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Study on effects of Alumina nanoparticles as additive with Poultry litter biodiesel on Performance, Combustion and Emission characteristic of Diesel engine *

*Ramesh D K [a], Dhananjaya Kumar J L [b], Hemanth Kumar S G [c], Namith V [c], Parashuram Basappa Jambagi [c], Sharath S [c], **

[a]*Associate Proffesor, University Visvesvaraya College of Engineering, Bangaore University,K R Circle, Bengaluru-560001, India*
[b] *PG Scholar, University Visvesvaraya College of Engineering, Bangaore University, K R Circle, Bengaluru- 560001, India*
[c]*UG Scholar, University Visvesvaraya College of Engineering, Bangaore University,K R Circle, Bengaluru-560001, India*

Abstract

In the recent research, as a result of depletion of world petroleum reserves, considerable attention has been focused on the use of different alternative fuels in diesel engines. The present work aims to ensure the possibility of using poultry litter oil biodiesel obtained from wastes of poultry industries as an alternative fuel for diesel in a compression ignition engine. In this study, biodiesel is obtained from poultry litter oil by acid and base catalyzed transesterification with methanol when sulfuric acid and potassium hydroxide as catalyst. The experimental work is carried out in a CI engine using poultry litter oil B20 biodiesel blend and B20 biodiesel blend with 30mg/l alumina nanoparticles as an additive. The performance, emission, and combustion characteristics of B20 biodiesel blend and alumina added B20 biodiesel are investigated by comparing them with neat diesel. The experimental test results reveal that the combustion and performance characteristics improved with B20 biodiesel blend with and without nanoparticles. Considerable reductions in carbon monoxide, unburned hydrocarbon and increase in nitrogen oxide emissions are attained while using B20 biodiesel blend compared with neat diesel. However, there is a significant reduction in CO, UBHC and NOx emissions for B20 biodiesel blend with nanoparticles as an additives compared with B20 biodiesel blend and neat diesel.

Keywords: Diesel engine; poultry litter oil methyl ester; biodiesel; alumina nanoparticles; transesterification; performance; combustion; emission.

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1. INTRODUCTION

The compression ignition engines are widely used due to its reliable operation and economy. As the petroleum reserves are depleting at a faster rate due to the growth of population and the subsequent energy utilization, an urgent need for search for a renewable alternative fuel arise. Also the threat of global warming and the stringent government regulation made the engine manufacturers and the consumers to follow the emission norms to save the environment from pollution. Among the many alternative fuels, biodiesel (vegetable/animal oil methyl esters) is considered as a most desirable fuel extender and fuel additive due to its high oxygen content and renewable in nature [1, 2].

Finding alternative, non food, feedstock such as waste vegetable oil, grease, and animal fats [3, 4] is considered a necessity for the industry. Through continued research to produce bio-fuels from non food sources, it has been discovered that poultry litter offers another promising feedstock source for biodiesel production. The major components of vegetable oils and animal oils are triglycerides. Triglycerides are esters of glycerol with long-chain acids (fatty acids) [4]. The use of straight animal oil (poultry litter oil) in CI engine results in carbon deposition and clogging of fuel injector in the combustion chamber. This can be minimized by reducing the viscosity of the oil by transesterification. The concept of transesterification process of edible oil with an alcohol (methyl or ethyl) provides a clean burning fuel (Commonly Known as biodiesel) having less viscosity. At industrial level, biodiesel is normally produced by this transesterification process, a chemical process in which triglyceride react with an alcohol(methyl or ethyl) in the presence of an alkali catalyst (usually NaOH or KOH in proportions of about 1 % weight of oil) to form fatty acid alkyl mono esters (biodiesel) and glycerol (by-product) [5, 6]. This occurs in a multiple reaction process including three reversible steps in series, where triglyceride are converted to diglycerides, then diglycerides are converted to monoglycerides, and monoglycerides are converted to esters and glycerol. The poultry litter oil obtained after this transesterification process is usually referred to as poultry litter oil methyl ester. Several legislations were followed for improving the disadvantages of biodiesel fuel such as increased NO_x emissions and soot particles. To achieve these standard emission norms, fuel additives namely antioxidants and nanoparticles were preferred for minimizing the NOx emissions effectively [7]. Alumina Nano particles were used as additives in biodiesel blend and percentage reduction of emissions with increase in Brake thermal efficiency were observed. From nanoparticle study it is observed that in order to improve the performance, combustion and emission characteristics of engine evenly, nanoparticle will be the most promising additive. Hence the potential use of biodiesel fuel using poultry litter oil methyl ester and alumina nanoparticles added biodiesel presented in this paper.

Abbreviations and Symbols

BP	Brake Power
BTE	Brake Thermal Efficiency
HRR	Heat Release Rate
B20	20% Biodiesel & 80% Diesel
CI	Compression Ignition
CO	Carbon monoxide
PLOME	Poultry Litter Oil Methyl Ester
NOx	Oxides of Nitrogen
O2	Oxygen
ppm	Parts per million
UBHC	Unburnt Hydrocarbons
ASTM	American Society for Testing and Materials
B20PLOM	20% Poultry Litter Oil Methyl Ester + 80% Diesel
B20PLOME30A	20% Poultry Litter Oil Methyl Ester + 80% Diesel + 30mg/Lt Al2O3
BTDC	Before Top Dead Center

2. Preparation of Materials

2. 1. Biodiesel production:

The non-edible poultry litter raw oil is used to produce the biodiesel fuel using a laboratory-scale setup. The setup consists of mechanical stirrer with controllable stirring speed and temperature, beakers, thermometer to observe the reaction temperature. The properties of both base diesel fuel and the received PLOME are listed according to ASTM standard in Table 1.

2. 2. Acid value determination:

The acid value of raw oil has been determined by a standard titrimetric method as per European standard EN14104.

2. 3. Transesterification

2. 3. 1. Esterification setup

A round bottom flask is used as laboratory scale reactor for these experimental purposes. A hot plate with magnetic stirrer arrangement is used for heating the mixture in the flask. The mixture is stirred at the same speed for all test runs. The temperature range of 50-60^{o}C is maintained during this experiment.

2. 3. 2. Acid transesterification:

One litre of poultry litter oil requires 600 ml of methanol for the acid esterification process. The poultry litter oil is poured into the flask and heated to about 50^{o}C. The methanol is added with the preheated poultry litter oil and stirred for a few minutes. 0.5% of sulphuric acid is also added with the mixture. Heating and stirring is continued for 30–50 min at atmospheric pressure. On completion of this reaction, the product is poured into a separating funnel for separating the excess alcohol. The excess alcohol, with sulphuric acid and impurities moves to the top surface and is removed. The lower layer is separated for further processing (base esterification).

2. 3. 3. Base transesterification:

Alkaline catalysed esterification process uses the experimental setup of acid catalysed pre-treatment process. The products of first step are preheated to the required reaction temperature of 55±5^{o}C in the flask. Meanwhile, 30ml of oil is taken in a round bottom flask 0.24 g of KOH is dissolved in 15 ml methanol and is poured into the flask. The mixture is heated and stirred for 40-50 min. The reaction is stopped, and the products are allowed to separate into two layers. The lower layer, which contained impurities and glycerol, is drawn off. The ester remains in the upper layer. Methyl esters are washed to remove the entrained impurities and glycerol. Hot distilled water (10% by volume) is sprayed over the surface of the ester and stirred gently. Lower layer is discarded and yellow colour layer (known as biodiesel) is separated. The parameters affecting the process such as alcohol to oil molar ratio, catalyst amount, reaction temperature and duration are analysed.

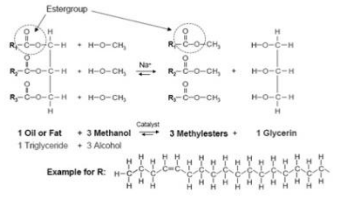

Figure 1.Mechanism of transesterification process

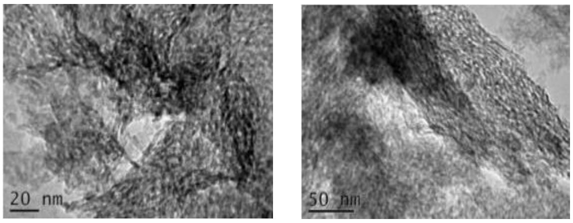

Figure 2.Transmission electron microscope image of alumina nano

2. 3. 4. Preparation of blend:

B20PLOME is prepared by mixing 20% by volume of biodiesel with 80% of diesel in a beaker and constantly stirred for 15min on a magnetic stirrer. B2PLOME30A is prepared by adding 30mg of alumina nanoparticle per litre of B20 biodiesel blend.

2. 4. 1. Dispersion of alumina nanoparticles:

The nanoparticles are dispersed into a mixture of poultry litter oil biodiesel-diesel fuel in the recommended composition (20 % by vol. of PLOME and 80 % of diesel fuel) with the aid of an ultrasonicator at a frequency of 24 kHz for 30 minutes. The ultra sonication technique is the best-suited method to disperse the nanoparticles in a base fluid to prevent the agglomeration of nanoparticles using pulsating frequencies to disperse nanometre ranges into the fluid. The alumina nanoparticles of average size of 20 to 50 nm with detailed specifications list in table 2. The morphology of alumina nanoparticle is as shown in Figure 2. The nanoparticles are weighted according to the predefined mass fraction of 30 mg/l and mixed with B20PLOME in an ultrasonicator. Correspondingly the received mixture is symbolized as B20PLOME30A indicating nano content of 30 mg/l in PLOME-diesel mixture, respectively [8]. Surfactants are added to lower the surface tension between liquid fuel and solid nanoparticles in order to stabilize nanoparticles.

3. Engine Test

Whole set of experiments were conducted at the designed injection timing of 23 degrees BTDC, Injection pressure of 180 bar, speed of 1500 RPM and 17.5:1 compression ratio. The engine was started by hand cranking with diesel fuel supply and it was allowed to get its steady state (for about 10 minutes). The engine tests were conducted on a computerized single cylinder four-stroke diesel engine test rig. It was directly coupled to an eddy current dynamometer that permitted engine motoring either fully or partially. The engine and the dynamometer were interfaced to a control panel, which was connected to a digital computer. The computer software ‘Engine Analysis Software’ was used for recording the test parameters such as fuel flow rate, temperatures, air-flow rate, load etc. and for calculating the engine performance characteristics such as brake thermal efficiency, heat release rate etc. The experiments were conducted at no-load to full load condition. The engine was next run with the B20PLOME and then with B20PLOME30A for the same above conditions and performance, combustion and emission tests were carried out. For exhaust gas analysis, OROTECH Exhaust Gas analyzer was used whose specifications are given in table 3 and for recording smoke opacity, AVL437C Smoke Meter was used whose specifications are given in Table 4. Uncertainty analysis was conducted for both the analyzers which is discussed below.

3.1 Uncertainty analysis

The uncertainties of the parameters are calculated by sequential perturbation. Some of average uncertainties of measured and calculated parameters are air flow rate(1.1%), liquid fuel flow rate(0.1%), gas flow rate(2%), engine load(0.1%), engine speed(1.3%), cylinder pressure(0.8%), temperature(1.0%), LCV of liquid fuel (1.0%). Based on these, the calculated accuracy of the performance and combustion studies of the engine is found to be within ±4.6%. However, the accuracy of emission study is found to be ±4.6%. The maximum values of coefficient of variance of the performance parameters, viz., BTE and BSFC are 3 and 4% respectively. Whereas, the combustion emission parameters namely, Peak Cylinder Pressure, Ignition Delay, CO, HC and NOx have shown COVs of 5,4, 2, 2 and 6% respectively.

4. Results and Discussion

4. 1. Performance analysis

4. 1. 1. Brake thermal efficiency

The variation of BTE with load for tested fuels is shown in Fig.3. For all fuels BTE improved with increase in load. This is due to reduction in heat loss and increase in power with increase in load [9, 10, 11]. Biodiesel-diesel blend with and without alumina nanoparticles shows better BTE than diesel due to an effective combustion by making use of the rich oxygen content within the ester(PLOME). B20PLOME30A shows higher BTE with respect to diesel and B20PLOME due to high surface area to volume ratio of nanoparticle resulting in fine atomization and rapid evaporation of fuel promoting improved brake thermal efficiency [12].

4. 2. Combustion analysis

4. 2. 1. Heat release rate

Fig. 4 shows the variation of HRR with various crank angles for the fuels. Both B20PLOME and B20PLOME30A show a marginal increase in HRR compared to diesel. Diesel at full load is chosen as a baseline for comparison of combustion characteristics. At full load B20PLOME and B20PLOME30A showed slightly greater HRR than diesel. Owing to more oxygen molecules present in the molecular structure of B20PLOME and B20PLOME30A than diesel. But for the nanoparticle blended tested fuel B20PLOME30A observed lower heat release rate than B20PLOME due to the advancement of combustion phase by improved atomization and rapid evaporation [9, 13].

4. 2. 2. Peak cylinder pressure

The comparison of peak cylinder pressure with load has been shown in Fig. 5. The peak pressure increases steadily with the load. It is seen from the Fig. 6 that the peak pressure of B20PLOME is higher than that of diesel at all loading conditions. At full load, B20PLOME and B20PLOME30A showed a greater peak pressure than diesel. At full load condition the B20PLOME blend shows an increase in peak pressure due to its higher ignition delay which arises due to premixed combustion. As it has higher viscosity it takes more time to mix with air and get ignited than other fuels. The other reason could be that it contains more oxygen content than diesel leading to a more complete combustion.

Table 1.Properties of fuel

Sl. No.	Property	ASTM Method	Limits (B100)	Units	Diesel	Poultry Litter Oil Methyl Ester(PLOME)
1	Colour	-	-	-	Orange	Pale Yellow
2	Density	D941	-	Kg/m3	850	737
3	Kinematic Viscosity, 40°C	D445	1.9-6	mm^2/s	2.5	5.48
4	Calorific Value	D2015	-	KJ/Kg	42000	29000
5	Fire Point	D93	-	°C	56	178
6	Flash Point	D93	130 min.	°C	50	154
7	Cetane Index	D613	47 min.	-	55	61

Table 3: Specifications OROTECH Exhaust Gas analyser

Measurement Parameters	Range	Resolution
Carbon Monoxide (CO)	0 – 10% vol.	0.001% vol.
Hydrocarbon (HC)	0 – 9999% ppm vol.	1.0 ppm vol.
Oxides of Nitrogen (NO_x)	0 – 5000 ppm vol.	1.0 ppm vol.

Table 2.Specification of alumina nanoparticles

Properties	Specification
Chemical name	Gamma Aluminum Oxide (Alumina, Al2O3) Nano powder, gamma phase,99.9%
Average particle size	20-50nm
Appearance	White
Melting point	2045 °C
Boiling point	2980 °C
Density	3.9 g/cm^3

4. 3. Emission analysis

4. 3. 1. Oxides of nitrogen

Fig. 6 depicts the variation of NO_X with load for all tested fuels. The nitrogen oxides result from the oxidation of atmospheric oxygen at high temperature inside the cylinder of an engine rather than just resulting from a contaminant present in the fuel. It is observed from the figure that the amount of NO_X increased with increase in the load for all fuels. It happens because with increase in the load the temperature of the combustion chamber increases as NO_X formation is strongly temperature dependent phenomenon [10, 11]. The figure indicates that NO_X emission of B20PLOME30A appears to decrease marginally as compared to that of diesel, as the catalytic behavior of nanoparticles will precede the reaction to be completed forming final products with the least thermal break down of the hydrocarbon compounds. The B20PLOME blend fuel shows increased NO_X emission compared to diesel. The reason for this trend is higher HRR in case of B20PLOME blend, due to which the temperature inside cylinder would also increase, thereby increasing NO_X emissions [14].

4. 3. 2. Unburnt hydrocarbons

From the Fig. 7 it is observed that UBHC emissions for all blends are lower than the diesel. At full load B20PLOME and B20PLOME30A showed lesser UBHC emission than diesel. The biodiesel is comprised of animal fat oil methyl esters i.e. there are hydrocarbon chains whose one end of the chain is oxygenated. The presence of oxygen in the biodiesel promotes more complete combustion that leads to lowering the hydrocarbon emissions [15]. Drastic decrease in UBHC emissions when alumina nanoparticles were added to B20PLOME is due to the catalytic behavior alumina nanoparticle. In addition to that, the improved ignition characteristics of alumina nanoparticles and the shortening of the ignition delay were observed [16].

4. 3. 3. Carbon monoxide

The variation of CO with load is presented in the Fig 8. The CO is a toxic by-product of combustion of all hydrocarbons due to incomplete combustion. It is reduced by increasing the oxygen content of the fuel [17]. From the figure, it is found that the amount of co is decreased at part load and again increased at full load condition for all tested fuels. It is observed that CO emissions for B20PLOME and B20PLOME30A are lower than the diesel fuel. The presence of oxygen content in methyl esters and catalytic behavior of nanoparticles, the improved ignition characteristics of alumina nanoparticles and the shortening of the ignition delay [16], leads to the further decrease in the CO emissions compared to that of biodiesel-diesel blends and diesel fuel. Carbon monoxide emission is mainly due to the lack of oxygen, poor air entrainment, mixture preparation and incomplete combustion process [18, 19]. CO emission decreases with increase in cylinder temperature as combustion tends to be more complete.

Table 4: Specifications AVL437C Smoke Meter

Measurement Parameters	Range	Resolution
Opacity	0-99.9%	0.1%
Linearity	±0.1 m^{-1}	
Repeatability	±0.1 m^{-1}	
Response time – Physical	< 0.4 seconds	
Response time – Electrical	< 1 millisecond	
Warm up time @ Atm. Conditions	< 7 minutes	
Engine RPM	400-9990RPM	10RPM
Engine oil temperature	0-150^{0}C	1^{0}C
Operating Temperature	+5^{0}C to + 50^{0}C	
Smoke measuring cell length	215mm (430mm folded length)	

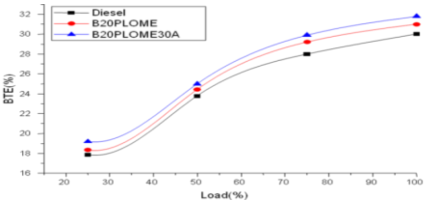

Figure 3.Variation of BTE with load

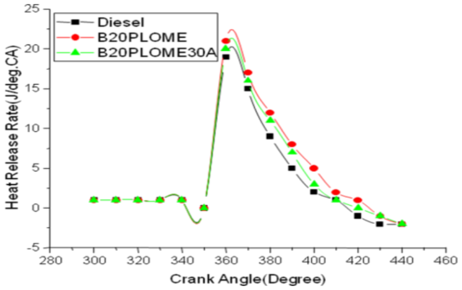

Figure 4.Variation of HRR with crank angle

4. 3. 4. Smoke opacity

Fig.9 shows the variation of smoke opacity with load. The amount of smoke present in the exhaust gas gives a measure of particulate matter present in it. It is observed that, the smoke opacity of the exhaust gas increases with load for all fuels. It can be noticed that, the smoke opacity for the blends is higher than the diesel. This is due to poor volatility and mixing of the fuel droplets with air because of higher viscosity of the blends. The molecules of B20PLOME and B20PLOME30A being heavier also attributes to the increase in smoke emission [20].

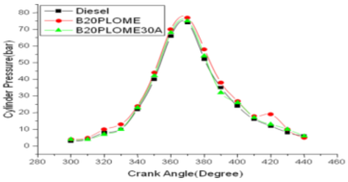

Figure 5.Variation of cylinder pressure with crank angle

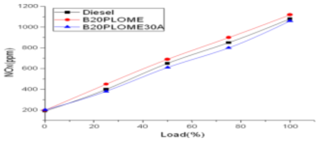

Figure 6.Variation of NO_X with load

5. CONCLUSION

The engine tests were conducted with blends of B20 poultry litter oil and B20 poultry litter oil with 30mg/l of alumina nanoparticles as additive 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. Poultry litter oil biodiesel blended with diesel is determined to be suitable replacement to pure diesel. From the results, following features were noticed. Transesterification of the poultry litter oil leads to reduction in kinematic viscosity and density whereas the calorific value is increased. The B20 poultry litter oil biodiesel with and without alumina nanoparticle as additive showed increased BTE with respect to diesel at full load. The cylinder pressure was found to be same for all. During full load condition, the variations of heat release rate were almost similar for all blends. The oxygen content in B20PLOME30A helps in the premixed combustion phase to progress in a better way which leads to better combustion. For B20PLOME the emission of HC, CO decreases with a slight increase in NOx as compared to diesel. The use of nano additives of alumina not only improves the mechanical performance of diesel engine, but also reduces the emission level of all pollutants (NOx, UBHC and CO) in the exhaust gases due to its catalytic effect on the fuel combustion process, especially in comparison with the effect of biodiesel-diesel mixture. A low dose of alumina nanoparticles in the range of 30 mg/l is used to achieve the best engine performance with optimal emission characteristics, particularly to remove the disadvantages related to use of biodiesel blends into diesel fuel (increase of NOx, UBHC, CO). Thus these factors strongly support the fact that poultry litter oil blended with diesel can be a promising fuel for diesel engines in future as they have good efficiency and reduced emissions. Further nanoparticles blended biodiesel showed better properties than poultry litter oil blended with biodiesel. Using renewable and eco-friendly fuels like poultry litter oil biodiesel with alumina, a significant percentage of the limited diesel can thus be eliminated. It also provides a novel method to waste management. This research aims to achieve the goal “**food for hunger and waste for fuel”.**

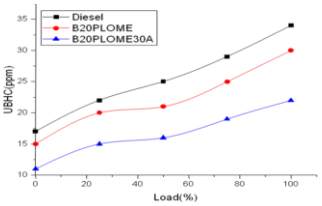

Figure 7.Variation of UBHC with load

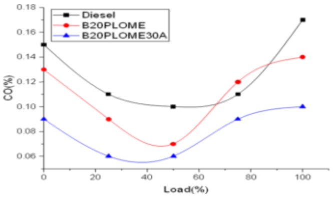

Figure 8.Variation of CO with load

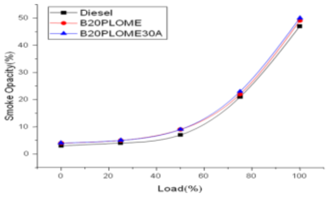

Figure 9.Variation of smoke opacity with load

References

[1] Prommes Kwanchareareon, Apanee Luengnaruemitchai, Samai Jai-In. 2007. Solubility of a Diesel-Biodiesel-Ethanol Blend, Its Fuel Properties, and Its Emission Characteristics from Diesel Engine. Fuel. 86: 1053-1061.

[2] Arul Mozhi Selvan V., Anand R.B., Udayakumar M. 2008. Stability and Performance Characteristics of Diesohol Using Biodiesel as Additive in Compression Ignition Engine. Proc. of the Int. conference on Fascinating Advances in Mechanical Engineering, India. pp. 667-673.

[3] Nebel, B. A.; Mittelbach, M. Biodiesel from extracted fat out of meat and bone meal. Eur. J. Lipid Sci. Technol. 2006, 108, 398–403.

[4] Lebedevas, S.; Vaicekauskas, A.; Lebedeva, G.; Makareviciene, V.; Janulis, P.; Kazancev, K. Use of waste fats of animal and vegetable origin for the production of biodiesel fuel: Quality, motor properties, and emissions of harmful components. Energy Fuels 2006, 20, 2274–2280.

[5] K. Murugu Mohan Kumar, J. Saragan, Critical Review on Biodiesel as Substitute Fuel for Diesel Engines (XVII NCICEC 2001), pp. 181–188

[6] A.K. Agarawal, L.M. Das, Biodiesel development and characterization for use as a fuel in compression ignition engines. Trans. ASME 123, 440–447 (2001)

[7] Sadhik, B. J., Anand, R. B. "Effects of nanoparticle additive in the water diesel emulsion fuel on the performance, emission and combustion characteristics of a diesel engine." Journal of Vehicle Design. 59(2/3). pp.164-181. 2012. DOI: 10.1504/ijvd.2012.048692.

[8] Ali M.A. Attia.; Ahmed I. El-Seesy.; Hesham M. El-Batsh.; Mohamed S. Shehata. Effects Of Alumina Nanoparticles Additives Into Jojoba Methyl Ester-Diesel Mixture On Diesel Engine Performance. Proceedings of the ASME 2014 International Mechanical Engineering Congress and Exposition IMECE2014, Montreal, Quebec, Canada.

[9] Ren, Y., Huang, Z. H., Jiang, D. M., Li, W., Liu, B., Wang, X. B. "Effects of the addition of ethanol and cetane number improver on the combustion and emission characteristics of a compression ignition engine." Proceedings of the Institution of Mechanical Engineers, Part D: Journal of Automobile Engineering. 222 (6). pp. 1077-1087.2008.DOI: 10.1243/09544070jauto516.

[10] Amba Prasad Rao. G & Rama Mohan. P, “Effect of supercharging on the performance of a DI diesel engine with Cotton Seed oil”, Energy Conversion and Management, Vol 44, pp. 937-944, 2003.

[11] Samaga BS “Vegetable oil as alternative fuels for the CI engine” pp. B-10 to B-12, VIII NCICEC, 1983.

[12] Sadhik, B. J., Anand, R. B. "Performance, emission and combustion characteristics of a diesel engine using Carbon Nanotubes blended Jatropha Methyl Ester Emulsions." Alexandria 9 Engineering Journal. 53. pp. 259-273. 2014. DOI: 10.1016/j.aej.2014.04.001.

[13] Sadhik, B. J., Anand, R. B. "Effects of nanoparticle additive in the water diesel emulsion fuel on the performance, emission and combustion characteristics of a diesel engine." Journal of Vehicle Design. 59 (2/3). pp.164-181. 2012. DOI: 10.1504/ijvd.2012.048692.

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

[15] Senthil Kumar, Ramesh.A and Nagalingam.B Experimental investigation on a Jatropha oil-Methanol dual fuel engine pp. 1-7, SAE 2001-01-0153, 2001.

[16] Yetter R. A., Grant A. R., Steven F. S. Metal particle combustion and nanotechnology. Proceedings of the Combustion Institute 2009; 32:1819-1838.

[17] D K Ramesh, Rajiv K T, Rajiv Simhasan, Manjunath N and Prithvish M Gowda A Study on Performance, Combustion and Emission Characteristics of Compression Ignition Engine Using Fish Oil Biodiesel Blends, Journal of The Institutions of Engineers India Ser. C DOI10.1007/s40032-012-0030-4.

[18] Murugan S, Ramaswamy MC, Nagarajan G. Tyre pyrolysis oil as an alternate fuel for diesel engines. Journal of SAE 2005; 01:2190.

[19] SoloiuA, Yoshinobu Y, Masakatsu H, Nishiwaki Kazuie, Mitsuhara Yasuhito, Nakanish Yasufumi. The investigation of a new diesel produced from waste plastics. ISME; 2000.

[20] Balusamy T, Marappan R. Performance evaluation of direct injection diesel engine with blends of the vetiaperuviana seed oil and diesel. J Sci Ind Res 2007:66:1035:40.