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COMBINE EFFECT OF COMPRESSION RATIO AND PALM SEED OIL BLENDS ON PERFORMANCE OF CI ENGINE USING RSM APPROACH

Darshan m. Desai*[1], DhananjayH.Joshi[2], Tushar M. Patel[3]

*[1](ME Scholar, Mechanical Engineering Department, LDRP-ITR, KSV University, Gandhinagar, India)
[2](Lecturer, Mechanical Engineering Department, LDRP-ITR, KSV University, Gandhinagar, India)
[3](Doctor, Mechanical Engineering Department, LDRP-ITR, KSV University, Gandhinagar, India)

Abstract- *Objective of this work optimizes specific fuel consumption to single cylinder diesel engine with respect to response surface methodology. A single cylinder 3.8 KW engine is selected for experiment. Three parameters compression ratio, load, and blend are variance and response like specific fuel consumption optimize completely .The experiments include use of different palm oil blend such as 100D0B (100% diesel 0% palm oil), 50D50B (50% diesel 50% palm oil), 0D100B (0% diesel 100%palm oil) at different compression ratio in the range of 16, 17, 18 and load variation from 2, 7, 12 Kg. the result obtained from experiment that load has significant effect of SFC. For mathematical and statistical analysis response surface method is used. The numbers of experiments run are developed by using RSM approach in Minitab'18 software. The result obtained from experiment is that load has significant effect on the SFC .The value of specific fuel consumption is less when the engine is running with high load and fueled with 100D0B blend of diesel.*

Keywords- *Palm seed oil, Response surface method, Compression ratio, Blend ratio, Load, C.I engine*

Nomenclatures	
RSM	Response Surface Method
CCD	Central Composite Design
BTHE	Brake Thermal Efficiency
SFC	Specific Fuel Consumption
MECH EFF	Mechanical Efficiency
D.O.E	Design of Experiment
100D0B	100% Diesel 0% Palm seed oil
50D50B	50% Diesel 50% Palm seed oil
0D100B	0% Diesel 100% Palm seed oil

I. INTRODUCTION

In this day diesel engines are more popular in all over world because of petrol price increasing everyday and world face big problem today is pollution from emission form gasoline engines. So this reasons better fuel efficiency of fuel obtains from more use of diesel as fuel. All of above problems best option to use alternative fuel. In this day climate change are big problem so we have assurance about energy security and less pollution of environment by fuels .In this days 65% of air pollution by emission from vehicles. So this reason here find alternative fuel. Alternative fuels are giving proper performance and efficiency. But vehicle speed is much lesser than gasoline fuels so these causes find better performance and efficiency with least pollution [1] it is important to use alternative fuels instead of fossil fuels, based on renewable and natural resources like vegetable oils. Diesel fuels from petroleum sources have chemical structure of vegetable oils. [2] A different bio-liquids used to produce biodiesel. The plants oil has been considered as fed stocks for bio-fuel for palm oil. [3] Oil palm of West Africa and grown in south east Asian country and African countries and south American countries. Malaysia, Indonesia and Nigeria are the best production of palm oil and also Malaysia has increase production to everyday increase with population. [3]

II. LITERATURE REVIEW

For experiment run use of RSM method**. Pandian et al. (2011)** have studied to optimize increasing injection pressure for better brake thermal efficiency with lesser BSFC at all injection timing with lower CO, HC, and smoke emission and higher NO_x and when high injection pressure the results were neglected[4]. **Abuhabaya et al. (2013)** have studied optimal condition for the maximum methyl ester yield to be at methanol/oil molar ratio of 7:7:1, NaOH catalyst of 1%, rate of mixing 200 rpm and a reaction time of 60 min [5].**Hirkude et al.(2014)** have studied increase in compression ratio increases brake thermal efficiency for all injection pressures and injection timing of when CR of 18 decrease in brake thermal efficiency observed. Brake thermal efficiency finds to increase with increase in injection pressure [6]. **Modi et al.(2014)** have studied 30% blend of palm seed oil find best blend compare to other blend. For B30 blend NO_x reduced compare to other blend. This blend directly used in single cylinder 4-stroke diesel engine without modification of the engine [7].**Benajes et al.(2016)** have studied optimization of first stage find that combustion system geometry improve ISFC by 0.5% without increasing NO_x emissions level. This study also indicates that swirl supported with re-entrant bowl shape combustion system is still required for this engine and input parameter ranges. After, Injection and air management setting were included to increase the potential of the optimization and significantly reduce ISFC around 50%, for constant NO_x emissions, as confirmed by the second optimization stage. It is also noticeable that 40% NO_x reduction can be obtain keeping on constant ISFC and soot emissions. Optimization path leads to advanced sol for improved ISFC, increased EGR to control NO_x emissions keeping impact on ISFC, while adjusting IP and P2 helps to control soot emissions. This path fits with the current trends followed in the field of diesel engine development. [8].

III. PALM SEED OIL PROCESS CHART

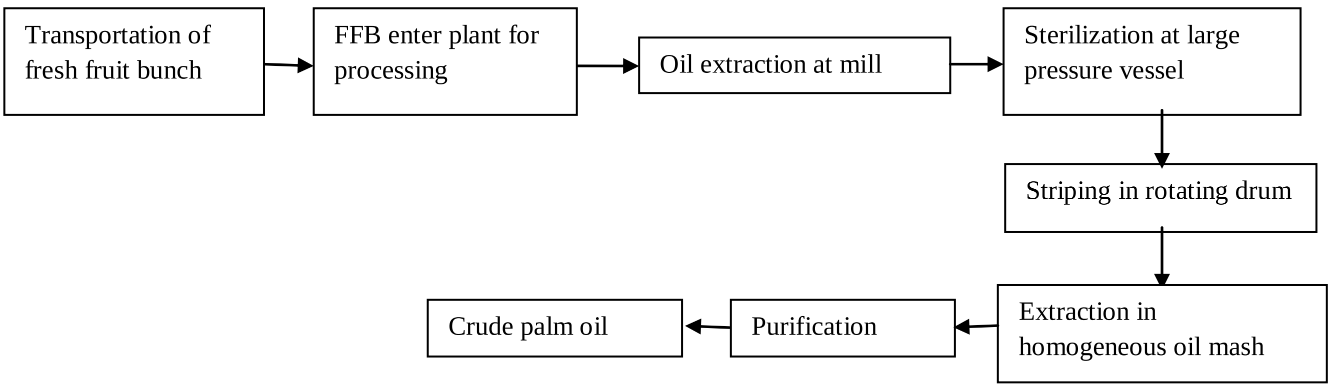


Figure 1. Palm seed oil process chart [12]

First step of palm oil to transport fresh fruit bunch and then after enter the plant for processing. Then boil palm fruits until they are softening for oil extraction. In this process water is not more than palm fruits. The next step to meshing boil palm nuts to mash in bowl by our hands and mash until get the juice. When complete become juice until see palm oil in floating surface of the water. Finally gating of palm oil further extraction from water surface and boiled it again.

Table 1. Properties of palm seed oil

Parameter	Unit	Result
Density @ 15°C	Kg/m^3	925
Kinematic viscosity@ 40°C	mm^2/sec	41
Flash Point	°C	260
Cloud point	°C	-
Fire point	°C	341
Iodine value	g/100g	44-51
Melting point	°C	35
Calorific value	KJ/kg	39849

IV. EXPERIMENTAL SETUP

In experimental purpose experiment setup consist of single cylinder, four stroke, and multi fuel engine connected with eddy current dynamometer for loading. In this engine CR can be varied continuous running of engine. Setup consist instruments for combustion pressure, diesel line pressure and crank angle measurements. These signals are connecting with computer for pressure crank-angle diagrams. The setup also observe VCR engine performance for BP, IP, FP, BMEP, IMEP,BTHE, mechanical efficiency, volumetric efficiency, specific fuel consumption.

Figure 2. Experiment setup [13]

Table 2. Engine specification [13]

Number of cylinder	Single cylinder
Number of stroke	Four
Swept volume	552.64 cc
Cylinder diameter	80 mm
Stroke length	110 mm
Connecting rod length	234 mm
Fuel	Diesel
Power	5.7 KW
Speed	1500 rpm
Orifice diameter	20 mm
Injection point variation	0 to 25 BTDC
Compression ratio range	12 to 18
Dynamometer rotor radius	141 mm

V. METHODOLOGY

Response surface method consist present study for modeling and analytic of response parameters to obtain characteristic of engine. First step is selection of parameters depends on performance and emission characteristic of engine CR, load, and blend are input parameters.

Compression ratio is variable at three levels with high, low, and medium ranges of input parameters are selecting based on modification of engine. Advantage using design of experiment is evaluate variation of SFC with number of experiment. As per run order experiments are conducting on the engine and responses fed on response column. CCD is factorial or fractional factorial design with center points, augmented with group of axial points that estimate curvature. Efficiency estimated first and second order terms. Model response variable with curvature by adding center and axial points to previously factorial design.CCD has properties of orthogonal blocks and ratability. CCD generate more than one block.CCD generate orthogonal blocks and minimizing variation in regression coefficients. Also the CCD has face centered design which is use for this experiment .In face centered design axial points are at the center of each face of the factorial space. In this case design requires three levels of each factor.

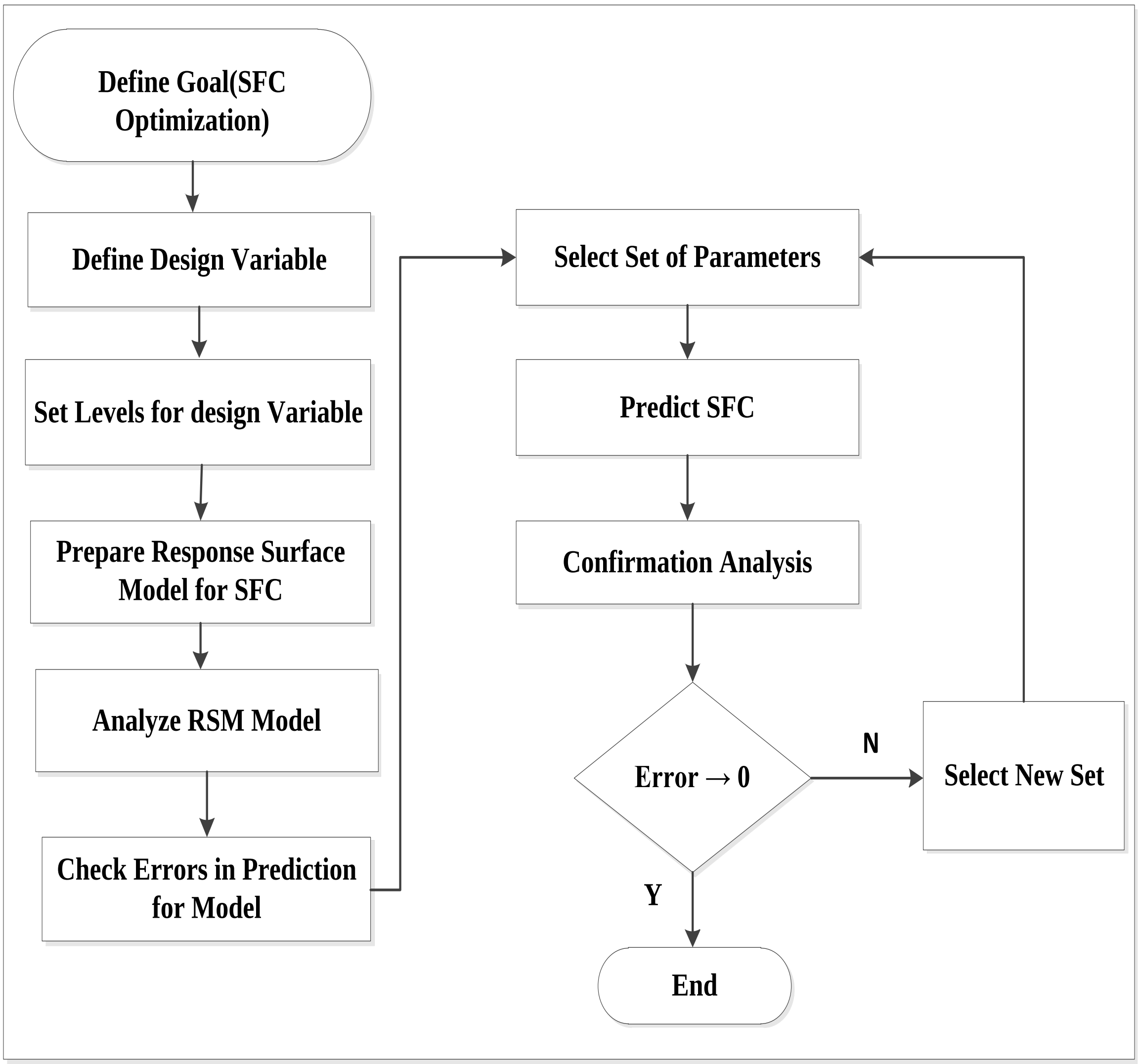


Figure 3. Flow chart of Experiment [12]

The selected process variable up to three levels and CCD has adopted to design the experiments. Response surface methodology has been used to develop a second order regression equation relating response characteristic and process variables. Three parameters considered for this study are compression ratio, blend ratio, and load. The parameters set at three levels each. The summary of the parameters is shown in Table.

Table 3. Parameters and their levels

Parameters	Levels		
	(-1)	**(0)**	**(1)**
Compression ratio	16	17	18
Blend ratio	100D0B	50D50B	0D100B
Load	2	7	12

The values of SFC for all variants are measure using Minitab for finding out the value of compression ratio, blend ratio, and load central composite design is applied to select the control factor levels to come up with optimal response value.

VI. RESULTS AND DISCUSSIONS

Experiments are designing according to test condition specified by second order central composite design, the analysis are conducting for all data sets, with process parameter levels set as given Table 3. To study about process parameters over the output parameters experimental results for SFC are given Table 4. Altogether 20 experiments have been conducted to prepare data set for response surface model.

Table 4. Coded value of variables and response

Run	CR	BR	LOAD	SFC(kg/KWh)
1	1	1	-1	0.38
2	0	0	0	0.18
3	0	-1	0	0.16
4	1	-1	-1	0.41
5	0	0	0	0.18
6	0	1	0	0.14
7	0	0	0	0.18
8	0	0	-1	0.38
9	0	0	1	0.14
10	0	0	0	0.18
11	0	0	0	0.18
12	1	-1	1	0.14
13	-1	1	-1	0.38
14	1	1	1	0.15
15	-1	1	1	0.14
16	1	0	0	0.16
17	-1	0	0	0.18
18	-1	-1	1	0.14
19	0	0	0	0.18
20	1	-1	-1	0.38

All the coefficients are to be estimated using experimental data as shown in Table 5

Table 5. Estimated regression coefficients

Term	Coef	SE Coef	P-Value
Constant	0.17345	0.00427	0.000
CR	0.00200	0.00393	0.622
BR	-0.00400	0.00393	0.333
LOAD	-0.12200	0.00393	0.000
CR*CR	0.00636	0.00749	0.416
BR*BR	-0.01364	0.00749	0.099
LOAD*LOAD	0.09636	0.00749	0.000
CR*BR	-0.00250	0.00439	0.582
CR*LOAD	-0.00250	0.00439	0.582
BR*LOAD	0.00500	0.00439	0.282
R-sq = (99.20%)			

Coefficient of determination (R^2) was 99.20% which show the estimated model fits the experimental data satisfactory. P value is less than 0.005 show model terms are indicative. So here load indicative mode terms in this case.

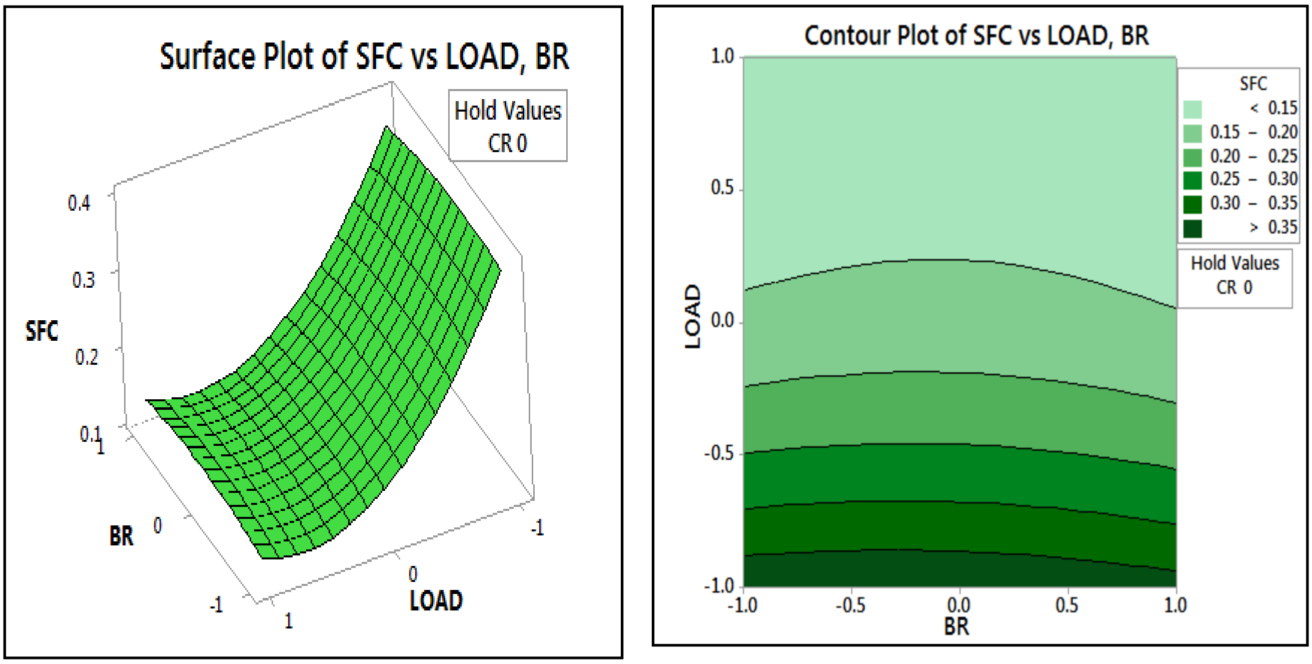


Figure 4. Surface and contour plot of SFC vs. Load, BR

As shown in figure 4 SFC value is minimum when load is maximum and blending ratio is maximum .it can be understood that the value of SFC is maximum when load is minimum and also blend ratio is minimum

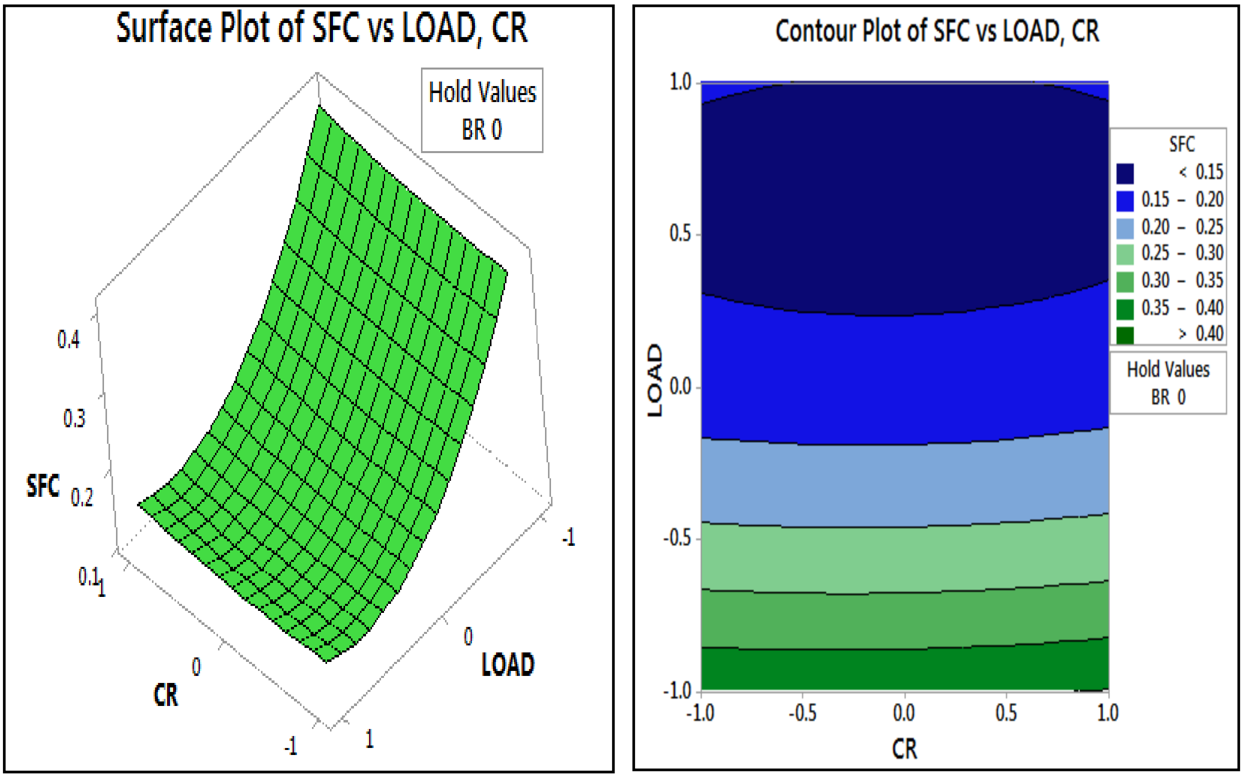


Figure 5. Surface and contour plot of SFC vs. Load, CR

As shown in fig 5 SFC value is minimum when load is maximum and compression ratio is lower. Also SFC value is maximum when load is minimum and compression ratio is maximum.

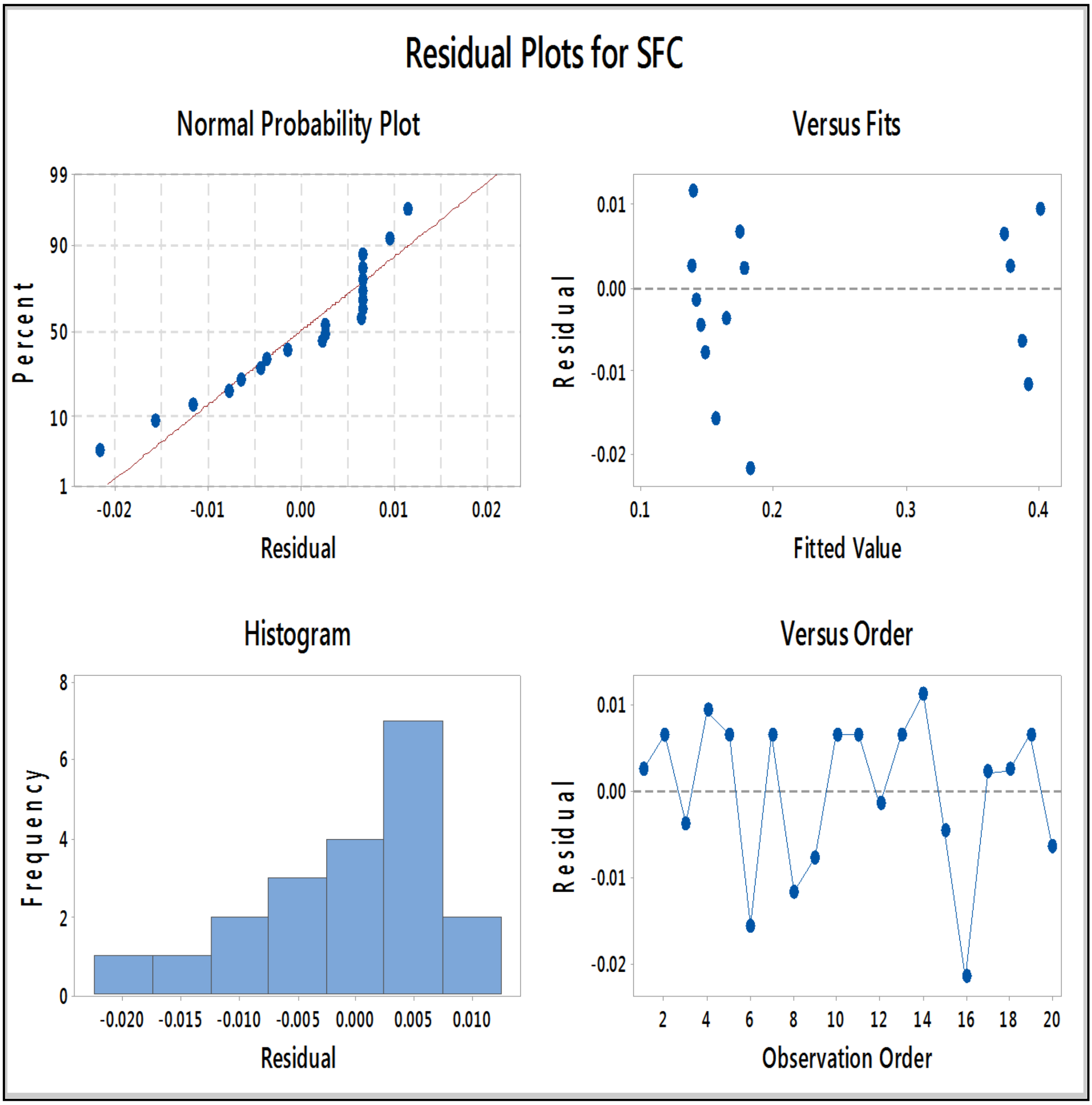


Figure 6. Residual Plots For SFC

For screening non-random variation, non-normality, outliners and non constant variance four in one residual plot are drawn. In normal probability plot straight residual line and histogram's symmetric nature shows that residuals are distributed normally. Residual have scattered randomly near zero in residual versus fitted value. There is random pattern in residual versus order graph. So response can be written as,

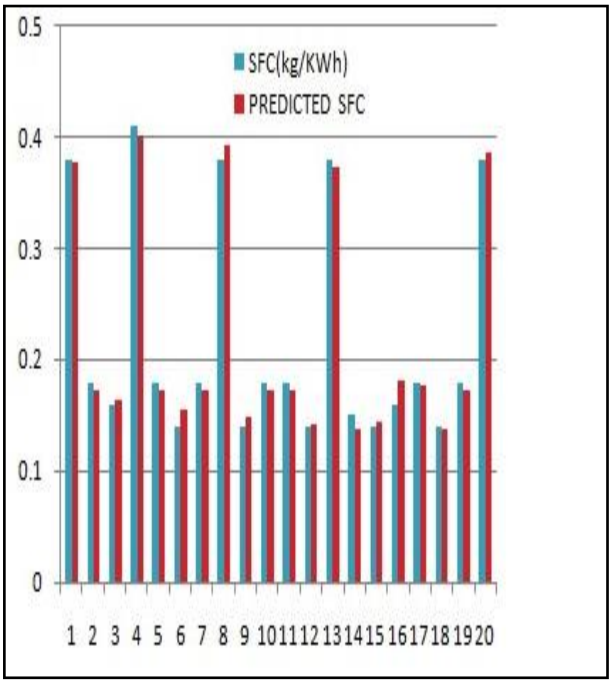
$Y=b_0+b_1+b_2X_2+b_3X_3+b_{11}X_{12}+b_{22}X_{22}+b_{33}X_{32}+b_{12}X_1$, there is no adverse effect. These four graphs not indicate that any problem. The second order polynomial equation to calculate $X_2+b_{13}X_1X_3+b_{23}X_2X_3$ (i)

The second- order polynomial models used to show SFC as a function of response variables

SFC(coded)=0.17345+0.00200CR-0.00400BR-0.12200LOAD+0.00636 CR*CR-0.01364 BR*BR +0.09636 LOAD*LOAD-0.00250CR*BR-0.00250CR*LOAD+0.00500BR*LOAD (ii)

Table 6. Comparison of results

EX NO	SFC(kg/KWh)	PREDICTED SFC(kg/KWh)	ERROR	%ERROR	MSE	RMSE	R^2
1	0.38	0.37753	0.00247	0.65	0.000077	0.008785	0.998649
2	0.18	0.17345	0.00655	3.638889			
3	0.16	0.16381	-0.00381	-2.38125			
4	0.41	0.40053	0.00947	2.309756			
5	0.18	0.17345	0.00655	3.638889			
6	0.14	0.15581	-0.01581	-11.2929			
7	0.18	0.17345	0.00655	3.638889			
8	0.38	0.39181	-0.01181	-3.10789			
9	0.14	0.14781	-0.00781	-5.57857			
10	0.18	0.17345	0.00655	3.638889			
11	0.18	0.17345	0.00655	3.638889			
12	0.14	0.14153	-0.00153	-1.09286			
13	0.38	0.37353	0.00647	1.702632			
14	0.15	0.13853	0.01147	7.646667			
15	0.14	0.14453	-0.00453	-3.23571			
16	0.16	0.18181	-0.02181	-13.6313			
17	0.18	0.17781	0.00219	1.216667			
18	0.14	0.13753	0.00247	1.764286			
19	0.18	0.17345	0.00655	3.638889			
20	0.38	0.38653	-0.00653	-1.71842			



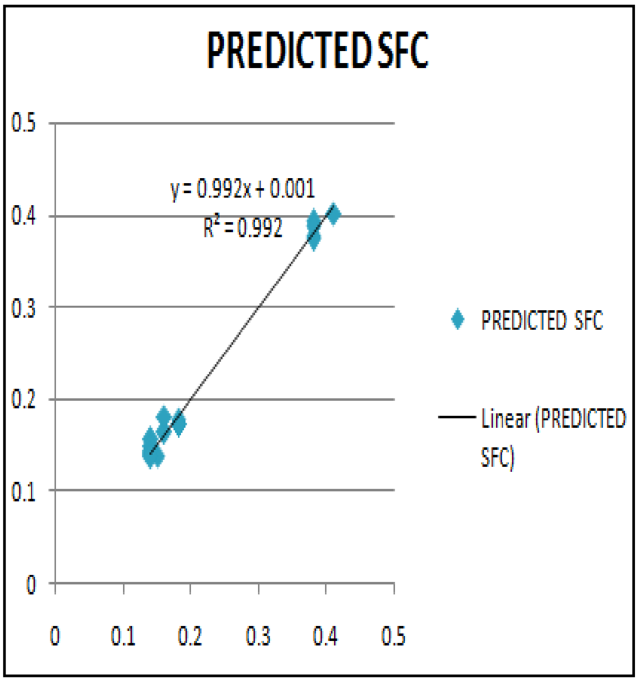


Figure 7. Comparison of experimental vs. predicted SFC result

Figure 7 shown the comparison of number experiment versus predicted SFC obtains equation. A linear distribution is obtained, which indicate that well fitting model.

Table 7. Optimum set of parameter

CR	BR	LOAD
17	100D0B	12

Table 7 shown the parameters value for minimum SFC which is obtaining from actual number of sets. The optimal set has CR of 17, blend ratio as 100D0B, with load of 12 kg. For this set of values experiment was executed and reading was taken. Analysis of the optimum set of parameter gives predicted value of SFC as 0.13317 by use of RSM and the value gained through experiment was 0.13. So, the error between predicted and experimented value is 0.00317 and percentage of error is 2.43 which is illustrated in Table 8. The values of error and % error are less so it confirms the validity of RSM design.

Table 8. Predicted and experimental values

Response	Predicted value	Experiment value	Error	% Error
SFC(kg/KWh)	0.13317	0.13	0.00317	2.43

VII. CONCLUSIONS

- Central composite RSM design is used to prepare prediction model to get specific fuel consumption for the given parameters of CI engine.
- It is derived that blend ratio, load and compression ratio parameters effecting SFC. For showing correlation between predicted and observed SFC second order polynomial equation was developed.
- RSM design utilization for design of number of experiment run has significantly time taken and efforts.
- From the validation of experiment it is clear that value of error and percentage of error is low i.e. the model gives value close to experimented value.
- The value of SFC is lower when the engine was running with high load of 12 kg and fueled with 100D0B blend of diesel.

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