RSM based Empirical Model for the Performance and Emission Characteristics of ROME Biodiesel

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Abstract*: In the current scenario, the production of biodiesel for IC engine plays important role due to the undesirable pollution and cost hike of the conventional fuels. In India, milk from the rubber tree (HeveaBrasiliensis) is used for the production of elastic materials which are most widely used in engineering applications. But the seed from the rubber tree is kept wasted without any further usage and hence in this research the oil produced from the rubber seed is suggested for effective biodiesel production. The rubber seed oil (RSO) is converted in to usable rubber seed oil methyl ester (ROME) biodiesel using trans-esterification and tested for the characteristics of performance and emission through variable compression ratio (VCR) engine. The detailed set of experiments are conducted in the VCR engine with different biodiesel-diesel ratios to evaluate the BTE, SFC, CO, CO_2 and NO_x levels of the blends. A mathematical model also developed using Response Surface Method (RSM) for these parameters such that the compression ratio, fuel blend, engine load, and injection pressure are the design variables, The experimental results are used in the RSM to create the mathematical models and the models are checked for the ANOVA and p-test. Finally the models are tested with the new sets of experimental results.

Index Choice: ROME, VCR engine, RSM, Emission, biodiesel

Nomenclature			
VCR	Variable Compression ratio	NOx	Oxides of nitrogen
SD	Standard deviation	B20	20% biodiesel + 80% diesel
CR	Compression ratio	B40	40% biodiesel + 60% diesel
BTE	Brake thermal efficiency	B60	60% biodiesel + 40% diesel
BSFC	Brake specific fuel consumption	B80	80 % biodiesel + 20% diesel
CO	Carbon monoxide	HC	Hydrocarbon
CO_2	Carbon dioxide	RSM	Response surface methodology

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I. INTRODUCTION

Renewable sources are playing major role in energy sector. Day to day increase in demand for energy and depletion of fossil fuels leads to utilize the different resources available in earth surface. Biodiesel is the mode of renewable source available in plenty of different varieties includes edible, non-edible seeds, algae, animal fats and vegetable oils. Varieties of designed experiments are functionalized on the VCR engine to identify the best blend and various parameters that affects engine power and emission. The optimum input variables and output response parameters are identified from optimization technique to improve the performance and combustion of the engine. RSM mode of design of experiments is used to optimize the emission of NOx and bsfc. Single cylinder direct injection 5.2 kW diesel engine is selected with five factors such as injection timing, injection pressure, nozzle hole diameter, load torque and clearance volume using diesel fuel. Valve opening pressure had greater influence among five factors and deviation is less than 10 % with experimental value[1]. ANN based feed forward back propagation algorithm is trained to predict the performance, emission and combustion characteristics of VCR engine with different CR, load and the blend are the input variables. The mean square error of output is less than 0.05 and R^2 values are greater than 0.95 for training and tested experiment model [2]. Kernel based extreme learning machine (K-ELM) and cuckoo search (CS) model is used to optimize the fuel blend with fuel price and weightage as factor compared with least square support vector machine (LS-SVM) with swarm optimization and experimental values. K-ELM contributes better result compared to LS-SVM and CS gives effective result on optimization [3]. Biodiesel produced from Australian Beauty leaf tree is blended with diesel (B5 & B10) on volume basis. To improve the engine performance of the engine and to reduce the emission characteristics of fuel used, the experimental and numerical studies were carried out. CFD program AVL fire software is used to develop an engine combustion model and simulation results were validated with experimental results and deviation was found to be less than 4.4%. B10 shows the better performance and low emission compared diesel and B5 [4]. Engine test is conducted with different speed(1360,1700 and 2000rpm) and fuel blend of B25, B50, B75 and B100 using experimental and Numerical simulation using AVL BOOST program with empirical sub-model to control mixed combustion parameter at full load. Increase in blend in fuel mixture reduces the heating value, engine power and also reduces the NOx and CO emission at all speeds. Numerical results are 10% higher than experimental results and bsfc increase 12% for both results of diesel and B100 [5]. SI engine fueled with propane, hydrogen, methane and methanol to study the fuel emission and engine performance characteristics using 3D CFD code and the effect of EGR and supercharging. 10% EGR reduces the NOx and CO emission by 10-20% of all fuels. The effect of EGR on CO emission is more than other fuel for methanol. The effect of supercharging has noticeable effect on gasoline and least effect on hydrogen [6]. Blend of 40% n-butanol, n-propanol and n-pentanol are mixed with diesel individually in DI diesel engine to study the performance and emission characteristics using EGR percentage, injection timing and type of alcohol as parameters. 3^k factorial design matrix is used to define a numerical model using RSM and are compared with experimental results with the of 5% in the predicted error. 10% EGR gives best result for n-butanol and n-pentanol diesel blends at 24°CA bTDC at optimum condition [7]. 2-butanol gasoline blends of 5%,10% and 15% is blended to the petrol for optimizing the performance and emission of SI engine for different speed and fuel blends using RSM. Blend of 15% gives optimum value at 3205 rpm with best performance and emission compared to other blends [8]. Impact of methanol addition in to neat biodiesel with 5%, 10% and 15% on volume basis to analyze the performance, combustion and emission of a diesel engine using 3-D CFD simulation with KIVA4 code CHEMKIN II under 10%,50% and 100% load and is compared with experimental results. Results revealed that addition of methanol improves cylinder pressure under 10% load condition with 5% blend ratio and overall reduction CO and soot emission observed under every load conditions [9]. RSM is used to determine the performance responses of BP, brake torque and bsfc of a diesel engine. Developed model fits with input factors for the corresponding outputs and verified with experimental results. Brake power and brake torque reduces up to 18% when biodiesel is used and increase in bsfc up to 15% recorded [10]. Numerical model is developed to optimize the parameter which directly affecting the performance of the diesel engine is predicted among fuel flow, speed, injection pressure and throttle positions. Fuel flow is function of the engine speed when compared with the experimental results matching R^2 value of 0.9338[11]. Biodiesel produced water hyacinth blended with diesel at 5,10,15,20 and 25 proportions on volume basis to investigate the performance and combustion using numerical model with experimental results. Compression ratio, injection pressure, loads and blends are input factors are validated with combustion pressure and emission responses. B5 and B10 produces significant combustion pressures compared to other blends using RSM [12].

In this research work, ROME biodiesel is produced from the RSO and is tested for performance and emission characteristics. The experiments are conducted on the VCR engine at the different range of blend, compression ratio (CR), injection pressure and engine loads to evaluate the performance parameters (BTE, SFC) and emission parameters (CO, CO_2, and HC). RSM is utilized to develop the empirical models for these input parameters from the design variables range. The results of the models are verified and are used as hypothesis for the experimental setup.

II. EXPERIMENTAL SETUP

The Experimental set up (fig.1) consists of single cylinder variable compression ratio multi fuel water cooled engine coupled with the eddy current dynamometer. The setup is attached with strain gauge load cell, and computerized data acquisition system. Various sensors are provided in the engine setup to measure speed, airflow, fuel flow and temperatures of engine water inlet, outlet and exhaust gas. The sensors are connected to the data acquisition system such that the data related to sensors are stored in it. The sensors are well calibrated before the start of the experiments. For the measurement of CO, HC, CO_2, O_2 and NOx emissions a calibrated gas analyzer (Mars technology Inc.) is connected to both the engine and to the data acquisition.

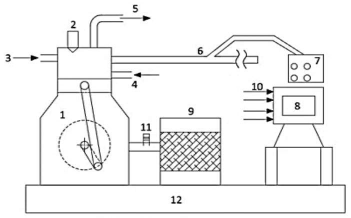

Fig. 1 VCR Experimental setup for testing the ROME

The ROME is prepared using the RSO through the transesterification process and tested for the fuel properties. For conducting the experiments on the biodiesel, the ROME blends are prepared with various proportions (B20, B40, B60& B80) with the diesel. The ROME and its blends are also subjected to laboratory test (as per ASTM standard) to measure the viscosity, density, flash point, fire point, calorific value and Cetane index (table.1).

PROPERTIES	B20	B40	B60	B80	Diesel	Biodiesel standards	
						ASTM D 6751-02	DIN EN 14214
Density (gm/cc)	0.82	0.86	0.87	0.88	0.83	-	0.86-0.9
Viscosity at 40 °C (centipoise)	0.643	1.032	1.45	2.235	1.382	1.9-6.0	3.5-5.0
Flash point (°C)	50	56	65	120	42	> 130	> 120
Fire point (°C)	54	60	75	160	65		
Gross caloric value (kJ/kg)	41343	40200	39129	38070	44500	41min	51 min
Cetane index	49	47	45	41	55		

Table: 1 Properties of biodiesel

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III. RSM Based Empirical Model

The prediction of the performance and combustion characteristics becomes critical when the blend ratio, compression ratio, load and fuel injection pressure are varied in the range B0-B80, 18-22, 0-8 & 140-160 respectively. The prediction of emission characteristics at varied range provides information for the determination of right values of design variables and optimum operating condition for the engine user. Hence the possibility to quantify the emission characteristics of the engine for a given biodiesel is of practical importance. RSM provides relatively simple mathematical relation with the parameters and for the desired output on available data. When the problem involved is subjected to experimental errors, statistical methodology is the promising approach to analyze the problem. The prime advantage of employing experimental design and statistical methods is the reduction in number of experimental runs required to generate sufficient information for a statistically adequate result. Hence RSM is an efficient and cost-effective method to model and analyze the relationship between the engine variables and the engine performance and emission parameters. The central composite rotatable design (CCD) with full factorial approach in the RSM is used to model such that compression ratio, load, biodiesel blends and injection pressure (table.3) are the design variables and the performance parameters (BTE & SFC) and emission responses (CO, HC, CO_2 and NOx) are the objective functions. Minitab 16 statistical software is used to design and run the four factor RSM model. To run the RSM design model, the results of the standards runs are obtained experimentally (Table 2).

Run Order	(A) Compression ratio	(B) Load (Kg)	(C)` Biodiesel blends (%)	(D) Injection pressure (bar)	CO (%)	HC (ppm)	CO_2 (%)	NO_x (ppm)	BTE (%)	SFC (Kg/Kwh)
1	20	4	40	140	0.246	8	2.79	232	23.612	0.379
2	20	4	40	150	0.161	3	2.4	243	25.937	0.345
3	18	8	80	160	0.456	16	3.7	374	31.182	0.312
4	18	8	80	140	0.612	38	5.152	593	28.166	0.346
5	18	0	0	140	0.191	11	1.702	186	0.000	0.000
6	20	4	0	150	0.082	7	2.4	288	23.499	0.348
7	20	4	40	150	0.158	4	2.1	242	25.937	0.345
8	22	0	80	140	0.231	9	1.7	253	0.000	0.000
9	18	0	0	160	0.142	3	1.1	226	0.000	0.000
10	18	4	40	150	0.201	6	2.412	298	25.937	0.336
11	18	8	0	160	0.153	9	2.984	436	33.665	0.243
12	20	0	40	150	0.101	1	1.55	140	0.000	0.000
13	22	8	80	140	0.74	27	3.9	562	26.178	0.372
14	18	0	80	140	0.292	13	3.1	262	0.000	0.000
15	20	4	40	150	0.167	4	2.2	241	25.937	0.362
16	20	4	40	150	0.159	4	2.2	241	25.937	0.362
17	22	0	80	160	0.246	9	1.9	300	0.000	0.000
18	22	0	0	140	0.104	11	1.648	162	0.000	0.000
19	20	4	40	150	0.181	4	2.2	241	25.937	0.362
20	22	0	0	160	0.136	15	2.3	347	0.000	0.000
21	22	8	0	140	0.309	17	3.924	462	34.006	0.241
22	22	8	0	160	0.293	14	4.1	512	29.527	0.277
23	22	4	40	150	0.278	8	2.784	328	24.321	0.368
24	20	4	40	150	0.164	4	2.2	241	25.937	0.345
25	18	0	80	160	0.193	2	2.03	178	0.000	0.000
26	20	4	40	150	0.162	4	2.124	241	25.937	0.345
27	20	4	100	150	0.269	18	3.012	388	17.427	0.559
28	20	8	40	150	0.339	13	3.356	392	36.608	0.245
29	20	4	40	160	0.189	1	1.98	219	22.938	0.378
30	22	8	80	160	0.707	17	3.892	471	25.804	0.377
31	18	8	0	140	0.319	25	3.924	504	35.312	0.232

Table: 2 RSM Design Matrix with Results of Objective Functions

The results of the analysis of variance (ANOVA) for the models are verified for model adequacy (table 3) through the p-test. Effect of p-value determines the model is statically significant or not. If p value is less than 0.05 the coefficient terms are significant. From the results it has been understood that the coefficients are most significant at all responses and are less than 0.05. The statistics of regression is used to decide whether a regression model is appropriate. The coefficient validation is based on R^2 which is a measure of the amount of reduction in the variability of response obtained using the regression variables in the model. The value of R^2 equals to 1 if the model exactly matches and the R^2 decreases as the residual decreases. The R^2 values are high and close to 1 for every the response models and are close agreement with the corresponding R^2adj, which are desirable (Table 3). Based on the these conformity tests the regression equation established for BTE, SFC, CO, CO_2, HC, NO_x responses (Eqn 1-4).

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Parameter	BTE	BSFC	CO	HC	CO_2	Nox
Mean	19.347	0.24126	0.25745	10.424	2.6698	316.14
SD	13.135	0.16719	0.16453	8.4189	0.93616	122.15
R^2	0.9924	0.9922	0.9926	0.9971	0.9873	0.9993
Pred. R^2	0.9721	0.951	0.952	0.9822	0.9531	0.9955
Adj. R^2	0.9895	0.9854	0.9861	0.9946	0.9761	0.9987

Table: 3 Model Adequacy Test

After verification of the model adequacy and p-test the empirical equations (Eqn 1-6) are developed using the model coefficients that are functions of the design variables. The equations are desirable to produce the desired outputs.

$$\mathrm{BTE} = -362.1154 - 0.266 \times \mathrm{A} + 10.2947 \times \mathrm{B} - 0.04638 \times \mathrm{C} + 4.922 \times \mathrm{D} + 0.08106A^2 - 0.406 \times B^2 - 0.00161 \times C^2 - 0.0152 \times D^2 - 0.10007 \times AB - 0.00150 \times AC - 0.01944 \times AD - 0.00827 \times BC - 0.00544 \times BD + 0.00137 \times CD \quad (1)$$

$$\mathrm{SFC} = 0.44458 + 0.168659 \times \mathrm{A} + 0.129509 \times \mathrm{B} - 0.001654 \times \mathrm{C} - 0.023212 \times \mathrm{D} - 0.004993 \times A^2 + 0.015610 \times B^2 + 0.000035 \times C^2 + 0.000066 \times D^2 + 0.001049 \times AB + 0.000038 \times AC + 0.0002 \times AD + 0.000162 \times BC + 0.000031 \times BD - 0.000012 \times CD \quad (2)$$

$$\mathrm{CO} = 23.0335 - 0.9471 \times \mathrm{A} - 0.0425 \times \mathrm{B} - 0.0014 \times \mathrm{C} - 0.1775 \times \mathrm{D} + 0.0178 \times A^2 + 0.0032 \times B^2 - 0.00019 \times C^2 + 0.0005 \times D^2 + 0.0048 \times AB + 0.0003 \times AC + 0.0015 \times AD + 0.0004 \times BC - 0.0004 \times BD - 0.000019 \times CD \quad (3)$$

$$\mathrm{HC} = 764.581 - 45.969 \times \mathrm{A} + 11.923 \times \mathrm{B} + 0.449 \times \mathrm{C} - 4.114 \times \mathrm{D} + 0.611 \times A^2 + 0.185 \times B^2 + 0.003 \times C^2 + 0.003 \times D^2 - 0.199 \times AB - 0.011 \times AC + 0.153 \times AD + 0.016 \times BC - 0.058 \times BD - 0.003 \times CD \quad (4)$$

$$CO_2 = 90.8147 - 5.0783 \times A + 0.4439 \times B + 0.1096 \times C - 0.5316 \times D + 0.0709 \times A^2 + 0.0087 \times B^2 + 0.0001 \times C^2 + 0.0007 \times D^2 + 0.0034 \times AB - 0.0038 \times AC + 0.0159 \times AD - 0.0001 \times BC - 0.0022 \times BD - 0.0003 \times CD \quad (5)$$

$$\mathrm{NOx} = 5974.99 - 895.65 \times \mathrm{A} + 159.16 \times \mathrm{B} + 9.63 \times \mathrm{C} + 34.87 \times \mathrm{D} + 16.59 \times \mathrm{A}^2 + 1.21 \times \mathrm{B}^2 + 0.03 \times \mathrm{C}^2 - 0.21 \times \mathrm{D}^2 - 0.86 \times \mathrm{AB} + 0.04 \times \mathrm{AC} + 1.62 \times \mathrm{AD} + 0.01 \times \mathrm{BC} - 0.8 \times \mathrm{BD} - 0.09 \times \mathrm{CD} \quad (6)$$

Optimized parameters				Mode of Evaluation	BTE (%)	BSFC (Kg/Kwh)	CO (%)	HC (ppm)	CO2 (%)	NOx (ppm)
CR	Load (Kg)	Blend (%)	Pressure (bar)							
18.36	7.84	20	155	**Predicted**	35.91	0.232	0.222	9.726	3.086	399.063
				Actual	36.88	0.2402	0.2218	9.1	3.24	403.7
				% Error	**2.63**	**3.42**	**0.09**	**6.88**	**4.75**	**1.15**
19	6	40	145	**Predicted**	31.97723	0.3599343	0.2780429	11.856609	3.0774166	334.93654
				Actual	30.08846	0.3276298	0.225	10.2	3.18	341.2
				% Error	**6.27**	**9.86**	**5.3**	**16.24**	**3.23**	**1.84**
20	7	20	150	**Predicted**	33.38514	0.3194343	0.2485072	9.7287868	3.1854929	379.23906
				Actual	34.86253	0.32115	0.25712	9.231	3.6325	392.21
				% Error	**4.24**	**0.54**	**3.35**	**5.39**	**12.31**	**3.31**
21	8	20	150	**Predicted**	35.19128	0.241624	0.2543836	11.730157	3.3385837	396.13885
				Actual	37.95453	0.229423	0.235	10.2	3.556	412.36
				% Error	**7.28**	**5.32**	**8.25**	**15**	**6.13**	**3.93**
22	5	40	140	**Predicted**	27.39625	0.3725352	0.3643811	9.8148123	2.7955001	323.01315
				Actual	26.582	0.357254	0.32653	11.2	3.01	341.23
				% Error	**3.06**	**4.23**	**11.59**	**12.37**	**7.13**	**5.34**

Table: 6 Validation of experiments

Based on the empirical equations the results of the output responses for the different sets of parameters are obtained and verified with the experimental results. The variables are also optimized through the Miniab16 to determine two different categories objective functions of maximum BTE and least SFC on performance characteristics and, least of HC, least HC, CO, CO_2 and NO_xon emission characteristics. The table.5 shows optimized parameters for the required objective functions within the range of variables defined.

Here the intention is to the emission responses and BSFC and to maximize the brake thermal efficiency.
The optimality test is conducted to arrive more than one optimized set of solutions from the empirical models. The composite desirability of 0.995867 is achieved at the optimized solution of CR 18.36, load 7.84 kg, blend 20% and injection pressure 155 bar. The respective parameters of optimal solution are used to find the influence of responses using the empirical models. The experiments also conducted at the optimized variables of CR 21, 8 kg load , B20 blend and with an injection pressure of 150 bar. The responses of the optimum factors are presented in table.6. The optimum predicted solution is compared with experimental results and the closer to be closer.

IV. RESULTS AND DISCUSSION

Brake thermal efficiency

Figure.2 shows the main interaction effect of mean vs input parameters like CR, load, blend and injection pressure of brake thermal efficiency. The fig.3 show the effect of compression ratio vs biodiesel blends. The main effect of mean vs compression reveals the same trend in the graph. The addition biodiesel after B40 leads to decreases the mean level to low. At CR 21 for the blend B20 at 8 kg load with an injection pressure of 150 bar gives maximum efficiency of 37.95453% and error is found to be 7.28% with the predicted range. This is due to addition of biodiesel content in fuel blends and lower calorific value of fuel. The load on the engine increase the mean from low to high due to its optimum utilization of the fuel blends. The change in injection pressure from low to high shows the trend of no change in efficiency compared to standard injection pressure of 150bar.

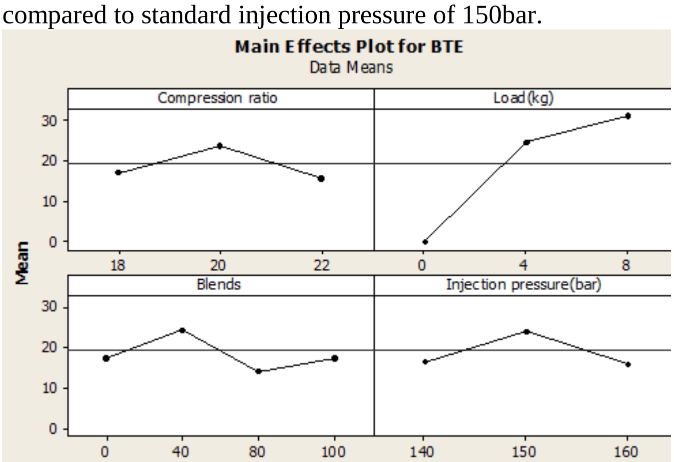

Fig.2 Main effects of input parameters with respect to mean values of BTE

Brake specific fuel consumption

Fig.4-5 shows the variation of main effect for different input factors and surface plot for brake specific fuel consumption. The results revealed that the increase in compression ratio increase the fuel consumption of all blends except B20. The optimal solution at CR 21 obtained for B20 at 150 bar is 02294kg/Kwh at 8kg less than other blends at all CR and pressure. The amount of biodiesel volume in the blend increases the fuel consumption owing to its lower heating value of the fuel. At the same time, the load and injection pressure increases, the fuel consumption decreases due to its better spray formation and atomization of the fuel. The optimized value of specific fuel consumption is 3.42% higher than the predicted value.

CO emission

The rise of CR, decrease the CO emission at CR 20 and reaches mean level at all CR shown in fig.6. Increase in biodiesel content slightly increase the CO emission and is high at B80 due to its poor spray formation of fuel. There is a high to low level of CO emission shows that at high compression ratio and high cylinder temperature reduces the CO for pure biodiesel. Change in injection pressure increase the CO emission and increase in load increase the CO emission because of its poor atomization of fuel. Surface plot shows that increase in compression ratio and biodiesel blends increase CO emission shown in fig.7. The error of the predicted solution at CR 21 is found to be 8.25% for the actual blend of 20 at 150bar and at full load.

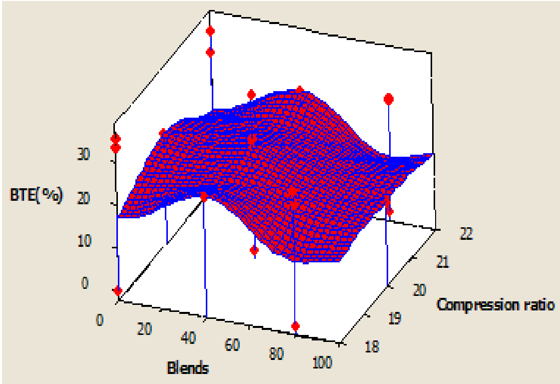

Fig.3. variation of fuel blends and compression ratio with respect to BTE

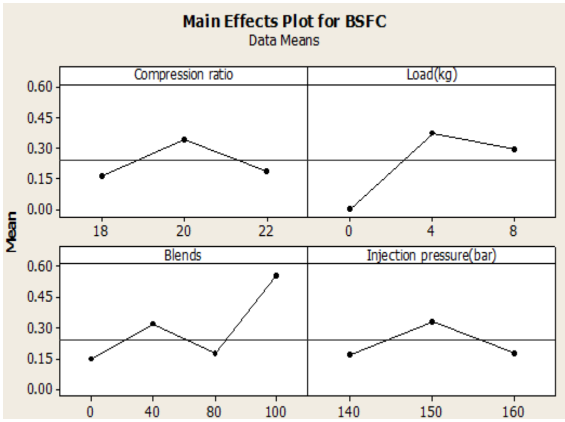

Fig.4 Main effects of input parameters with respect to mean BSFC

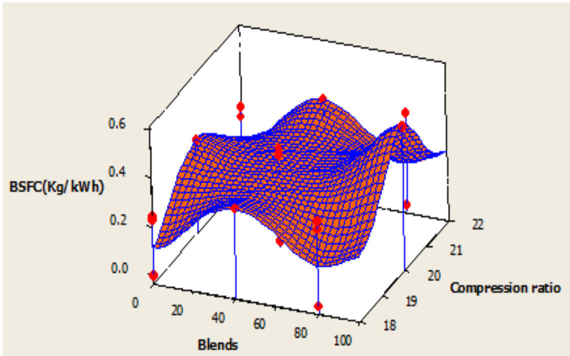

Fig.5 Variation of BSFC with respect to fuel blends and compression ratio

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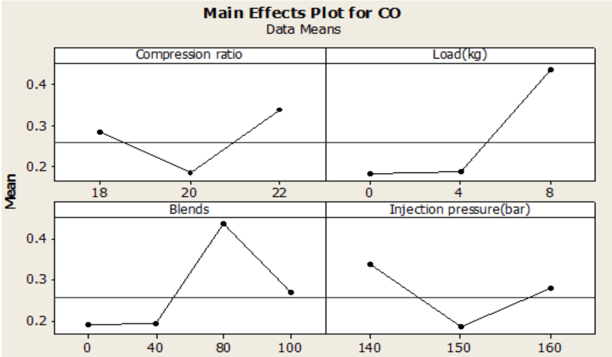

Fig.6 Variation of input parameters with respect to mean CO

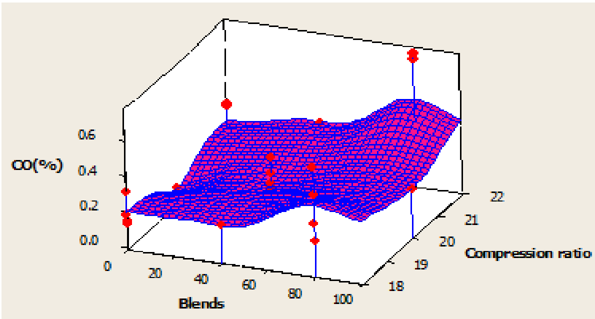

Fig.7 Variation of CO emission with respect to blend and compression ratio

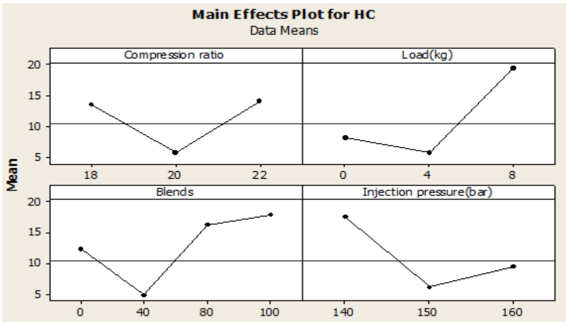

Fig.8 Variation of input parameters with respect to mean HC

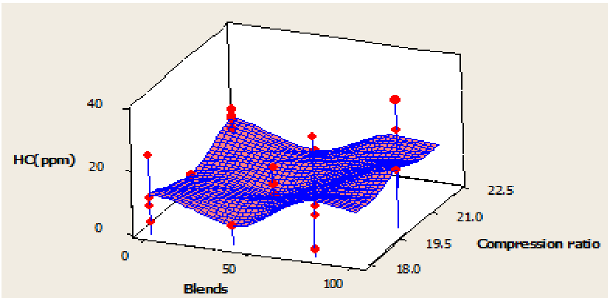

Fig.9. Variation of HC with respect to fuel blends and compression ratio

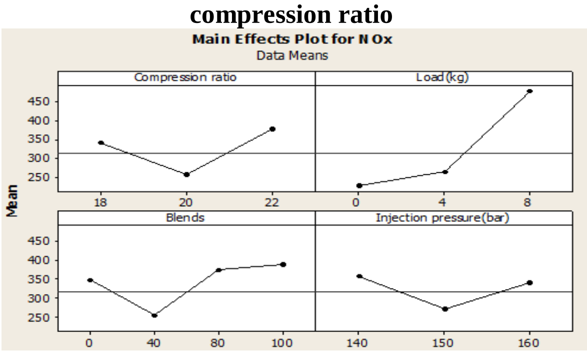

Fig.10. Variation of input parameters with respect to mean NO_x

HC emission

Main effect plot of mean vs input parameters and surface plot are shown in fig.8-9. When there is a rise in injection pressure decrease the HC for its better mixing of fuel. Increase in biodiesel blend increase the HC emission at high CR at full load due to its insufficient air available for combustion. When the compression ratio increase up to 20 gives better result in terms of emission shown in surface plot. HC emission at part load operation at 150bar for B40 is less than 2ppm. The predicted value of HC emission is 6.88% higher than actual value. HC emission depends upon cylinder temperature and compression ratio of the blend.

NOx emission

Fig 10-11 shows the mean plot of factors and surface plot for NOx. At CR 20, blend B20 and B40 gives reduction in

NOx emission at part and full load operations shown in surface plot. Increase in load and blends increase the NOx emission at CR 22.

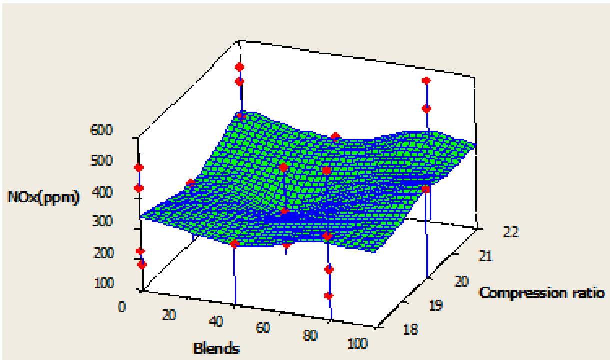

Fig.11. Variation of NO_x with respect to fuel blends and compression ratio

Effect of increase in injection pressure maintains the mean level. Ignition delay is shorter for biodiesel due to its high cetane index. In case of rubber seed oil, cetane index is 38, less than diesel and other biodiesels, increase the ignition delay as longer. But increase in compression ratio, injection pressure at part and full load operation increase the cylinder temperature which reduces the ignition delay and emission of NOx when compared diesel for blends B20 and B40 at all injection pressure for part and full load operation. Mean of biodiesel blends keeps the average in the graph proved the same.

V.CONCLUSION

The ROME biodiesel is prepared from RSO using the transesterification process and the blends are prepared with different ratio of diesel. The blends are tested for the physical and chemical properties as fuel. The ROME blends are tested for the performance and emission characteristics with different range of compression ratio, load, fuel blends and injection pressure as input variables. The results of BTE, BSFC as performance responses and CO,HC and NOx as emission responses are obtained for the blends. RSM design matrix is developed using the defined range input parameters and the results of their respective objective functions are obtained through experiments.

The regression equations are obtained for the objective functions through the coefficients. The model adequacy is tested through ANOVA table such that the R^2 and R^2_{adj} values are more than the 0.95. It is found that predicted coefficient are significantly fit with the model and the error is found to be less than 5%. The developed model produced 0.9921 of R^2 value with 0.9527 of predicted R^2. Adj R^2 gives good result over experimental value of 0.9846 with its numerical model. The regression is developed to fit the factors to validate the numerical model. Desirability optimal test also is conducted to obtain the optimum parameter for least SFC and emission parameters and Maximum BTE and are responses are validated through experimental results. The optimum parameters are found to be CR 21, 8 kg load, B20, and 150bar pressure and the optimized objective functions are

Among the input factors injection pressure plays less dominant over other factors. In the performance parameters, at CR 21 with 8 kg load at 150 bar, B20 gives a maximum efficiency of 37.94453% with a specific fuel consumption of 0.229423Kg/kWh. The CO and NOxemissions for the same condition is less than 10% of predicted value. Increase in compression ratio increases the thermal efficiency of B20 and B40. Subsequently, there is an efficiency reduction found because of its lower calorific value of fuel. The compression ratio rise lowers the specific fuel consumption of fuel blends and the optimum value is found is 0.2402 kg/kWh of B20 is 3.42% higher than predicted value. CO emission is less for all compression ratio and increase in biodiesel content increase the CO emission at all CR shown in surface plot. HC emission of optimum blend is 6.88% higher than predicted value due to its low in cylinder temperature. Increase in fuel blend increases the NOx emission at compression ratio but at optimum value, the error is found to be less than 2%.

The RSO is comparatively cheaper as it is not being used for any other commercial purpose. The RSO is processed to produce ROME biodiesel and will be effectively used in the IC engines with B20 proportion. The RSM developed a hypothesis for the use of ROME in the experimental setup chosen. This hypothesis will be extended for the other engines to design and run the diesel engines with ROME at emission less and low cost.

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