Studies on utilization of different preheated straight vegetables oil in a CI engine

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Abstract - Renewable energy befits as an attractive and sustainable solution to compensate for the imbalance in the supply and demand of fossil fuels. Continuous depletion of fossil fuels, price variations and detrimental effect of greenhouse gas emissions are the burning issues in the current scenario. Non-edible vegetable oil can be considered as a comparable alternative to replace conventional diesel fuel. There are some operational issues with straight vegetable oils (SVOs) such as their less calorific value, higher density and higher viscosity etc. which may be dealt with by adopting an appropriate treatment before combustion. Present study has been undertaken on the use of non-edible oils available in the vicinity of the Institute Research Lab. Oils derived from the seeds of Jatropha and Mahua have been preheated to reduce their high viscosity, surface tension and density for meeting the fuel requirements and to use on engines. Experimental and comparative study about the emission and performance parameters has been carried out on a 3.5 KW diesel engine fuelled with preheated straight vegetable oils and diesel fuel. It has been found that at full load the brake thermal efficiency (BTE) of preheated straight vegetable oil is lower by about 8–10% as compared to diesel. Brake specific fuel consumption (BSFC) has been found comparable to diesel with a variation of approximately 2–5%. Emission components hydrocarbon and carbon mono oxide have been found to be reduced significantly in case of preheated oils. The results support the use of non-edible straight vegetable oils directly on the engine in preheated form without converting them into biodiesel by transesterification process. This research motivates the rural areas of developing countries to become self-reliant in energy production as most of these areas are enriched with huge amount of vegetation which can be used to produce edible and non-edible vegetable oil.

Keywords - Alternative fuel, Preheated straight vegetable oil, Engine Performance, Emission

NOMENCLATURE
SVO - Straight vegetable oil
BTE - Brake thermal efficiency
BSFC - Brake specific fuel consumption
CO - Carbon mono oxide
CO₂ - Carbon di oxide
HC - Hydro carbon

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NOX - Nitrogen oxides
μ - Viscosity of fluid
ρ - Density of fluid

1. Introduction

The escalating demand of fossil fuels in transportation sector, industrial sector, automobile sector, power sector etc. and the fast evolving mechanization has led to the search for alternative fuels which are globally acceptable technically and can be treated as an optimal solution to the problems of environmental degradation, energy security issues, employment and ultimately GDP of any country. R. Altin [1] elaborated that vegetable oils are not harmful for environment because of less content of HC, CO and NOX. Also, these oils have fairly good energy content and their properties are comparable to fossil fuels. These oils can be extracted from various plants and seeds which can be produced easily in variety of agricultural lands. Bernat Esteban et al [2] has done experimental research on vegetable oil and found that viscosity can be lower down by preheating at a temperature of about 140°C. It also improves the spray pattern, atomization and cetane rating of the fuel. Jeyachandran et al [3] analyzed that the peak pressure level (with SVOs) in engine cylinder was considerable when experimentation has done with diesel due to the notable modification in value of oil viscosity and improved droplet size. P Psonune [4] found from experiments that emission percentages of CO, HC and CO2 were dropped down due to preheating of fuel but at the same time NOx slightly increased. Nandkishore D. Rao [5] analyzed that vegetable oil emulsions with alcohol result in reduced viscosity, better combustion, and improved volatility.

Vijay Sisarwal et al [6] found from experimental investigations that the brake thermal efficiency with blends of vegetable oil was better than that obtained from straight vegetable oils because of improved combustion features. The brake specific fuel consumption with blends was found to be lower as compared to that obtained with straight vegetable oils due to better atomization of blends. M. Pugazhvadivu et al [7] analyzed that the performance of engine was enhanced and carbon oxide & hydrocarbon emissions decreased when diesel engine was run with preheated vegetable oil at 130°C. They concluded that SVO can be used as an alternative of diesel in extra ordinary conditions. Gaurav Dwivedi et al [8] analyzed five edible and four non-edible SVOs on the basis of structure of fatty acids. The findings were based on oxidation stability index and cold flow properties and SVOs were graded for biodiesel production.

M.S. Reddy et al [9] conducted an experimental study on a non-firing engine equipped with FIE simulator. The study was conducted to confirm the long-term compatibility and durability of bio-fuel blends. The major parts of FIE were investigated for wear. The fuels used for experimentation study were blends of Karanja, Jatropha, Biodiesel and baseline mineral diesel. The various parameters like dimensional loss, weight loss and surface texture deviation were estimated to analyze the compatibility of FIE with test fuels. Biodiesel blends showed relatively reduced percentage of wear compared to mineral diesel however SVO blends showed no specific trend compared to baseline mineral diesel. A.T. Hoang et al [10] revealed from the experimentation study that specific fuel consumption, carbon mono oxide, hydro carbon and smoke emissions were higher, but thermal efficiency and nitrogen oxide emissions were lower on using heated coconut oil (HCO) in comparison with diesel fuel. The study confirms the use of heated raw coconut oil (up to 100°C) as the most substitute fuel to attain the
better engine performance and emission characteristics.

Marym Dabi et al [16] has performed an experimental study on a CI engine and elaborated that use of excessive high preheated fuel may affect injection system, combustion and emission characteristics of the engine. Further, additional investment is required to sustain such higher preheating temperature. Therefore, the major issue is to optimize the fuel preheating temperature before feeding to the engine. He found that the best technique to use vegetable oil in the engine was blending in different percentages.

Narayan Lal Jain et al (17) conducted his study on preheated thumba oil and revealed that preheated optimized thumba oil (B20) blend gives 1.27% higher thermal efficiency and 0.02 kg/kwh lesser brake specific fuel consumption than the unheated same blend.

Anh Tuan Hoang et al (18) experimentally investigated the high-speed direct-injection diesel engine performance when operated for 300 hours with diesel fuel and preheated jatropha oil. The study focused on the deposit formation on the injector tips, spray characteristics, output power, and emissions. On the basis of SEM and EDS analysis, the deposits formed in the injector tips for preheated jatropha oil were found much more than the case of diesel fuel. The deposits formed on injector tip reduced the injector holes diameter and also partly obstructed injector holes which results the increase of penetration length and a reduction of cone angle

Based on the literature, it is derived that the preheated straight vegetable oils have a substantial potential for use in diesel engine. In the present experimental study, preheated Jatropha and Mahua SVOs have been used in a 4-stroke single cylinder diesel engine. Performance and emission characteristics have been determined at different loading conditions by maintaining a temperature range of 130°C to 150°C. The results have been compared with the performance and emission characteristics of the engine run on diesel fuel.

2. Material and Experimental Setup

2.1 Materials

In the present work, non-edible oils (Mahua and Jatropha) were used for experimental work, because they are not directly associated with human consumption. Oils used for the tests were properly filtered and used directly in the test engine. An electric heater was incorporated for oil heating and an eddy current dynamometer was used for torque measurement. In Table-1, various physical and chemical properties of diesel and vegetable oils have been enlisted.
Table-1 Properties of Diesel, Jatropha and Mahua Oils [11-15]

| Property                              | Jatropha | Mahua | Diesel |
|---------------------------------------|----------|-------|--------|
| Density at 15 °C (kg/m³)              | 920      | 920   | 840    |
| Flash point (°C)                      | 210      | 232   | 86     |
| Kinematic viscosity at 38 °C (cSt)    | 52       | 30    | 5.7    |
| Pour point (°C)                       | -3       | -10   | -15    |
| Total acid number (mg KOH/g)          | 0.92     | -     | 0.15 - 0.24 |
| Cetane number                         | 35-40    | 38-41 | 45-55  |
| Specific gravity                      | 0.918    | 0.92  | 0.867  |
| API gravity                           | 22.7     | 24    | 31.7   |
| Calorific value (MJ/kg)               | 39.774   | 36    | 43.8   |
| Saponification value                  | 198      | 192   | -      |
| Acid Value                            | 11       | 23.93 | -      |
| Iodine number                         | 94       | 73    | -      |
| Carbon residue (% w/w)                | 0.64     | 0.65  | 0.1    |

2.2 Experimental Setup

Table-2 shows typical specifications of the diesel engine used for the testing. The water cooled diesel engine was used with some modifications in the fuel intake system.

Table-2 Specifications of four stroke Diesel Engine

| Type                        | 4-Stroke DI single cylinder diesel engine, water cooled |
|-----------------------------|--------------------------------------------------------|
| Speed                       | 1500 rpm                                               |
| Rated Power                 | 3.5 kW                                                 |
| Cylinder Diameter           | 85 mm                                                  |
| Stroke length               | 110 mm                                                 |
| Compression Ratio           | 16.5:1                                                 |

A four stroke constant speed Single cylinder, direct injection diesel engine (Figure-1) was used for experimental investigations. Thermocouples were used in the engine for measuring temperature of heater cell and heated oil in flow at the fuel inlet passage. Fuel intake line was connected to the heater and burette, and burette showed the level of fuel in the fuel tank. Initially the fuel level was low due to high viscosity but with increase in the temperature, the viscosity reduced and the fuel level increased in the burette.
The engine was run maintaining a temperature range of 130°C - 150°C during the tests, which was controllable by switching on the electric heater to attain the temperature in the desired range.

3. Results and Discussions

3.1 Performance Parameters

The effect of using SVOs on the brake thermal efficiency (BTE) and the brake specific fuel consumption (BSFC) when used on the test engine are summarised as follows:

3.2 Brake thermal Efficiency (Figure 2)

The Brake thermal efficiency (BTE) is an ideal parameter to identify the engine performance. It was found that the BTE of diesel, preheated Jatropha oil and preheated Mahua oil were about 25.50%, 23.95% and 23.64% respectively at full load. The possible reason for low BTE with SVOs could be their low calorific value and low volatility, leading to improper spray pattern and poor atomization.

Figure-1 Experimental Engine Setup

Figure-2 BTE versus Load for different fuels
case of diesel, the smaller fuel particles might have lead to better atomization of fuel, thus providing improved combustion efficiency. In case of SVOs, non-homogenous fuel distribution also could have resulted in poor spray pattern in the combustion chamber, thus causing the improper combustion and thereby low efficiency.

3.3 Brake specific fuel consumption (Figure 3)

The results indicate that with increasing loads, brake specific fuel consumption (BSFC) reduced consistently, probably due to improved fuel combustion and minimum heat losses. At full load condition of the engine, the BSFC for Diesel, preheated Mahua and Jatropha oils were found to be 482, 472 and 461 gm/kWh respectively. With heated vegetable oils, there was an improvement in BSFC, the possible reason being the reduction in viscosity and thereby improved volatility and atomization.

![Figure-3 BSFC versus Load for different fuels](image)

3.4 Emission parameters

The main exhaust emissions in the engine are hydrocarbon, carbon monoxide and nitrogen oxide which are discussed subsequently as follows:

3.5 Hydrocarbon emissions (Figure 4)

During the experiments, it was found that the HC content in the exhaust was slightly lower when the engine was run on SVOs instead of diesel, possibly because at high temperatures, the viscosity of
SVOs got reduced resulting in the improved vaporization and the improved air fuel mixture leading to better combustion.

3.6 Carbon monoxide emissions (Figure 5)

CO concentration in the exhaust was found to be higher in case of diesel as compared to the preheated Mahua and Jatropha oils. This was possibly due to the oxygen content present in SVOs causing better and complete combustion and thereby lesser CO emissions.

3.7 Nitrogen Oxide Emissions (Figure 6)

The results indicate that nitrogen oxide emissions rapidly increase with increasing load condition. It is possibly due to the fact that increasing the fuel quantity influences the increasing oxygenated fuel and
promotes the high combustion temperature in the combustion chamber thus predominantly affecting the increase of NOx production.

It was observed during the tests that NO\textsubscript{x} formation was higher with preheated Mahua and Jatropha oils as compared to diesel. The increase in NOx emissions with preheating may be attributed to the increase in combustion gas temperature with the increase in fuel inlet temperature. Further, the increase in NOx emissions with preheated oils may be due to various reasons, such as improved fuel spray characteristics, better combustion due to high oxygen content in vegetable oil, and higher temperature in the cylinder as a result of preheating. Hence to reduce NOx emissions, the temperature in the cylinder should be reduced.

4. Conclusion

In the present experimental work, the diesel engine was fuelled with SVOs and diesel to test the engine performance and emission characteristics. It was observed that the viscosity of both Jatropha and Mahua oils decreased remarkably with increase in temperature and viscosity became closer to mineral diesel above 95°C. The brake thermal efficiency (BTE) was found maximum for diesel at full load and relatively lower (about 8 – 10% lower) for preheated Mahua and Jatropha oils respectively (figure 2). The reason for lower BTE with SVOs might be due to their lower calorific value and low volatility, which lead to improper spray pattern and poor atomization. The values of brake specific fuel consumption (BSFC) were found comparable and at full load condition, a variation of approximately 2 - 5% was observed when engine was run on preheated Jatropha and Mahua oils instead of diesel (figure 3).

The emission levels were also tested and it was found that hydrocarbon (HC) emissions (figure 4), and carbon mono oxide (CO) emissions (figure 5) were reduced when engine was run with preheated Mahua and Jatropha oils instead of diesel. Also it was noted that nitrogen oxide (NO\textsubscript{x}) emissions
(figure 6) were lower with diesel as compared to the preheated Mahua and the Jatropha oils, possibly because of the considerably high inlet temperature. It is suggested that this can be dealt with by modifying the engine making provision for exhaust gas recirculation (EGR).

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