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Experimental Investigation of Mahua Methyl Ester as an Alternative Fuel for Diesel Engine

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Abstract: Energy consumption increases rapidly due to increase in population. Today, the energy crisis becomes one of the global issues confronting us. It is impossible to satisfy the needs in forthcoming years with fossil fuels itself. So, there is an urgent need for suitable alternative fuels for use in diesel engines. The non edible vegetable oils like Jatropa oil, Karanji or Pongamia oil, Neem oil, Jojoba oil, Mahua oil, Cottonseed oil, Linseed oil are considered as alternate fuels to diesel. Mahua oil which is promising alternative because they have advantages like they are renewable, Eco-friendly and produced easily in rural areas, where there is an acute need for modern forms of energy. In this investigation, Mahua Oil Methyl Ester was prepared by transesterification using Methanol (CH_3OH) and sodium hydroxide (NaOH) as catalyst and it is tested. The test has focused on the performance and emission characteristics of Mahua non-edible vegetable oil and its blend with diesel on a single cylinder diesel engine. The oil blended with diesel in 20/80%, 40/60%, 60/40%, 80/20% and 100% on the volume basis, then analyzed and compared with diesel at different loads at constant rated speed. From the test results showed that brake thermal efficiency of Mahua Oil Methyl Ester (MOME) was comparable with diesel and it was observed that 29.25% for diesel whereas 30.14% for MOME. Emissions of carbon monoxide, hydrocarbons, oxides of nitrogen and smoke number were considerably reduced in case of MOME compared to diesel. The present analysis reveals that the biofuel from mahua is quite suitable as an alternate fuel to diesel.
Keywords: Biodiesel, Raw Mahua oil, Transesterification, Mahua oil methyl ester, Engine performance and emissions.

Introduction

The transport sector plays a major role in the economic development of the country [1]. Diesel engines are used to power automobiles, locomotives, ships, irrigation pumps and also used widely to generate electric power[2]. Increase in population and standard of living of human beings will lead to energy crisis[3]. The rapid increase in the demand for diesel and other petroleum products India's dependence on oil import is expected to rise to 92% by the year of 2030[4]. Due to recent energy crises and dwindling reserves of crude oil the demand for alternate liquid fuels particularly the diesel is increasing[5]. There are many advantages in using bio-diesel as an alternate liquid fuels such as they are easily available, environmentally friendly potential, biodegradable and contribute to sustainability[6].

Biodiesel can be extracted from various edible and non-edible vegetable oils. Many researchers have recommended non-edible oils to be a sustainable alternative to edible oils for biodiesel production. They have identified several non-edible crops that can be used for biodiesel production which include Jatropa oil, Karanji or Pongamia oil, Neem oil, Jojoba oil, Cottonseed oil, Linseed oil, Mahua oil, Deccan hemp oil, Kusum oil, Orange oil and Rubber seed oil[7,8]. In this study, we took mahua oil biodiesel as an alternate fuel for diesel engine. The chemical composition of mahua oil is almost similar to that of other non-edible oils. It is prime reason behind selecting mahua oil as the raw material for bio diesel production [9]. Mahua oil is obtained from the seeds of madhuca indica, a deciduous tree which can grow in semi-arid, tropical and sub-tropical areas[10]. This oil is generally available in India and neighboring countries[11]. It has an approximate annual production possible of 181 thousand metric tones in India[12]. The drying and decortication yield 70% kernel on the weight of seed. The kernel of seed contains about 50 % oil. The oil yield in an expeller is nearly 34 - 37%[13,14]. When mahua oil is directly used as fuel in engine it causes problems like poor fuel atomization, incomplete combustion and carbon deposition formation, engine fouling and lubrication oil contamination, which is due to higher viscosity. To reduce the viscosity of mahua oil we may go for several conversion methods such as blending of oils, micro emulsification, cracking / pyrolysis and transesterification. Among this transesterification is widely used for industrial biodiesel production. Mahua oil gives better yield than other transesterified non edible oil[3]. Therefore, this study is mainly focused on production of mahua methyl ester using hybrid technology transesterification unit and measure the performance and emission characteristics of four stroke diesel engine.

Experimental

Transesterification

Transesterification is the process of using an alcohol (methanol, ethanol, proponol, or butanol) in the presence of catalyst to chemically break the molecule of the raw re-newable oil into methyl or ethyl esters of the renewable oils with glycerol as by-product.

$$\begin{array}{llcll}
CH_2-COO-R & CH_3OH & & R-COO-CH_3 & CH_2-OH \\
| & | & & | & | \\
CH-COO-R & +CH_3OH & \xleftrightarrow{\text{Catalyst}} & R-COO-CH_3 & +CH-OH \\
| & | & & | & | \\
CH_2-COO-R & CH_3OH & & R-COO-CH_3 & CH_2-OH
\end{array}$$

$$\text{Triglyceride} + 3\ \text{Methanol} \xleftrightarrow{\text{Catalyst}} 3\ \text{Bio diesel} + \text{Glycerol}$$

Table 1: Materials need for Transesterification

Sr. No	Chemical	Proportions
1	Mahua oil	1000ml
2	Catalyst- NAOH	6.5gram
3	Methanol	200ml

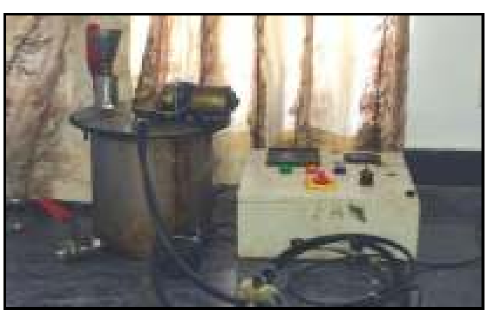

Figure 1: Transesterification unit

Transesterification Procedure

- The catalyst is dissolved into methanol by vigorous stirring in a flask.

- The oil is transferred into a round bottomed flask and is heated in a water bath at 70°c in water the prepared catalyst and alcohol mixture is added at first by constant stirring.
- The final mixture is stirred vigorously for 2hours at 340K in ambient pressure in an esterification unit.
- A successful transesterification produces two liquid phases: ester and crude glycerol. Crude glycerol being heavier liquid is collected at the bottom of the flask after several hours of settling.
- Phase separation can be observed within 10min and can be completed within 2hours of settling in the separating funnel. Complete settling can take as long as 20hours.
- Before collecting the oil in the separating funnel it is mixed water for distillation and easy phase separation.
- The separating funnel should be shaken well by bubble washing for two to three times while the mixture is allowed for phase separation.
- Finally, after 20hours, complete settling of oil and glycerol will take place.
- The esterified oil is collected after few times of bubble washing.

Biodiesel is then extracted from mahua oil and the fuel properties were checked.

Table 2: Properties of Diesel, Raw mahua and Mahua methyl esters

Properties	Diesel	Raw mahua oil	Mahua methyl ester
Kinematic viscosity at 40°C(cSt)	4.2	40.14	5.9
Calorific value (MJ/kg)	43.4	36	40
Density (kg/m3)	830	940	895
Flash point (°C)	57	224	136
Fire point (°C)	68	235	148

We found that properties of biodiesel were close to diesel properties. All the testing and analyses were done with biodiesel and their performance are compared with diesel fuel.

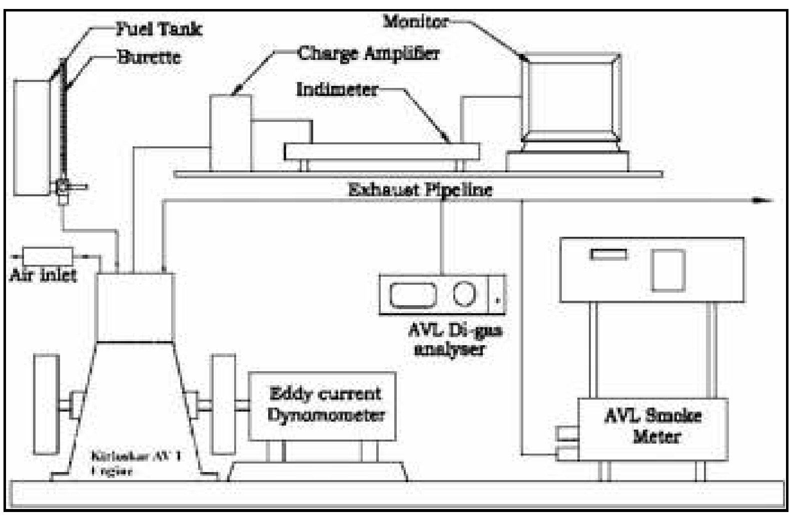

Figure 2: Experimental set up

1. Engine
2. Eddy Current Dynamo Meter
3. AVL Smoke Meter
4. AVL Di-Gas Analyses
5. Exhaust Gas
6. U Tube Mano Meter
7. Air box
8. Diesel Tank
9. Bio Diesel Tank
10. Control Valve
11. Load Indicator
12. Temperature Indicator
13. Speed Indicator
14. Charger Amplifier
15. Monitor

A four stroke diesel engine along with Di-gas analyzer and smoke meter is used in this experiment. The fuel properties of various blends of fuel where determined according to standard procedure. The engine was coupled with an eddy current dynamometer. The standard instrumentation was used to measure the fuel consumption, exhaust temperature, coolant temperature for the stabilization of measuring parameters at each load setting and at the start of each test, certain time period were allowed. The engine is started initially with diesel and the characteristics were checked with standard properties of fuel. Five blends of transesterified mahua oil with diesel, pure oil and pure diesel were tested with the engine. The fuel blends were prepared in the proportion of M0, M20, M40, M60, M80 and M100 volume by volume with diesel, respectively. The values of power output, specific fuel consumption (SFC) and brake thermal efficiency, and heat input and brake specific energy consumption etc. readings are automatically calculated and stored in high speed computer based design data acquisition system.

Engine specification:

Make	:	Kirloskar engine
Type	:	Naturally aspirated four stroke engine
Number of cylinders	:	Single Cylinder
Brake Power	:	3.7KW
Speed	:	1500rpm
Bore	:	80mm
Stroke	:	110mm
Stroke Volume	:	552.64CC
Ignition	:	Compression Ignition
Cooling	:	Water cooled
Load System	:	Resistive loading system

Results and Discussion

The fuel properties of diesel, raw mahua oil and mahua methyl ester is given in the table. It was observed that mahua methyl ester has close properties to diesel. The raw mahua oil has increased viscosity and density. After transesterifiction process the properties of the oil is changed. Though the specification of MOME matches with that of biodiesel, the kinematic viscosity is slight higher compared with standard diesel fuel. The specific gravity is comparable with that of diesel. Flash and fire points are higher in case of MOME than those of diesel so it has advantages for transportation.

Performance

Specific fuel consumption

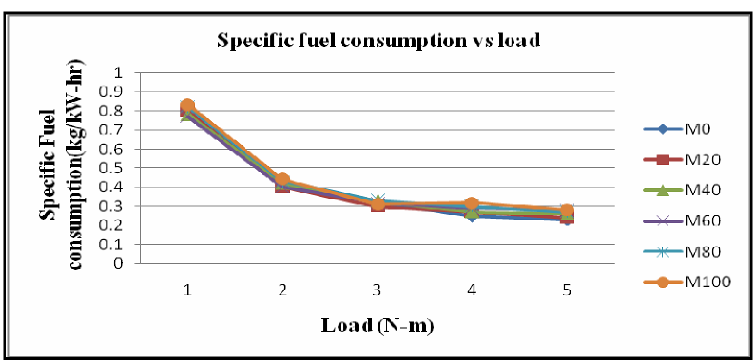

Figure 3: Variation in Specific fuel consumption vs load

The calorific value of biodiesel is less than diesel. Due to this reason the BSFC is higher than diesel. At low load condition the specific fuel consumption of fuel blends is lower than that of diesel. At full load condition the specific fuel consumption of the fuel blends is higher than the diesel fuel.

Brake thermal efficiency

The analysis is based on various test conditions and different composition of mahua methyl ester. Though the fuel used in engine test have different properties but their results were almost similar. The lower brake thermal efficiency is due to reduction of calorific value and due to increase in fuel consumption. At full load condition the M20 blend of mahua gives higher brake thermal efficiency of 30.14%. The brake thermal efficiency depends upon the combustion quality of the fuel. The decrease in values is due to poor combustion, low volatility, high viscosity and density.

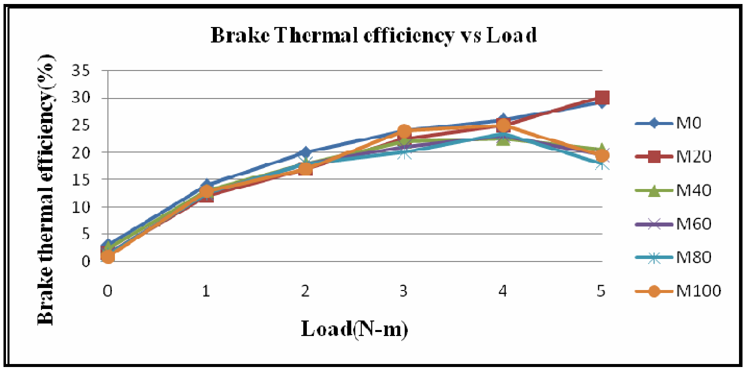

Figure 4: Variation in Brake Thermal efficiency vs Load

Emission

Carbon Monoxide (CO)

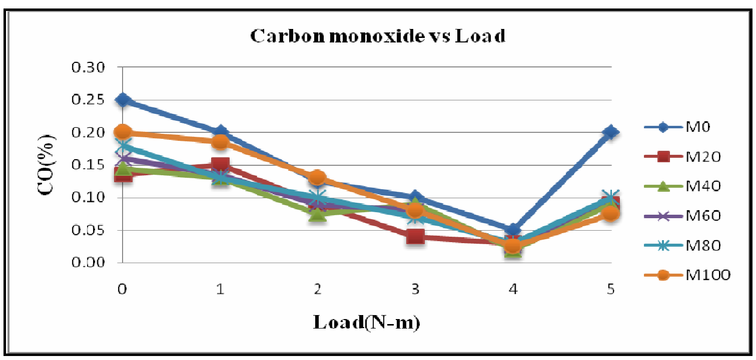

Figure 5 Variation in CO vs Load

At low and medium loads, the carbon monoxide emission for blends and mahua oil fuels were not much different from those of diesel. At full load, the carbon monoxide emissions of the mahua oil fuels decrease significantly when compared with diesel.

It is also observed that the carbon monoxide emission increase as the fuel air ratio becomes greater than the stoichiometric value. The carbon monoxide emission depends upon the oxygen content and cetane number of the fuel. The biodiesel has more oxygen content than the diesel fuel. So the biodiesel blends are involved in complete combustion process. The maximum carbon monoxide emission was observed at full brake power of the engine. So as to conclude that the fuel blends of M100 give low emission at full load conditions.

Unburned hydrocarbon (HC)

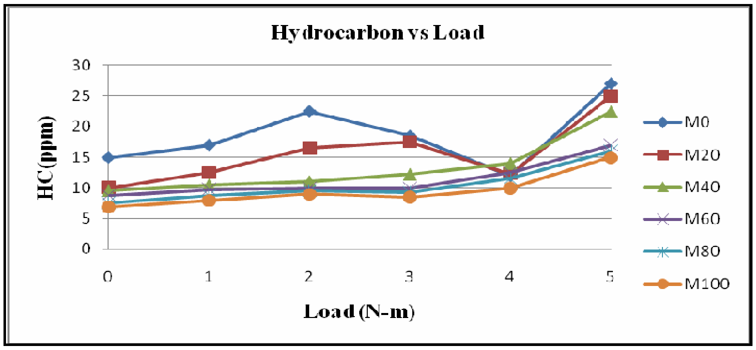

Figure 6: Variation in HC vs Load

The hydro carbon emission of various fuels is lower in low and medium loads but increased at higher loads. This is because, at higher loads, when more fuel is injected into the engine cylinder, the availability of free oxygen is relatively less for the reaction. The hydrocarbon emissions of the biodiesel blends are lower than the standard diesel due to complete combustion process.

Smoke

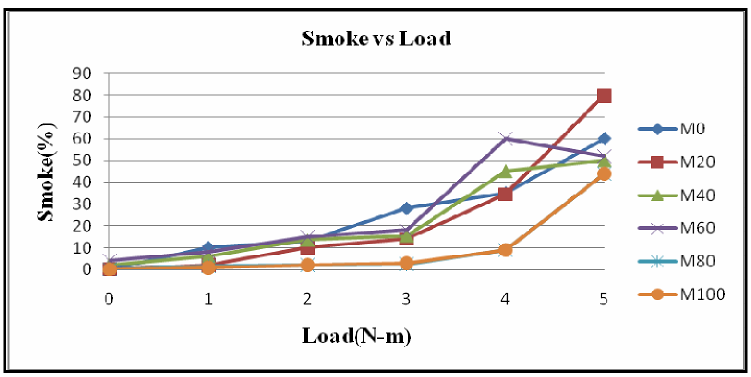

Figure 7: Variation in Smoke vs Load

Emission of smoke at low load and part load for mahua oil is lower than diesel this is due to the higher efficiency of mahua oil. It is found that the smoke density of the engine with mahua oil operation M20 was higher than diesel at full load condition. This negative effect is mainly due to the high viscocity and poor voltality of mahua oil caused poor injection and mixing characteristics and incomplete combustion, these can be overcome by preheating the mahua oil better performance. This is due to shorter delay period of fuel blends. The shorter delay period is mainly due to higher cetane number and better vaporization of fuel additives hence this duel effect helps to improve combustion temperature.

Oxides of Nitrogen (NOx)

NOx emissions depend up on the oxygen concentration and the combustion time. At all loads conditions NOx emission of biodiesel blends is always higher than that of standard diesel due to the oxygen concentration and combustion timing. The cetane numbers of the biodiesel blends are lower than that of standard diesel.

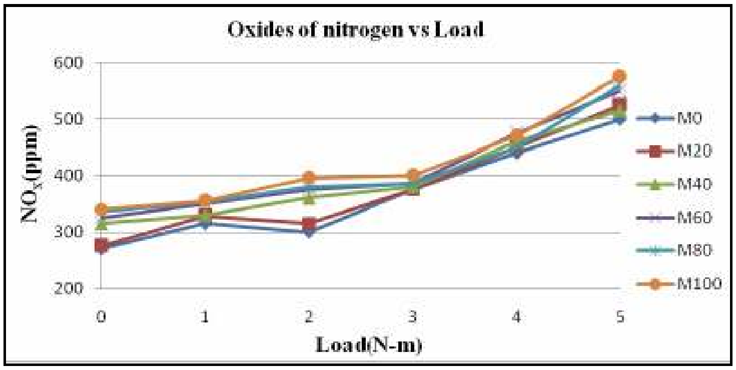

Figure 8:Variation in NO_x vs Load

Conclusion

By transesterification process the fuel (biodiesel) properties are closer to diesel fuel. The better yield obtained for transesterification process at 200 ml of methanol, 6.5 gms of NaOH for 1000 ml of mahua oil. When biodiesel was used as fuel, increments in the engine efficiency were mainly caused by the higher mixture heating value of the biodiesel. The deterioration of the engine efficiency for biodiesel fuel was caused by the higher viscosity of the biodiesel. If the % of biodiesel is increased more than 20% then viscosity slightly increases. Therefore efficiency gets decreases. If the % of biodiesel is less than or equal to 20% then viscosity is optimum. So that M20 has maximum efficiency. The performance and emission characteristics of use of mahua oil as engine fuels-a single cylinder compression ignition engine fuelled with mahua biodiesel and its blends have been analyzed and compared to the standard diesel fuel. Based on the experimental results, the following conclusions are obtained.

- The brake thermal efficiency of mahua biodiesel blends is higher than that of diesel at full load condition. The specific fuel consumption of M20 was minimum because of less fuel consumption. This is due to the density of the biodiesel is little much higher than diesel.

From the emissions test, we can say that M100 is more effective which has very less emissions than compared to any blends except for NO_x emissions. The emissions of carbon monoxide and hydro carbons are less when the percentage of bio diesel is increasing in the blend. This is because generally the vegetable oils have fewer emissions.

- The HC and CO emissions at different loads were found to be higher for diesel compared to mahua blends.
- At full load condition, M20 blend has more smoke density than the standard diesel.
- NO_x of biodiesel blends were always higher than the standard diesel.

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