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Development of Mathematical Model using Jatropha Oil by optimising SFC with RSM Method

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Abstract: *Ever increasing fuel price, the continuous addition of on-road vehicles, fast depleting petroleum resources and the continuing accumulation of greenhouse gases is the main reasons for the development of alternative fuels. Here Jatropha oil is used as an alternative fuel along with diesel. The purpose of the experiment is to create a mathematical model of the SFC using response surface methodology(RSM). Input parameters like compression ratio, Load, different blend of Diesel-Jatropha oil is used. The table of random readings is created using response surface methodology in an arithmetical software Mini tab 17. A single cylinder engine is selected for the experiment.*
In response surface methodology different blend ratio(D0B100, D50B50, D100B0) up to level 3 is used.

Keywords: *Specific Fuel consumption(SFC), Jatropha oil, Centred composite design (CCD), Response Surface Method(RSM), Load, Compression Ratio*

I. INTRODUCTION

Continuous increase in vehicles and fuel value, quick draining petroleum resources, the greenhouse effects and ozone depletion are the main reasons for the evolution of alternative fuels. Many optional or blend fuels are recognised and tried effectively in the current engine with and without engine adjustment. However, research is as yet proceeding to this field to locate the best option fuel to the current diesel fuel.

It is feasible to use alternative sources of fuel to diesel engine parts which is proved by various researchers. The diesel engine is made for diesel and it's all systems are developed for diesel fuel only. Also, its parameters are optimised for diesel engine. If we use a blend of diesel and other supplementary fuel, then it will not give satisfactory performance as per our requirement. So, it is required to optimise parameter for blended fuel.

The goal of our experiment is to optimise our parameter (SFC) which gives maximum performance. For achieving desired results, it is required to perform a number of experiments with different Blend Ratio at different Load condition.

II. METHODOLOGY

RSM is a collection of numerical and statistical methods for observed model building and analysis of response parameters. The design and analysis of experiment involve the following method. In the first step, choose the design and influence performance, selected for the parameters. In our study different blend(Jatropha Oil), load and compression ratio have been considered as input parameters. RSM is used for testing the liaison between the answer and set of enumerative experimental variables.

Flow chart of the experiment is given in Figure 1.

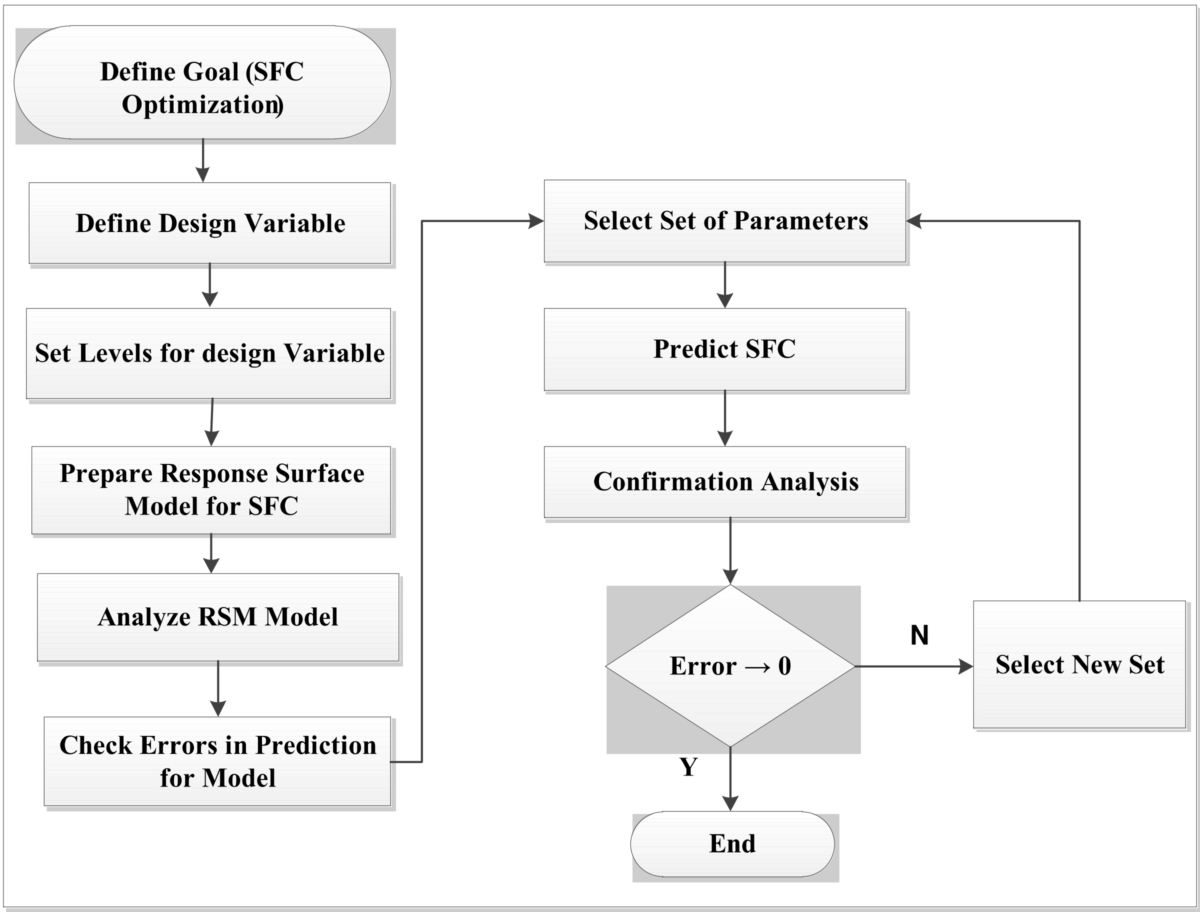

Figure 1. Flow chart of experiment

The design of Matrix has been selected based on the centred composite design (CCD) to apply to select the control factor levels. The three parameters deliberated for this study are different blend(Jatropha Oil), load and compression ratio. The three parameters are established at three levels each and one parameter set at two levels.

The precipitate of the parameters is shown in Table 1.

Table 1. Parameters and Their Level

Process parameter	Level		
	-1	0	1
CR	16	17	18
BR	D100B0	D50B50	D0B100
LOAD	2	7	12

III. RESULT AND DISCUSSION

Experiments were designed according to the test conditions specified by the second order central composite design. The analysis was conducted for all data sets, with the process parameter levels set as given in Table 1, to study the effect of process parameters over the output parameters.

Experimental results for SFC are given in Table 2.

Table 2. Observed values of Specific Fuel Consumption

Run	CR	BR	LOAD	SFC(kg/kwh)
1	0	0	0	0.17
2	1	1	1	0.13
3	0	0	1	0.13
4	0	0	0	0.17
5	1	-1	-1	0.38
6	0	0	0	0.17
7	0	0	-1	0.33
8	0	0	0	0.17
9	-1	-1	1	0.14
10	-1	1	-1	0.33
11	-1	1	1	0.13
12	0	-1	0	0.17
13	-1	-1	-1	0.41
14	0	0	0	0.17
15	1	0	0	0.15
16	0	1	0	0.14
17	-1	0	0	0.17
18	0	0	0	0.17
19	1	1	-1	0.28
20	1	-1	1	0.14

All the coefficients are to be predicted using experimental data as shown in Table 3.

Table 3. Expected Retrogression coefficients

Term	Coef	SE Coef	P-Value
Constant	0.16455	0.00329	0.000
CR	-0.01000	0.00302	0.008
BR	-0.02300	0.00302	0.000
LOAD	-0.10600	0.00302	0.000
CR*CR	0.00364	0.00576	0.542
BR*BR	-0.00136	0.00576	0.818
LOAD*LOAD	0.07364	0.00576	0.000
CR*BR	-0.00250	0.00338	0.476
CR*LOAD	0.01000	0.00338	0.014
BR*LOAD	0.02000	0.00338	0.000
R-Sq = 99.40%			

The coefficients of determination R-sq.=99.40% which indicated that the estimated model fits the experimental data satisfactorily.

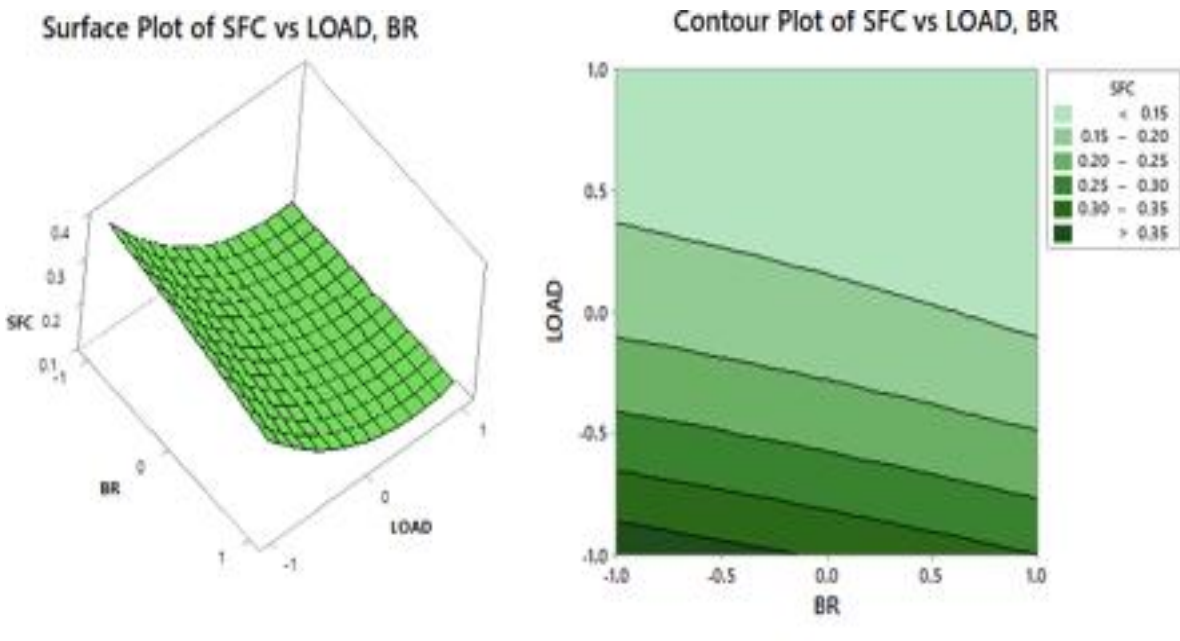

Figure 2. shows Contour plot and 3D surface graph for SFC

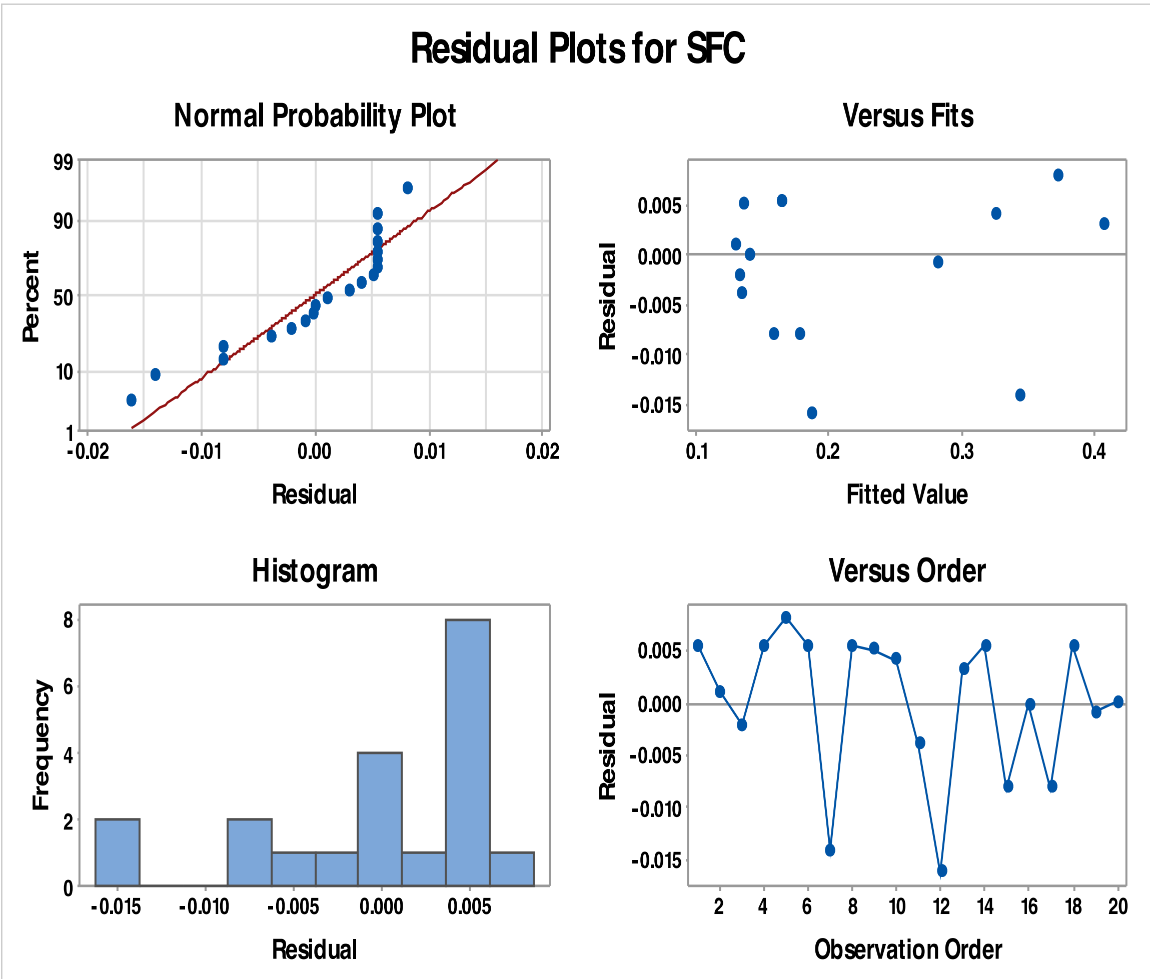

Figure 3. Residual plots for SFC

Four in one residual plot are drawn to draught a data for the non-constant, non-random variation, non-normality and variance in Figure 3. The residuals follow a nearly straight line in normal probability plot, and an approximate symmetric nature of the histogram indicates that the residuals are customarily scattered. The general equation for the second-order polynomial models used to explicit the SFC as an occasion of liberated variables (Eq. 1) is shown below in expressions of code level:

$$Y = b_0 + b_1X_1 + b_2X_2 + b_3X_3 + b_{11}X_1^2 + b_{22}X_2^2 + b_{33}X_3^2 + b_{12}X_1X_2 + b_{13}X_1X_3 + b_{23}X_2X_3 \quad (1)$$

Equation in coded Divisions below:

$$SFC(coded) = 0.2488 - 0.0170\,A + 0.0390\,B - 0.2100\,C - 0.0320\,D + 0.00545\,A*A - 0.00455\,B*B + 0.06545\,C*C - 0.00562\,A*B + 0.01437\,A*C + 0.0000\,A*D + 0.00687\,B*C - 0.0200\,B*D + 0.0480\,C*D \quad (2)$$

This equation (2) is used to discern the SFC in the stint of code level. In Table 4 comparisons of 20 combinations of experimental SFC and predicted SFC were calculated. Here in term of error, % error shows the difference between the experimental and predictive value of SFC.

Table 4 shows different values of SFC for experiments and predictive SFC are also defined in the table. Difference and % errors of the SFC and predictive SFC are also mentioned.

Table 4. Target vs Predicted SFC comparison results

NO.	SFC(kg/kwh)	Predicted SFC	Error	MSE	RMSE	R2
1	0.17	0.16455	0.00545	4.568E-05	0.006759	0.999059
2	0.13	0.12897	0.00103			
3	0.13	0.13219	-0.00219			
4	0.17	0.16455	0.00545			
5	0.38	0.37197	0.00803			
6	0.17	0.16455	0.00545			
7	0.33	0.34419	-0.01419			
8	0.17	0.16455	0.00545			
9	0.14	0.13497	0.00503			
10	0.33	0.32597	0.00403			
11	0.13	0.13397	-0.00397			
12	0.17	0.18619	-0.01619			
13	0.41	0.40697	0.00303			
14	0.17	0.16455	0.00545			
15	0.15	0.15819	-0.00819			
16	0.14	0.14019	-0.00019			
17	0.17	0.17819	-0.00819			
18	0.17	0.16455	0.00545			
19	0.28	0.28097	-0.00097			
20	0.14	0.13997	3E-05			

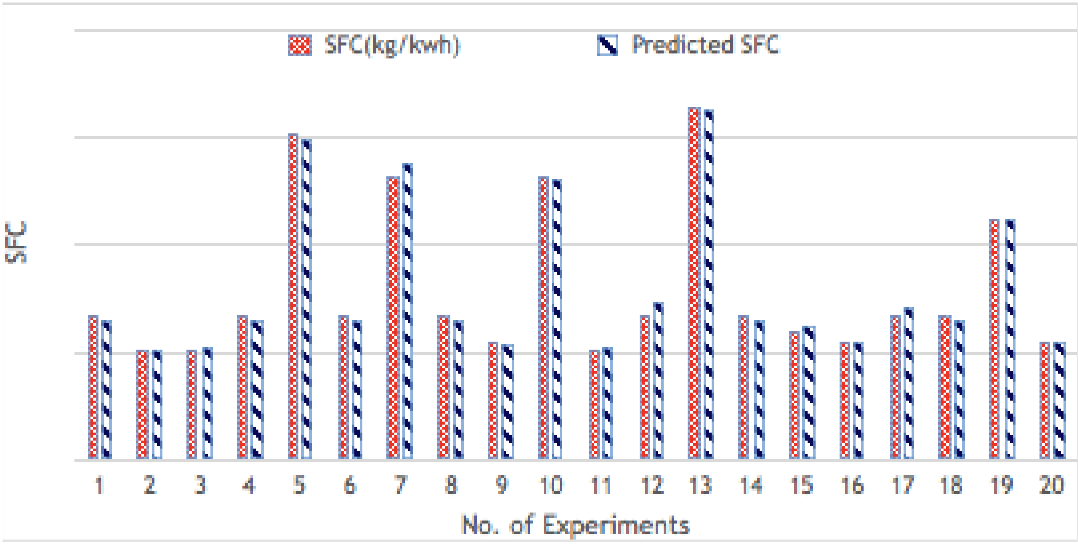

Figure 4. Experimental & Predicted SFC

Figure 4 shows the judgement of all experiments versus predictive SFC, in fig shows graph by distinctive colours and all experiment outcomes of predictive are appropriate impassable to the concrete reading, which is signposted that model has good relevant model.

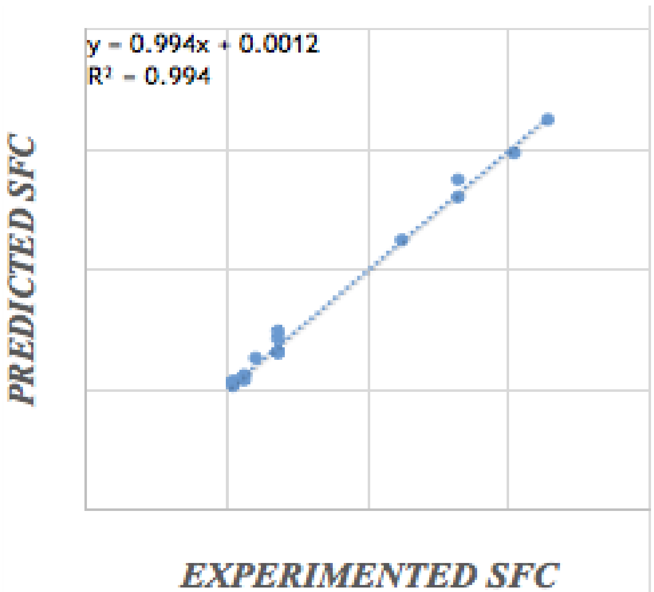

Figure 5. Experimental vs Predicted SFC.

Table 5 Predicted and Experimented value for SFC

Response	Predictive Value	Experimental Value	Error	% Error
SFC (kg/kWh)	0.20251	0.093	0.00317	3.4

IV. CONCLUSION

RSM design has been used to formulate prediction models of SFC using a certain set of factors. The equations used to find SFC shows interrelation between experimented and predicted SFC values. The predictive value of SFC is calculated by using all set of the experiment and optimum set is occupied. By using that optimum set predictive value and experiment value is measured. Error and % error are also found out. The predictive value for optimum set is 0.20251 which is nearer to experiment value which is 0.093. Error of model is 0.00317 and % error is 3.4.

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