported crude oil has been about 79% of the total demand in 2009/10 valued at Rupees 3753 billion which is 9% higher than the 2008-09.

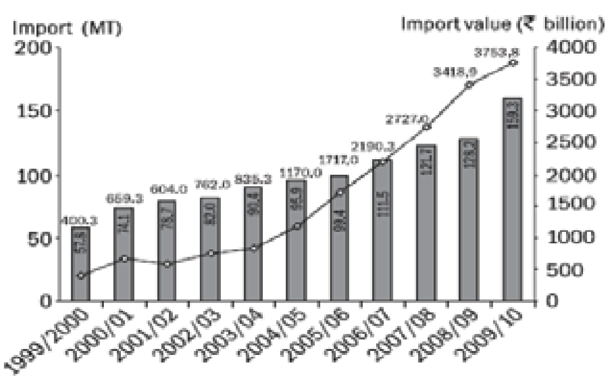

Fig 1. Annual imports and cost of crude oil imports [101]

Fig I shows that the demand of crude has reached to 159.3MT during 2009-10which is about three times more than 57.8MT during1979-2000. The rapidly increasing demand of crude oil coupled with increase in fuel demand has forced the countries to look for alternative to conventional fuels As stated above, the biodiesel production from non edible seed plant like jatropha, pongamia, mahua etc are being considered as indigenous source of oil for biodiesel production. Once the oil resources starts to available in the country, the availability of biodiesel as substitute of diesel fuel will increase and dependency on oil import would reduce there by making the country self sufficient in fuel supplies.

The demand of diesel is five times more than the gasoline in the country. Indian Government has formulated an ambitious National Biodiesel mission in the year to substitute about 20% of the total diesel demand by biodiesel by 2011-2012. Transportation fuels are currently the main refinery products around 38% of the world's petroleum products being used in the transportation sector. It is expected that the demand of petroleum products will increase until 2015 and after that, will reduce due to the commercialization of alternative fuels. The most common alternative fuels currently in use are : Compressed natural gas (CNG) , Liquefied natural gas (LNG) , Liquefied propane gas (LPG), methanol (M85 or M100) and ethanol (E85 or E100). Currently the total no. of vehicles operated using alternative fuels is 330000 in the United states only, with well over 25 million worldwide.

III. Transesterification Process

The transesterification process will be adopted for the preparation of ethyl ester or methyl ester of vegetable oil. In the preparation of ethyl ester (biodiesel), five distinct stages will be involved.

1) Heating of oil.
2) Preparation of alkaline mixture.
3) Adding of alkaline alcohol to oil and stirring the mixture.
4) Settling of separation of glycerol.
5) Washing of methyl ester with water.

The biodiesel can be obtained by transesterification of vegetable oil using either ethanol or methanol as the Trans-esterifiction agent. Transesterification reaction is a stage of converting oil or fat into methyl ester or ethyl esters of fatty acids which constitutes to biodiesel. Biodiesel (methyl esters) is obtained though the reaction of triglycerides of vegetable oils with an active intermediary formed by reaction of an alcohol with a catalyst. The general reaction for obtaining biodiesel though transesterification.

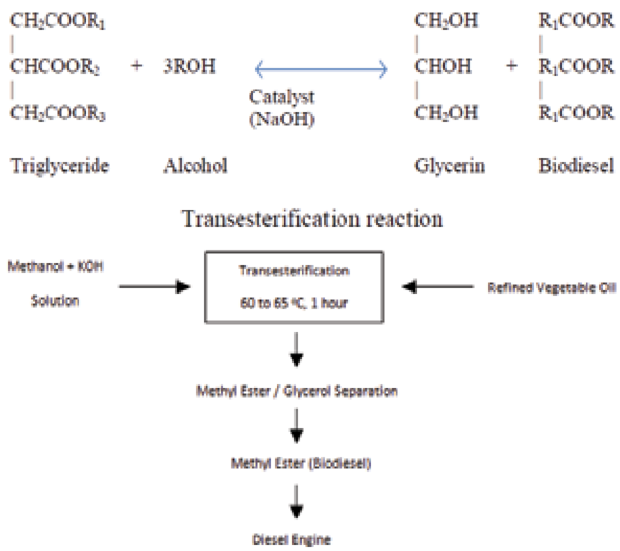

Fig.1 Procedure of manufacturing biodiesel through transesterification with vegetable oil

The reaction requires heat and a strong catalyst (alkalis, acids, or enzymes) to achieve complete conversion of the vegetable oil into the separated esters and glycerin.

Generally potassium hydroxide (KOH) and sodium hydroxide (NaOH) are used as alkaline catalysts with methanol (CH_3OH) for production of biodiesel. The alcohol & catalyst is charged into a closed reaction vessel and the vegetable oil is added. The reaction is heated to the boiling temperature of the alcohol (normally 50-60 deg C) and is refluxed for a certain length of time under agitation. When agitation is stopped (after 60minutes) the reaction mixture separated into an upper layer of methyl ester and lower layer of glycerol diluted with un reacted methanol. Once the reaction is complete, two major products are produced: Glycerin and biodiesel (methyl ester). The quantity of glycerin varies according varies according to the vegetable oil used, the process used, and the amount of the excess alcohol that is used in the reaction. The fatty ester produced in the upper layer is neutralized and vacuum distilled for the removal of excess methanol. The methyl ester produced from the reaction is then washed with hot water and separated out by centrifugation.

IV. Fuel Properties of Biodiesel

Biodiesel is mono-alkyl ester made from natural and renewable vegetable oil and animal fats based feedstock. The biodiesel is similar in fuel characteristics to conventional diesel as shown in table 1 which also compare the fuel characteristics specified by standard specification of different countries. The data indicates that the biodiesel is compatible with petroleum diesel and can be blended in any proportion with diesel to create suitable biodiesel blend. The blending of biodiesel with diesel is expressed as Bxx where xx indicates the percentage of biodiesel in the blend For example B20 blend is made by mixing 20% biodiesel with 80% diesel which can be used in CI engine with no modification with comparable power output.

Table I Comparison of Fuel Properties of Biodiesel of Different Standards

S.No.	Fuel Properties	Austria (ONC-1191)	India (BIS-15607)	France (EU-15412)	Germany (DIN-EN-590)	Italy (UNI-10946)	USA (ASTM-424720)
1.	Density at 15^{0}C (g/cm^3)	0.85-.89	0.87-0.89	0.87-0.89	0.875-0.89	0.86-0.90	0.88
2.	Viscosity at 40^{0}C (mm^2/s)	3.5-5	1.9-6	3.5-5	3.5-5	3.5-5	1.96
3.	Flash point ^{0}C	100	130	100	110	100	130
4.	Cold Filter Plugging Point ^{0}C	0-5	0-5	N.A	0-10/-20	N.A	N.A
5.	Pour point ^{0}C	N.A	N.A	10	N.A	1-5	15-18
6.	Cetane number	≥49	≥40	≥49	≥49	N.A	≥47
7.	Neutralization number (mgKOH/g)	≤0.8	≤0.5	≤0.5	≤0.5	≤0.5	≤0.8
8.	Carbon residue (%)	≤0.05	≤0.05	N.A	≤0.05	N.A	≤0.05

TABLE II COMPARISONS OF PROPERTIES OF VEGETABLE OILS AND THEIR ESTERS WITH DIESEL FUEL

Type of vegetable oil	CN	HV (kJ/kg)	Viscosity (mm^2/s) Temp)	Cloud Point (°C)	Pour Point (°C)	Flash Point (° C)	Density (kg/m^3)
Castor oil	N.A	39500	297 (38°C)	N.A	-31.7	260	961
Coconut oil	N.A	N.A	N.A	N.A	N.A	N.A	924.27
Cottonseed oil	41.8	39468	33.5 (38 °C)	1.7	-15.0	234	925.87
Linseed oil	34.6	39307	27.2 (38°C)	1.7	-15.0	241	929.07
Olive oil	N.A	N.A	N.A	N.A	N.A	N.A	918
Palm oil	42	N.A	N.A	N.A	N.A	N.A	910.1
Peanut oil	41.8	39782	39.6 (38 °C)	12.8	-6.7	271	914
Rapeseed oil	37.6	39709	37.0 (38 °C)	-3.9	-31.7	246	920
Sesame oil	40.2	39349	35.5 (38 °C)	-3.9	-9.4	260	922
Soybean oil	37.9	39623	32.6 (38°C)	-3.9	-12.2	254	997.5
Sunflower oil	37.1	39575	37.1 (38 °C)	7.2	-15.0	274	920
Tallow oil	N.A	40054	51.15 (40°C)	N.A	N.A	201	820
Jatropha oil	51	39700	51 (30^0C)	16	N.A	242	932
Pongamia oil	51	46000	55.1(30^0C)	23	N.A	110	884
Diesel	47	45343	2.7 (38 °C)	-15.0	-33.0	52	870.20

The table 2 shows that cetane number of all the oils is slightly lower than the diesel indicating that straight vegetable oil SVO are the potential substitute of diesel but the viscosity ranging from 27.2 (linseed oil) to maximum of 51.15 mm2/sec (tallow oil) is considerably higher than diesel which indicates that there is a need to bring the viscosity of oil near to the diesel either by physical or chemical modification producing the resulting product as perfect substitute of diesel in all respect. The cold flow properties of SVO are lower than diesel indicating that performance of oil as fuel is difficult at low temperature due to its solidification as compared to diesel.

IV. ENGINE PERFORMANCE & EMISSION CHARACTERISTICS

Engine Performance Parameters

Literature survey reveals that biodiesel perform satisfactorily during diesel engine operation. And B20 blend provides the fuel economy almost similar to the diesel. Due to its high lubricity, it causes less wear and tear to engine part. Numerous studies have are reported on the performance and emission of CI engines, fuelled by B100 biodiesel as well as its blends with diesel. The following parameters are used to evaluate the performance of diesel engine using biodiesel and its blends:

Brake Specific Fuel Consumption (BSFC):

The BSFC defined as the fuel flow rate per unit of power output is a measure of the efficiency of the engine in using the fuel supplied to produce work. It is desirable to obtain a lower value of BSFC meaning that the engine used less fuel to produce the same amount of work. It can be calculated by BSFC (g/kWh) = mf /BP Where, mf = fuel consumed (g/h) BP = brake power (kW) which can be calculated by: BP = 2*3.14*NT/60000 Where, T=WR, W = load (kW) at generator end R= Dynamometer effective radius, Numerous, authors [5, 15, 39, 42, 45, 46] have performed the experiment on the diesel engine to increase the BSFC using various blends of biodiesel from various resources including diesel. The finding these authors indicates that there is increase in the BSFC when using biodiesel as compared to diesel for the same power output. This is because that the heating value of biodiesel is less as compared to diesel.

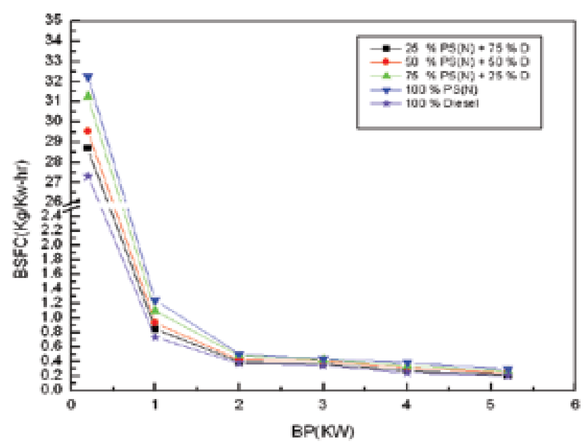

Fig.1

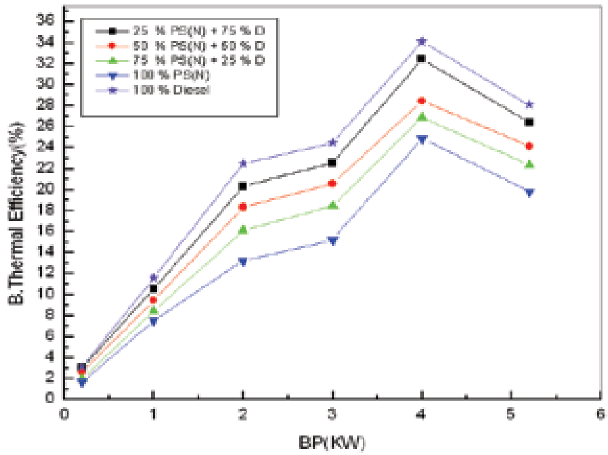

Fig.2

Fig. 1 & 2 Shows the variation of BSFC & BTE with Brake power output for Palm Stearin oil and its blends with Diesel in the test engine.

Brake Thermal Efficiency (BTE)

It is the ratio of the thermal energy in the fuel to the energy delivered by the engine at the crankshaft. It greatly depends on the manner in which the energy is converted as the efficiency is normalized respect to the fuel heating value. It can be expressed by: BTE (b) = BP/(mf x CV) Where, BP = brake power (kW) mf = fuel consumption (kg/sec) CV = calorific value (kJ/kg) BTE has also been determined by various workers [18, 26, 39, 42, 45, 46] using biodiesel as fuel and it is found that there is no significant change in the thermal efficiency while using biodiesel up to B20 but there is a slight decrease in thermal efficiency when B100 was used which is due to the lower energy content of biodiesel.

Engine Emission Parameters:

Literature has further reveals that the engine operation on biodiesel blend with diesel emit lower gaseous emission than diesel fuel expect NOX which increase to 2% with B20 and 10% with B100 use. Further, the use of biodiesel or its blend with diesel increases the NOx emission and decreases the CO and HC emission.

The comparison of emission of B100, B20 and diesel is given in following table 3.

Table III Emission Comparison of Biodiesel And Diesel

S.No.	Type of emission	B100	B20
1	Hydrocarbon (HC)	-67%	-20%
2	CO	-48%	-12%
3	Particulate matter (PM)	-47%	-2%
4	NOX	+10%	+2%
5	SO2	-100%	-20%
6	PAH	-80%	-13%

Exhaust Gas Temperature

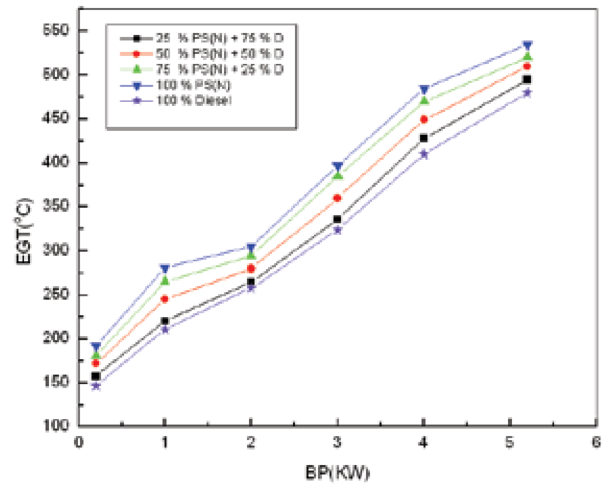

Fig. 3 Shows the variation of Exhaust Gas emperature with Brake power output for Palm Sterin oil and its blends with diesel in the test engine. 25% blend of Palm stearin has lower EGT compared to all other blends for all loads.

V. Results and Conclusion

In this review, it was shown that there are so many different types of biodiesel and blends of biodiesel with diesel as alternative fuel which can be used successfully operated in different types of diesel engines such as direct, indirect, turbocharged and naturally aspirated without modifications. It can be concluded that the use of biodiesel will lead to loss in engine power mainly due to the reduction in heating value of biodiesel compared to diesel, and it result in the increase in biodiesel fuel consumption. Thermal efficiency of engine was found similar with pure biodiesel and blended biodiesel at low loads. However at high loads efficiency got decrease for pure biodiesel compared to blended one. The vast majority of literatures agree that NO*x* emissions will increase when using biodiesel. This increase is mainly due to higher oxygen content for biodiesel. It is predominant viewpoint that HC & CO emission reduces when biodiesel is fuelled instead of diesel.

REFERENCES

[1] B. Deepanraj, C. Dhanesh "Use of palm oil biodiesel blends as a fuel for compression ignition engine" in *American Journal of Applied Sciences* 8(11) , pp.1154-1158, 2011.

[2] S.S. Wiraman, A.H. Tambunan, " The effect of palm biodiesel fuel on the Performance and Emission of the automotive diesel engine" Agricultural Engg. International, the CIGR Ejournal, Manuscript EE 07 005 Vol. X April 2008

[3] H. Mulimani M.C. Navindgi, " Extraction of biodiesel from vegetable oils and their comparisons" Issue 2, Volume 2 *International Journal of Advanced Scientific Research and Technology.*

[4] C. Solaimuthu, D. Senthilkumar , " An experimental investigation of performance, combustion and emission characteristics of mahua oil methyl ester on four stroke direct injection diesel engine" in *Indian Journal of Engg. & Material Sciences*. Vol 20, February 2013, pp. 42-50.

[5] C. Naga Prasad, Vijaya Kumar Reddy, "Performance & Emission characteristics of a diesel engine with castor oil" in *Indian Journal of science & technology"* Vol. 2 No. 10 (Oct. 2009).

[6] K. Arumugam, S. Veeraraja, " Methyl ester of vegetable oil – A promising alternate fuel" in *International Journal of Applied Engg. Research* Vol. 8, No. 15, 2013 pp. 1765-1772.

[7] Kalam MA, Masjuki HH .Biodiesel from palmoil an analysis of its properties and potential. BiomassBioenergy 2002; 23:471–9.

[8] Anand K, Sharma RP, Mehta PS. Experimental investigationson combustion of Jatropham methyl ester in a turbochargeddirect-injection diesel engine. P MechEng D-JAut 2008.

[9] A. Haiter Lenin, R. Ravi, "Performance Characterstics of a diesel engine using Mahua Biodiesel as alternate fuel" in *Iranica Journal of Energy & Environment* 4(2), pp.136-141, 2013.