Performance Study of IC Engine Fueled with Biodiesel and Its Blend Obtained from Waste Cooking Oil

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Abstract—The demand for alternate energy has increased which resulted in exploiting waste cooking oil (fried oil). This fried oil is transesterified to biodiesel. By using microwave assisted conventional process transesterification is done. The presence of fatty acid methyl ester (FAME) was confirmed by Fourier transform infrared spectrometer (FTIR) analysis. The peaks obtained around 1741 cm⁻¹ confirmed the presence of ester carbonyl bonds. The properties like fire point, flash point, density and viscosity were determined for biodiesel and for blends (B10:D90 and B20:D80). The values obtained suggested that the quality of the biodiesel was found to improve when it was blended with diesel. The blends were used to study the performance and emission characteristics of internal combustion engine. Pure diesel was used as reference. The engine performance test including parameters like brake power (BP), brake thermal efficiency (BTE), indicated thermal efficiency (ITE), mechanical efficiency ηME were determined and were found to increase with increase in load. Emission characteristics like HC, NOX, CO, CO₂ and SOX for pure diesel and for the blends are found. Overall, the performance of the IC engine was found to improve when biodiesel was blended with diesel.

Key words: Microwave Assisted Transesterification, Biodiesel, Engine Performance, Emission tests

I. INTRODUCTION

The increasing demand for energy and the pollution problems caused by the use of fossil fuels has paved way for alternative fuels and renewable sources of energy. Biofuel is one of the widely accepted and used fuel which is derived from biomass. It is a non-toxic, biodegradable and eco-friendly fuel used in diesel engines. Biodiesel does not contain any Sulphur or aromatic compounds and its combustion results in lower emission of carbon monoxides, hydrocarbons and particulates. Feedstock for blended fuel include animal fats, waste cooking oil, vegetable oils, soya bean, neem oil, jatropha, mustard, sunflower, palm oil, algae, etc. are used for the blended fuel production. The waste cooking oil can be used as an effective source of biodiesel. The reuse of fried oil has hazardous health impacts. This fried oil can be collected and transesterified to produce bio diesel[1]. Triglycerides are esters of saturated and unsaturated monocarboxylic acids with the trihydric alcohol glyceride, which can react with alcohol in the presence of a catalyst in a process known as transesterification to produce Fatty Acid Methyl Esters (FAMEs) and glycerin[2]. This biodiesel can blended with the diesel in various proportions to improve the properties of the biodiesel and the performance test is carried for that blends.[3] The types of transesterification are acid catalyzed, base catalyzed, enzyme catalyzed transesterification[4]. An experimental verification of combustion characteristics and engine emissions of a diesel engine fueled with diesel and treated waste cooking oil blends and given the feasibility of using treated waste cooking oil biodiesel blend in a diesel engine.[5] production of biodiesel from waste cooking oil by using acetic acid or water as a washing agents. The addition of washing agent does not affect the reaction productivity.

This study focuses on the production of biodiesel from waste cooking oil by microwave assisted[6] transesterification reaction. The internal combustion engine was studied for its performance based on the combustion characteristics, performance and exhaust emissions of a diesel engine fueled with a blended mixture of diesel and biodiesel in different ratio. The mixture of biodiesel and diesel was blended in 5% and 10% with No.2 Diesel fuel.

II. MATERIALS AND METHODS

A. Biodiesel Production:

The waste cooking oil or the fried oil is collected from the nearby shops. The oil was palm oil by nature. Various methods to produce biodiesel are conventional, microwave assisted and ultrasonic transesterification[7].

B. Microwave Assisted Transesterification Using Base Catalyst:

Microwave is an electromagnetic wave with frequencies between 0.3 GHz and 300 GHz and is a form of energy that resides fairly low in the electromagnetic spectrum. During microwave irradiation, the bonds are neither formed nor broken but the energy is rapidly transferred to the sample. The microwave irradiation can be used as the heat source during transesterification reaction because it accomplishes the transesterification reactions in sec or min. In microwave assisted biodiesel production unit, 100ml of waste cooking oil, alcohol and catalyst NaOH(1wt% concentration) were mixed of molar ratio 6:1 using suitable stirring device and heated by the microwave heat source. The reactants are subjected to the microwave irradiation (with an output power of 800W) for 3mins. After that the products of the transesterification were allowed to settle for phase separation. The separation of the biodiesel and glycerin phase takes 30 to 60 min. The crude biodiesel was subjected to water wash to remove impurities and dried to remove the moisture content. The reaction time and setting time required for this method is low and hence the production cost also reduces significantly. The fuel properties of The biodiesel produced by this method are similar to the biodiesel produced by conventional method[8].
C. Test Engine
The four stroke single cylinder with direct injection system as shown in fig.1 is used as a test engine.

![Fig. 1: Line diagram of experimental setup with Eddy Current Dynamometer with IC engine](image)

D. Smoke Meter
The smoke meter used for analyzing the exhaust gas is I3sys. It has the capacity to measure five exhaust gas emissions namely CO2, CO, HC, SOX and NOX. CO and CO2 were measured in % of sample and HC, NOX were measured in ppm.

E. Estimation Of Viscosity:
The viscosity (at 40°C) of oil samples was measured using Redwood viscometer and expressed in cSt according to ASTM D6751 (2003)standard.

F. Estimation Of Flash Point And Fire Point:
The flash point and fire point of the oil sample was measured using Pensky Martin's open cup apparatus.

G. Formulae Used:
1) Brake Power (Kw):
\[ B.P = \frac{2\pi NL \times 9.81 \times LD}{60,000} \]
Where,
- \( N \) – Speed of engine (rpm),
- \( L \) – Load (kg),
- \( LD \) – Dynamometer arm length (92.5 mm).

2) Brake Mean Effective Pressure (bar):
\[ \text{BMEP} = \frac{Bp \times 60}{\pi \times 4 \times dc2 \times LS \times (N/n) \times \text{No. of Cylinder} \times 100} \]
Where,
- \( dc \) - Cylinder diameter (0.080m)
- \( LS \) – Stroke length (0.11 m)
- \( n \) – no. of rev / cycle

3) Specific Fuel Consumption (kg/kw hr):
\[ \text{BSFC} = \frac{(3600 \times 10 \times \text{fuel density})}{(Bp \times \text{fuel flow} \times 1000)} \]
Where,
- Fuel flow – Time taken for 10 ml fuel consumption,
- Fuel density – (Fd).

4) Brake thermal efficiency (%):
\[ \text{BTE} = \frac{(Bp \times 60,000 \times \text{fuel flow})}{(10 \times 0.06 \times Fd \times Cv)} \]

III. RESULTS AND DISCUSSION
A. Production And Characterization Of Biodiesel:
The waste cooking oil was collected from the near by shops and it was subjected to microwave assisted conventional transesterification to produce biodiesel. The presence of methyl ester in the sample was confirmed by fourier transform infrared transesterification (FTIR). The presence of FAME layer in biodiesel was confirmed by FTIR analysis. The intense peak located at 1742cm-1 corresponds to the carbonyl bond of ester group which confirms the presence of FAME in biodiesel. The best hit was found at 1742cm-1 and it corresponds to Methyl linoleate (C18:2) which was determined from the FLUKA library.

B. Property Analysis: The Flash Point And Fire Point Of:
- B0: 63 and 72°C
- B10: 71 and 82°C
- B20: 68 and 76°C

C. Performance Analysis:
The performance test was carried out for different blend ratio. Initially the engine performance was taken for pure diesel which was considered as the base line reference and the different blends were tested in the engine.

![LOAD Vs BTE](image)

**Fig. 2: Load (kg) Vs Brake Specific Fuel Consumption (kg/kW hr)**

Brake Specific Fuel Consumption (BSFC) decreases with increase in load. BSFC of biodiesel upto 20% is in same range equal to diesel. BSFC increases at higher concentration of biodiesel above 20%. BSFC decreases for WCO blend when compared with other blends.
Brake thermal efficiency ($\eta_{BT}$) increases with increase in load. $\eta_{BT}$ of biodiesel upto 20% is in same range equal to diesel. $\eta_{BT}$ increases at higher concentration of biodiesel in the blend due to increased combustion character. $\eta_{BT}$ for WCO blend is similar to diesel B0 blend.

Mechanical Efficiency ($\eta_{Mech}$) increases with increase in load. $\eta_{Mech}$ of biodiesel upto 20% is in same range equal to diesel. $\eta_{Mech}$ decreases at higher concentration of biodiesel above 20%. $\eta_{Mech}$ is less for WCO blend when compared to other blends.

D. Emission characteristics:
The emission test is carried for pure diesel and also for different blend proportions. The emission values are given in ppm.

Carbon monoxide content (CO) decreases with increase in load. CO emission of Waste cooking oil biodiesel blends decreases when compared to that of diesel. CO emission of Waste cooking oil biodiesel blends decreases with increase in biodiesel concentration.

Carbon dioxide content (CO2) increases with increase in load for diesel. CO2 emission of Waste cooking oil biodiesel blends decreases when compared to that of diesel. CO2 emission of Waste cooking oil blends decreases with increase in biodiesel concentration.

Hydrocarbon content (HC) decreases with increase in load. HC emission of Waste cooking oil blends decreases when compared to that of diesel. HC emission of Waste cooking oil biodiesel blends decreases with increase in biodiesel concentration.

Oxides of Nitrogen content (NOX) increases with increase in load. NOX emission of Waste cooking oil biodiesel blends increases heavily when compared to that of diesel due to high oxygen content in biodiesel. NOX emission
of Waste cooking oil blends increases with increase in biodiesel concentration.

IV. CONCLUSION

Brake Specific Fuel Consumption (BSFC) has been increased for B10 and B20 blends for high load when compared with diesel (B0 Blend). Mechanical Efficiency (ȠMECH) has been increased for WCO B20 Blend and ȠMECH for B10 blend is comparatively same when compared with diesel (B0 Blend).

Carbon monoxide content in the emission for B10 and B20 blend has been reduced for high load when compared with diesel (B0 Blend). Carbon dioxide content in the emission of B20 blend has been reduced for high load when compared with diesel (B0 Blend). Hydrocarbon content in the emission of B20 blend has been increased for high load when compared with diesel (B0 Blend). Increase in biodiesel content in diesel shows slighter reduction in performance parameters and better emission characteristics except NOX content. Diesel-Waste cooking oil biodiesel blend shows better result in Brake specific fuel consumption and Brake thermal efficiency alone, other characteristics are lower when compared to biodiesel blends but little higher than diesel. Biodiesel up to 20% blend with diesel shows nearly equal performance characteristics and enhanced emission characteristics compared with diesel. So B20 blend could be used as a commercial applicant.

REFERENCES


