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Effects of Nano Additives in engine emission Characteristics using Blends of Lemon Balm oil with Diesel

J.Senthilkumar[1], S. Ganesan[2], S.Sivasaravanan[3] , S.Padmanabhan[4] , L.Krishnan[5]andV.C.Aniruthan[6]
[1]Research scholar, Faculty of Mechanical Engineering, Sathyabama University, Chennai, India,
[2]Mechanical Engineering, Chennai Institute of Technology, Chennai, India.
[3-6]Faculty of Mechanical Engineering, Sathyabama University, Chennai, India,
j.senthilkumar1981@gmail.com[1], gansuma@gmail.com[2], sivakriya16@gmail.com[3,] krishnalaxman25@gmail.com[1], and caniruth999@gmail.com[1]

Abstract

Economic growth in developing countries has led to enormous increase in energy demand. In India the energy demand is increasing at a rate of 6.5% every year. The crude oil demand of country is meet by bring in of about 70%. Thus the energy safety measures have become key issue for our country. Bio diesel an eco-friendly and renewable fuel alternate for diesel has been getting the consideration of researcher's entire world. The main aim of this paper is to evaluate the engine parameters using blend of pure lemon balm oil with diesel. Also nano Additives is used as a catalyst with blends of bio fuel to enhance the Emission Characteristics of various effective gases like CO2 ,NOx , CO and UHC with various levels of engine process parameters.
Keywords – Bio diesel, nano Additives, Emissions, lemon balm oil.

Introduction

In the transportation and agriculture sector, various renewable liquid bio-fuels derived from biological resources have proved to be good alternatives for fuels derived from crude oils. For the problems of environmental effects, energy safety, restricting imports, village people employment and agricultural wealth, these bio- fuels are gaining global acceptance as a solution. The smartest technologies deliver benefits to multiple interests, including improved economy, and a positive impact on the environment and governmental policies. One of the greatest advantages to biofuel is that it can be used in existing engines, vehicles and infrastructure with practically no changes. Bio diesel can be pumped ,stored and burned just like petroleum diesel fuel, and can be used pure,or in blends is practically identified to petroleum diesel fuel , and year round operation can be achieved by blending with diesel fuelMuthukumar et al [1] Calopylluminophyllum oil as alternate fuel for diesel engine creaked by fly ash.Then the oil is mixed with pure diesel of 75% in volume this reduce the emission of nitrogen oxide but the efficiency will be reduced by increasing the amount of Calopylluminophyllum oil in the biodiesel mixture.

Ganesan .S et al [2] used alternative fuel as lemongrass oil. An attempt was made to optimize the engine parameters such as Fuel Consumption, Nano Catalyst Proposition and Injection Pressure. Experiments were carried out based on Taguchi's Design of Experiments approach method to limit the

Number of experiment by the formation of orthogonal array, yet without sacrificing momentous information. On comparison, the predicted values from Taguchi and the experimental values are nearer, but the experimental values are higher than the predicted values. The results are well supported by the confirmatory test.

J.Senthilkumar et al [3] used jatropha and rubber seed oil with pure diesel as a alternative fuel .He compared B20,B40,B60 and found B20 is having the lower fuel consumption and also found that CO and HC emission were reduced with increase in blends.But NOx increases with increase in blends.

Viswanath K. Kaimal et al [4] studied the different blends of plastics waste oil and diesel such as P25,P50,P75 and found that P25 can replace pure diesel which increases the peak cylinder pressure, Ignition delay, combustion timing, heat released and also found that thermal efficiency of the engine reduced by increasing the blends.

S. Vedharaj et al [5] used KME (kapok methyl ester) – diesel blends of B25,B50,B75,B100 with two different combustion chamber geometries such as TRCC (trapezoidal combustion chamber) and TCC (toroidal combustion chamber) and found that B50 with TCC gives the maximum output which is increase in break thermal efficiency of 5.2% and reduces the CO and smoke by 15 and 8 percentage respectively.

M.S. Shehata et al [6] used corn and sugarcane oil as alternative fuel with different pressures 180,190,200 Bar At 200 Bar pressure the break thermal efficiency increased and specific fuel consumption decreased by 15% compared to pressure of 180 Bar.

Jo-Han Ng et al [7] The author proposed that In this study, a 0D/1D gas dynamics numerical model of a single-cylinder, 4-stroke diesel engine is used to simulate entire engine cycle from air intake to exhaust product. The engine model is successfully validated against experimental data of both palm biodiesel and fossil diesel for pertinent combustion parameters such as pressure trace, rate of heat release and ignition delay period.

K. Nanthagopal et al [8] They suggested the effect of Calophylluminophyllum methyl ester on diesel engine performance, emission and combustion characteristics at different injection pressures. Experimental investigations with varying injection pressures of 200 bar, 220 bar and 240 bar have been carried out to analyse the parameters like brake thermal efficiency, specific fuel consumption, heat release rate and engine emissions of direct injection diesel engine fuelled with 100% biodiesel and compared with neat diesel. The experimental results revealed that brake specific fuel consumption of C. inophyllum methyl ester fuelled engine has been reduced to a great extent with higher injection pressure. Significant reduction in emissions of unburnt hydrocarbons, carbon monoxide and smoke opacity have been observed during fuel injection of biodiesel at 220 bar compared to other fuel injection pressures.

Fuel Preparation

Sonication process was the second stage of the project where different fuel preparation takes. Various blends of biodiesel along with different proportion of CeO_2 were prepared using an ultra-sonication process. The different mixture of fuel was prepared in 1000ml beaker and was kept in ultra-sonication machine for 45 minutes to prepare the homogenous mixture of various combinations. This allows to for uniform mixing of nanoparticles in fuel. Various blends of biodiesel along with different proportion of CeO_2 were prepared using an ultra-sonication process. The different mixture of fuel was prepared in 1000ml beaker and was kept in ultra-sonication machine for 45 minutes to prepare the homogenous mixture of various combinations. This allows to for uniform mixing nanoparticles in fuel. The different mixture of fuel was prepared in 1000ml beaker and was kept in ultra-sonication machine for 45 minutes to prepare the homogenous mixture of various combinations. This allows to for uniform mixing of nano particles in fuel during the process the amount of nano particle to be mixed is being calculated by ultra-weighing machine with the accuracy of 0.001mg

Experimental Setup and Procedure

The performance test was conducted on a single cylinder CI engine to study the performance, emission, combustion characteristics at various load condition.The diesel engine is a high speed four

stroke, vertical, air cooled type. The loading is by means of an electrical dynamometer. The fuel tank is connected to a graduated burette, to measure the quantity of the fuel consumed in unit time. An orifice meter with u-tube manometer is provided along with an air tank on the suction line for measuring air consumption. An AVL145 smoke meter is provided for measuring FSN of exhaust gases. The rig is installed with AVL software forobtaining various curves and result during operation. A five gas analyzer is used toobtain the exhaust gas composition.
The filters of the engine were replaced and the injectors were cleaned and calibrated according to the desired pressure. Then the AVL gas analyzer and smoke meter were installed. The input to the gas analyzer was taken from the exhaust port of the engine. The fuel tank was then filled with diesel and the engine was run. After the fuel is filled to the engine it was run at various loads of the dynamometer like 5,10,15,20,25kgs and respective readings were taken for fuel consumption/ sec. The readings of gas analyzer and smoke meter were noted in each case. After all the readings were taken, the leftover diesel was drained out of the tank and emulsion was poured. Same steps were taken and the readings were noted down for the emulsion. Before using the next emulsion the engine was again run with diesel so that the results are not biased. After taking all the observations finally graphs were plotted to compare the performance characteristics and emission characteristics of the engine in case of diesel and emulsion.Before using the next emulsion the engine was again run with diesel so that the results are not biased. The table 1 shows engine specifications.

Table 1. The Test Engine Specifications

Engine type	Four stroke, single cylinder, vertical air cooled diesel engine.
Brake power	4.4 KW
Speed	1500 (constant speed)
Bore Diameter (D)	80 mm
Stroke (L)	110 mm
Number of Cylinders	1
Type of loading	Electrical rheostat
Orifice diameter	13.4 mm
Cd of orifice	0.62
Number of Stroke	4 Stroke
Manufacturer	Kirloskar oil engine
Model	Model

Design of Experiment
Different optimization techniques have been discussed in the coming sections. Methods like Taguchi Technique, grey relational analysis have been discussed in detail. Once the experimental design has been determined and the trials have been carried out, the measured performance characteristic from each trial can be used to analyses the relative effect of the different parameters. Design of Experiments (DOE) techniques enables designers to determine simultaneously the individual and interactive effects of many factors that could affect the output results in any design. Table shows the factors and levels for present experiment.
The Taguchi method utilizes orthogonal arrays from theory of design of experiments to study a large number of variables with a small number of experiments. Using orthogonal arrays significantly reduces the number of experimental configurations to be studied. Figure 1 shows the orthogonal array for the present experiment.

Table 2. Design Factors and their Level

Factors	**Level 1**	**Level 2**	**Level 3**
Lemon balm oil - % (A)	10	20	30
Injection Pressure - Bar (B)	200	220	240
BP - KW (C)	1.5	3	4.4
MgO - ppm (D)	15	30	45

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To select an appropriate orthogonal array for the experiments, the total degrees of freedom need to be computed. The degrees of freedom are defined as the number of comparisons between process parameters that need to be made to determine which level is better and specifically how much better it is.

Orthogonal Array	No of experiments	No of factors	Max no of factors at theses levels			
			Level 2	Level 3	Level 4	Level 5
L-4	4	3	3	-	-	-
L-8	8	7	7	-	-	-
L-9	9	4	-	4	-	-
L-12	12	11	11	-	-	-
L-16	16	15	15	-	-	-
L-'16	16	5		-	5	-
L-18	18	8	1	7	-	-
L-25	25	6	-	-	-	6
L-27	27	13	-	13	-	-
L-32	32	31	31	-	-	-
L-'32	32	10	1	-	9	-
L-36	36	23	11	12	-	-
L-'36	36	16	3	13	-	
L-50	50	12	1		-	11
L-54	54	26	1	25	-	-
L-64	64	63	63	-	-	-
L-'64	64	21	-	-	21	-
L-81	81	40	-	40	-	-

Fig: 1. Orthogonal array

For example, a two-level process parameter counts for one degree of freedom. Once the degrees of freedom are known, the next step is selecting an appropriate orthogonal array to fit the specific task. . The degrees of freedom are defined as the number of comparisons between process parameters that need to be made to determine which level is better and specifically how much better it is. Figure shows L9 orthogonal array of the present study.

Table 3.L9 Array with Design Factor

Ex. No	L.B oil(%)	IP(Bar)	BP(KW)	Mgo(ppm)
1	10	200	1.5	15
2	10	220	3	30
3	10	240	4.4	45
4	20	200	3	45
5	20	220	4.4	15
6	20	240	1.5	30
7	30	200	4.4	30
8	30	220	1.5	45
9	30	240	3	15

Experimental data using Taguchi Methodology

In the present experiment , using Taguchi methodology of L 16 orthogonal array, after the total number of experiment was done, the array with design factors, levels and responses for engine performance are given below in table 3.

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Table 4. Experimental Results Taguchi Methodology

Ex. No	L.B oil (%)	IP (Bar)	BP (Kw)	MgO(ppm)	BTE (%)	SFC(kg/kw hr)	HC (ppm)	CO (%)	NOx(ppm)
1	10	200	1.5	15	28.9	0.575	30	12.7	750
2	10	220	3	30	22.95	0.38	32	14.98	821
3	10	240	4.4	45	28.52	0.27	34	13.43	780
4	20	200	3	45	28.27	0.313	40	12.67	700
5	20	220	4.4	15	22.05	0.41	17	15.04	745
6	20	240	1.5	30	29.4	0.626	21	16.88	428
7	30	200	4.4	30	23.67	0.381	33	15.46	722
8	30	220	1.5	45	26.8	0.6	32	16.82	430
9	30	240	3	15	28.9	0.575	30	12.7	750

Analysing Experimental Data

To determine the effect each variable on the output, the signal-to-noise ratio, or the SN number, needs to be calculated for each experiment conducted. The calculation of the SN for the first experiment in the array above is shown below for the case of a specific target value of the performance characteristic.

There are 3 Signal-to-Noise ratios

- Smaller the better
- Larger the better

Smaller-The-Better

This is usually the chosen S/N ratio for all undesirable characteristics like defects etc. for which the ideal value is zero. Also, when an ideal value is finite and its maximum or minimum value is defined then the difference between measured data and ideal value is expected to be as small as possible.The S/N ratio for Smaller -The-Better is calculated by using the following formulae.

$$S / N \ ratio \ (\eta) = -10\log10\left(\frac{1}{n}\sum_{i=1}^{n} {y_{ij}}^{2}\right)$$

In this current above formulae is used to calculate the smaller S/N Ratio for SFC, CO,HC and NOX.

Larger-The-Better

This case has been converted to smaller-the-better by taking the reciprocals of measured data and then taking the S/N ratio as in the smaller-the-better case. These are used for analyzing the output of the industries and study of different property enhancing experiments. The S/N ratio for Larger – The – Better is calculated by using the following formulae.

$$S / N \ ratio \ (\eta) = -10\log10\left(\frac{1}{n}\right)\sum_{i=1}^{n}\frac{1}{{y_{ij}}^{2}}$$

In this current above formulae is used to calculate the Larger S/N Ratio for BTE.S/N Ratio for the all the responses mention below the table.

Table.5.S/N ratio

BTE (%)	SFC(Kg/Kw hr)	HC (ppm)	CO (%)	Nox (ppm)
29.218	4.8066	-29.54	-22.08	-57.5
27.216	8.4043	-30.1	-23.51	-58.29
29.103	11.373	-30.63	-22.56	-57.84
29.027	10.089	-32.04	-22.06	-56.9
26.868	7.7443	-24.61	-23.54	-57.44
29.367	4.0685	-26.44	-24.55	-52.63
27.484	8.3815	-30.37	-23.78	-57.17
28.563	4.437	-30.1	-24.52	-52.67
29.218	4.8066	-29.54	-22.08	-57.5

RESULTS AND DISCUSSION

Response Curve Analysis for BTE

The effects of the following combinations were plotted, as shown in the figure. It was observed that the Brake Thermal Efficiency escalates at the points A1, B3, C1 and D3. Graph A highlights the optimal increase of BTE when B10 oil blend is compared with B20 and B30, the average value remaining relatively similar. Graph B shows the responses observed when the Injection Pressure is varied, and shows maximum efficiency at point B3 which is at 240 bars. Brake Power of 1.5KW, point C1, increases the efficiency to around 29%, and 45ppm of MgOnano additive also shows an increase in the BTE. Hence, according to the observations made, the best combination of parameters turns out to be A1-B3-C1-D3 shown in fig.2.

Response Curve Analysis for SFC

The observations made in the prediction stage, to get optimal engine output values, the lowest value in each of the graph has to be considered .It was observed that B30 oil blend, 240 bars of injection pressure, 1.5KW Brake Power and 15 ppm of MgO gives the best combination of parameters in order to achieve the minimum SFC value. The variations in each graph are quite high except the graph plotted for the Injection Pressure in which the values obtained are almost similar as show in fig.3.

Response Curve Analysis for HC

The graph plotted below shows the main effects of LB oil, injection pressure, brake power and parts per million of nano additive added in order to obtain a minimum value of HC. It was observed in the prediction stage, that B30 level of LB oil decreases the HC to a value around -30 which is comparatively the least among the other values. The second graph indicates that the optimum pressure to be 200 bars. The third and fourth graph shows that 3.0KW and 45 ppm of MgO gives the lowest required value of HC in the experiment and hence the best combination of parameters being A3-B1-C2- D3 as shown in fig.4.

Response Curve Analysis for CO

The graph given below compares the different combinations of bio diesel blend which points that the A3-B2- 4C1-D2 combination reduces the maximum amount of CO gas. the successful combination is 10% of mint oil and 90% of pure diesel at220 bar pressure and the break power is 1.5KW then finally 30 ppm of MgO as shown fig.5.

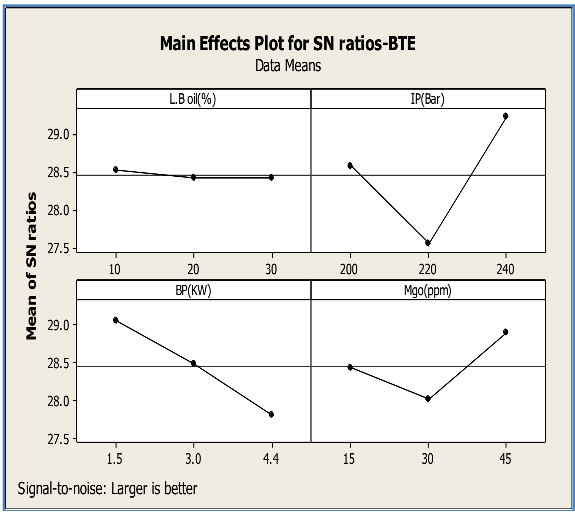

Fig.2: Response curve analysis for BTE

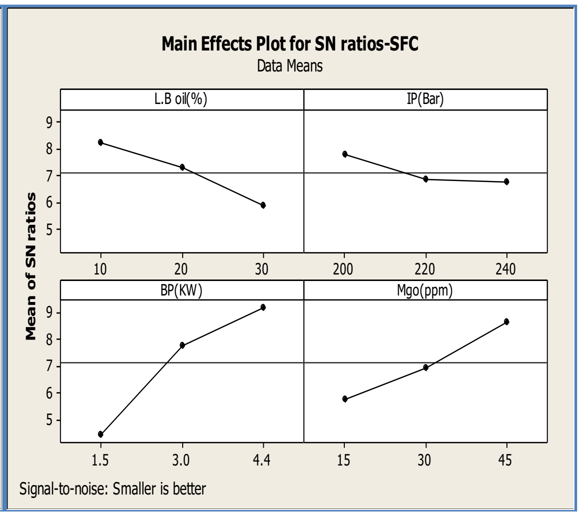

Fig.3: Response curve analysis for SFC

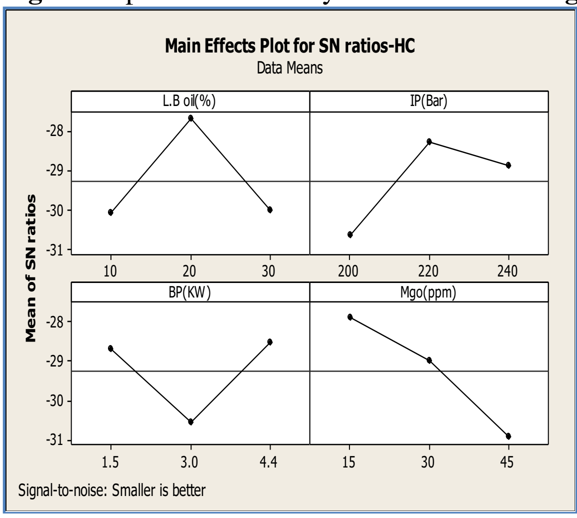

Fig.4: Response curve analysis for HC

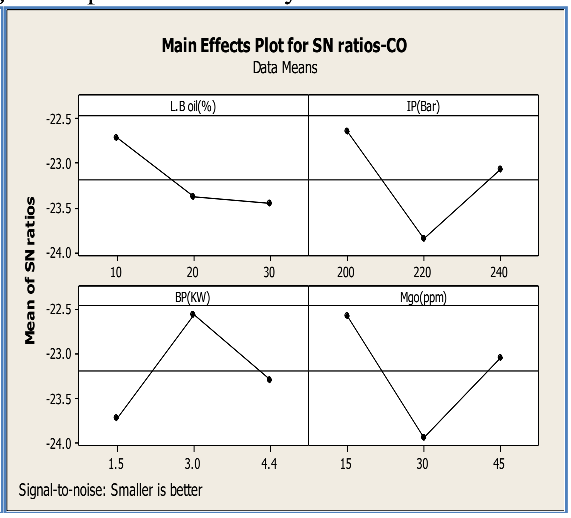

Fig.5: Response curve analysis for CO

Response Curve Analysis for NOx

The graph given below compares the different combinations which points that the A1-B1-C2-D1 combination reduces the maximum amount of NOx gas. the successful combination is 10% of mint oil and 90% of pure diesel at200 bar pressure and the break power is 3KW then finally 15 ppm of MgO as shown in fig.6.

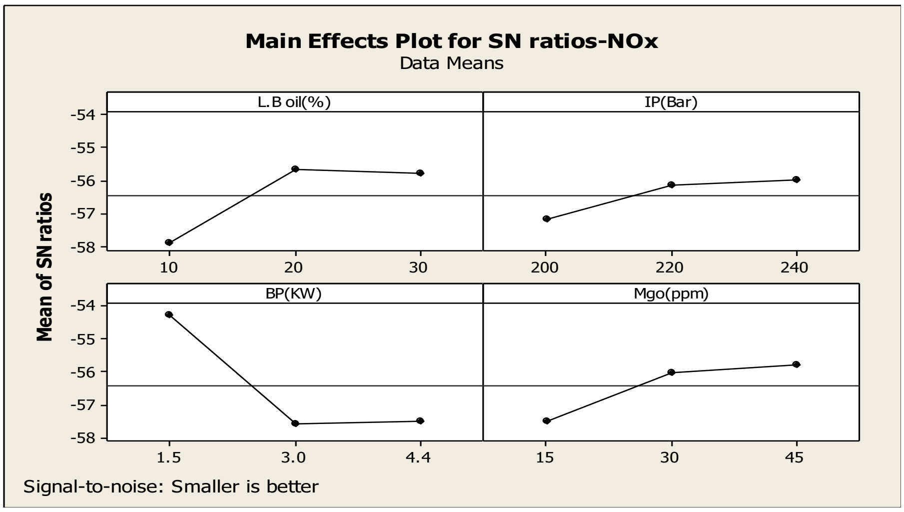

Fig.6: Response curve analysis for CO

Conclusion

From this experiment it is seen that biodiesel is going to be the natural choice for our future transport fuel. The foregoing combination of experience and reasoning it is possible to distil some conclusions about biodiesel as an automotive fuel particularly in a developing country like India. The following facts have been established through the present work. From the above experiment the multi-response parameters (engine performance and emission study) are optimized using grey relational analysis and converted into a single response. Then we have used Taguchi‘s methodology to analyze the experimental data.

For Optimum BTE, Larger the better S/N ratio consider. The engine operating condition A1B3C1D3.For Better Specific fuel consumption, Smaller the better S/N ratio consider. The predicted optimized Engine parameter of A3B3C1 and D1. Better HC, Smaller the better S/N ratio consider. The predicted optimized Engine parameter A1B1C2D3.In prediction stage an experiment should be conducted with MgO in 45 ppm, BP in 3KW, 200 bar of injection pressure and L.B in 10% levels to obtain optimal values .For Better CO, Smaller the better S/N ratio consider. The engine operating condition A3B2C1D2. For Better Specific fuel consumption, Smaller the better S/N ratio consider. The predicted optimized Engine parameter of A3B3C1 and D1.Better HC, Smaller the better S/N ratio consider. The predicted optimized Engine parameter A1B1C2D3.In prediction stage an experiment should be conducted with MgO in 45 ppm, BP in 3KW, 200 bar of injection pressure and L.B in 10% levels to obtain optimal value. For Better CO, Smaller the better S/N ratio consider. The engine operating condition A3B2C1D2. For Better NOx, Smaller the better S/N ratio consider.The predicted optimized Engine parameter A1B1C3D1.In prediction stage an experiment should be conducted with MgO in 15 ppm, BP in 4.4 KW, 200 bar of injection pressure and L.B in 10% levels to obtain optimal values.The predicted optimized Engine parameters were obtained from Response curve Analysis .Nox, CO, HC and Smoke emissions are lower for MgO nanoparticles blended fuels.

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References

[1] MuthukumaranN, SaravananCGa, Prasanna Raj S Yadav, Vallinayagam R, VedharajS and RobertsWL 2015 Synthesis of cracked Calophylluminophyllum oil using fly ash catalyst 4 for diesel engine application, *Fuel*,Article in press.

[2] Ganesan S, Elango A, EluriVamsi Krishna and BalajiA 2014 Influence of Nano catalyst on Emission Characteristics of Di Diesel Engine with Blends of lemon grass oil Using Taguchi Approach in *International Journal of Applied Engineering Research*, Research India publication, **9, 2**1, 9941-9949, ISSN: 0973-4562.

[3] Senthilkumar J and Mahalingam S 2015Effect of Injection Timing on Performance and Emission Analysis of Single Cylinder Diesel Engine Fuelled with Dual Bio-Fuels*International Journal of Applied Engineering Research*, **2**5041-5047.

[4] Viswanath KKaimal and Vijayabalan P 2015A detailed study of combustion characteristics of a DI diesel engine using waste plastic oil and its blends*, Energy Conversion and Management,***105**, 951-956.

[5] VedharajS, Vallinayagam R, Yang WM, SaravananCG and Lee PS 2015Optimization of combustion bowl geometry for the operation of kapok biodiesel – Diesel blends in a stationary diesel engine,*Fuel*, **139**, 561-567.

[6] ShehataMS, Ali MA,Attia SM and Abdel RazekR Corn and soybean biodiesel blends as alternative fuels for diesel engine at different injection pressures*Fuel***161**49-58.

[7] Jo-Han Ng, Jing Huey Khor, Kang Yao Wong, SritharRajoo and Cheng Tung Chong 2015, Statistical Analysis of Engine System-Level Factors for Palm Biodiesel Fuelled Diesel Engine ResponsesThe 7th International Conference on Applied Energy – ICAE2015*Energy Procedia***75**99-104.

[8] NanthagopalK, AshokB and ThundilKaruppa Raj R2016Influence of fuel injection pressures on Calophylluminophyllum methyl ester fuelled direct injection diesel engine *Energy Conversion and Management***116**165-173.