Comparative Analysis of Performance Characteristics of a C. I. Diesel Engine Fuelled with Biodiesel Blends Derived from Mahua oil and Jatropha oil. A Review

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Abstract: The increasing demand of green energy, awareness of the depletion of conventional fossil fuel resources and the environmental benefits of biodiesel fuel has made it more attractive in recent times. To fulfill the requirement of demand for consumption of petroleum products the alternate fuel must be produced in such a manner that it can be used directly in present engines without much engine modifications. Due to economic, environmental and social factors, biodiesel is becoming the preferable alternative to conventional petro-diesel fuel options. The objective of this to study the engine performance and emission characteristics of biodiesels and its blends produced from various vegetable oils like jatropha oil, mahua oil, karanja oil, etc. and compare those with that of pure diesel. The cost of biodiesel is the major hurdle to its commercialization in comparison to petroleum-based diesel fuel. To overcome price issue /resolve this, dual biodiesel fuel blending is one of the option which solve this problem. Biodiesel produced from different vegetable oils are blended with diesel fuel in varying proportions in compression ignition (CI) engine and the most preferable combination of the blend for diesel engine is determined.

Index Terms: *CI engine fuel Verses Biodiesel.*

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I. INTRODUCTION

During the last century, the consumption of energy has increased a lot due to the change in the life style and the significant growth of population. This increase of energy demand has been supplied by the use of fossil resources, which caused the crises of the fossil fuel depletion, the increase in its price and the serious environmental impacts as global warming, acidification, deforestation, ozone depletion, Eutrophication and photochemical smog. As fossil fuels are limited sources of energy, this increasing demand for energy has led to a search for alternative sources of energy that would be economically efficient, socially equitable and environmentally sound. The expected scarcity of petroleum supplies and the negative environmental consequences of fossil fuels have spurred the search for renewable transportation biofuels. The demand for transport fuel has been increasing and expectations are that this trend will stay unchanged for the coming decades. However, resources of these fuels are running out, prices of fossil fuels are expected to rise and the combustion of fossil fuels has detrimental effects on the climate. [1]

In spite of giving a relatively lower thermal efficiency the power output offered by vegetable oils is almost the same as that by diesel. High viscosity of neat vegetable oils causes the main problem in using it fuel for diesel engines. Problems caused due to high viscosity are as follows; the choking of fuel lines and filters, poor atomization of fuel, incomplete combustion, severe engine deposits, injector choking with trumpet formation and piston ring sticking, gum formation and thickening of lubricating oil. The problem of high viscosity is approached with various methods to reduce the viscosity such as biodiesel blending with other fuels. [2]

A. Biodiesel

In the most general sense, biodiesel refers to any diesel fuel substitute derived from renewable biomass. More specifically, biodiesel is defined as an oxygenated, sulfur-free, biodegradable, non-toxic, and eco-friendly alternative diesel oil. Chemically, it can be defined as a fuel composed of mono-alkyl esters of long chain fatty acids derived from renewable sources, such as vegetable oil, animal fat, and used cooking oil designated as B100, and also it must meet the special requirements such as the ASTM and the European standards. One popular process for producing biodiesel is transesterification. Biodiesel is made from a variety of natural oils such as soybeans, mahua, jatropha, rapeseeds, coconuts, and even recycled cooking oil. Biodiesel can however be effectively used to replace our diesel requirements.

There are various advantages of vegetable oil & derived biodiesel as listed below:

- Biodiesel can be produced by individuals on a small scale relatively inexpensively when compared to Petrodiesel.
- Vegetable oil if used as fuels can provide good lubrication to the engine.
- No large amount of toxic gases would be emitted, no greenhouse gas emission as the carbon which is taken during the growth of plants would be sent back into the air. This is known as ‘carbon neutrality’.
- When Biodiesel is used to power diesel engines, the emissions at the tailpipe are significantly reduced. Studies by the US National Renewable Energy Lab indicate drops in several key areas’ that help the environment.

- Vegetable oil seeds can be grown in wastelands and other lands with low nutritional content. The plant is also a Nitrogen fixer.
- However the biggest advantage of using it is the economic aspect. The dependence on vegetable oil would generate large scale employment in rural areas.
- The average income of the households will increase the government which spends thousands of crores providing subsidies on the petroleum goods can use this huge pool of money in other sectors.

Hence we observe that the use of vegetable oil is definitely oil which has the potential to solve our energy needs in the future. [3-7]

B. Properties of vegetable oil:

Biodiesel is a better fuel than diesel fuel in terms of sulphur content, flash point, and aromatic content. The fuel characteristics of biodiesel are close to diesel fuels, and therefore biodieselbecomes a strong alternative to replace the diesel fuels. The conversion of triglycerides into methyl or ethyl esters through the transesterifcation process reduces the molecular weight to one-third that of the triglyceride reduces the viscosity by a factor of about eight and increases the volatility marginally.These esters contain 10 to 11% oxygen by weight, which may improve combustion as compared to hydrocarbon based diesel fuels in an engine. Since the volatility increases marginally, the starting problem persists in cold conditions. Biodiesel has lower volumetric heating values (about 12%) than diesel fuels but has a high cetane number and flash point. Some of the desirable fuel properties of biodiesel derived from different vegetable oils are presented in Table I.

Table I
Property of vegetable oil and diesel fuel

Properties	Diesel	Mahua oil	Jatropha oil	Karanja oil
Density (gm./cc)	0.840	0.918	0.921	0. 929
Calorific value (kJ/kg)	42490	37614	39071	38507
Cetane number	45	40	43	41
Viscosity@ 40 ^{0}C	3.05	39.45	35.98	46.5
Flash point ^{0}C	58	276	229	248

II. LITERATURE REVIEW

Rahul Patel, Kshitiz K. Jain, Satyam Sharma, Saurabh Barange (Dec. 2014): 'Performance and emission characteristics of diesel engine using vegetable oils and its blends'; IJAERS IV.

Recent studies have shown that vegetable oil can be a high potential component for production of biodiesel. Due to economic, environmental and social factors, biodiesel is becoming the foremost alternative to conventional petro-diesel fuel options. The objective of this article is to study the engine performance and emission result of biodiesel produced from various vegetable oils like jatropha oil, mahua oil, cottonseed oil, etc. Viscosity of vegetable oil is high as compared to conventional diesel fuel which causes some problems. To solve the problem of high viscosity, various methods and techniques are used. Fuel blending is one of the techniques which solve this problem. Different vegetable oils are blended with diesel fuel in constant speed single cylinder engine and showing its effect on performance and emission characteristics of diesel engine. [2]

Purna C. Mishra, Swarup. K. Nayak, Durga. P. Ghosh, Manoj Ukamanal,Sushanta.K. Sahu (Aug. 2013): 'Performance Characteristics of a Diesel Engine Fuelled with Biodiesel Produced from Mahua Oil Using Additive'; IOSR-JMCE.

The demand for consumption of petroleum products increased with vehicles population. For addressing the present problem we discussed alternate fuel. Moreover, the alternate fuel must be produced in such a manner that it can be used directly in present engines without much engine modifications. Edible and non-edible oils are the main source for alternate fuel. In this paper we have discussed the performance characteristics of a diesel engine fuelled with mahua oil using additive. Due to high viscosity and low volatility of non-edible oils their prolonged use is not advisable. These problems can be minimized by the transesterification process which is a reaction of triglyceride and alcohol in presence of a catalyst to produce mono alkyl ester which is known as biodiesel and glycerol .The biodiesel was blended with additive in various proportions to prepare a number of test fuels which are tested on a diesel engine to study various parameters. The result shows biodiesel with 10% additive (Dimethyl carbonate) is best suited for diesel engine. [3]

B. L. Maharana, Dr. H. Chnadra (2015): Evaluation of performance of diesel engine with biodiesel; E-ISSN2249–8974/Bitcon-2015.

Biodiesel is an environmentally friend renewable diesel fuel alternative. The performance characteristics of the engine with pure diesel a blended diesel fuel have been compared. From the results obtained, it is understood that the thermal efficiency is slightly less with biodiesel when compared with pure Diesel. This is due to addition of oxygen atoms with increase in value of blending. And specific fuel consumption is slightly higher with bio-diesel when compared with pure diesel due to the lower calorific value of the biodiesel. It is concluded that the biodiesel can be used as alternative fuel in the Diesel engine without any engine modifications. [4]

A.F. Sherwani , A. Sharma, A.K. Yadav (Sept. 2013): 'Comparative Analysis of Performance and Emission Parameters of A C.I. Engine Fuelled With Different Blends Of Biodiesel Derived From Mahua Oil And Waste Cooking Oil'; IJIRSET Vol. 2.

Now a day the world is facing the duel crises of fossil fuel depletion and environmental degradation. Alternative fuels should be, not only sustainable but also environmentally friendly. Biodiesel is a safe alternative fuel to replace traditional petroleum diesel. The present study focuses on comparison of performance and emission of a 4-stroke CI engine run on three different biodiesels viz. MOME, MOEE and WCOME separately. MOME, MOEE and WCME blended with diesel in proportions of 5%, 10%, 15% and 20%, by volume and pure diesel were used as fuel. Engine performance (specific fuel consumption, brake thermal efficiency, and Brake power) and exhaust emission (HC, CO, CO_2 and NOx) were measured to evaluate and compute the behavior of the diesel engine running on biodiesel. The engine test result shows higher brake thermal efficiency and lower NOx Emission in case of methyl ester of Mahua oil compared to other two fuels i.e. MOEE and WCOME. [5]

III. MATERIALS AND METHODS

A. *Materials*

1) *Mahua (Madhuca Indica) & Jatropha:* The two major species of genus madhuca found in India are Madhuca Indica (Longifolia) and Madhuca Indica (Latifolia). The seed potential of this tree in India is 500,000 tons and oil potential is 180,000 tons. Mohua a large ever green tree found in south India and evergreen forest of the Western Ghats. Similarly Jatropha oil is derived from its seeds.The kernels are 70% of seed by weight. Oil content in Mahua is 46% and 52% in Jatropha. In seed, oil content 35% and 32% protein.
2) *Dimethyl carbonate:* Di methyl carbonate is a colourless, transparent liquid under normal temperature.

B. *Fuel Formulation Techniques*

One of the main problems of vegetable oil use in diesel engine is their higher kinematic viscosity because of heavier triglycerides and phospholipids, due to which problems occur in pumping and atomization, ring-sticking, carbon deposits on the piston, cylinder head, ring grooves, etc. Straight vegetable oils are not suitable as fuels for diesel engines; since they have to be modified to bring their combustion related properties closer to mineral diesel. Heating/ pyrolysis, dilution/ blending, micro and transesterification are some well-known techniques available to overcome higher viscosity related issues associated with use of vegetable oil in diesel engine and to make them compatible with the hydrocarbon-based diesel fuels.

1) *Heating/ Pyrolysis*

Heating/ Pyrolysis is the process in which high molecular weight compound breaks in to smaller compounds by means of heat with or without catalyst. Pyrolysis refers to a chemical change caused by the application of heat energy in the absence of air or oxygen. The liquid fractions of the thermally decomposed vegetable oils are likely to get converted into liquid oils. Many investigators have studied the Pyrolysis of triglycerides to obtain products suitable for diesel engines. The Pyrolyzate oils have almost same viscosity, flash point, and pour point compared to diesel fuel with equivalent calorific value. The cetane number of the Pyrolyzate oil has been found to be lower. The Pyrolyzate oils from vegetable oils contain acceptable sulphur content, water and sediment and give acceptable copper corrosion values but unacceptable ash and carbon residue.

2) *Dilution/ Blending*

High viscosity fuels like vegetable oils can be mixed with low viscosity fuel like diesel to overcome overall viscosity. These blends can then be used as diesel engine fuels. Dilution of vegetable oils can be accomplished with a solvent, methanol or ethanol. Vegetable oil can be directly mixed with diesel and may be used to run diesel engines.

3) *Micro-Emulsification*

A micro-emulsion is a system consists of a liquid dispersed, with or without an emulsifier, in an immiscible liquid, usually in droplets smaller then colloidal size. Micro-emulsions are isotropic, clear, or translucent thermodynamically stable dispersions of oil, water, surfactant, and often a small amphiphilic molecule, called co-surfactant. The droplet diameters in micro-emulsions range from 100 to 1000 Å. A micro-emulsion can be made of vegetable oils with an e dispersant (co-solvent), or of vegetable oils with an alcohol and a surfactant and a cetane improver, with or without diesel fuels. Micro because of their alcohol content have lower volumetric heating values than diesel fuels, but the alcohols have high latent heat of vaporization and tend to cool the combustion chamber, which would reduce nozzle choking. A micro methanol with vegetable oils can perform nearly as well as diesel fuels.

4) *Transesterification reaction*

Transesterification is a reversible reaction between triglyceride and alcohol in presence of catalyst to produce glycerol and mono alkyl ester which is known as biodiesel. Weight of the mono alkyl ester is one third of that of typical oil and therefore has lower viscosity. Alkali (NaOH, KOH), acid (H_2SO_4, HCL) or enzymes (lipase) catalyzed reaction. Acid catalyzed transesterification is most commonly used process because it is a reversible reaction. The chemical reaction which describes the preparation of biodiesel is:

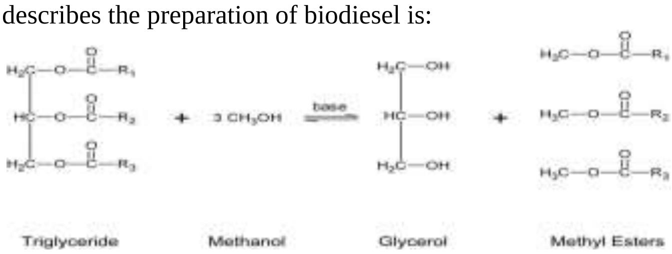

Fig. 1 Reaction process for transesterification

In this figure R1, R2, R3 represent long carbon chains. In the transesterification process methanol and ethanol are more common. Methanol is more extensively used due to its low cost and physiochemical advantages with triglycerides and alkali are dissolved in it. Mostly biodiesel is produced by base catalyzed transesterification process of oil and it is more economical.

C. *Biodiesel Production Methodology:*

1) *Heating and Cooling*

One litre of mahua oil was poured into the glass beaker and placed on heater for heating. Oil was heated above 100^0c (approximately 115^0c) with beaker mouth open to atmosphere and maintained this temperature about 15 minutes, this is done to remove the water particles present in the oil which effect the reactions that are performed on the oil further. Heating was performed with continuous stirring and this is performed by magnetic stirrer which is placed inside the glass beaker in the oil. After this part cool the oil to 45^0C-50^0C. Filter the cooled oil with a neat cloth for removing any dust or dirt particles present in it.

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2) Acid Treatment

Add 120-150ml of CH_3OH methanol per litre of oil and close the conical flask with rubber stopper, this is done to avoid evaporation of methanol (since the boiling point temperature of methanol is 55^0 C to 60^oC). After half an hour add 3-7 ml of H_2SO_4 and maintain the temperature between 50^0C-55^oC (should not be more than 60^oC). After 1 hour (reaction time) take this liquid into separating flask for 2 or 3 hours later the liquid separates into two immiscible liquids.

Take 200ml of methanol in round bottom flask and add 6.5gm of sodium hydroxide pellets and shake well so that there is no solved particle of sodium particles. This forms the sodium methoxide solution. Mix the sodium methoxide with the acid treated oil n maintains the temperature of (50-58) ^0C in conical flask. The colour of the oil changes from pale yellow to dark brown. Pour the oil in the separating funnel.

3) Settling

The oil has been settled for 12hr. we observe the biodiesel at the top of funnel glycerol at the bottom. Remove the glycerol from the bottom of the separating funnel.

Fig. 2 Settling of base treatment

IV. EXPERIMENTAL SETUP

A. *Specification of engine*

4 Stroke single cylinder diesel engine is tested and performance is obtained for pure diesel and blended diesel.

4 Stroke diesel engine having a loading system, a rope brake arrangement, water cooling system, engine base to minimize the vibration, a manometer, thermocouples for temperature measurement.

Fig 3: 4-stroke compression ignition engine

The specification of diesel engine in which experiment is performed is as follows:

Table II
Specification of engine

FUEL	DIESEL
TYPE OF IGNITION	COMPRESSION
MAKER	KIRLOSKAR
TYPE	VRC-1
POWER	3.7 KW
BHP	5
NO. OF CYLINDER	ONE
COMPRESSION RATIO	16.5:1
BORE	80 mm
STROKE	110 mm
ORIFICE DIAMETER	22 mm
METHOD OF LOADING	ROPE BREAKE
METHOD OF STARTING	CRANK START
TYPE OF GOVERNOR	CENTRIFUGAL
SFC	250 gm/kwh

B. *Result analysis*

1) Total Fuel Consumption (TFC)

Accurate measurement of fuel consumption is very important in engine testing work. The figure 4 shows the comparison between the fuel consumed by various biodiesel blends and conventional diesel.

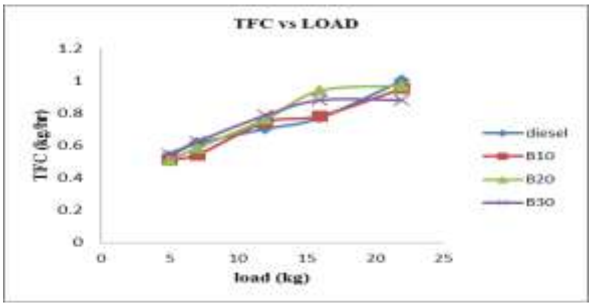

Fig. 4: Variation of TFC with Load

The amount of fuel required is higher as the amount of biodiesel in the blend increases. This may be due to the lower calorific value of biodiesel. However the values are comparable with that of conventional diesel.

2) Effect of Load on Specific Fuel Consumption

Specific Fuel Consumption (SFC) 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 SFC indicating that the engine used less fuel to produce the same amount of work. Figure 5 gives a comparison of SFC of various blends of biodiesel with that of conventional diesel. The specific fuel consumption keeps on decreasing with increasing load. Fuel consumption is more for biodiesel blends since the calorific value of biodiesel is lesser than conventional diesel. However the value of SFC of biodiesel blends are not very high when compared to pure diesel. This shows that the using of blended biodiesel is economically acceptable.

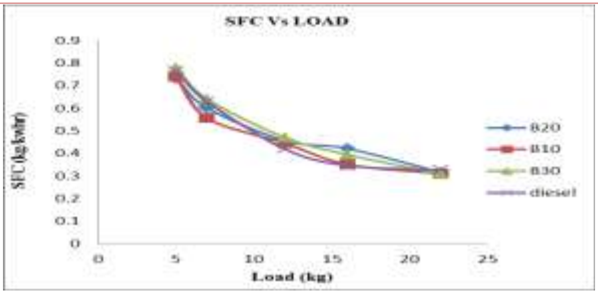

Fig.5: Variation of Specific Fuel consumption with Load

3) Effect of Load on Brake Thermal Efficiency

The brake thermal efficiency is defined as the ratio of brake horse power to the heat energy of the fuel supplied during the same interval of time. Figure 6 shows the variation of brake thermal efficiency with different loads for different biodiesel blends and pure diesel. From the plot it is clear that thermal efficiency increases with load. This is due to the reduction in heat loss and increase in power developed with increase in load. The brake thermal efficiency of biodiesel blends is slightly lower than conventional diesel. This reduction in brake thermal efficiency with biodiesel blends was due to higher viscosity, poor spray characteristics and lower calorific value. The higher viscosity leads to decreased atomization, fuel vaporization and combustion.

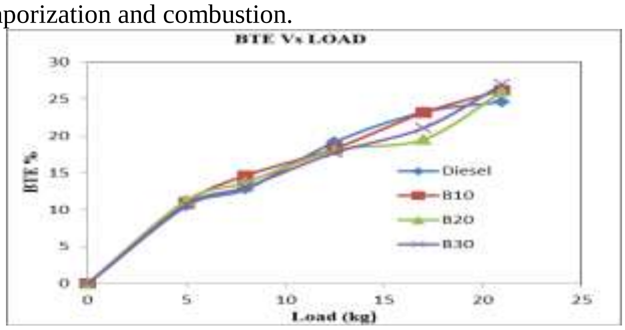

Fig. 6: Variation of Brake Thermal Efficiency with Load

4) Effect of Load on Indicated Thermal Efficiency

The efficiency of various biodiesel blends and conventional diesel is shown in figure 7. Here efficiency increases with load. However the efficiency of the prepared biodiesel blends is comparable with the efficiency of conventional diesel. Hence the biodiesel blends can be used in engines to obtain good performance.

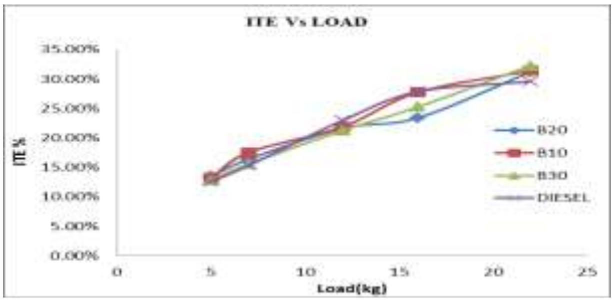

Fig. 7: Variation of Indicated Thermal Efficiency with Load

V. EXPERIMENTAL WORK

The biodiesel was blended with additive in various proportions to prepare a number of test fuels which are tested on a diesel engine to study various parameters like carbon residue, fire point, flash point, viscosity, pour point, cloud point, cetane index etc. and compare those with that of diesel .

Further the blending of Diesel with single & dual Biodiesel is done in different proportion which to be tested. The proportions are as follows:

- B00 fuel (Pure Diesel)
- DuB5 fuel (95% Diesel + 5% Dual Biodiesel Blends)
- DuB10 (90% Diesel + 10% Dual Biodiesel Blends)
- DuB15 (85% Diesel + 15% Dual Biodiesel Blends)
- DuB20 (80% Diesel + 20% Dual Biodiesel Blends)
- DuB25 (75% Diesel + 25% Dual Biodiesel Blends)
- DuB30 (70% Diesel + 30% Dual Biodiesel Blends)

Dual Biodiesel blending: In dual biodiesel blending, we are going to blend two different biodiesel like combination of 50% Mahua oil & 50% Jatropha oil derived biodiesel. The dual blending contains equal blending quantity of two different biodiesels.

VI. CONCLUSION

After experimentation the performance characteristics and the most preferable combination of the blend for diesel engine will be determined. The overall result will be verified & hence concluded.

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