Performance and Emission Characteristics of a Four Stroke Single Cylinder Diesel Engine Fueled with Waste Fried Cooking Methyl Ester and Diesel Blends

SWARUP KUMAR NAYAK[*,1], PURNA CHANDRA MISHRA[1], SANTOSH KUMAR NAYAK[1], SAGARIKA PATEL[1]
1School of Mechanical Engineering, KIIT University, Bhubaneswar - 751024, Odisha, India
*Corresponding Author. Tel: (0674) 2315204, Mob: (91) 8763709850, E-mail: rohanrocks319@gmail.com

Abstract:- This paper emphasizes on the production of methyl ester from waste cooking oil and the 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. Biodiesel obtained from straight vegetable oil through a process known as a base catalyze transestrification process. In this process the reversible reaction between the triglyceride of vegetable oil and methanol in the 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.

Keywords- Waste cooking oil, Biodiesel, 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.

1.1 Transesterification reaction

Transesterification 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 (H_2SO_4, 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 o biodiesel is:

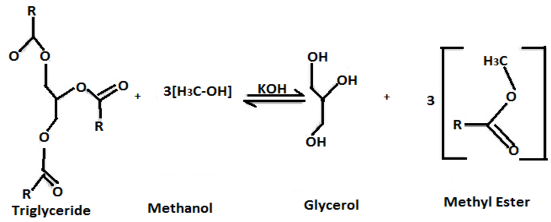

Fig. 1 Reaction process for transesterification.

2 Materials And Methods

2.1 Materials

2.1.1 Waste cooking oil

For carrying out the experimentation waste cooking oil was obtained from various restaurants in Bhubaneswar using refined Sunflower oil for making different food items.

Table 1 Fatty acid composition in waste cooking oil.

Sl.No	Fatty acid	Structure	Formula	Weight (%)
1	Palmitic	16.0	$C_{16}H_{32}O_2$	23.1
2	Stearic	18.0	$C_{18}H_{36}O_2$	21.6
3	Arachidic	20.0	$C_{20}H_{40}O_2$	1.5
4	Oleic	18.2	$C_{18}H_{34}O_2$	37.2
5	Linoleic	18.2	$C_{18}H_{32}O_2$	11.3

2.1.2 Methodology

One litre of Waste fried cooking oil is heated in an open beaker to a temperature of 100-110 ^{0}C to remove water particles present in oil followed by filtration of oil. The oil is processed under base catalyzed transesterification method where it is mixed with 200 ml of methanol and 6.5 gms of sodium hydroxide pellets in a round bottom flask on a hot plate magnetic stirring arrangement for 1-1.5 hours upto 60 ^{0}C and then it is allowed to settle down for about 6-8 hours to obtain biodiesel and glycerol. The biodiesel obtained in the process is further washed with distilled water for 2 to 3 times for removal of acids and heated above 100^{0}C to separate the moisture present in the biodiesel. Hence, pure waste fried cooking biodiesel is obtained.

2.1.3 Preparation of test fuel blends

Various test fuel blends were prepared by blending Waste cooking biodiesel with additive in various volume proportions. In the present work B85, B90, B95, B100 and the diesel fuel are used as the test fuels where B85 represent 85% biodiesel and 15% additive. Similarly B90 and B95 represents 90% biodiesel with 10% additive and 95% biodiesel with 5% additive respectively. B100 represents pure biodiesel without additive.

3 Experimentation

3.1 The Test engine

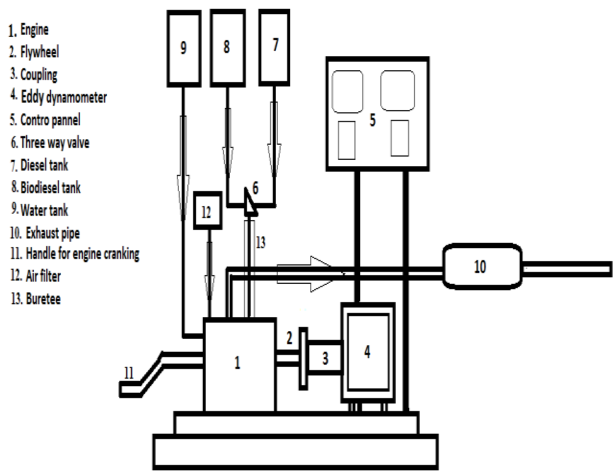

Fig. 2 Layout sketch of the test engine.

Fig. 3 Settling after base treatment

Table 2 Test Engine Specification.

Sl.No	Particulars	Description
1	Engine type	Single cylinder, 4-stroke. vertical water cooled diesel engine
2	Bore diameter	80 mm
3	Stroke length	110 mm
4	Compression ratio	16.5:1
5	Rated power	3.67 KW
6	Rated speed	1500 rpm
7	Dynamometer	Eddy Current type

The test bed consist of a four stroke single cylinder direct injection water cooled diesel engine equipped with eddy current dynamometer, orifice meter in conjunction with U-tube manometer measuring volume flow rate of air, graduate burette for volume flow rate of fuel in (cc) and measuring jar for measuring cooling water flow rate. The prepared bio-diesel is poured into the cylindrical tank. Then the level of fuel and lubricating oil is checked. The 3-way cock is opened so that the fuel flows to the engine. Cooling water is supplied through the inlet pipe. The engine is then started with the supply of the fuel. The speed of the engine is kept constant at 1500 rpm under varying load conditions and performance parameters like brake power, torque, brake thermal efficiency, brake specific fuel consumption and exhaust gas temperature were measured for diesel and all test fuels. CO, HC, CO_2 and NO_x emissions were also measured for both diesel and all test fuels with the help of a multi gas analyzer.

3.2 Characterization of test fuels

Table 3 Comparison of Fuel Properties For Diesel And Waste Cooking Methyl Ester

Sl.No	Properties of fuel	Unit	Diesel	Waste cooking methyl Ester
1	Kinematic viscosity at 40^0 C	cSt.	4.57	5.39
2	Specific gravity at 15^0 C	-	0.8668	0.8712
3	Flash point	^{0}C	42	157
4	Fire point	^{0}C	68	183
5	Pour point	^{0}C	-18	2
6	Cloud point	^{0}C	-3	16
7	Cetane index	-	50.6	51.2
8	Calorific value	KJ/Kg-K	42850	42293

4 Results and discussions

4.1 Brake thermal efficiency (BTE)

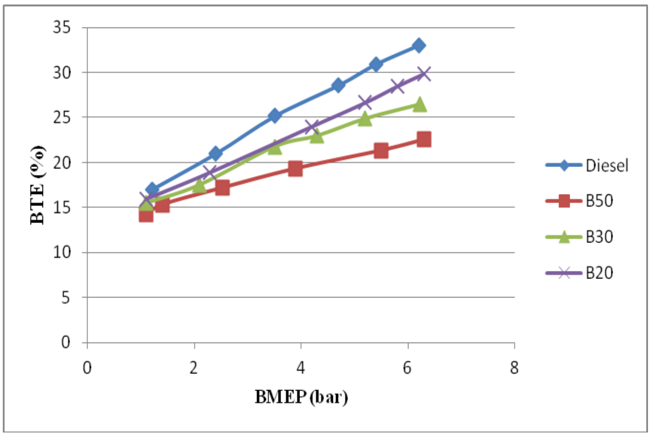

Fig.4. BTE with BMEP

Figure 4 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]-[18].

4.2 Brake specific fuel consumption (BSFC)

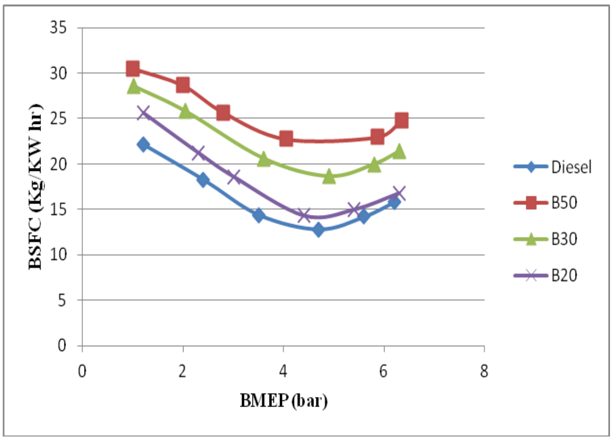

Fig. 5. BSFC with BMEP

Figure 5 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].

4.3 Brake Power (BP)

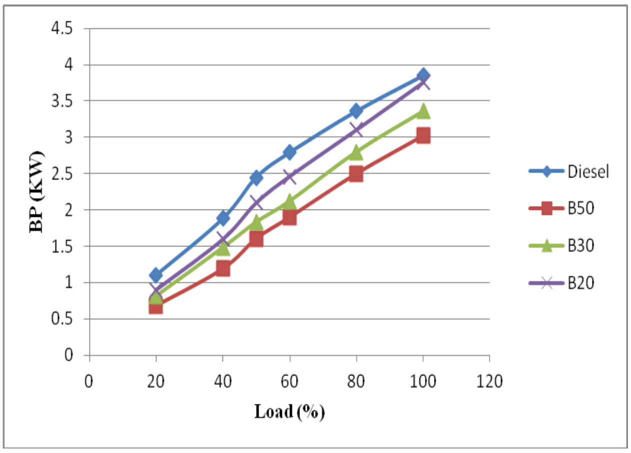

Fig. 6. BP with Load (%)

Figure 6 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].

4.4 Carbon monoxide emission (CO)

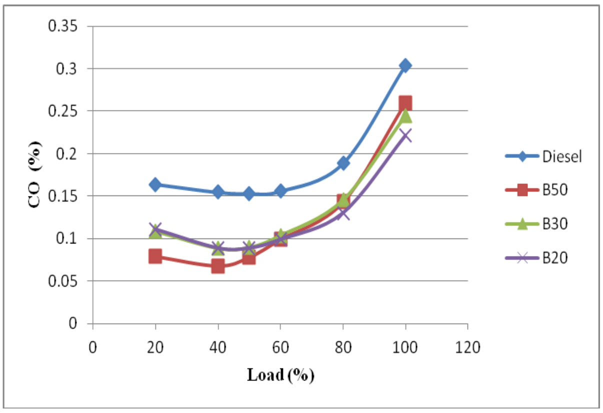

Fig. 7. CO with load (%)

Figure 7 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].

4.5 Hydrocarbon emission (HC)

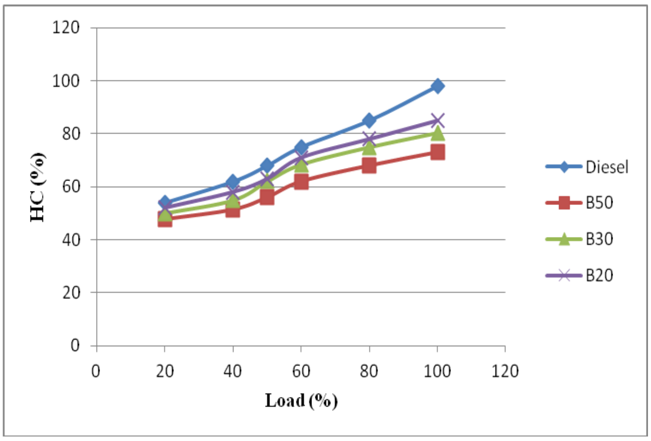

Fig. 8. HC with load (%)

Figure 8 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].

4.6 Smoke emission

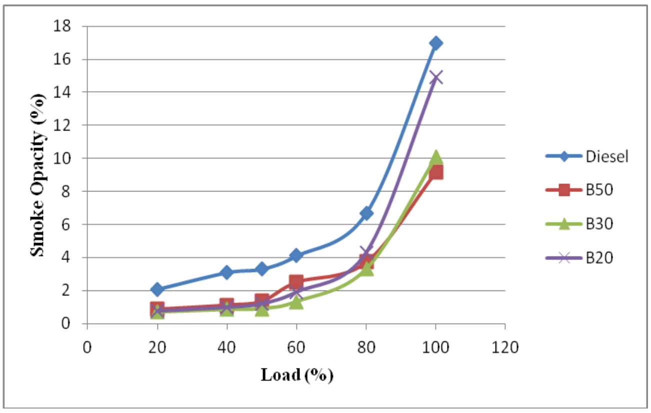

Fig. 9. Smoke Opacity with load (%)

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].

5 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

Reference

[1] Carlo Alessandro Castellanelli, Carolina Iuva de Mello, Analyzes of the used fried oil under environmental perspective and its possibilities for production of biodiese, *AJCS*, vol. 4, 2010, pp. 543-549.

[2] J.M. Encinar, J.F. Gonzalez, A. Rodríguezs, Ethanolysis of used frying oil. Biodiesel preparation and characterization, *Fuel Processing Technology*, vol. 88, 2007, pp. 513–522.

[3] Joana M. Dias, Conceicao A. Ferraz, and Manuel F. Almeida, Using Mixtures of Waste Frying Oil and Pork, Lard to produce Biodiesel, *World Academy of Science, Engineering and Technology* Vol-44, 2008.

[4] Z. Franco and Q.D. Nguyen, Flow properties of vegetable oil-diesel fuel blend, *Fuel*, Vol. 90, 2011, pp. 2129-2137.

[5] C.V. Sudhir, N.Y. Sharmal, and P. Mohanan, Potential of waste cooking oils as biodiesel feed stock, *Emirates Journal for Engineering Research*, vol.12, 2007, pp. 69-75.

[6] Padhi S.K. and Singh R.K, Non-edible oil as the potential source for the production of biodiesel in india: A review, *J. Chem. phar. Res.*, Vol. 3(2), 2011, 39-49.

[7] Shrivastava N., Varma S.N. and Pandey M, Experimental study on the production of karanja oil methyl ester and its effect on diesel engine, *Int. journal of renewable energy developement*, Vol. 1(3), 2012, 115-122.

[8] M. Kumar and O. Singh, Study of biodiesel as fuel for C I engines and its environmental effects: A research review, *International journal of advances in engineering and technology*, Vol. 5(2), 2013, 100-107.

[9] S. Puhana, N. Vedaraman, V.B. Bojanna Ram, G. Sankaranarayana and K. Jaychandran, Mahua oil (madhuca indica seed oil) methyl ester used as biodiesel preparation and emission characteristics, *Biomass and bioenergy*, 28, 2005, 87-93.

[10] S. Godiganur, Performance and emission characteristics of a kirloskar HA394 diesel engine operated on mahua oil ethyl ester, *Thammasat int. J. Sc. Tech.*, 15, 2010.

[11] D. Bajpai and V.K. Tyagi, Biodiesel: source, production, composition properties and its benefits, *Journal of OLEo science*, Vol. 55(10), 2006, 487-502.

[12] R.K. Pandey, A. Rehman, R.M. Sarviya and S. Dixit, "Development of clean burning fuel for compression ignition engines", *Asian J. exp. Sci* , 23(1), 223-234, 2009.

[13] R.K. Singh and S.K. Padhi, Characterization of jathropa oil for the preparation of biodiesel, *Natural product radiance*, Vol. 8(2), 2009, 127-132.

[14] H. Mulimani,O.D. Hebbal and M.C. Navindgi, Extraction of biodiesel from vegetable oil and their comparisons, *International journal of advance scientific research and technology*, Vol. 2(2), 2012, 242-250.

[15] S.K. Padhi and R.K. Singh, Non-edible oil as the potential source for the production of biodiesel in india: A review, *J. Chem. phar. Res.*, Vol. 3(2), 2011, 39-49.

[16] P.P. Sonune and H.S. Farkade, Performance and

emission of C.I engine fuelled with pre heated vegetable oil and its blend: A Review, *International journal of engineering and innovative technology*, Vol. 2(3), 2012, 123-127.

[17] M.R. Heyderiazad, R. Khatibi nasab, S. Givtaj and S.J. Amadi Chatabi, Biofuels production process and the net effect of biomass energy production on the environment, *World renewable energy congress*, 2011, 524-529.

[18] N. Shrivastava, S.N. Varma and M. Pandey, Experimental study on the production of karanja oil methyl ester and its effect on diesel engine, *Int. journal of renewable energy developement*, Vol. 1(3), 2012, 115-122.

[19] H. Raheman and S.V. Ghadge, Performance of compression ignition engine with mahua (madhuca indica) biodiesel, *Fuel*, Vol. 86, 2007, 2568-2573.

[20] S. Puhana, N. Vedaraman, V.B. Bojanna Ram, G. Sankaranarayana and K. Jaychandran, Mahua oil (madhuca indica seed oil) methyl ester used as biodiesel preparation and emission characteristics, *Biomass and* bioenergy, Vol. 28, 2005, 87-93.

[21] S. Godiganur, Performance and emission characteristics of a kirloskar HA394 diesel engine operated on mahua oil ethyl ester, *Thammasat int. J. Sc. Tech.*,Vol. 15, 2010.