Analysis of Four Stroke Single Cylinder Compression Ignition Engine Operated with Blends of Waste Cooking Oil Biodiesel/Diesel

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Abstract— **In the present study attention is being focused on comparison of performance of biodiesel derived from waste cooking oil when applied in different proportions in compression ignition engine. A single cylinder four stroke diesel engine (Kirloskar) was tested at various loads with the blended fuel at the rated speed of 1500 rpm. Waste cooking oil biodiesel blended with diesel in proportions of 5%, 10%, 20%, 50% and 100% by volume and pure diesel was used as fuel. Engine performance (specific fuel consumption, brake thermal efficiency, and exhaust gas temperature) were measured to evaluate and compute the behaviour of the diesel engine running on biodiesel. The results show that the brake thermal efficiency of diesel is higher at all loads followed by blends of waste cooking oil, biodiesel and diesel. Experimentally the maximum brake thermal efficiency and minimum specific fuel consumption were found for blends up to 20% waste cooking oil methyl ester at all loads among the blends. Exhaust gas temperature for WCOME100 is highest. For the diesel fuel, the exhaust gas temperature is the lowest among all the tested fuels. The reductions in brake specific fuel consumption and increase in brake thermal efficiency made the blend of biodiesel B20 a suitable alternative fuel for diesel engine.`**

Keywords– **Diesel Engine; Biodiesel; Waste cooking oil; Performance.**

I. INTRODUCTION

The large increase in number of automobiles in recent years has resulted in great demand for petroleum products. With crude oil reserves estimated to last for few decades, there has been an active search for alternate fuels. The depletion of crude oil would cause a major impact on the transportation sector. Biodiesel, chemically called methyl or ethyl esters are renewable fuels produced from vegetable oil and animal fat through a chemical process and is a best alternative for diesel fuel. Vegetable oils are highly viscous because of their higher molecular mass. This makes them unfit for usage directly in diesel engines. Utilizing biodiesel in diesel engines with slight modifications has proven to be more advantageous because of its reduction in pollution levels. It is estimated that India will be able to produce 288 metric tons of biodiesel by the end of 2012, which will supplement 41.14% of the total demand of diesel fuel consumption in India [1].The high cost of biodiesel is mainly due to the cost of virgin vegetable oil. Therefore, it is not surprising that the biodiesel produced from vegetable oil (for example, pure soybean oil) costs much more than petroleum-based diesel [2-3]. Hence, it is necessary to explore ways to reduce the production costs of biodiesel. The use of waste frying oil, instead of virgin oil, to produce biodiesel is an effective way to reduce the raw material cost because waste frying oil is estimated to be about half the price of virgin oil [3-4]. Each human being on this mother earth can feel the effect of economic crisis that is mainly caused by unstable price of petroleum. Another raw material that will be used in the research is waste cooking oil. It seems as a practical way for waste cooking oil (WCO) to be converted as biodiesel as it will give a comparable and cheap price than subsidized diesel. Waste cooking oils (WCO) can be used directly as a fossil diesel substitute; however, using this fuel can lead to some fairly serious engine problems. Due to its relatively high viscosity SVO leads to poor atomization of the fuel, incomplete combustion, coking of the fuel injectors, ring carbonization, and accumulation of fuel in the lubricating oil. The best method for solving these problems is the transesterification of the oil to produce biodiesel. Biodiesel is an alternative fuel similar to conventional or 'fossil' diesel. Biodiesel can be produced from straight vegetable oil, animal oil/fats, tallow and waste cooking oil. The process used to convert these oils to Biodiesel is called transesterification. The largest possible source of suitable oil comes from oil crops such as rapeseed, palm or soybean. Biodiesel can be produced from straight cooking oil, animal oil/fats, and tallow and waste oils. There are three basic routes to biodiesel production from oils and fats:

- Base catalysed transesterification of the oil.
- Direct acid catalysed transesterification of the oil.
- Conversion of the oil to its fatty acids and then to biodiesel.

The methods used for biodiesel production from used cooking oil are similar to that of conventional transesterification processes. Selection of a particular process depends on the amount of free fatty acid and water content of the used cooking oil. At present, production of vegetable oil and animal fat worldwide is not sufficient to replace liquid fossil fuel use. Almost all biodiesel is produced using base catalyzed transesterification as it is the most economical process requiring only low temperatures and pressures and producing a 98% conversion yield. For this reason only this process will be described in this report.

Energy is a key input in economic growth. There is a close link between the availability of energy and the future growth of a nation. To meet ever increasing energy requirements, there has been growing interest in alternative fuels like biodiesel to provide a suitable diesel oil substitute for internal combustion engines. One of the best alternatives is biodiesels obtained from different vegetable oils and waste cooking oil. Waste cooking oil, mainly coming from frying residues, can be used as raw material to obtain a diesel fuel (biodiesel).

II. SELECTION OF MATERIALS

Biodiesel is typically produced through the reaction of a vegetable oil or animal fat with methanol in the presence of a catalyst to yield glycerine and methyl esters. The methyl esters produced in this process are called biodiesels. This process of production of biodiesels is called transesterification [5-7]. In the last several years, many researchers have conducted studies on various compression ignition engines using biodiesels. Biodiesel is a diesel fuel that is made by reacting vegetable oil (cooking oil) with other common chemicals that are easily available in the market. Biodiesel may be used in any diesel automotive engine in its pure form or blended with petroleum-based diesel, so need not worry about anything. No modifications are required, and the result is a less-expensive, renewable, clean-burning fuel. Transesterification reactions were carried out in a 250ml glass reactor with a condenser. Used Groundnut Oil/Waste Cooking Oil which was heated to 100°C was obtained from a sweet stall. First, a known quantity of the catalyst system loaded externally was dispersed in methanol under magnetic stirring. Then Waste Cooking Oil (WCO) in the molar ratio of 6:1, methanol to oil was added to the mixture and heated to about 60°C. The reaction was allowed to take place for two hours after which the two phase product formed as a result of transesterification was separated using a separating funnel. Upper layer consists of biodiesel, alcohol and some soap (formed as result of side reaction saponification – free fatty acids get converted to soap). Lower layer consists of Glycerine, excess alcohol, Catalyst, impurities, and traces of unreacted oil. Purification of the upper layer was done by washing with warm water. As water is immiscible with Biodiesel it can easily be separated from biodiesel.

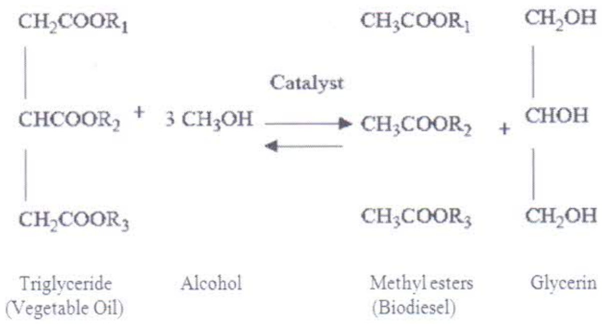

Fig. 1 Schematic representation of transesterification processes [9]

TABLE I
Comparison of Properties of Waste Cooking Oil, Biodiesel From Waste Cooking Oil And Commercial Diesel [17]

Fuel property	**Waste vegetable oil**	**Biodiesel from waste vegetable oil**	**Commercial diesel fuel**
Kinematic viscosity (mm2/s at 313 K)	13.6	5.3	1.9-4.1
Density (Kg/l at 288 K)	0.924	0.897	0.075-0.84
Flash point (K)	485	469	340-358
Pour point (K)	284	262	254-260
Cetane number	49	54	40-60
Ash content (%)	0.006	0.004	0.008-0.01
Sulphur content (%)	0.09	0.06	0.35-0.55
Carbon residue (%)	0.46	0.46	0.35-0.40
Water content (%)	0.42	0.04	0.02-0.05
Higher heating value (MJ/Kg)	41.40	42.65	45.62-46.48
Free fatty acid (mg KOH/g oil)	1.32	0.01	-
Iodine Value	141.5	-	-

III. EXPERIMENTATION

A. Experimental Setup

A single cylinder, four-stroke, water-cooled diesel engine with mechanical rope brake loading was used for this study which is developing a power output of 5 BHP @ 1500 rpm. The engine specifications are given in Table 2.

TABLE II
TEST ENGINE SPECIFICATIONS

BHP	**5**
Speed	1500
Number of cylinder	1
Compression ratio	16.5:1
Bore	80 mm
Stroke	110 mm
Orifice diameter	20 mm
Type of ignition	Compression ignition
Method of loading	Rope brake
Method of starting	Crank start

In a Test Engine Specifications a burette and a stop watch were used to measure the fuel flow rate on volume basis. The engine has run smoothly through the whole study and no major problem was reported. Performance parameters such as brake power, brake thermal efficiency, brake specific fuel consumption, brake specific energy consumption were evaluated. The experiments were carried out by using various blends of waste cooking oil methyl ester (WCO ME5,10,20, 50,100) with diesel at different load conditions on the engine keeping all the independent variables same. The engine performance test was done twice for all blends except the WCOME100 and average was taken.

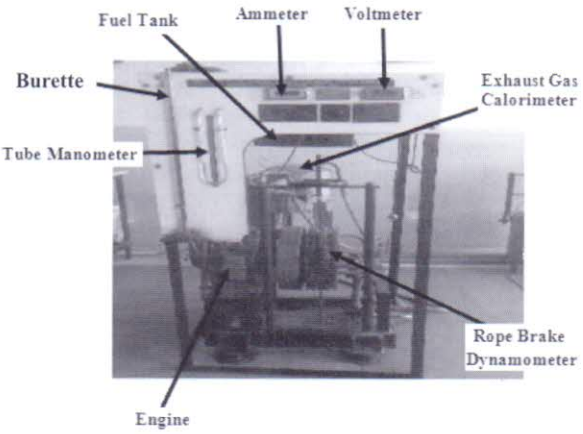

Fig. 2 Four stroke Diesel Engine

B. Working Procedure

The Biodiesel prepared by using waste Cooking oil was tested in a Single cylinder Four stroke diesel engine. Load was varied from 0 to 12 kg. Ambient temperature of the test laboratory was maintained at 30°C while carrying out the work. The WCO is blended with diesel in the different ratios. Load is given in terms of 3 kW starting from zero loads. The speed in revolutions per minute (rpm) of the diesel engine is noted down using a Tachometer. For every 10 cc rise in the oil level in the burette, the corresponding time has been noted down. From these data, the values of BSFC, BP, □Bth has been calculated using different formulas .

C. Engine Performance of WCO biodiesel and its blend with diesel

The engine performance tests were conducted with the engine setup. The engine tests were carried out using diesel, diesel blends with WCO. Performance is evaluated in terms of specific fuel consumption, brake thermal efficiency and exhaust temperature.

D. Engine performance test

Engine performance test with pure diesel, biodiesel B5, biodiesel B10, biodiesel B20, biodiesel B50, biodiesel B100 are given below:

TABLE III
ENGINE TEST WITH PURE DIESEL

Load(kg)	3	6	9	12
Spring weight(kg)	0.5	1	1.75	2
Net load(kg)	2.5	5.0	7.25	10
Time(sec)	63	48	38	32
Torque	4.78	9.56	13.86	19.12
B.P(kw)	0.75	1.50	2.17	3.00
Mf(kg/sec)	0.478	0.628	0.793	0.942
Heat supplied(J)	20076	26376	33306	39564
Sfc(Kg/kwh)	0.63	0.41	0.36	0.31
ηbt(%)	0.13	0.20	0.23	0.27

TABLE IV
ENGINE TEST WITH BIODIESEL B5

Load(kg)	3	6	9	12
Spring weight(kg)	0.5	1	1.75	2
Net load(kg)	2.5	5.0	7.25	10
Time(sec)	67	50	37	33
Torque (Nm)	4.78	9.56	13.86	19.12
B.P(kw)	0.75	1.501	2.177	3.003
Mf(kg/sec)	0.450	0.603	0.815	0.914
Heat supplied (J)	18797	25188.5	34044.1	38179
Sfc(Kg/kwh)	0.6	0.40	0.37	0.30
ηbt(%)	0.143	0.214	0.229	0.282

TABLE V
ENGINE TEST WITH BIODIESEL B10

Load(kg)	3	6	9	12
Spring weight(kg)	0.5	1	1.75	2
Net load(kg)	2.5	5.0	7.25	10
Time(sec)	68	50	41	34
Torque (Nm)	4.78	9.56	13.86	19.12
B.P(kw)	0.75	1.501	2.177	3.003
Mf(kg/sec)	0.445	0.605	0.738	0.890
Heat supplied(J)	18406.9	25025.2	30526.6	36813.9
Sfc(Kg/kwh)	0.593	0.403	0.340	0.296
ηbt(%)	0.146	0.215	0.255	0.293

TABLE VI
ENGINE TEST WITH BIODIESEL B20

Load(kg)	3	6	9	12
Spring weight(kg)	0.5	1	1.75	2
Net load(kg)	2.5	5.0	7.25	10
Time(sec)	69	51	39	35
Torque (Nm)	4.78	9.56	13.86	19.12
B.P(kw)	0.75	1.501	2.177	3.003
Mf (kg/sec)	0.440	0.596	0.780	0.869
Heat supplied(J)	17920.3	24273.8	31767.8	35392.6
Sfc(Kg/kwh)	0.586	0.397	0.359	0.289
ηbt(%)	0.150	0.222	0.245	0.305

TABLE VII
ENGINE TEST WITH BIODIESEL B50

Load(kg)	3	6	9	12
Spring weight(kg)	0.5	1	1.75	2
Net load(kg)	2.5	5.0	7.25	10
Time(sec)	68	52	42	36
Torque (Nm)	4.78	9.56	13.86	19.12
B.P(kw)	0.75	1.501	2.177	3.003
Mf(kg/sec)	0.455	0.595	0.737	0.860
Heat supplied(J)	17663.1	23097.9	28610.3	33385.2
Sfc(Kg/kwh)	0.606	0.396	0.338	0.286
ηbt(%)	0.152	0.233	0.273	0.323

TABLE VIII
ENGINE TEST WITH BIODIESEL B100

Load(kg)	3	6	9	12
Spring weight(kg)	0.5	1	1.75	2
Net load(kg)	2.5	5.0	7.25	10
Time(sec)	70	50	39	35
Torque (Nm)	4.78	9.56	13.86	19.12
B.P(kw)	0.75	1.501	2.177	3.003
Mf(kg/sec)	0.455	0.637	0.816	0.910
Heat supplied(J)	16216.2	22702.6	29082.2	32432.4
Sfc(Kg/kwh)	0.606	0.424	0.374	0.303
ηbt(%)	0.166	0.238	0.269	0.333

IV. RESULT AND DISCUSSION

A. Brake specific fuel consumption of engine using WCOME and its blends.

Fig. 3 shows the variation in BSFC is more for Diesel when compared to Biodiesel from WCO. For the fuels tested, brake specific fuel consumption decreased with increase in load. This reduction in BSFC happens due to higher percentage of increase in brake power with load.

Increasing load on engine resulted in decreasing BSFC in all cases as shown in fig.3. This reduction in BSFC happens due to higher percentage of increase in brake power with load. It can be observed that diesel fuel had the highest fuel economy at all loads in all cases with the pure vegetable oils recording the least fuel economy at all loads. This is expected as pure vegetable oils are much denser and more viscous as well than diesel. Also, the calorific value of the pure cooking oils was found to be lower than diesel thereby making the engine consume more fuel to overcome identical load. Lower blends of waste cooking oil as in 5%, 10%, 20% and 100% by volume produce remarkably close BSFC values.

B. Brake Thermal Efficiency (BTE)

Figure 4 shows the variation of BTE with respect to load. It is observed that the Brake Thermal Efficiency increased with increase in load. This was due to reduction in heat loss and increase in power with increase in load. Brake Thermal efficiency is more for Biodiesel obtained from Waste Cooking Oil when compared with pure petroleum diesel. The improved thermal efficiency for lower concentrations of WCO is due to more complete combustion. The lower brake thermal efficiency obtained for diesel could be due to reduction in calorific value and increase in fuel consumption. This trend of BTE with increasing load in different biodiesel blends were also reported by some researchers [10].

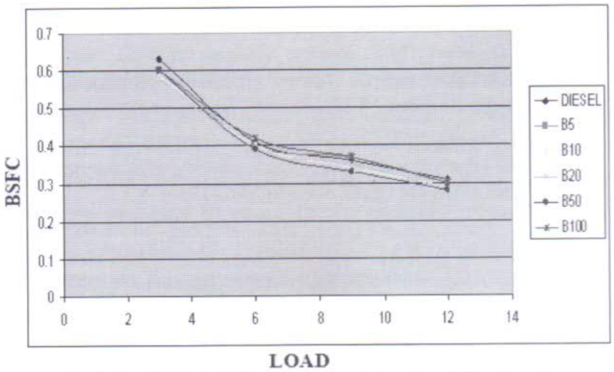

Fig.3 Specific Fuel Consumption of diesel and blends of waste cooking oil with diesel

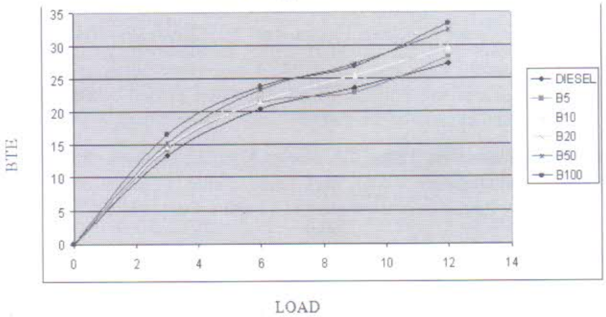

Fig. 4 Variation of brake thermal energy consumption with load

C. Exhaust Gas temperature (EGT)

Figure 5 shows the variation of the exhaust gas temperature with change in load. The exhaust gas temperature of an engine is an indication of the conversion of heat into work. Exhaust gas temperature for WCOME100 is highest. For the diesel fuel, the exhaust gas temperature is the lowest among all the tested fuels. The exhaust gas temperature rises from 800 C at no load to 1250 C at full load for WCOME100.

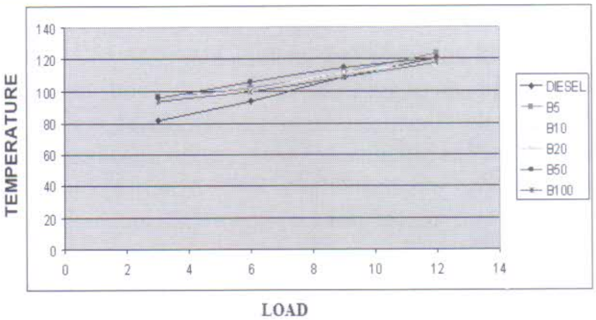

Fig 5 Variation of exhaust gas temperature with load

V CONCLUSIONS

- From the following work, we get three conclusions and they are explained as follows:
- Increasing load on engine resulted in decreasing BSFC in all cases.
- Increasing load on engine resulted in increasing brake thermal efficiency.
- Increasing load on engine resulted in increasing temperature in all cases.

REFERENCES

[1] R.D. Misra, M.S. Murthy, Straight vegetable oils usage in a compression ignition engine-A review Renewable and Sustainable Energy Reviews, 14, (2010) 3005–3013.

[2] B. Supple, R. Howard-Hildige, E. González-Gómez, J.J. Leahy, The effect of steam treating waste cooking oil on the yield of methyl ester, J.Am. Oil Chem. Soc. 79 (2002) 175–178.

[3] Y. Zhang, M.A. Dubé, D.D. McLean, M. Kates, Biodiesel production from waste cooking oil: 1. Process design and technological assessment,Bioresour. Technol. 89 (2003) 1–16.

[4] M.J. Haas, Improving the economics of biodiesel production through the use of low value lipids as feedstocks: vegetable oil soapstock, FuelProcess. Technol. 86 (2005) 1087–1096.

[5] Padhi, S.K., Singh, R.K., "Optimization of esterification and transesterification of Mahua (MadhucaIndica) oil for production of biodiesel"l,J. Chem. Pharm. Res. 2(5) (2010) 599-608.

[6] Sahoo P.K. and Das L.M., Combustion analysis of Jatropha, Karanja and Polanga based biodiesel as fuel in a diesel engine, Fuel. 88 (2009) 994-999.

[7] Sahoo P.K., Das. L.M, Babu M.K.G. and Naik. S.N., Biodiesel development from high acid value Polanga seed oil and performance evaluation in a CI engine, Fuel., 86(2007) 448-454.

[8] Sharma Y.C., Singh. B. and Upadhyay. S.N., Advancements in development and characterization of biodiesel: A review, Fuel. 87 (2008) 2355-2373.

[9] Jon Van Gerpen, Biodiesel processing and production, Elsevier, Fuel Processing Technology, 86 (2005) 1097– 1107.

[10] Banerjee.T., Bhattacharya. T.K. and Gupta R.K., Process Optimization of Catalyst Removal and Characterization of Waste Water After Alkali Catalyzed Transesterification of Jatropha Oil, International Journal of Green Energy, 6 (2009) 392-400.

[11] Ram BVB, Ramanathan V, Phuan S, Vedaraman N, A Process for the preparation of biodiesel from Mahua oil by Transesterification, Indian chemical Engg. Journal, 14(2) (2004) 12-15.

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