Experimental Investigation on Combustion, Performance and Emission characteristics of blends of Plastic oil and Biodiesel as a substitute fuels in Diesel Engine

D. K. Ramesha[a], G Prema Kumara[b], Abhishek Jain C N[a], Akash B[a],

BabuReddy R[a], Kalappa M. Kammara[a] ,

[a]*Department of Mechanical Engineering, University Visvesvaraya College of Engineering, Bangalore University, K. R. Circle, Bangalore – 560001, India*
[b]*Department of Mechanical Engineering, University of Victoria, EOW Building, Room 548, 3800 Finnerty Road, P.O. Box 1700, Victoria, BC V8W 2Y2, Canada,*

---***---

Abstract - *The thirst for fuel is steadily increasing as technology continues to open new areas of exploration. At the same time, the indiscriminate extraction of fossil fuels also may results in depletion of petroleum deposits. Diesel being the main transport fuel in India, finding suitable alternative to diesel in an urgent need. Environmental concerns and limited amount of petroleum resources have caused interests in development of alternative fuels for internal combustion engines. Biodiesel is an alternative to diesel fuel, environment friendly and biodegradable and is produced from either edible or non-edible oils. In this context, waste plastic solid is currently receiving renewed interest. Waste plastic oil is suitable for compression ignition engines and more attention is focused in India because of its potential to generate large-scale employment and relatively lower scale degradation. The present investigation was to study the effect of plastic oil blend with B20 rubber biodiesel and B20 honge biodiesel on four stroke, single cylinder direct Injection diesel engine. Experimental results show that performance characteristics were found to be comparable with diesel. The emission characteristics shows that NOx emission levels are slightly higher and other emissions like CO, HC are compatible with diesel modes of operation. Hence plastic oil can be used as substitute fuel in place of conventional diesel fuel.*

Key words: Plastic oil; Pongamia biodiesel; Rubber Seed biodiesel; Performance; Emission; Combustion characteristics

1. Introduction

According to the U.S energy information administration the average global energy consumption grows at a rate of 1.6% p.a. This indiscriminate consumption will lead to extinction of Fossil Fuels [1].Diesel being the main transport fuel in India has imported about 90 million tons of Crude oil (17% of its requirement) and petroleum products during the year 2012-2013 causing heavy burden on foreign exchange out go. To cut the foreign exchange and contribute towards protection of earth from the threat of environmental degradation, bio fuels can be good alternative for diesel for most of the developing countries. Vegetable oils and plastic oil have considerable potential to be considered as appropriate alternative as they possesses fuel properties similar to that of diesel. Vegetable oils can be classified into two types one is edible oil and other being non-edible oil [2]. Since edible oils are in great demand for domestic consumption, the non-edible oil likes honge and rubber Seed oil used as a substitute fuel due to following reasons. The use of bio diesel in conventional diesel engine results in substantial reduction of unburnt hydrocarbon, carbon monoxide and particulate matter [but NOx about 2% higher]. Biodiesel has almost no sulphur (0.05%), no aromatics and has about 10 % built in oxygen which helps in better combustion [1].High viscosity, high flash and fire point and low volatility are main disadvantages of vegetable oils as alternative fuels in IC Engines. Transesterification processes are carried out to remove impurities, reduce viscosity and to match most of properties closely with petroleum diesel properties [2].Waste plastics are indispensable materials in the modern world and application in the industrial field is continually increasing. More attention is focused worldwide because of its potential to large scale employment and relatively low environmental degradation [3]. The countries have to simultaneously address the issues of energy insecurity, increasing oil prices and large scale employment. The waste plastic oil is obtained from the process called Pyrolysis. Pyrolysis is the thermal decomposition of organic material at elevated temperatures, in the absence of gases such as air or oxygen. The objective of this study is to experimentally investigate and to compare performance, combustion and emission characteristics in a CI engine using B20 blend of biodiesel (mainly HOME and ROME) and plastic blend of respective biodiesel, to further replace diesel. It is in this context a diesel engine was fuelled with waste plastic oil in present work. But it was found to be giving more NO_X emissions [4].The waste plastic oil is compared with petroleum products and found that it can also be used as fuel in CI engine. Plastic oil is non-biodegradable and renewable oil [3]. The engine behavior with respect to combustion, performance, and emission characteristics, are compared against a baseline of a standard diesel run.

Nomenclature	
BP	Brake Power
BTDC	Before Top Dead Centre
BTE	Brake Thermal Efficiency
HRR	Heat release rate
B20	20% biodiesel& 80% Diesel
CI	Compression Ignition
CO	Carbon monoxide
HOME	Honge Oil Methyl Ester
ROME	Rubber Oil Methyl Ester
EGT	Exhaust Gas Temperature
IC	Internal combustion
NOx	Oxides of Nitrogen
ppm	Parts per million
UBHC	Unburnt hydrocarbons
WPO	Waste plastic oil

2. Transesterification

Transesterification: the chemical process of making biodiesel refers to a reaction between an ester of one alcohol and a second alcohol to form an ester of the second alcohol and an alcohol from the original ester, as that of methyl acetate and ethyl alcohol to form ethyl acetate and methyl alcohol. Chemically, Transesterification means taking a triglyceride molecule or a complex fatty acid, neutralizing the free fatty acids, removing the glycerin and creating an alcohol ester. This is accomplished by mixing methanol with sodium hydroxide to make sodium methoxide. This liquid is then mixed into vegetable oil. The entire mixture then settles. Glycerin is left on the bottom and methyl esters, or biodiesel, is left on top. The glycerin can be used to make soap and the methyl esters is washed and filtered. Transesterification of honge seed oil and rubber seed oil is normally done with ethanol and sodium ethanolate serving as the catalyst.

Sodium ethanolate can be produced by reacting ethanol with sodium. Thus, with sodium ethanolateas the catalyst, ethanol is reacted with the algal oil (the triglyceride) to produce bio-diesel& glycerol. The end products of this reaction are hence biodiesel, sodium ethanolate and glycerol. The honge seed oil and rubber seed oil after this trans-esterification process is usually referred to as honge oil methyl ester [HOME] and rubber oil methyl ester [ROME] respectively. Figure 1 shows the chemical reaction of transesterification. The properties of honge biodiesel and rubber biodiesel after transesterification are tabulated in Table 2.

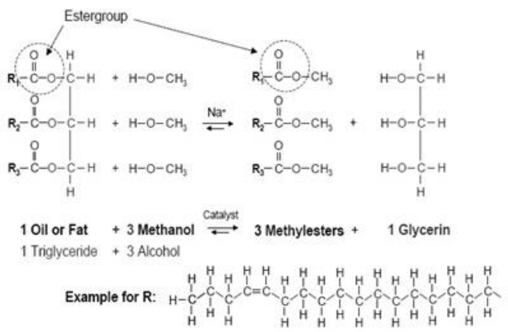

Fig -1: Trans-esterification of oil and fat

Table 1: Engine Specifications

Make	Kirloskar
Speed	1500RPM
Compression Ratio	17.5:1
Cylinder Bore	87.5mm
Stroke	110mm
Connecting Rod Length	234mm
Cooling	Water Cooling
Orifice Diameter	20mm
Rated Power	7.5kW
Maximum Load	12KN
Injection Opening Pressure	180 bar
No. of Cylinders	1

Table 2: Properties of various fuel

Properties	Diesel	Pongamia Oil	Rubber Seed Oil	HOME	ROME	WPO
Colour	Orange	Yellowish Brown	Dark Brown	Brown	Brown	Pale Black
Density (kg/m^3) at 40^0C	828	915	860	873	865	835
Specific Gravity at 40^0C	0.828	0.909	0.87	0.873	0.873	0.835
Kinematic Viscosity (centi-stokes) at 40^0C	3.78	42.78	6.0	5.46	5.46	2.52
Calorific Value (kJ/kg)	44030	37304	37500	40210	38565	44340
Iodine Value (gm I_2/kg)	38.3	82.78	146	90	146	Nil
Saponification Value	Nil	179.55	194	90	186	Nil
Cetane number	55	42	45	Nil	43	51
Flash Point (^0C)	47	220	72	171	130	42
Fire Point (^0C)	63	243	210	184	181	45

3. Experimental Setup

The experiments were conducted on a computerized diesel engine test rig shown in Figure 1. Kirloskar make single cylinder, 4-stroke, naturally aspirated direct injection, water cooled diesel engine of 7.5KW rated power at 1500 rpm was directly coupled to an eddy current dynamometer. The engine and the dynamometer were interfaced to a control panel which is connected to a digital computer. The computerized test rig was used for recording the test parameters such as fuel flow rate, temperature, air flow rate, load etc. and for calculating the engine performance characteristics such as brake power, brake thermal efficiency, brake specific fuel consumption, volumetric efficiency etc. The calorific value and the density of the particular fuel were fed to the engine software for calculating the performance parameters. Similarly combustion characteristics such as heat release rate, peak pressure, etc. were also calculated.

A DELTA 1600-L of MRU make Exhaust gas analyser is used to find the NOx(ppm),CO(%vol),UBHC(ppm),CO_2(%) and O_2(%) emission in the exhaust. The AVL437C smoke meter is used to measure the opacity of the exhaust gases. Opacity is the extinction of light between light sources and receiver. Opacity is measured in percentage. The Exhaust gas analyser and smoke meter are shown in Figure 2 and The specifications of engine are tabulated in Table 1.

The whole set of experiments were conducted at a Compression ratio of 17.5:1 and injection timing of 27° BTDC. The tests were conducted at 20%, 40%, 60%, 80% and 100% of maximum load condition with diesel, diesel blended with 20% of honge oil, diesel blended with 20% of honge oil, 10% of waste plastic oil, diesel blended with 20% of rubber seed oil, diesel blended with 20% of rubber seed oil 10% of waste plastic oil, This was done in order to obtain optimum results without over stressing the engine. The data recording was done after the experiment was carried out for three times to obtain a repeatability of values for each blend [5].

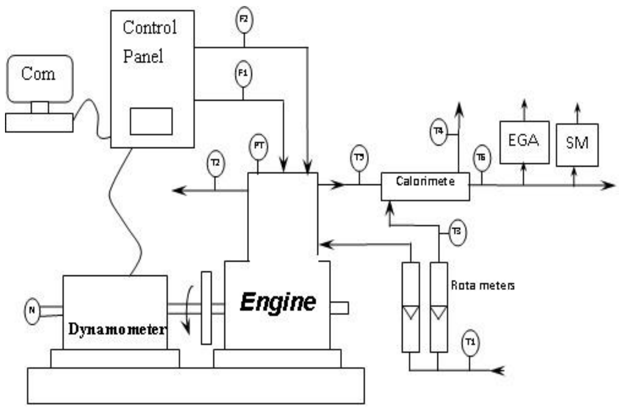

Fig -2: Schematic Representation of the Experimental Setup.

Fig -3: Kirloskar Engine

Fig -4: Exhaust Gas Analyzer

Fig -5: Smoke Meter

4. Results and Discussion

a) Performance Analysis

i) Brake Thermal Efficiency (BTE)

Figure 6 portrays the variation of BTE with Load for different fuel blends and diesel. The thermal efficiency indicates how efficiently energy in the fuel is converted into mechanical output .The BTE for diesel is 23.2% at full load, which is highest among all fuels tested. For B20 HOME, B20 HOME-10 WPO, B20 ROME, B20 ROME–10 WPO, it is 21.4%, 21.41%, 19.1%, 19.12% respectively at full load .The Thermal Efficiency of plastic blends is lower than that of diesel and slightly higher than B20 bio diesel at full load, due to higher density and poor volatility. Hence the performance of engine with biodiesel and plastic oil blend is comparable to that of diesel in terms of BTE.

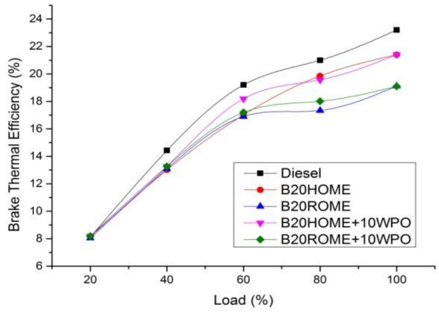

Fig -6: Variation of BTE with Load

b)Combustion Analysis

i) Heat release Rate (HRR)

Figure 7 illustrates heat release pattern with respect to crank angle at full load. Heat release diagram is a quantitative description of timely burning of fuel in engine. It is apparent from the figure, that the heat release rate is the highest for biodiesel blends and lowest for diesel at full load .The reason for this could be that oxygen content is more in biodiesel blends which leads to more complete combustion[1]. In general, during ignition delay, the fuel droplets spread over a wide area around fresh air to form the fuel-air mixture. Once the ignition delay is over, the premixed fuel- air mixture burns, releasing heat at a very rapid rate. The maximum value of HRR is shown by B20 ROME-WPO at 7000kJ/sec whereas B20 ROME and Diesel showed 6520 kJ/sec and 6190 kJ/sec respectively. It is observed that B20 ROME-WPO showed greater HRR than diesel by 12%. The similar characteristics are observed for honge biodiesel also. Because of vaporization of the fuel during ignition delay, a negative heat release rate is observed at the beginning and after the combustion is initiated, it becomes positive [14].

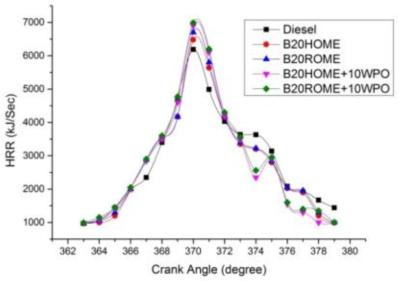

Fig -7: Variation of HRR with Crank Angle

ii) Peak Cylinder Pressure

Figure 8 shows the variation of peak pressure of different blends with load. The peak pressure increases steadily with load, it is seen from the Figure that the peak pressure of all blends is higher as compared to that of diesel at all loads. The peak pressure for B20ROME-10WPO is 41.143% which is higher than 39.878% of B20ROME, the reason being inbuilt oxygen in WPO. At full load the B20ROME-10WPO showed more peak pressure than diesel by 6%. The similar characteristics are observed for HOME biodiesel and plastic blends.

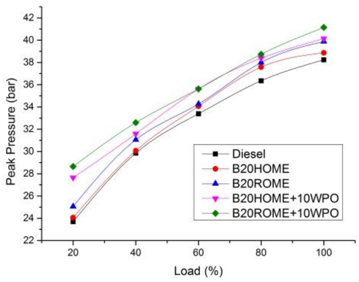

Fig -8: Variation of Peak Pressure with Load

c) Emission Analysis

i) Unburned Hydrocarbons

The variation of UBHC with load for tested fuels is depicted in Figure 9.From the results it can be noticed that concentration of UBHC of blends is significantly lesser than diesel fuel (this could be due to higher oxygen content in biodiesel which improves the combustion).For efficient combustion the fuel has atomized, mixed and ignite properly [11, 12, 13].The cetane number plays an important role in ignition process. As the cetane numbers of blends are higher than that of diesel, it exhibits shorter delay period and results in better combustion. Further oxygen content of WPO blend with B20 HOME leads to low CO and HC emissions. From Figure 9 it is very clear that plastic oil blend emits low UBHC emission than diesel.

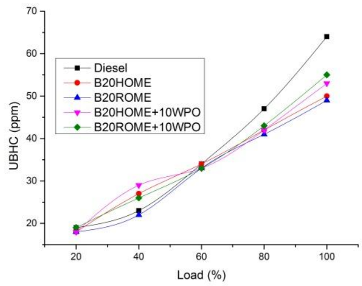

Fig -9: Variation of UBHC with Load

ii) Carbon Monoxide

The Figure 10 depicts the variation of CO emission of blends and diesel with loads. The CO emission depends on oxygen content, carbon content and combustion efficiency of fuel. During combustion, the carbon content of fuel undergoes a series of oxidation and reduction reaction [7]. The mean CO emissions of blends were less than that of the diesel. The main reasons for reduction are presence of oxygen in biodiesel and WPO, and its higher combustion temperature which improves the combustion.

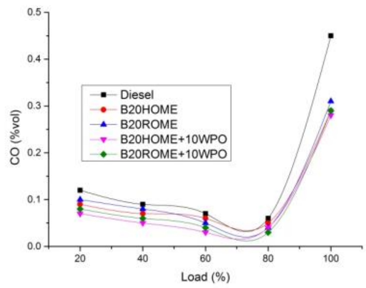

Fig -10: Variation of CO with Load

iii) Oxides of Nitrogen

Figure 11 shows the variation of oxides of nitrogen with load for tested fuels. The formation of NOx depends on gas temperature and ignition delay [10]. Nitrogen oxides are considered as major contributor for ozone depletion, they are also reality of operation IC Engines. It is observed from Figure 11 the amount of NOx increased with increase in load for all fuels, it happens because with increase in load, the temperature of combustion chamber increases, as NOx formation is strongly temperature dependent phenomena. The Figure indicates that the NOx emission of B20 biodiesel appears to decrease marginally as compared to that of diesel. The plastic blend fuel shows increased NOx emission compared to other fuels. The reason for this trend is higher HRR in case of plastic blend. Due to higher HRR the incylinder temperature would also increase thereby NOx emissions will be more [2].

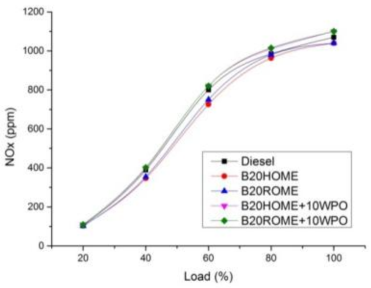

Fig -11: Variation of NOx with Load

iv) Exhaust Gas Temperature

The variation of EGT with respect to the load as shown in Figure 12. The EGT is an indicator of heat of fuels tested at combustion period [9].From the reading it can be seen that EGT of B20 ROME, B20 ROME- 10WPO ,B20 HOME, B20 HOME- 10WPO blends are 355.008^{o}C,360.334^{o}C, 349.334^{o}C, 352.008^{o}Cwhich are higher than that of diesel. Slight increase in EGT of plastic blends is due to higher viscosity and poor volatility which leads to late burning that causes increase in temperature [5]. The biodiesel with plastic blend has higher EGT compared with diesel.

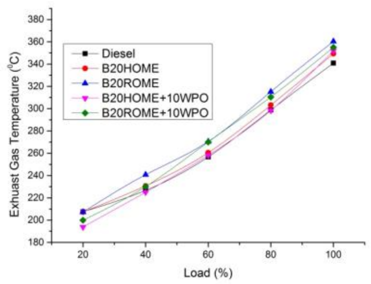

Fig -12: Variation of EGT with Load

v) Smoke Opacity

Smoke emission is nothing but solid soot particles suspended in exhaust gas. The Figure 13 shows the variation of smoke with load for all fuels tested. It is observed from Figure that the smoke opacity of exhaust gas increases with load for all blends. The smoke emission for blended fuels are high compared to that of the diesel. This is due to poor volatility, higher viscosity of blends. The molecule of blends being heavier also attributes to increase in smoke emission [8] .The smoke opacity of plastic blend is slightly higher compared to B20 biodiesel due to presence of plastic oil which contributes in higher viscosity and poor volatility of the blend.

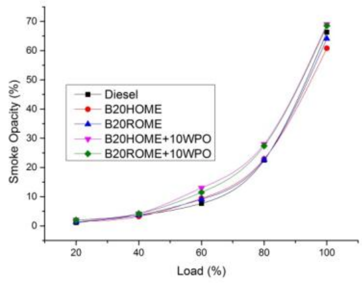

Fig -13: Variation of Smoke Opacity with Load

5. Conclusion

The engine tests were conducted with pongamia oil, rubber oil and plastic oil blends for no load to full condition and the corresponding performance and combustion characteristics were studied in comparison with diesel fuel. All the tests were conducted under the same conditions and repeated for three times to obtain consistent values. Pongamia oil blended with waste plastic oil is determined for suitable replacement of conventional diesel. In combustion analysis B20HOME-10WPO blend exhibits a higher cylinder peak pressure compared to B20 biodiesel blend and diesel because of evaporation of WPO inside the cylinder by absorbing heat from combustion chamber. The heat release rate with B20HOME-10WPO blend is higher compared toB20 biodiesel blend and diesel fuel due to better combustion as a result of presence of WPO. With the addition of WPO, NOx increases due to higher heat release and combustion temperature and the CO and HC emissions are considerably lower. Engine with B20HOME-10WPO blend results in better performance than B20 biodiesel blend and diesel.

References

[1]. M. Mani, G. Nagarajan, S. Sampath. Characteristic and effect of using waste plastic oil and diesel fuel blends in compression ignition engine. Energy 36 (2013) 212-219.

[2]. M. Mani, G. Nagarajan, S. Sampath. An experimental investigation on a DI diesel engine using waste plastic oil with exhaust gas recirculation. Fuel 89 (2010) 1826-1832.

[3]. D K Ramesh, G Premakumara, Abhishek Jain C N, Akash b, Babureddy, Kalappa M Kammar Experimental investigation on Combustion, Performance and Emission characteristics of a Plastic oil and B20 Pongamia Biodiesel as a substitute fuel in Diesel Engine International Conference on Environment and Energy,JNTUH, ISBN 978-93-81212-96-7

[4]. Prajwal Tewari, Eshank Doijode, N.R. Banapurmath, V.S. Yaliwal. Experimental investigation on a diesel fuelled with multiwall carbon nanotubes blended biodiesel fuels. ICESTD 2013, Feb 2013, ISSN 2250-2459

[5]. S.H. Park, S.H. Yoon, C.S. Lee, Effect of the temperature variation on properties of biodiesel and Biodiesel–ethanol blends fuels, Oil & Gas Science and Technology 63 (6) (2008) 737–745

[6]. D K Ramesh, Rajiv K T, Rajiv Simhasan, Manjunath N and Prithvish M Gowda A Study On Performance Combustion and Emission Evaluation of Corn oil as Substitute fuel in a CI Engine, Journal of The Institutions of Engineers India Ser. C DOI 10.1007/s40032-012-0030-4.

[7]. Vedaraman N, Puhan S, Nagarajan G, Velappan KC. Preparation of palm oil biodiesel and effect of various additives on NOx emission reduction in B20 : an experimental study. Int J Green Energy 2011; 8:383-97.

[8]. Balusamy T, Marappan R. Performance evaluation of a direct injection diesel engine with blends of Thevetiaperuviana seed oil and diesel. J Sci Ind Res 2007;66:1035-40.

[9]. Behcet R. Performance and emission study of waste anchovy fish Biodiesel in a diesel engine. Fuel Process Technology 2011;92:1187-94.

[10]. Lin CY, Lin HA. Engine performance an emission characteristics of a three phase emulsion of biodiesel produce by peroxidation. Fuel Process Technology 2007; 88:35-41.

[11]. Godiganur S, Murthy CS, Reddy RP. Performance and emission characteristics of Kirloskar HA394 diesel engine operated on fish oil methyl esters. Renew energy 2010;35:355-9.

[12]. Lin CY, Li RJ. . Engine performance emission characteristics of marine fish oil produced from the discarded parts of marine fish. Fuel Process Technology 2009; 90:883-8.

[13]. Jayasinghe P, Hawboldt K. A review of bio-oils from waste biomass; focus on fish processing waste Renewable Sustainable Energy Review 2012;60:798-821.

BIOGRAPHIES

Prof. D K Ramesha passed BE from Mysore University, and did his M.Tech and Ph.D National Institute of Technology Karnataka (NITK),Surathkal. He presently works as Associate Professor in Department Of Mechanical Engineering in University Visvesvaraya College of Engineering (UVCE), Bangalore India. He presented 45 technical papers in International/national seminars and published 15 papers in International journals. He is guiding 5 candidates for Ph.D .

Prof. G Prem Kumar passed BE from Bangalore University, and did his M.Tech from Karnataka Regional Engineering college(KREC),Surathkal and Ph.D degree from IIT Delhi and doing another Ph.D in University of Victoria. He is presently working as Assistant Professor in Department Of Mechanical Engineering in University Visvesvaraya College of Engineering (UVCE), Bangalore University, Bangalore, India. He presented 15 technical papers in International/national seminars and published 4 papers in International journals

Abhishek Jain C N Akash B Babureddy R Kalappa M K

are the B.E scholars in University Visvesvaraya College of Engineering (UVCE), Bangalore University, Bangalore, India. They have presented a Technical Papers in 1 International Conference and 2 National Conferences.

