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Emission characteristics of a four-stroke single cylinder diesel engine fueled with used waste cooking oil and diesel blends

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Abstract: -- **This paper emphasizes 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 petrodiesel vehicles. Therefore global interest is generated to find out a substitute for the current pilot fuel. Biodiesel has attracted interest in recent times due to its oxidation characteristics and environmental benefits. Biodiesel 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 the 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 Hydrocarbons 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 be degrading the engine performance and emissions.**

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

1. 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 challenges for 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 non renewable 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 [1-3]. Work is going on for production of alternative fuels using renewable energy sources.

A. The Transesterification Reaction

Transestrification is a process of producing a reaction in triglyceride and alcohol in presence 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 commercially, because the reaction is reversible, excess alcohol is used to shift the equilibrium to product side [4-7]. 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 stoichiometrically 3:1 molar ratio of alcohol to triglycerides is needed [6-9]. Studies have been carried out in different oils such as soybean, sunflower, ape, coconut, palm, used frying oil, Jatropha, rubber seed and coconut seed. Mostly biodiesel is produced by Base catalyzed Transesterification 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 [7-11]. The chemical reaction which describes preparation of biodiesel is

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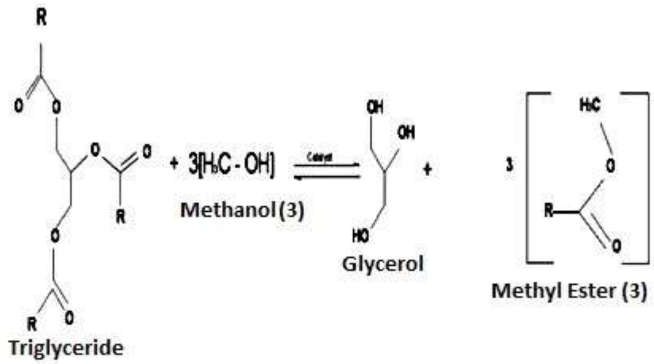

Fig.1 Reaction Scheme of Transesterification

EXPERIMENTAL

A. Biodiesel Preparation Methodology

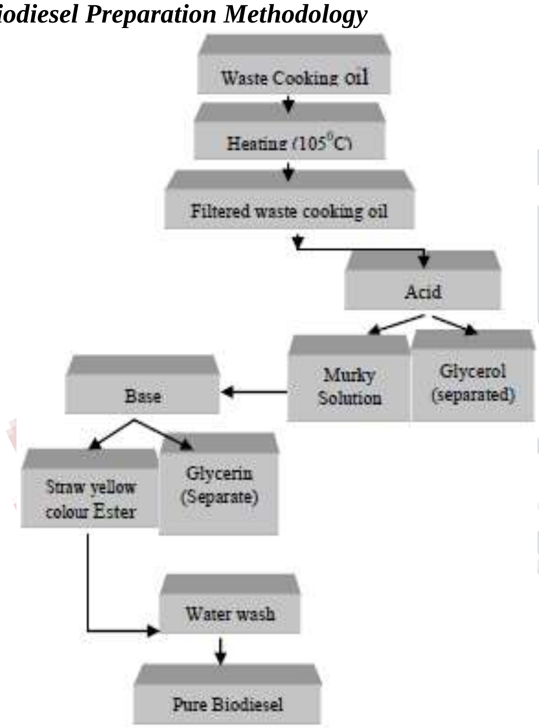

Fig.2 Flow chart for biodiesel preparation

Table 1. Process Parameter

Process parameter	Description
Process selected	Alkali catalyzed Transesterification
Reaction Temperature	55-60 ^{0}C
Sample oil used	1000 ml of used cooking oil
Methanol used	120 ml/kg of methanol
Catalyst used	0.5-1 % per kg of oil
Reaction time	1.5-2 hours
Settling time	12-14 hours
Water wash	4-5 times (30 min.)
Stirring speed	500 rpm

Fig. 3 Settling after base treatment

Table 2. Comparison of fuel properties for biodiesel and diesel

Fuel property	Unit	Diesel	Biodiesel
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

B. The Test Engine

Fig. 4 Photograph of the test engine

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Table 3. Engine Specification

Particular	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	150 rpm
Dynamometer	Eddy current

The specification of CI Engine used for testing of biodiesel is 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 experimental 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. without 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 observations are taken. Now the engine parameters are found at different load percentage and different blends of biodiesel. 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 preheated 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..

RESULTS AND DISCUSSION

A. Brake Power (BP)

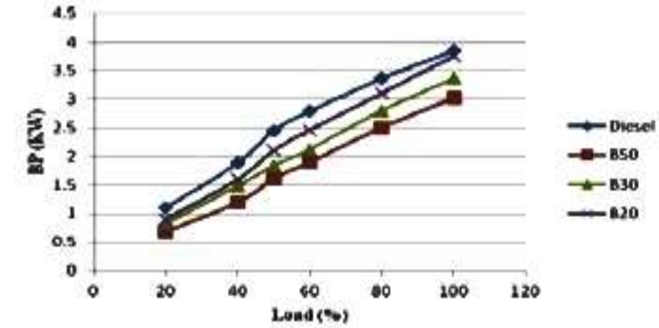

Fig. 5 BP with Load (%)

Figure 5 shows the variation of brake power with respect to percentage of load. The above result shows that diesel has highest BP for varying loads when compared with other test fuels. Brake power developed with B20 blend is somewhat close enough to that of diesel [11-13].

B. Brake specific fuel consumption (BSFC)

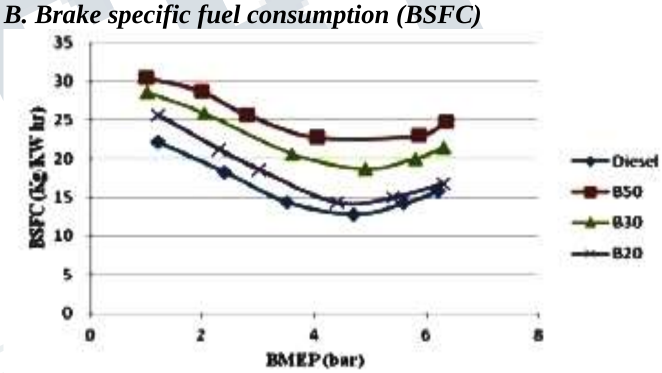

Fig. 6 BSFC with BMEP

Figure 6 shows the variation of BSFC with respect to BMEP. The above result shows that BSFC reduces with increase in BMEP. It is highest for pure biodiesel and lowest for diesel because the heating value is very low and high viscosity of the biodiesel blends [12-15].

C. Brake thermal efficiency (BTE)

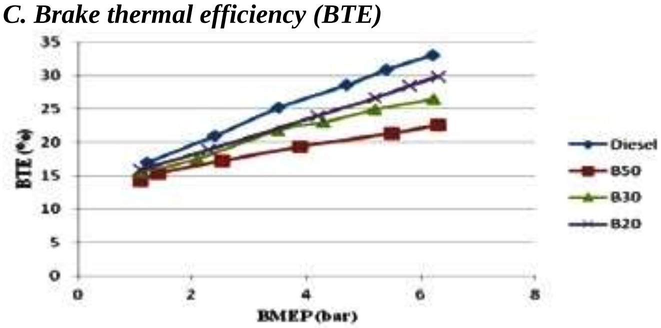

Fig. 7 BTE with BMEP

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Figure 7 shows the variation of BTE with respect to BMEP. The above result shows that BTE increases as BMEP increase. It was observed that BTE was higher for diesel when compared with biodiesel and its blends. When there is increase in blending of biodiesel, there is a decrease in BTE because of high viscosity of biodiesel. Therefore the test fuels are more viscous for which they have a low heating value [14, 16 and 17].

D. Carbon monoxide (CO)

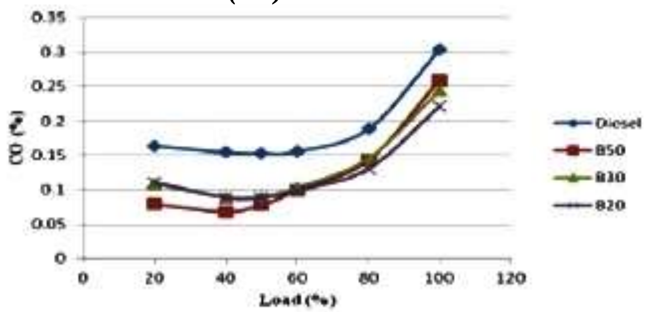

Fig. 8 CO with load (%)

Figure 8 shows the variation of CO with respect to load. The above result shows that at lower load there is decrease in CO emissions but at higher loads CO emission increases. The lowest and highest CO emission was obtained for B50 and B20 at low and full load conditions. This may be due to the reason that at low load total power output is low which complete combustion. Similarly at higher load total power output is high which causes incomplete combustion [17-19].

E. Smoke Opacity

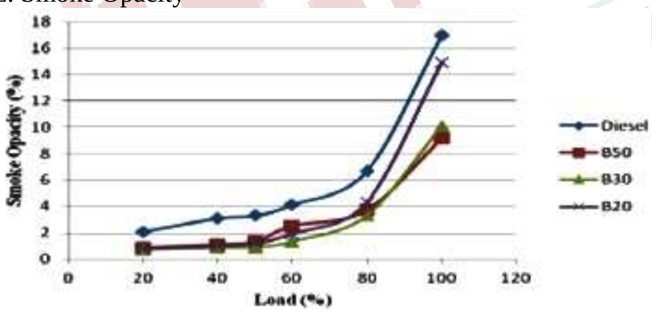

Fig. 9 Smoke Opacity with load (%)

Figure 9 shows the variation of smoke opacity with respect to load. The above result shows that smoke emission increases with increase in load for all test fuels. B50 blend produce less smoke incomparision with other test fuels because of better combustion as there is sufficient availability of oxygen in biodiesel [19-21].

F. Hydrocarbon (HC)

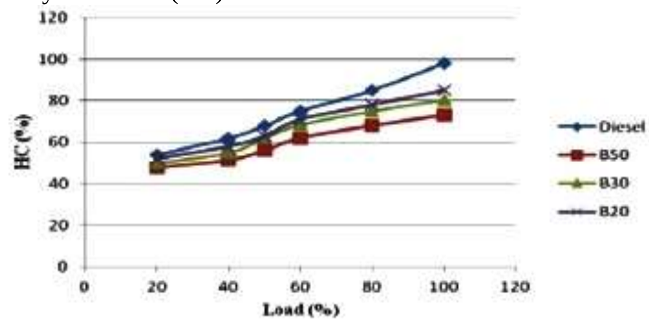

Fig. 10 HC with load (%)

Figure 10 shows the variation of HC with respect to load. The above result shows that HC emission increases with increase in load and is highest for diesel when compared with other test fuels. B50 blend has lowest HC emission at high load of all the test fuels [20, 21].

CONCLUSION

From the above experimental data we may conclude that:

•The BP was found to be increasing with increase in load (%). BP was highest for diesel and lowest for B50 blend. B20 blend curve was somewhat close to that of diesel curve.

•The CO emission decreases with increase in load, but at 60% CO emission increases with increase in load and was lowest for B20 blend at full load condition.

•The smoke emission increases with increase in load, B50 blend have the lowest smoke emission at full load when compared with all other test fuels.

•The HC emission gradually increases with increase in load, B50 blend have the lowest HC emission of all the test fuels

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