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International
Journal
Of Modern Engineering Research (IJMER)

Study of Performance of Different Blends of Biodiesel Prepared From Waste Cottonseed Oil

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Abstract : *The use of biodiesel is rapidly expanding around the world, making it imperative to fully understand the impacts of biodiesel on the diesel engine combustion process and pollutant formation. Biodiesel was made by the well-known transesterification process. Waste cottonseed oil was selected for biodiesel production. Three different blends of biodiesel were prepared i.e. B10, B20 and B30. These three blends were fuelled in a compression ignition (C.I.) engine. A maximum of 77% biodiesel was produced with 20% methanol in presence of 0.5% sodium hydroxide. Different parameters for the optimization of biodiesel production were investigated in the first phase of this study, while in the next phase of the study performance test of a diesel engine with neat diesel fuel and biodiesel mixtures are to be carried out. The performance characteristics like brake power (B.P.), brake specific fuel consumption (BSFC) and brake thermal efficiency. This performance was then compared with that of petro diesel.*
Keywords: *Alternative fuel; Vegetable oil; Biodiesel; Viscosity; Transesterification; Methanol.*

I. INTRODUCTION

With self-sufficiency as the most important national energy goal, the options are easily broken down into two fuel types: renewable and non-renewable. Using a combination of the two, that goal is in fact readily achievable. Biodiesel is gaining more and more importance as an attractive fuel due to the depleting fossil fuel resources. Chemically biodiesel is mono-alkyl esters of long chain fatty acids derived from renewable feed stock like vegetable oils and animal fats. It is produced by transesterification in which, oil or fat is reacted with a monohydric alcohol in presence of a catalyst to give the corresponding mono-alkyl esters. The alkali-catalyzed transesterification of vegetable oils proceeds faster than the acid-catalyzed reaction [1]. For an alkali catalyzed transesterification, the triglycerides should have lower free fatty acid (FFA) content, and the alcohol must be anhydrous to render soap formation. Soap formation lowers the yield of esters and renders the separation of esters and glycerol [3, 4, and 5]. Up to about 5% FFA, the reaction can be catalyzed using an alkali catalyst [6]. The extent of transesterification and side reactions depends upon the type of feedstock, catalyst formulation, catalyst concentration, alcohol to-oil ratio, reaction temperature and reaction time [7, 8]. Cottonseed oil was converted into biodiesel by alkali-catalyzed transesterification reaction at different factors. It was found that catalyst concentration 0.75%, temperature 65^{0}C, methanol to oil molar ratio 6:1 and agitation intensity 600 rpm provided optimum condition producing excellent yield (96.9%) of cottonseed methyl ester. [9] The increased viscosity and low volatility of vegetable oils lead to severe engine deposits, injector chocking and piston ring sticking [10]. However, these effects can be reduced or eliminated through transesterification of vegetable oil to form methyl ester [11-14]. Transesterification provides a fuel viscosity that is close to that of No. 2 diesel fuel. Transesterification has shown good potential for reducing engine problems associated with vegetable oils. Transesterification is the process of reaction of a triglyceride with an alcohol in the presence of a catalyst to produce glycerol and fatty acid esters.

The molecular weight of the ester molecule is roughly one-third that of a neat vegetable oil molecule and the ester has a viscosity approximately twice that of diesel fuel [15]. Yamane et al. [20] found that with unwashed biodiesel fuel, the engine is unstable and shows higher exhaust emissions compared with those of washed biodiesel fuel. In the present investigation different parameters for biodiesel production have been investigated and then engine emissions have been studied with neat diesel fuel and the biodiesel mixtures. Here the 100% biodiesel is termed as biodiesel and the different blends of biodiesel with diesel fuel are termed as biodiesel mixtures in the following. The effects of reaction temperature, catalyst percent-ages, alcohol percentages and reaction time for optimum biodiesel production have been studied. The biodiesel from CSO is termed as CSOME. Finally exhaust gas emissions with biodiesel mixtures have been investigated and compared with those of neat diesel fuel.

Nomenclature

B.S.E.C	Brake Specific Energy Consumption	CSOME	Cottonseed Oil Methyl Ester
B.S.F.C	Brake Specific Fuel Consumption	DI	Direct Injection
B.T.D.C	Before Top Dead Center	EL	Engine Load
B.T.E	Brake Thermal Efficiency	FAME	Fatty Acid Methyl Ester
B10	10% Biodiesel + 90% Diesel	FFA	Fat Free Acid
B100	100% Biodiesel	HC	Hydrocarbon
B20	20% Biodiesel + 80% Diesel	IMEP	Indicated Mean Effective Pressure
B30	30% Biodiesel + 70% Diesel	KOH	Potassium Hydroxide
BD	Biodiesel	M	Mass Flow Rate (Kg/S)
BMEP	Brake Means Effective Pressures	NA	Naturally Aspirated
BP	Brake Power	Naoh	Sodium Hydroxide
CA	Crank Angle	NOx	Nitrogen Oxide
CI	Compression Ignition	P	Power (Kw)
CR	Compression Ratio	p	Pressure (Kpa) (Mpa)
CSO	Cotton Seed Oil	Pm	Particulate Matter

II. Purposes Of This Work

The purposes of this work were as follows:

1. To produce test quantities of methyl ester (biodiesel) from waste CSO.
2. To determine the fuel properties of the biodiesel fuel.
3. To compare the performances of a diesel engine using neat diesel fuel and biodiesel mixtures separately.

Lots of research works on biodiesel production have been carried out so far, but data on the effect of reaction temperature, effect of catalyst, influence of alcohol on biodiesel production form CSO have not been investigated so far. The authors have an academic interest to investigate different parameters, like reaction temperature, catalyst percentage and alcohol percentage for optimum biodiesel production and the influence of biodiesel on engine Performance.

III. Measurement Of Properties Of The Biodiesel

Fuel properties of biodiesel such as density, viscosity, flash point and ester etc. of waste cottonseed oil content were determined using the standard test methods. After producing the biodiesel the properties of the biodiesel were determined by using various methods. The following properties were tested:-

Table 0-1 Apparatus used for calculating the properties

Property	Apparatus used
Density	Weighing balance
Kinematic viscosity	Redwood viscometer
Flash point	Flash and fire point apparatus
Fire point	Flash and fire point apparatus
Cloud point	Cloud and pour point apparatus
Pour point	Cloud and pour point apparatus

The observations measured by above methods of bio-diesel B100 fuel properties are compared with the standard petro-diesel fuel properties in the following table.

Table 0-2 Comparative properties of the petro-diesel and biodiesel

Property of oil	ASTM	Diesel Standard	Biodiesel B100 (from Waste CSO)
Density (30^0C), kg/m^3	-	850	910
Kinematic viscosity, cSt	<5	2.049	3.6
FFA, %	<2.5	-	3.6
Cloud point, ^{0}C	-3 TO 12	<10	-3
Pour Point, ^{0}C	-15 TO 10	-6	-8
Flash point, ^{0}C	>130	78	160
Fire point, ^{0}C	>53	83	165

IV. Experimental Setup And Procedure Of Experimentation

4.1 Testing of biodiesel in engine

A four stroke, single cylinder variable compression ratio diesel engine is employed for the present study. The detail specification of the engine used is given in table 4.1 below and experimental set up as shown below. The performance tests are carried out on the C.I. engine using various blends of biodiesel and diesel as fuels. The tests are conducted at the constant speed of 1500 rpm at various loads. The experimental data generated are documented and presented here using appropriate graphs. These tests are aimed at optimizing the concentration of ester to be used in the biodiesel-diesel mixture for 1 hr. engine test operation. In each experiment, engine parameters related to thermal performance of engine such as brake power, brake thermal efficiency, break specific fuel consumption.

4.2 Specifications of the engine

The performance characteristics were carried out on variable compression diesel engine. The specifications of the engine are as stated as below.

Table 4-1 Specifications of the engine

Engine	4 stroke, Variable compression diesel engine
No. of cylinders	Single cylinder
Cooling media	Water cooled
Rated capacity	3.5 kW @ 1500 RPM
Cylinder diameter	87.5 mm
Stroke length	110 mm
Connecting rod length	234 mm
Compression ratio	12:1-18:1
Orifice diameter	20 mm
Dynamometer	Eddy current dynamometer
Dynamometer arm length	145 mm

4.3 Experimentation Methodology

First the experimentation is performed with diesel (for getting the base line data of the engine) and then cotton seed oil methyl ester and also its different blends. The performance of the engine is evaluated in terms of brake thermal efficiency, brake specific energy consumption. It also found out economic viability. An eddy current dynamometer, a piezoelectric transducer and digital PT-100 type temperature sensor was calibrated and used in the setup by Apex Innovations. Following parameters were measured from the experimental CI engine setup.

1. Brake power (BP)
2. Brake specific fuel consumption (BSFC)
3. Cooling water temperature (inlet and outlet)
4. brake thermal efficiency
5. Speed of the engine

V. Results And Discussion

5.1 Performance Parameters

Worldwide, biodiesel is largely produced by methyl transesterification of oils. The recovery of ester as well as its kinematic viscosity is affected by the transesterification process parameters such as catalyst concentration, reaction temperature and reaction time. The above parameters were standardized to obtain methyl ester of waste cotton seed oil with lowest possible kinematic viscosity and highest level of recovery. The engine performance parameters and exhaust gas emission characteristics of B10, B20, B30 and diesel were compared.

5.1.1 Brake Power (BP)

Graph of the brake power (BP) as a function of load obtained during engine operation on different blends of biodiesel i.e. B10, B20 and B30 with diesel (petro diesel) at compression ratio of 18:1 has been shown in Figure 5.1. Brake power of the engine increases with increase in the load on the engine. Brake power is the function of calorific value and the torque applied. Diesel has more calorific value than the biodiesel, so diesel has the highest brake power among the different blends of biodiesel. Due to the more calorific value of B10 blend of biodiesel than B20 and B30, it has the more brake power as shown in figure 5.1.

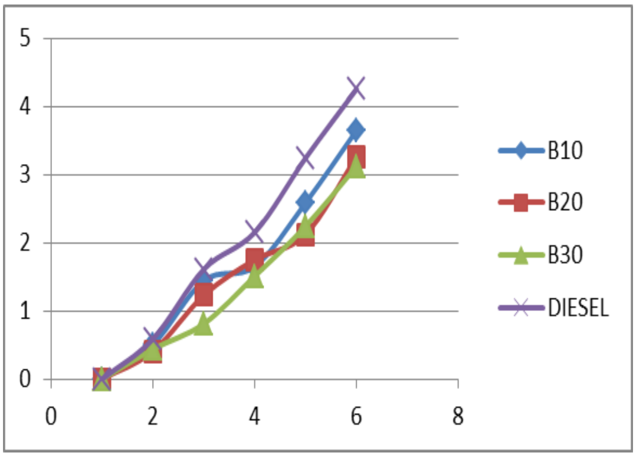

Fig 5-1 Variation in brake power with change in load

It can also be seen that as we increases the load, torque increases and thus there is an increase in brake power with the load.

5.1.2 Brake specific fuel consumption (BSFC)

Graph of the brake specific fuel consumption (BSFC) as a function of load obtained during engine operation on different blends of biodiesel i.e. B10, B20 and B30 with diesel (Petro-diesel) at compression ratio of 18:1 has been shown in Figure 5.2.

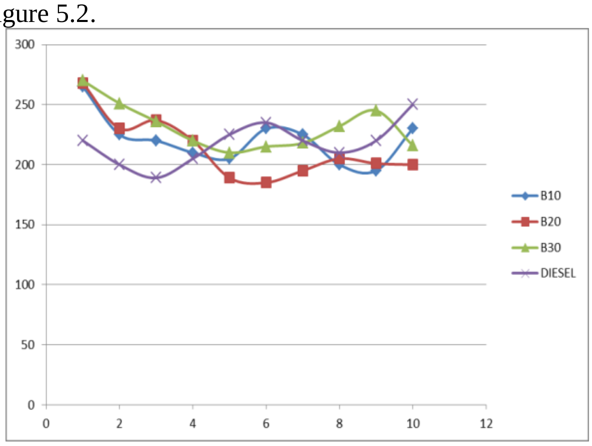

Fig.5-2 Variation in brake specific fuel consumption with change in load

For all blends and petro diesel tested, BSFC decreased with increase in load. One possible explanation for this reduction is the higher percentage of increase in brake power with load as compared to fuel consumption. It can be seen from the figure 5.2 that in case of biodiesel mixtures, the BSFC values were determined to be higher than those of neat diesel fuel. This trend was observed owing to the fact that biodiesel mixtures have a lower heating value than does neat diesel fuel, and thus more biodiesel mixtures was required for the maintenance of a constant power output. It is well known that brake specific fuel consumption is inversely proportional to the brake thermal efficiency. So diesel has the lowest brake specific fuel consumption. Among the three different blends of biodiesel B10 has the lowest value of brake specific fuel consumption.

5.1.3 Brake thermal efficiency (BTE)

Graph of the brake thermal efficiency as a function of load obtained during engine operation on different blends of biodiesel i.e. B10, B20 and B30 with diesel (petro diesel) at compression ratio of 18:1 have been shown in Fig 5.3. In all cases, brake thermal efficiency increases with an increase in load. This can be attributed to reduction in heat loss and increase in power with increase in load. It is also observed that diesel exhibits slightly higher thermal efficiency at most of the loads than CSOME and its blends. The molecules of bio-diesel (i.e. methyl ester of the oil) contain some amount of oxygen, which takes part in the combustion process. Test results indicate that when the mass percent of fuel oxygen exceeds beyond some limit, the oxygen loses its positive influence on the fuel energy conversion efficiency in this particular engine. So the brake thermal efficiency of diesel is more than that of biodiesel blends. Among the three different blends of biodiesel, B10 has higher brake thermal efficiency than B20 and B30.

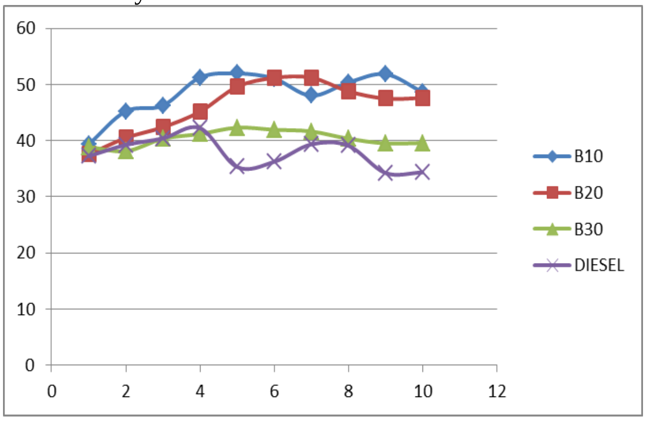

Fig 5-3 Variation in brake thermal efficiency with change in load

VI. CONCLUSION AND FUTURE SCOPE OF WORK

6.1 Conclusions

The overall studies based on the production, fuel characterization, engine performance and exhaust emission of different biodiesel blends of waste cotton seed oil methyl esters were carried out. The following conclusions can be drawn:

1. The recovery of ester by transesterification of waste cotton seed oil with methanol is affected by process parameters such as catalyst concentration and reaction temperature.
2. The graphical results show that diesel has better performance characteristics than biodiesel and biodiesel blends. Among the three different blends of biodiesel, B10 and B20 have the better performance characteristics than B30 blend of biodiesel when fuelled in an internal combustion engine.so we can fuel safely B10 and B20 in internal combustion engine without any modification.
3. The kinematic viscosity of diesel, waste cotton seed oil biodiesel were found as 2.049, 3.6 centistokes respectively at 40^0C. The results indicated that the waste cotton seed oil biodiesel had the kinematic viscosity 75.69 percent more than that of diesel.
4. The calorific value of diesel is 42000 KJ/kg and that of waste cotton seed oil is 40000KJ/kg. So the calorific value of waste cotton seed biodiesel is 4.76% less than that of mineral diesel.
5. Waste cotton seed oil biodiesel is non-toxic, biodegradable, environment-friendly, renewable fuels and do not add to global warming.

6.2 Scope of future Work

Biodiesel has distinct advantage as an automotive fuel. Initial cost may be higher but feedstock diversity and multi-feedstock production technologies will play a .2critical role in reductions in production cost and making the fuel economically viable.

The following points may be considered before introducing the fuel in India:

1. Biodiesel may be introduced as a diesel fuel extender or blends (B10, B20 and B30) and not as a sole diesel engine fuel (B100).
2. Government may consider providing support to the activities related to collection of seeds, production of oil from non-edible sources, production of bio-fuels and its utilization for cleaner environment.
3. Legal framework should be there to enforce regulations on bio-fuels.
4. The blends prepared for this project work were utilized within short time span. Thus, long term stability of blends was not studied. So there is scope for study of long term stability of blends.
5. Long-term performance and endurance test evaluate the durability of the engine with prolonged operation on these blends.
6. Energy education on biodiesel program and storing information and database for wider information dissemination among the public at large should be taken up at a larger scale.
7. Further studies can also be carried out on material compatibility, storage and utilization of by-product from biodiesel.

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