Performance and emission characteristics of a four stroke single cylinder diesel engine fueled with waste cooking oil and diesel blend

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Abstract: This paper emphasize on the production of methyl ester from waste cooking oil and application of this on four stroke single cylinder diesel engine to investigate its performance and emission characteristics. Keeping in mind about the current global energy crisis, global warming and adverse effect on human health due to the emission hazards emitted from the petro diesel vehicles. Therefore global interest is generated to find out a substitute to the current pilot fuel. Biodiesel has attracted interest in recent times due to its oxidation characteristics and environmental benefits. Bio-diesel obtained from straight vegetable oil through a process known as base catalyze transesterification process. In this process the reversible reaction between the triglyceride of vegetable oil and methanol in presence of base catalyst (KOH) to produce glycerol and methyl ester. The methyl ester produced in this process is then blended with biodiesel in various proportions before use in a diesel engine. The experimental investigation on the engine performance shows that the Brake power, Brake thermal efficiency and exhaust gas temperature gradually increases with increase in loads. Similarly the emission analysis with the above test fuels shows that Carbon monoxide, Carbon dioxide and Hydro carbons increase with increases in load for all test fuels including the pilot fuel and Oxides of nitrogen emission increases with load and is highest for pure biodiesel. From the above experimental results we may conclude that waste cooking methyl ester can successfully be used in a diesel engine without much engine modifications and degrading the engine performance and emissions.

Key words: Waste cooking oil; Biodiesel; Diesel; Transesterification; Performance; Emission

Introduction

The world energy demand is increasing at a very faster rate which is responsible for the world economic crisis. This present energy crisis in the world has created new challengesfor scientists and researchers to find another suitable alternative to the vastly popular petroleum products as the engine fuels. This increases the global demand for exploration of the renewable energy sources through a sustainable approach. Some common renewable energy sources are being hydropower, wind energy, solar energy, geothermal, biomass, biofuels etc. Extensive research is being carried out by most of the developed and developing countries for the development of renewable fuels for future use in engines. There is huge demand for nonrenewable energy sources and this demand is increasing day by day, where in the future the demand to supply ratio of nonrenewable energy sources is unbalanced which leads to energy crises. Work is going on for production of alternative fuels using renewable energy sources. The best alternative fuel for engines being biodiesel. Fig. 1 shows the contribution of various energy resources where nonrenewable energy resources like petrol, coal etc are contributed in major proportions.

The Transesterification Reaction

Transesterification is a process of producing a reaction in triglyceride and alcohol in pres-ence of a catalyst to produce glycerol and ester. Molecular weight of a typical ester molecule is roughly one third that of typical oil molecule and therefore has a lower viscosity. Alkalis (NaOH, KOH), acid (H2SO4.HCl, or enzymes (lipase) catalyzed reaction. Alkali catalyzed Transesterification is faster than acid catalyzed Transesterification is most often used com-mercially, because the reaction is reversible, excess alcohol is used to shift the equilibrium to product side [1, 2]. Alcohols are primary and secondary monohydric aliphatic alcohols (1-8 Carbon atoms). In the Transesterification process, methanol and ethanol are more common. Methanol is extensively used because of its low cost and its physiochemical advantages with triglycerides and alkalis are dissolved in it. To complete Transesterification stoichiometri-cally 3:1 molar ratio of alcohol to triglycerides is needed. Studies have been carried out in different oils such as soybean, sunflower, ape, coconut, palm, used frying oil, Jatropha, rub-ber seed and coconut seed. Mostly biodiesel is produced by Base catalyzed Transesterifica-tion of the oil as it is most economical. Here the process is reaction of triglycerides (oil/fat) with alcohol to form esters (biodiesel) and glycerol (by product). During this process the triglycerides is reacted with alcohol in the presence of a catalyst, usually a strong alkaline like sodium hydroxide [3, 4, 5]. The chemical reaction which describes preparation of biodiesel is:

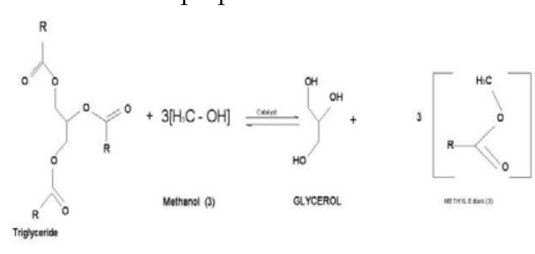

Fig. 2 Reaction scheme for trans-esterification

Biodiesel Preaparation Methodology

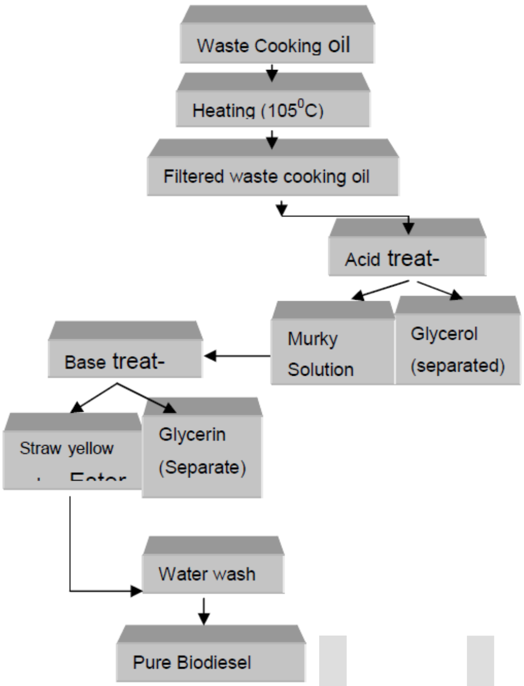

Fig. 3 Flow Chart for WCME Preparation

TABLE I. PROCESS PARAMETERS

Sl. No.	Process Parameters	Description
1	Process selected	Alkali catalyzed transesteri-fication
2	Reaction temperature	55-60^{0}C
3	Sample oil used	1000ml waste cooking oil.
		120ml/kg of oil.
4	Methanol used	0.5-1% per kg of oil.
5	Catalyst used(KOH)	1.5-2 hours.
		12-14 hours.
6	Reaction time	4-5 times (30min).
7	Settling time	500 rpm.
8	Water wash	
9	Stirring speed	

Fig. 8 Settling after base treatment

B. Characterization of Test Fuels

TABLE II. COMPARISON OF FUEL PROPERTIES FOR BI-ODIESEL AND DIESEL

Fuel property	Unit	Diesel	Bio-Diesel
Kinematic viscosity at 40◦C	cSt.	4.56	5.46
Specific gravity at 15◦C	---	0.8668	0.8802
Flash point	◦C	42	160
Fire point	◦C	68	185
Pour point	◦C	−18	3
Cloud point	◦C	−3	17
Cetane index		50.6	51.4
Calorific value	KJ/kg-K	42850	42293

The Test Engine

Fig. 12 Photograph of the test engine

Table III TEST ENGINE SPECIFICATIONS

Particulars	Description
Engine type	Single cylinder, 4-stroke,vertical water cooled diesel engine
Bore diameter	80 mm
Stroke length	110 mm
Compression ratio	16:1
Rated power	3.67 KW
Rated speed	1500 rpm
Dynamometer	Rope brake dynamometer

The specification of CI Engine used for testing of biodiesel is

ISSN 2229-5518

of single cylinder 4 stroke diesel engine with 3.67 KW power, speed 1500 rpm. The main objective has been to study the performance characteristics of Waste cooking oil as fuel in diesel engine. For conducting the desired set of experiments and to gather required data from the engine, it is essential to get the various instruments mounted at the appropriate location on the experi-mental setup. The prepared biodiesel is poured into cylindrical aluminum fuel tank which is inside the water tank; up to a level such that fuel tank is not immersed. Burette is adjusted such that there is continuity of fuel supply through the pipe to the engine (i.e. with-out air gap). The engine is then started with the supply of fuel. The speed of the engine varies for different load applied on the engine, it is adjusted and kept constant i.e. (N = 1500 rpm). The observations include manometer readings (left and right), time taken for 20cc of fuel consumption, load at which the reading is taken, inlet and outlet temperature of water and exhaust gas temperature. After changing the load on the engine speed must be checked and is made adjusted as per rated speed. The readings are noted carefully with respect to the load applied on the engine and blend composition of biodiesel and diesel. The same above procedure is repeated for biodiesel with different blends and the observa- tions are taken Now the engine parameters are found at different loads (0, 3, 6, 9, 12 kg) and different blends of biodiesel and result tables are drawn. The above experiment procedures are repeated for WCME and diesel fuel but at different blends of biodiesel and results are compared with the results obtained when pre-heated fuel is used. These values which are obtained from testing of biodiesel are used to determine the engine parameters in order to find the performance of the of C.I engine Fig..13 Variation in Exhaust temperature with load

Fig. 14 Variation in. Brake thermal efficiency with load

Fig. 15Variation in BSFC with load

Fig. 16 Variation in Equivalence ratio with load

Fig. 17 Variation in Mechanical efficiency with load

Fig. 18 Variation in A/F ratio with load

From the comparison of graphs, the following conclusions are quoted below

- From fig. 13 exhaust temperature with load, it was observed that diesel has less exhaust temperatures when compared with biodiesel blends. Highest ex-haust gas temperature was obtained with pure biodiesel which may be due to higher oxygen content [6, 7]

- From fig. 14 brake thermal efficiency with load, it was observed that diesel has better brake thermal efficiency than that of biodiesel blends which is be-cause of the higher calorific value of diesel [6, 7].

- From fig. 15 BSFC with load, diesel is more economic when compared with other test fuels, which indicates that mass of fuel consumed per unit brake power is less for diesel than that of biodiesel which may be due to the higher density and viscosity of biodiesel [8, 9].

- From fig. 17 Mechanical efficiency with load, it was observed that higher the mechanical efficiency lower will be the friction losses. B80 blend has highest mechanical efficiency when compared to other test fuels which may be due to higher lubricating characteristics of biodiesel [8, 9].
- From fig. 16 and 18, it was observed that the equivalence ratio was highest for pure biodiesel and the A/F ratio was highest for diesel which may be due to its higher viscosity and density of biodiesel [7, 8, 9].

NOMENCLATURE

CI : Compression Ignition

KOH : Potassium hydroxide

B20 :20% biodiesel + 80% diesel

B40 :40%biodiesel + 60% diesel

B60 :60% biodiesel + 40% diesel

B80 :80% biodiesel + 2S0% diesel

B100 :100% biodiesel

WCME : Waste cooking oil methyl Ester

BSFC : Brake specific fuel Consumption

A/F : Air fuel ratio

ASTM :American Society for Testing and Materials

KW : Kilo Watts

oC : Degree Centigrade

cSt : Centi Stoke

KWh : Kilowatt hour

NOx : Oxides of Nitrogen

Conclusion

From the results obtained during the engine testing of the biodiesel blends the following conclusions are drawn.

1. The highest brake thermal efficiency was obtained with B60 blend and the highest mechanical efficiency was obtained with B80 as compared to pure biodiesel and other blends.

2. The highest BSFC was obtained for pure biodiesel as compared with all test fuels.

3. The highest equivalence ratio and exhaust gat temperature was obtained for pure biodiesel when compared with all test fuels.

4. The highest A/F ratio was obtained for diesel when compared with all test fuels.

From the present experimental work it may be concluded that the biodiesel blends of WCME (B60 blend) can be successfully used as an al-ternative fuel in a diesel engine with no engine modifications.

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