Development of Mathematical Modeling of Mechanical Efficiency for Diesel Engine Fueled with Jatropha Biodiesel by using Response Surface Method

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Abstract: The latest problem of world is to control Climate change condition, and this problem only tackle by Controlling Earth's Temperature. There are huge amount of carbon is Emit by Automobile vehicles. In this study analysis of Mechanical Efficiency is observed by using Load, Blend Ratio and Exhaust Gas Recirculation as input parameters. For the optimization of the predicted Mechanical Efficiency is obtained from Response Surface Method. Aim of Experiment is to study decreasing polluted gas and check the performance of Diesel Engine fueled with jatropha biodiesel as alternative fuel.

***Keywords*:** *C.I. engine, Jatropha oil Biodiesel, EGR, Performance, RSM*

I INTRODUCTION

The increasing industrialization and modernization of the world has to a steep rise for the demand of petroleum products. Economic development in developing countries has led to huge increase in the energy demand. In India, the energy demand is increasing at a rate of 6.5% per annum. The crude oil demand of the country is met by import of about 80%. Thus the energy security has become a key issue for the nation as a whole. Petroleum-based fuels are limited. The finite reserves are highly concentrated in certain regions of the world. Therefore, those countries not having these reserves are facing foreign exchange crises, mainly due to the import of crude oil. Hence it is necessary to look forward for alternative fuels, which can be produced from feed stocks available within the country. Biodiesel, an eco-friendly and renewable fuel substitute for diesel has been getting the attention of researchers/scientists of all over the world. The R & D has indicated that up to B20, there is no need of modification and little work is available related to suitability and sustainability of biodiesel production from Jatropha as non-edible oil sources. In addition, the use of vegetable oil as fuel is less polluting than petroleum fuels. The basic problem with biodiesel is that it is more prone to oxidation resulting in the increase in viscosity of biodiesel with respect to time which in turn leads to piston sticking, gum formation and fuel atomization problems. The possibilities of production of biodiesel from edible oil resources in India is almost impossible , as primary need is to first meet the demand of edible oil that is already imported. India accounts for 9.3% of world's total oil seed production and contributes as the fourth largest edible oil producing country. Even then, about 46% of edible oil is imported for catering the domestic needs. Give the production and consumption of edible oil for country. The above table indicates that India imports about 40–50% edible oil of its domestic requirement and therefore, it is not possible to divert the edible oil resources for biodiesel production in the country. So the non-edible oil resources like Jatropha, pongamia, etc., seem to be the only possibility for biodiesel production in the country. As per Government of India survey, out of total land area, 60 Mha are classified as waste and degraded land. India has third largest road network in Asia having length about 3 million km the sides of which can be used for growing the Jatropha and Karanja crops and oil can be converted into biodiesel. India has railway network of 63,140 km and land along the track can be easily used for cultivation of Jatropha curcase to check the soil erosion and to improve fertility in addition to oil production [2]. India is located in one the favorable Environment for the development of the Jatropha. For development of Jatropha seeds dependent on many environment conditions such as tropical region which is available in India as mainly in region of Madhya Pradesh , Gujarat , Chhattisgarh etc[1].

II EXPERIMENT SET UP

For performing this work single cylinder four stroke diesel engine is use fueled with jatropha biodiesel and mineral diesel. And for measuring the temperature Thermocouple and for Speed Digital tachometer is used. Exhaust Gas Recirculation (EGR) set up is used to controlling the exhaust temperature. Instead of using after treatment systems to comply with exhaust emission legislation, it is also possible to avoid the formation of emissions during the combustion. The raw emissions are reduced and thus no after treatment is needed. It is common practice nowadays, to use EGR to reduce the formation of NO_X emissions. A portion of the exhaust gases is re-circulated into the combustion chambers. This can be achieved either internally with the proper valve timing, or externally with some kind of piping. The exhaust gas acts as an inert gas in the combustion chamber, it does not participate in the combustion reaction. This leads to a reduction of the combustion temperature by different effects. The fuel molecules need more time to find an oxygen molecule to react with, as there are inert molecules around. This slows down the combustion speed and thus reduces the peak combustion temperature, as the same amount of energy is released over a longer period of time. The energy is also used to heat up a larger gas portion than it would without EGR. As the air is diluted with exhaust gas, the mass of a gas portion containing the needed amount of oxygen gets bigger. Another effect is the change in heat capacity. Exhaust gas has a higher specific heat capacity than air, due to the CO_2- molecule's higher degree of freedom. So for the same amount of combustion energy a gas mass containing EGR will get a lower temperature than pure air. The lower combustion temperature directly reduces the NO_X formation, as the NO_X formation rate is highly temperature dependent, The Experimental tests steps followed in the present study started first by warming up the engine for approximately 10 min using Diesel fuel in the prime tank. Second the fuel line was adjusted so that the engine can use the test fuel. After that engine speed is adjusted. After that steady state condition is confirmed by recording Exhaust temperature.

Fig.1 Engine Set Up

Table 1 Engine Specification

Parameter	Details
Engine	Single Cylinder High Speed Diesel Engine
Cooling	Water cooled
Bore × Stroke	80 mm × 110 mm
Compression ration	16 : 1
Maximum Power	5 hp or 3.7 kW
Rated speed	1500 rpm
Capacity	553 CC

III RESEARCH METHODOLOGY

RSM method is used to find Optimum value from the relationship between Factors and Responses. In this study RSM is applies to find optimum Input Parameter gives maximum efficiency, minimum fuel consumption and less emission. The work investigates the influence of Load, Blend Ratio (%) and Exhaust Gas Recirculation (EGR) on the performance of Diesel Engine fueled with Jatropha Biodiesel (0%, 50% and 100%). The Experiment was designed using statistical tool DESIGN OF EXPERIMENT (DOE) based on Response Surface Methodology. The RSM result model was helpful to predict the responses parameter such as Break Specific Fuel Consumption, Break thermal Efficiency and Mechanical Efficiency. Optimization of parameters was performed using the desirability approach of the response surface methodology for better performance.

3.1 Observed Parameter

This experiment is performed on the basis of main three variable parameter.
Load, Blend and EGR.

3.1.1 Load

Load is one the most important parameter in whole experiment. As increasing the load, how the engine speed is affected with various blending ratio is observed. In the present work load is varies in range of 1, 6 and 11.

3.1.2 Blend

Blend is amount of Jatropha oil is mixed in diesel to check performance parameter such as Break power, Mechanical efficiency and Indicated power. Blend is set in ratio of 0, 50 and 100.

3.1.3 EGR

Exhaust Gas Recirculation (EGR) set up is used to controlling the exhaust temperature. Instead of using after treatment systems to comply with exhaust emission legislation, it is also possible to avoid the formation of emissions during the combustion.

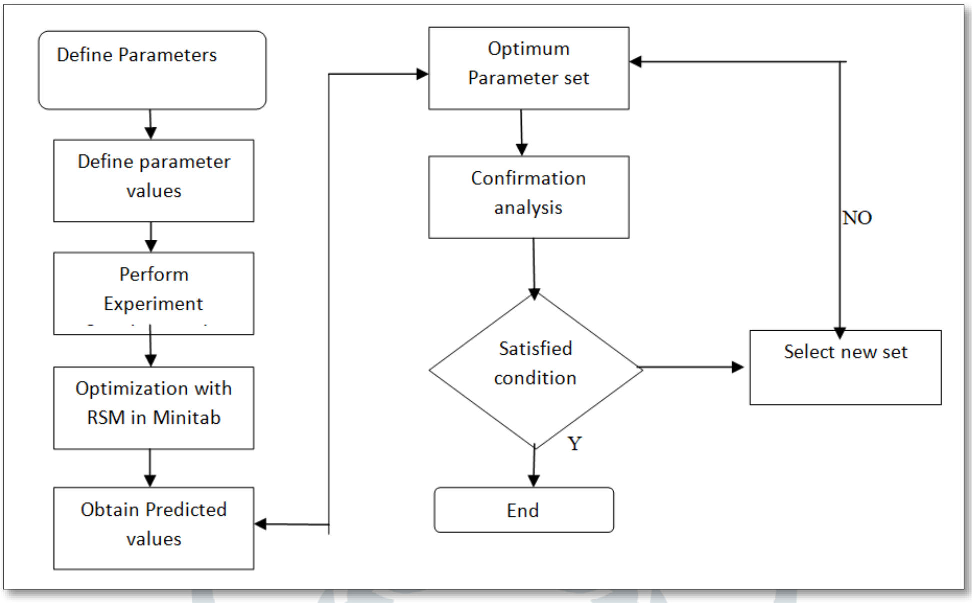

Fig.2 Flow Chart of Experiment

IV RESULT AND DISCUSSION

The selected variables are on 3 levels with central composite method

Table 2 Parameters and their Levels

Process Parameter	-1	0	1
Percentage of Blend (%)	0	50	100
Load(Kg)	1	6	11
EGR	0	25	50

4.1 RSM Analysis on Mechanical Efficiency

Experiment analyses according to central composite design. Analysis conducted for all the data sets with process parameter levels set as Table 1.

Where, A.B and C represented the all process parameter respectively.

The entire coefficients are to be estimated using experimental data as on table 1.

Table 3 all the process parameter over output parameter

Sr. No.	%BD	Load	EGR
1	50	6	25
2	100	1	0
3	100	1	50
4	50	6	25
5	50	1	25
6	100	11	0
7	50	6	25
8	0	1	0
9	0	1	50
10	50	6	25

11	50	6	25
12	0	11	0
13	50	6	50
14	0	6	25
15	50	6	25
16	0	11	50
17	100	11	50
18	100	6	25
19	50	6	0
20	50	11	25

Table 4 Response surface Regression: Mechanical vs. A, B, C

Source	DF	Adj SS	Adj MS	F-Value	P-Value
Model	9	6610.05	734.45	1274.96	0.000
Linear	3	6296.23	2098.74	3643.28	0.000
A	1	187.40	187.40	325.32	0.000
B	1	6108.81	6108.81	10604.48	0.000
C	1	0.03	0.03	0.05	0.836
Square	3	300.63	100.21	173.96	0.000
A*A	1	43.69	43.69	75.84	0.000
B*B	1	237.53	237.53	412.33	0.000
C*C	1	0.33	0.33	0.57	0.468
2-Way Interaction	3	13.18	4.39	7.63	0.006
A*B	1	13.17	13.17	22.87	0.001
A*C	1	0.00	0.00	0.01	0.931
B*C	1	0.01	0.01	0.01	0.921
Error	10	5.76	0.58		
Lack-of-Fit	5	5.76	1.15	*	*
Pure Error	5	0.00	0.00		
Total	19	6615.81			

Model Summary

S	R-sq	R-sq(adj)	R-sq(pred)
0.758985	99.91%	99.83%	99.37%

From above Table 2 Values of 'P' less than 0.0500 indicate model is significant.

5.1 Statistical Inferences:

1. The Model F-Value of 1274.96 implies the model is significant. There is no chance that a "Model F-Value " of this much value could occur due to other parameters.
2. The "Lack of Fit F-Value" doesn't indicate any such value which is good.
3. The "Pred R- Squared " of 0.9937 is in reasonable agreement with the "Adj R-Squared" of 0.9983.
4. Values of "Preb > F" less than 0.0500 Indicate model terms are significant. In this case A, B, , AA, BB, AB are significant model terms.

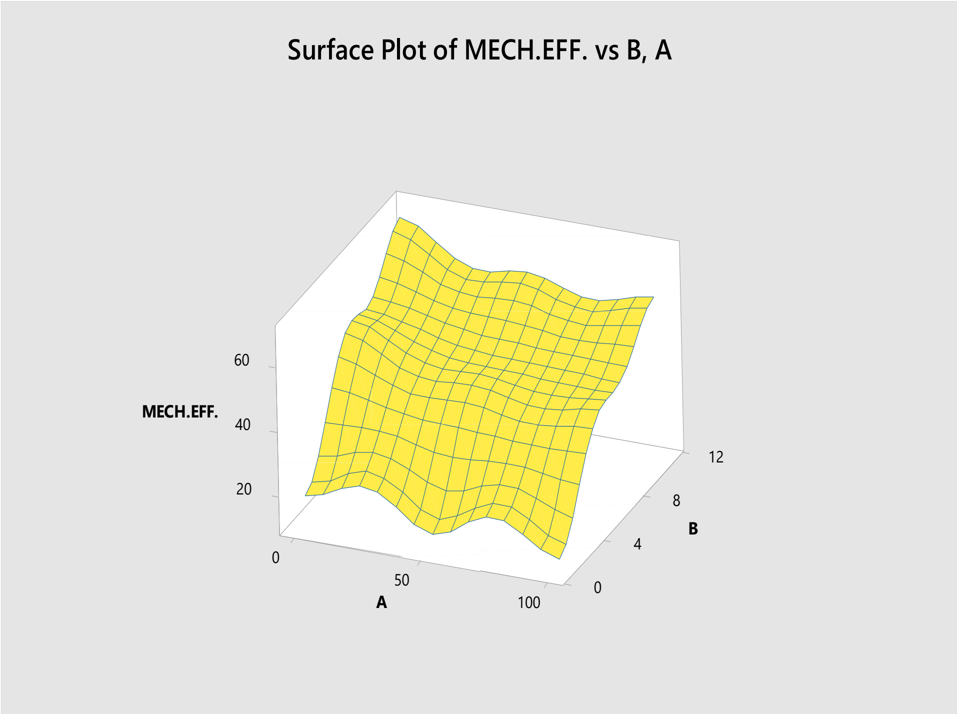

Fig 3 Surface plots of Mechanical Efficiency with respect to A and B

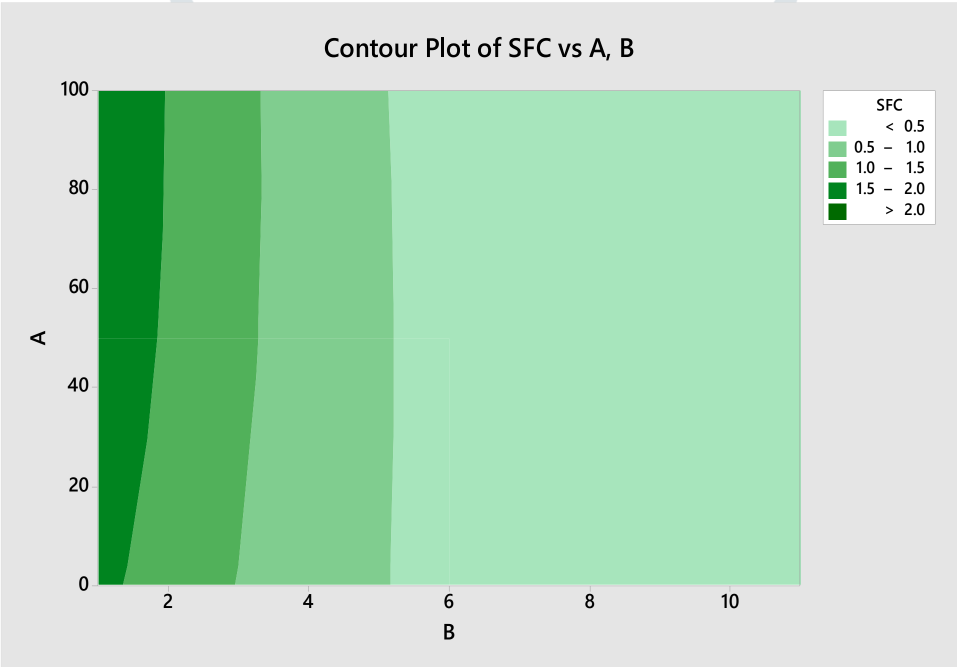

Fig 4 Contour Diagram of Mechanical Efficiency

3D surface diagram and contour diagram represent the all the desirable condition of Specific fuel consumption with the parameter of Percentage of Blend and Load.

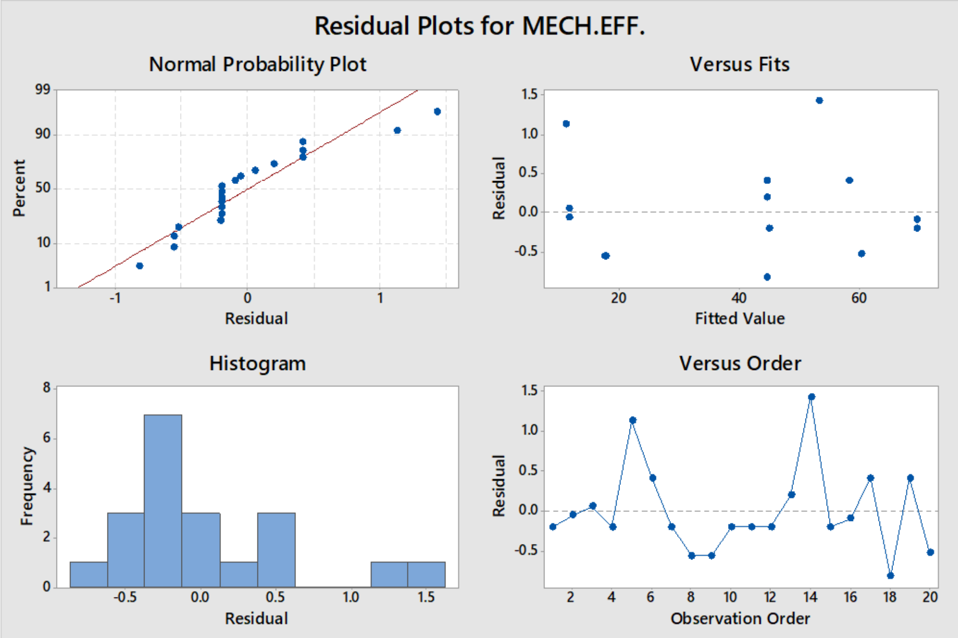

Fig 5 Residual Plots for Mechanical Efficiency

Four Residuals plots are drawn for estimating the accuracy of the model. The histogram plot indicates a mild tendency for the non normality; however the normal probability plots of these residuals do not reveal any abnormality, Residuals versus fitted value and residual versus observations order plot do not indicate any undesirable effect. Figure 5 shows Residual plots for Mechanical Efficiency to check the data for the non-random variation, non-constant variance and outliners. On the Normal Probability plot the straight line indicate residual are normally distributed. Versus fits, Histogram and versus graph represent there is no undesirable effect.

And for the prediction Values of Mechanical Efficiency can be calculated from the Regression Equation given below,

$$\text{Mechanical Efficiency} = 8.370 - 0.2157 \times A + 9.655\times B + 0.0233\times C + 0.001594 \times A\times A - 0.3717 \times B\times B - 0.000552\times C\times C - 0.00513\times A\times B + 0.000019\times A\times C + 0.00022\times B\times C$$

Table 5 Experimental and Predicted values of Mechanical Efficiency

Run Order	**Experimental Value**	**Predicted Value**	**Error**	**R^2**
1	44.673	44.874	-0.20108	0.9991
2	11.4586	11.5103	-0.0517	
3	11.4586	11.4013	0.0573	
4	44.673	44.874	-0.20108	
5	11.9969	10.8635	1.13333	
6	58.7385	58.3263	0.41221	
7	44.673	44.874	-0.20108	
8	17.0893	17.6533	-0.564	
9	16.8855	17.4493	-0.5638	
10	44.673	44.874	-0.20108	
11	44.673	44.874	-0.20108	
12	69.3936	69.5993	-0.20574	
13	44.673	44.4783	0.19467	
14	54.6182	53.1893	1.42891	
15	44.673	44.874	-0.20108	
16	69.4068	69.5053	-0.0985	
17	58.7385	58.3273	0.41121	
18	43.7093	44.5288	-0.81953	
19	44.9927	44.5798	0.4129	
20	59.7715	60.2995	-0.52805	

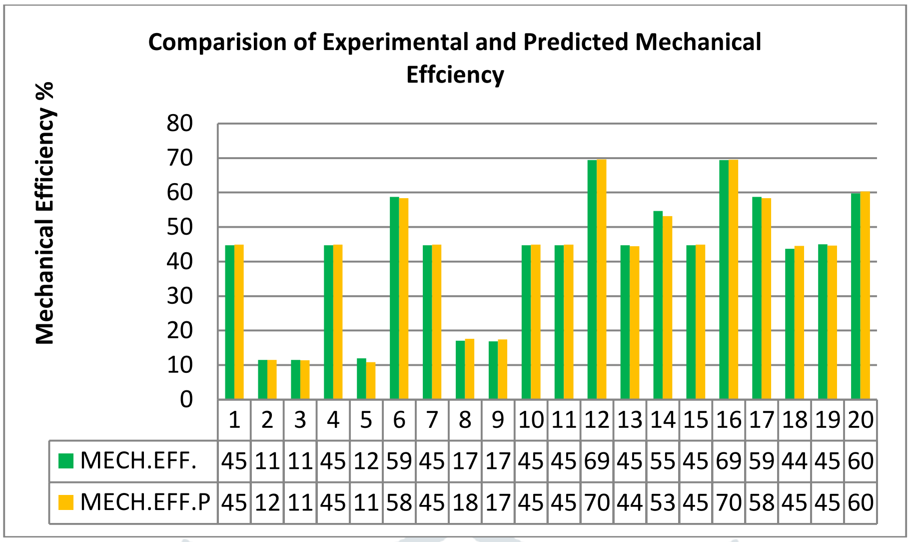

Fig.6 Numbers of Experiment vs. Mechanical Efficiency

Figure 6 describes the comparison between Experiment and Predicted Values of Mechanical Efficiency. On the graph all the values of Mechanical Efficiency with respect to number of Experiment is close to each other, which indicate a linear distribution in graph.

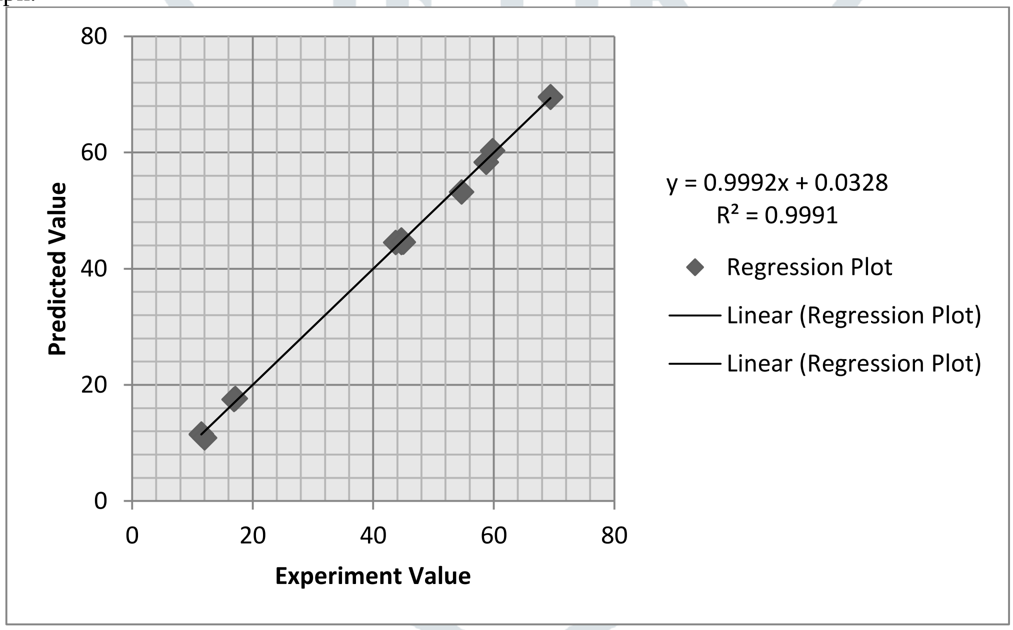

Fig.7 Regression Plots for Mechanical Efficiency

Figure 7 is Regression Plots for Mechanical Efficiency and from the equation y = 0.999x + 0.032, we can find the Experimental as well as Predicted value.

Table 6 Data Table for Mechanical Efficiency

SR. No.	**Parameter Set**			**Mechanical Efficiency(%)**		
	% of Blend	**Load(kg)**	**EGR**	**Predicted**	**Experimental**	**Error**
1	0	1	0	17.6533	17.0893	-0.564
2	0	1	25	17.8963	-	-
3	0	1	50	17.4493	16.8855	-0.5638
4	0	6	0	52.9188	-	-
5	0	6	25	53.1893	54.6182	1.4289
6	0	6	50	52.7698	-	-
7	0	11	0	69.5993	69.3936	-0.2057
8	0	11	25	69.8973	-	-

9	0	11	50	69.5053	69.4068	-0.0985
10	50	1	0	10.5968	-	-
11	50	1	25	10.86355	11.9969	1.13335
12	50	1	50	10.4403	-	-
13	50	6	0	44.5798	44.9927	0.4129
14	50	6	25	44.87405	44.673	-0.20105
15	50	6	50	44.4783	44.673	0.1947
16	50	11	0	59.9778	-	-
17	50	11	25	60.29955	59.7715	-0.52805
18	50	11	50	59.9313	-	-
19	100	1	0	11.5103	11.4586	-0.0517
20	100	1	25	11.8008	-	-
21	100	1	50	11.4013	11.4586	0.0573
22	100	6	0	44.2108	-	-
23	100	6	25	44.5288	43.7093	-0.8195
24	100	6	50	44.1568	-	-
25	100	11	0	58.3263	58.7385	0.4122
26	100	11	25	58.6718	-	-
27	100	11	50	58.3273	58.7385	0.4112

V CONCLUSION

The present Investigation is to check the Performance of Diesel Engine fueled with the Blend of Jatropha and Diesel. The optimization is Carry out by the Response Surface Analysis with help of Minitab software. This model is used to predict the value of Mechanical Efficiency. The study is gives the comparison of Experiment value and Predicted value. The whole study check the Experiment work is effective or not. So, after the analysis of all the above Regression plots, 3D Surface plots and Contour plots indicate that all the parameter is Effective with respect to Mechanical Efficiency. And doesn't contain any unsatisfied result.

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