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Optimization of Neem and Niger Oil Blends and IOP Used for Diesel Engine Using Taguchi Method

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Abstract - **According to the present days, the concerns on climate change, the high fuel prices and the dwindling oil reserves and supplies have necessitated a strong interest in the research for alternative fuel sources. Biodiesel is an alternative renewable fuel that has gained massive attention in recent years. Studies on the physical properties of biodiesel have shown that it is completely miscible with petroleum diesel. Since the combustion of biodiesel emits hazards particulate matter and gases which is lower than petro diesel, Combustion of biodiesel and biodiesel blends have shown a significant reduction in particulate matter and exhaust emissions. So in this paper the use of pure biodiesel or biodiesel blends of Neem & Niger Oil (B00, B20, B40, B60 and B80) in terms of performance and exhaust emissions has been studied in comparison to petroleum diesel at different injection pressure (190, 200 and 210 bar). Result shows that B40 blend of fuel sample shows best result. And if we increase the injection opening pressure of fuel pump at certain limit then diesel engine shows best performance.**

Keywords — Alternative fuel, Blends, Neem & Niger oil, Performance, Injection pressure, etc,.

I. INTRODUCTION

The growing demand for fuel and increasing concern for the environment due to the use of fossil fuel have led to the increasing popularity of biofuel as a useful alternative and environmentally friendly energy resource. The increasing population of both the developing nations of the world, their steady increasing in the diesel consumption, the non-renewability of the fossil fuels as well as their environmental effects are some of the reasons that has made the biofuels as alternative and attractive. Diesel engines are the major source of power generation and transportation hence diesel is being used extensively ,but due to the gradual impact of environmental pollution there is an urgent need for suitable alternate fuels for use in diesel engine without any modification. There are different kinds of vegetable oils and biodiesel have been tested in diesel engines its reducing characteristic for greenhouse gas emissions.

II. TAGUCHI METHOD

The Full Factorial Design requires a large number of experiments to be carried out as stated above. It becomes laborious and complex, if the number of factors increase. To overcome this problem Taguchi suggested a specially designed method called the use of orthogonal array to study the entire parameter space with lesser number of experiments to be conducted. Taguchi thus, recommends the use of the loss function to measure the performance characteristics that are deviating from the desired target value. The value of this loss function is further transformed into signal-to-noise (S/N) ratio. Usually, there are three categories of the performance characteristics to analyze the S/N ratio. They are: nominal-the-best, larger-the-better, and smaller-the-better. III. Steps Involved in Taguchi Method The use of Taguchi's parameter design involves the following steps [3]. a. Identify the main function and its side effects. b. Identify the noise factors, testing condition and quality characteristics. c. Identify the objective function to be optimized. d. Identify the control factors and their levels. e. Select a suitable Orthogonal Array and construct the Matrix f. Conduct the Matrix experiment. g. Examine the data; predict the optimum control factor levels and its performance.

III. RESULT AND DISCUSSIONS

A. Taguchi Experimental Design for factor level load and Blends

In order to identify the significances of input parameters on mentioned performance and emission parameters main effect plot are plotted. A main effect is the effect of independent

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variable on a dependent variable averaging across the level of any other independent variables. A main effect will merely look at whether overall there is something about a particular factor that is making a difference or not.

When the line is horizontal then there is no main effect. Each level of the factor affect the response in the same way and the response mean is the same across all the factor levels. But when line is inclined then there is a main effect. Different level of the factor affect the response differently. The steeper the slope of the line, the greater the magnitude of main effect.

1. *Main effect factor on brake power:*

The fig. shows the mean effect plot for brake power against various factor levels of load and Biodiesel blend. As the level of input parameters i.e. Biodiesel blend increases there is no any change in the brake power is observed except load. As the load increases the brake power increases which is the obvious reason. The significance of load is so strong that other factors seem to be insignificant.

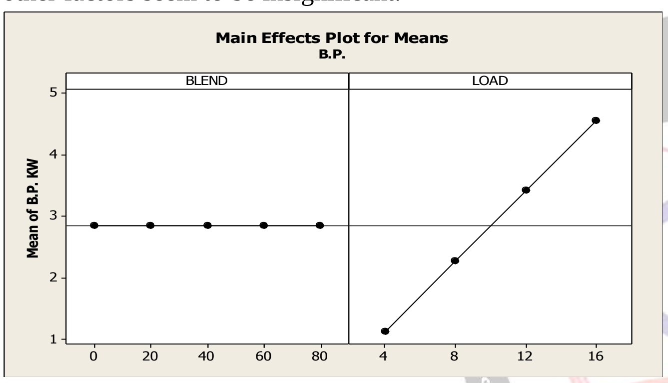

Figure No 3.1 .: Main effect plot for brake power

Table No. 3.1 :Analysis of Variance for BP

SOURCE	SS	DF	MS	F
Blend	0.01121	4	0.00280	0.8005
Load	42.21670	3	14.0722	4020.6
Residual	0.04200	12	0.00350	
Total	42.26991	19		

2. *Main effect factor on brake specific fuel consumption*

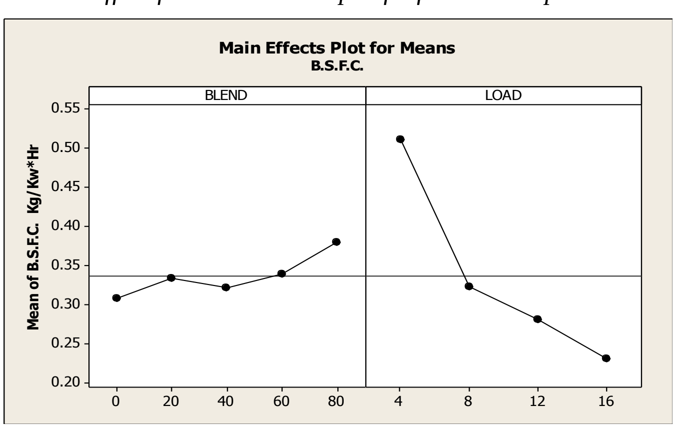

Figure No.3.2: Main effect plot for brake specific fuel consumption

The figure shows the mean effect plot for brake specific fuel consumption against various factor levels load and Biodiesel blend. With increase in load, brake specific fuel consumption decreases sharply. The main reason for this could be that percent increase in fuel required to operate the engine is less than the percent increase in load due to relatively less portion of the heat loss at higher loads. Increase in biodiesel percentage shows slight increase in brake specific fuel consumption. One of the reason for this is, higher density of the biodiesel which causes more mass of fuel consumed for same volume of the fuel. The significance of load is so strong that other factors seem to be insignificant.

Table No.3.2:Analysis of Variance for BSFC

SOURCE	SS	DF	MS	F
Blend	0.010027	4	0.002506	2.4861
Load	0.258786	3	0.086262	85.5773
Residual	0.012101	12	0.001008	
Total	0.280914	19		

3. *Main effect factor on brake thermal efficiency:*

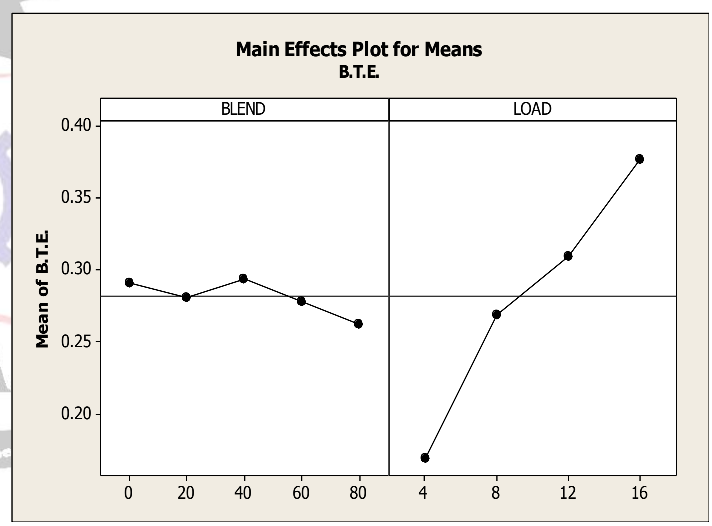

Figure No.3.3: Main effect plot for brake thermal efficiency

The figure shows the main effect plot for brake thermal efficiency against various factor levels of load and Biodiesel blend. As the amount of biodiesel blend increases the brake thermal efficiency decreases slightly. As the load increases there is sharp increase in brake thermal efficiency. This is because the density of the biodiesel is higher.

Table No.3.3 :Analysis of Variance for BTE

SOURCE	SS	DF	MS	F
Blend	0.001498	4	0.000374	0.9303
Load	0.145590	3	0.048530	120.72
Residual	0.004829	12	0.000402	
Total	0.151917	19		

4. *Main effect factor on exhaust gas temperature*

The figure shows the main effect plot for Exhaust Gas Temperature against various factor levels load and Biodiesel blend.

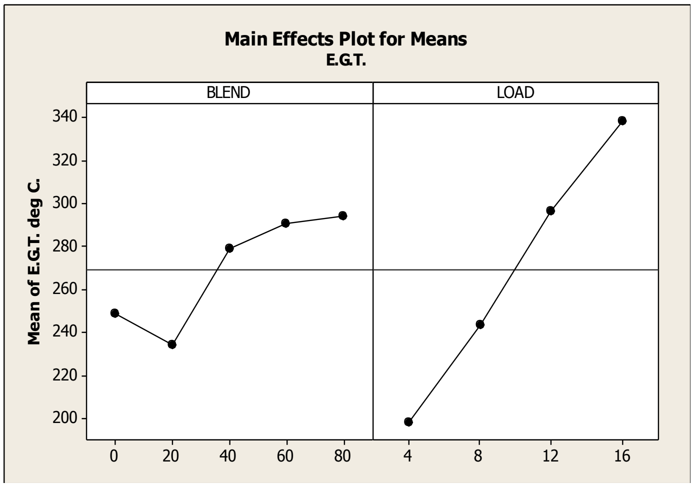

Figure No.3.4 : Main effect plot for exhaust gas temperature

With increase in load Exhaust Gas Temperature increases sharply. The main reason for this could be that increase in temperature of combustion chamber. Increase in heat formation inside the cylinder. As well as with increase in blend ratio exhaust gas temperature increases slightly.

Table No.3.4 :Analysis of Variance for EGT

SOURCE	SS	DF	MS	F
Blend	9314.7	4	2328.67	3.4361
Load	71798.6	3	23932.8	35.3147
Residual	8132.4	12	677.700	
Total	89245.7	19		

5. *Main effect factor on carbon monoxide:*

The figure shows the mean effect plot for Carbon Monoxide against various factor levels load and Biodiesel blend. With increase in load Carbon Monoxide level increases sharply. And as the increase in blend ratio there is sharp decrease in Carbon Monoxide level in emission.

Table No. 3.5 :Analysis of Variance for CO

SOURCE	SS	DF	MS	F
Blend	0.001511	4	0.000377	6.9814
Load	0.002862	3	0.000954	17.666
Residual	0.000655	12	0.000054	
Total	0.005028	19		

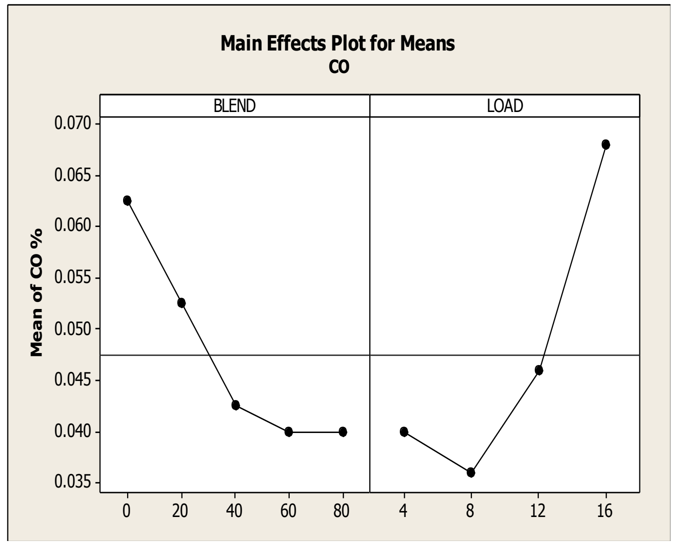

Figure No. 3.5 : Main effect plot for carbon monoxide

6. *Main effect factor on Hydrocarbon:*

The figure shows the mean effect plot for Hydro carbon against various factor levels load and Biodiesel blend. With increase in load Hydrocarbon level at start it slightly decreases but after that it increases sharply.

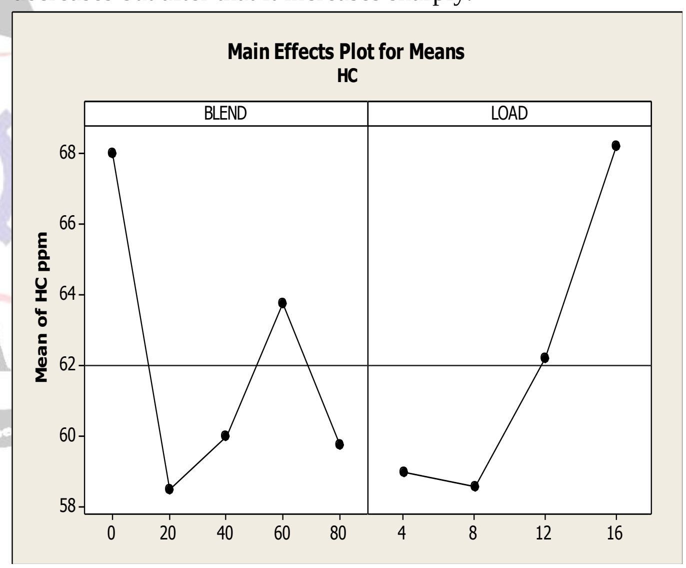

Figure No.3.6 : Main effect plot for hydrocarbon

And as the increase in blend ratio at start hydrocarbon level decreases sharply but in between blend ratio B20 to B60 it increases continuously and again decreases at the end.

Table No.3.6 :Analysis of Variance for HC

SOURCE	SS	DF	MS	F
Blend	52.430	4	13.1075	0.5437
Load	313.877	3	104.625	4.3404
Residual	289.257	12	24.1047	
Total	655.564	19		

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7. *Main effect factor on Carbon dioxide:*

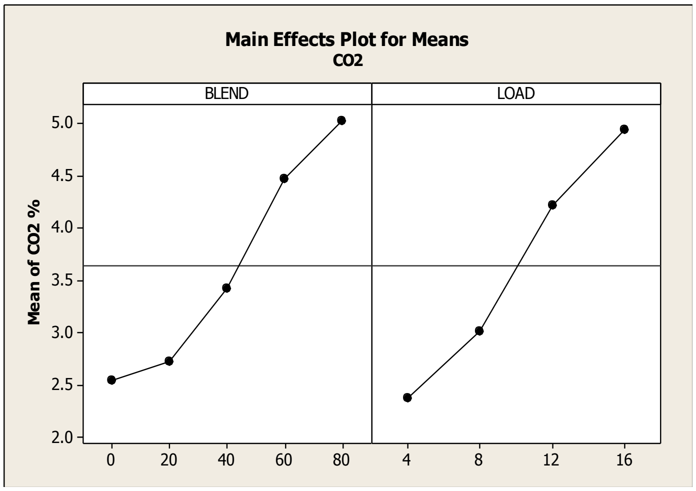

Figure No 3.7 : Main effect plot for carbon dioxide

Table No.3.7 : Analysis of Variance for CO2

SOURCE	SS	DF	MS	F
Blend	21.3393	4	5.3348	37.9971
Load	25.1680	3	8.3893	59.7528
Residual	1.6846	12	0.1404	
Total	48.1839	19		

The figure shows the mean effect plot for Carbon dioxide against various factor levels load and Biodiesel blend. With increase in both load and blend ratio there is sharp increase in Carbon dioxide level. As the biodiesel are oxygenated so CO2 level also increases at emission.

8. *Main effect factor on Oxygen:*

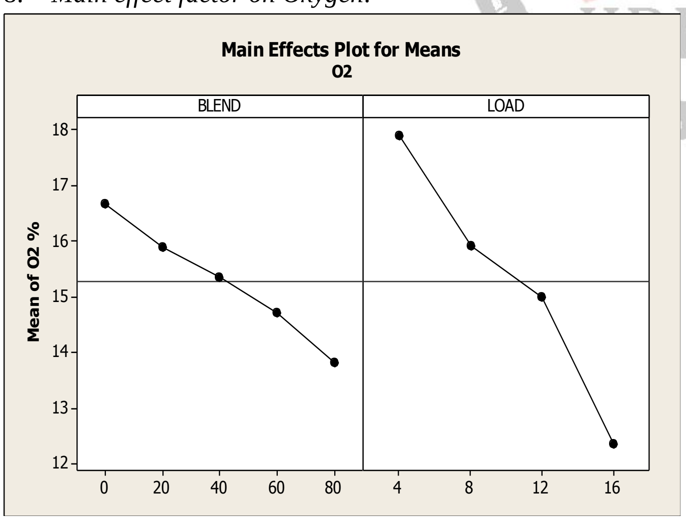

Figure No.: Main effect plot for oxygen

The figure shows the mean effect plot for Oxygen against various factor levels load and Biodiesel blend. With increase in both load and blend ratio there is sharp decrease in Oxygen level. As the biodiesel are oxygenated so CO2 level increases at emission therefore O2 level gets decreases.

Table No.3.8 : Analysis of Variance for O2

SOURCE	SS	DF	MS	F
Blend	21.170	4	5.2925	6.8458
Load	102.280	3	34.0933	44.0995
Residual	9.277	12	0.7731	
Total	132.727	19		

9. *Main effect factor on Nitrogen oxides:*

The figure shows the mean effect plot for Nitrogen oxide against various factor levels load and Biodiesel blend. With increase in both load and blend ratio there is sharp increase in Nitrogen oxides. Because of that only E.G.T. also increases with increase in load and blend ratio.

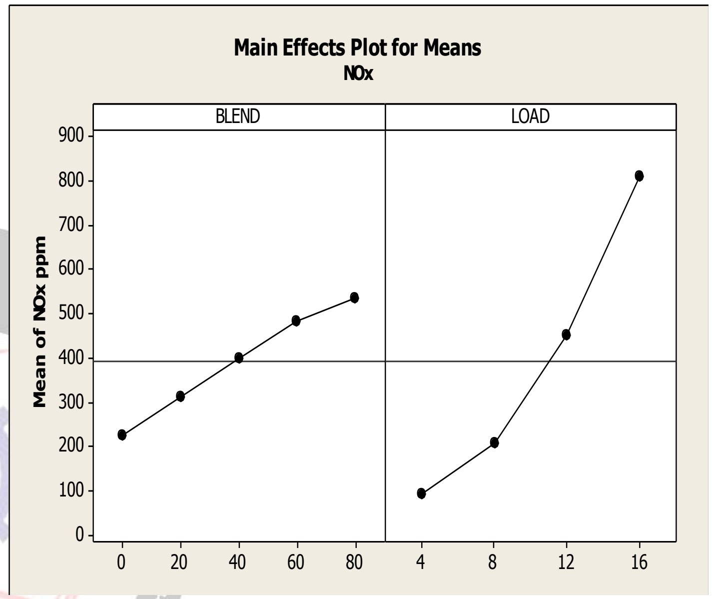

Figure No.3.9 : Main effect plot for nitrogen oxides

Table No.3.9 : Analysis of Variance for NOX

SOURCE	SS	DF	MS	F
Blend	296376	4	74094.00	34.9212
Load	1846408	3	615469.33	290.076
Residual	25461	12	2121.75	
Total	2168245	19		

10. *Optimization of Taguchi Design:*

Starting Point:
BLEND = 0
LOAD = 4
Global Solution:
BLEND = 42.10020
LOAD = 8.00201
Composite Desirability = 0.9310612

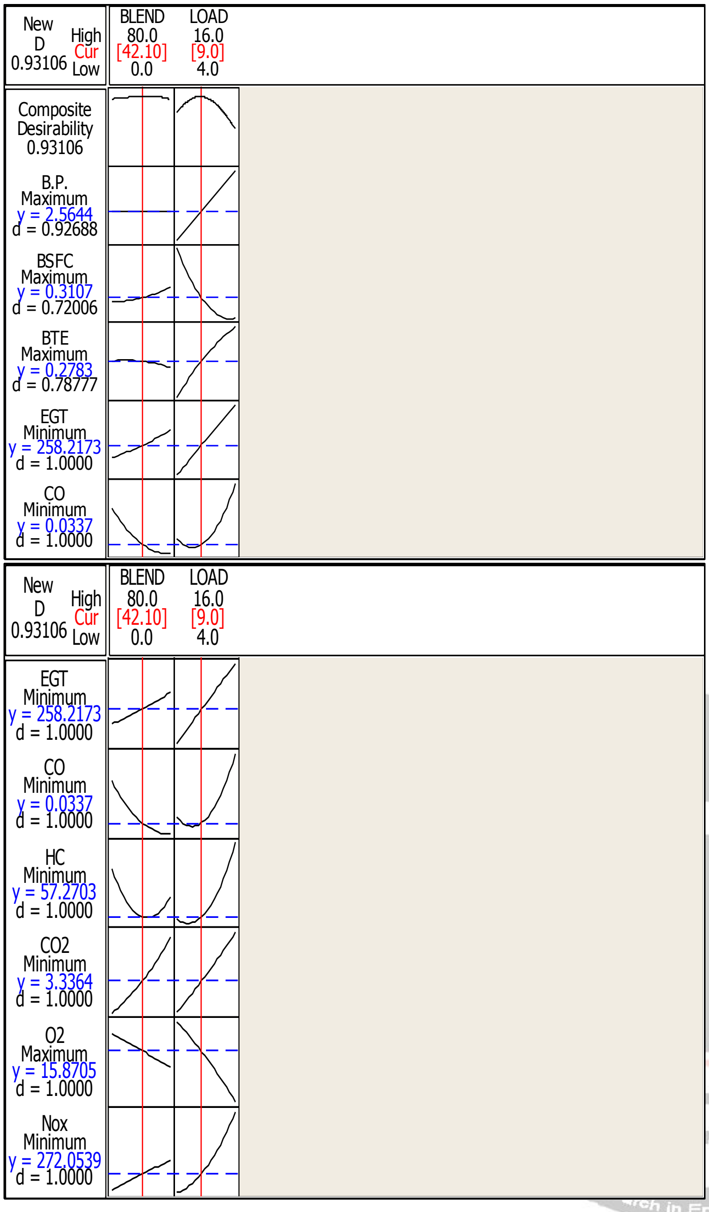

Figure No.3.10 : Optimization plot of Taguchi Design

B. Taguchi Experimental Design for factor level load and IOP:

In order to identify the significances of input parameters on mentioned performance and emission parameters main effect plot are plotted.

1. Main effect factor on brake power:

The fig. shows the mean effect plot for brake power against various factor levels of load and IOP. As the level of input parameters i.e. IOP increases there is no any change in the brake power is observed except load. As the load increases the brake power increases which is the obvious reason. The significance of load is so strong that other factors seem to be insignificant.

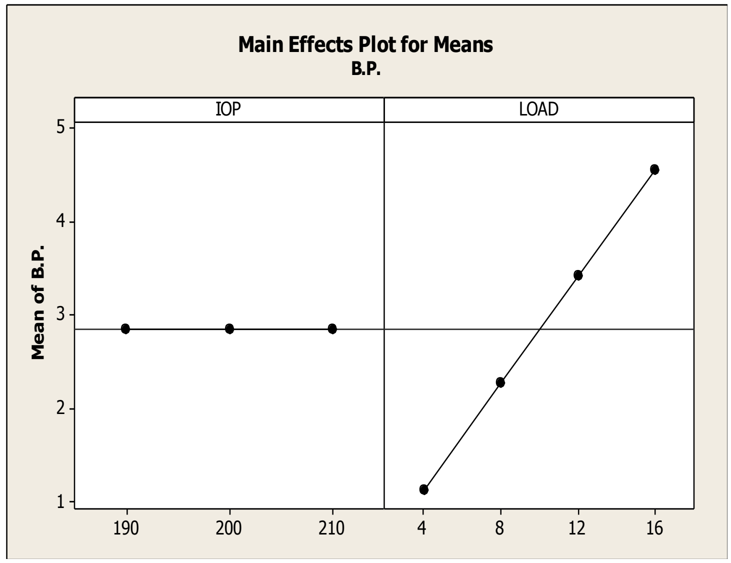

Figure No.3.11 : Main effect plot for brake power

Table No.3.11 : Analysis of Variance for BP

SOURCE	SS	DF	MS	F
IOP	0.01121	2	0.00561	8.0142
Load	23.8145	3	7.93817	11340.24
Residual	0.00420	6	0.0007	
Total	23.82991	11		

2. Main effect factor on brake specific fuel consumption:

The figure shows the mean effect plot for brake specific fuel consumption against various factor levels load and IOP. With increase in load, brake specific fuel consumption decreases sharply. The main reason for this could be that percent increase in fuel required to operate the engine is less than the percent increase in load due to relatively less portion of the heat loss at higher loads.

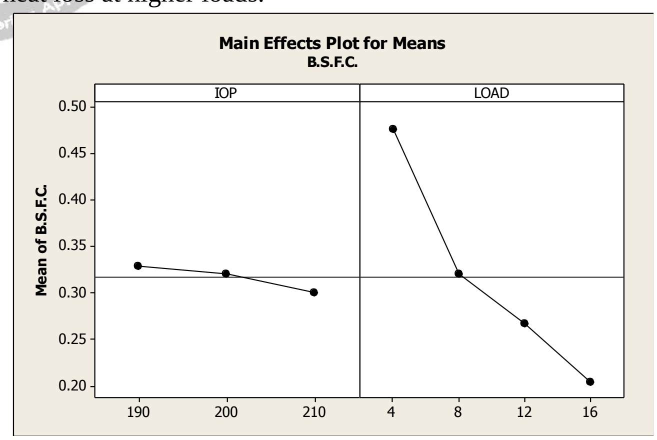

Figure No.3.12 : Main effect plot for brake specific fuel consumption

Increase in IOP shows slight decrease in brake specific fuel consumption. The significance of load is so strong that other factors seem to be insignificant.

Table No.3.12 : Analysis of Variance for BSFC

SOURCE	SS	DF	MS	F
Blend	0.002159	2	0.00107	2.0577
Load	0.138796	3	0.04627	88.980
Residual	0.003085	6	0.00052	
Total	0.14404	11		

3. *Main effect factor on brake thermal efficiency:*

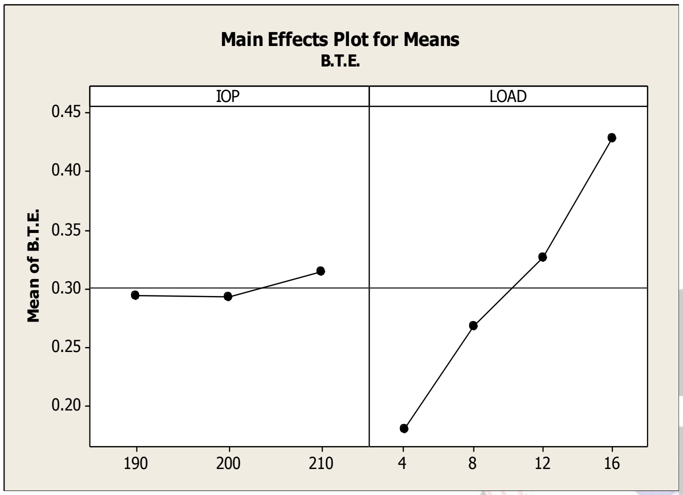

Figure No.3.13 : Main effect plot for brake thermal efficiency

The figure shows the main effect plot for brake thermal efficiency against various factor levels of load and IOP. As the amount of IOP increases the brake thermal efficiency increases slightly. As the load increases there is sharp increase in brake thermal efficiency. This is because the density of the biodiesel is higher.

Table No.3.13 : Analysis of Variance for BTE

SOURCE	SS	DF	MS	F
Blend	0.001063	2	0.00054	1.8948
Load	0.119524	3	0.03985	139.82
Residual	0.001706	6	0.000285	
Total	0.122293	11		

4. *Main effect factor on exhaust gas temperature:*

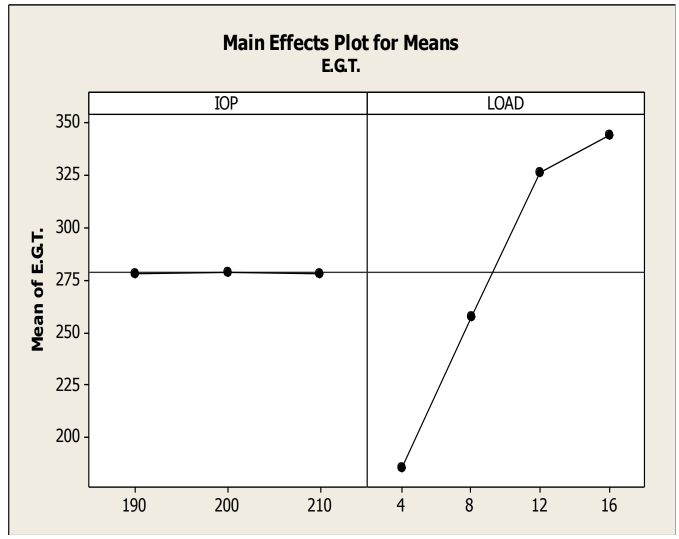

Figure No.3.14 : Main effect plot for exhaust gas temperature

The figure shows the main effect plot for Exhaust Gas Temperature against various factor levels load and IOP. With increase in load Exhaust Gas Temperature increases sharply. The main reason for this could be that increase in temperature of combustion chamber. Increase in heat formation inside the cylinder. And with increase in IOP there will not be any effect on EGT.

Table No.3.14 : Analysis of Variance for EGT

SOURCE	SS	DF	MS	F
IOP	0.1	2	0.05	0.0006
Load	53897.8	3	1795.93	21.409
Residual	503.3	6	83.8833	
Total	54401.2	11		

5. *Main effect factor on carbon monoxide:*

The figure shows the mean effect plot for Carbon Monoxide against various factor levels load and IOP.

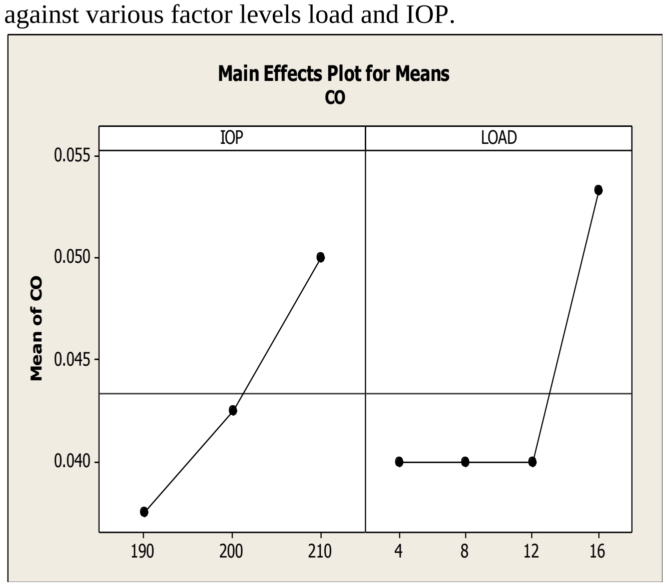

Figure No.3.15 : Main effect plot for carbon monoxide

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With increase in load Carbon Monoxide level increases sharply at higher load. And as the increase in IOP there is sharp increase in Carbon Monoxide level in emission.

Table No.3.15 : Analysis of Variance for CO

SOURCE	SS	DF	MS	F
IOP	0.000414	2	0.000207	10.35
Load	0.000151	3	0.000051	2.55
Residual	0.000122	6	0.000020	
Total	0.000687	11		

6. Main effect factor on Hydrocarbon:

The figure shows the mean effect plot for Hydro carbon against various factor levels load and IOP. With increase in load hydrocarbon level at start it slightly decreases but after that it increases sharply. And as the increase in IOP at start hydrocarbon level decreases sharply but it increases continuously.

Table No.3.16 : Analysis of Variance for HC

SOURCE	SS	DF	MS	F
IOP	1.500	2	0.75	0.0278
Load	84.388	3	28.1293	1.0432
Residual	161.783	6	26.9638	
Total	247.671	11		

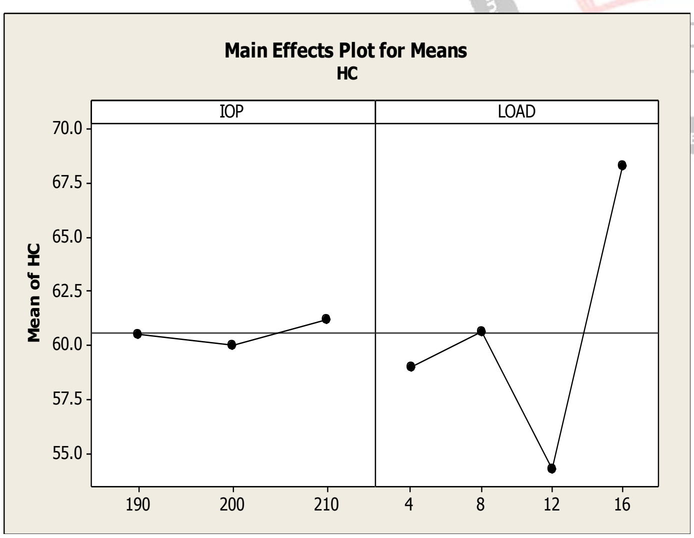

Figure No.3.16 : Main effect plot for hydrocarbon

7. Main effect factor on Carbon dioxide:

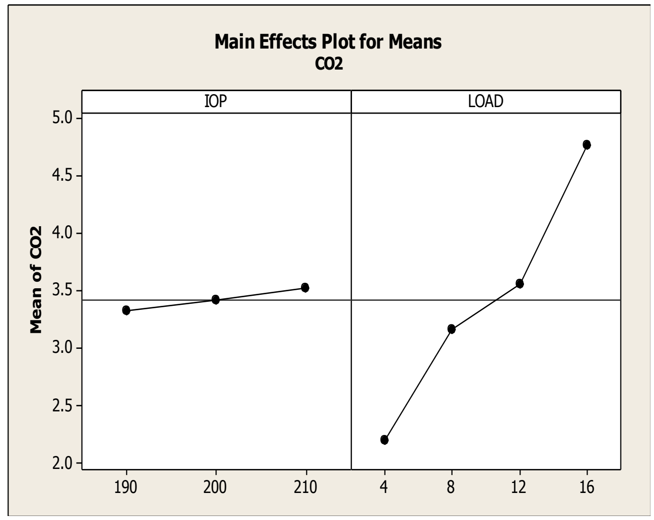

Figure No.3.17 : Main effect plot for carbon dioxide

The figure shows the mean effect plot for Carbon dioxide against various factor levels load and IOP. With increase in both load and IOP there is slight increase in Carbon dioxide level. As the biodiesel are oxygenated so CO2 level also increases at emission.

Table No.3.17 : Analysis of Variance for CO2

SOURCE	SS	DF	MS	F
IOP	0.1067	2	0.0534	0.8279
Load	11.9746	3	3.9915	61.8837
Residual	0.3873	6	0.0645	
Total	12.4686	11		

8. Main effect factor on Oxygen:

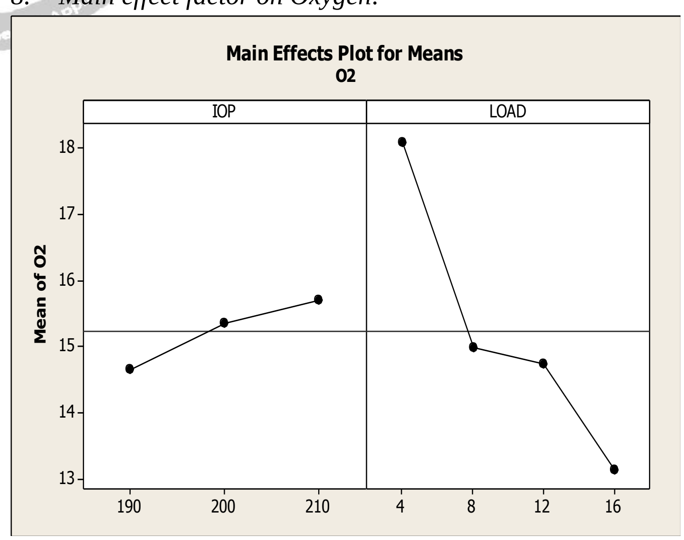

Figure No.3.18 : Main effect plot for Oxygen

The figure shows the mean effect plot for Oxygen against various factor levels load and IOP. With increase in load there is sharp decrease in Oxygen level. As the biodiesel are oxygenated so CO2 level increases at emission therefore O2 level gets decreases.

Table No.3.18 : Analysis of Variance for O2

SOURCE	SS	DF	MS	F
IOP	2.9681	2	1.4840	2.5768
Load	41.4553	3	13.8184	23.9945
Residual	3.4556	6	0.5759	
Total	47.879	11		

9. Main effect factor on Nitrogen oxides:

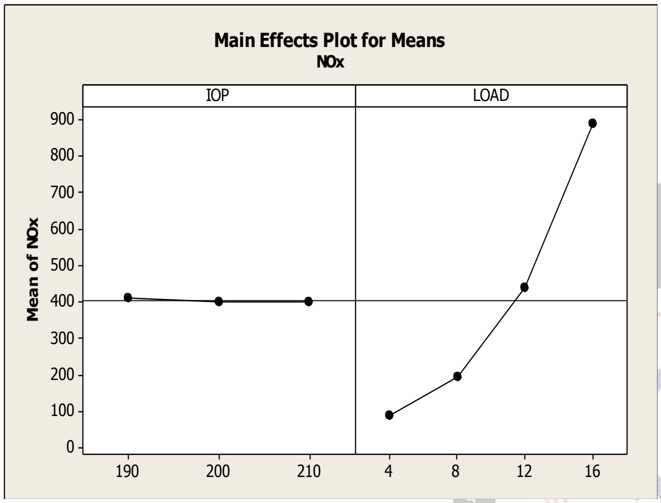

Figure No.3.19 : Main effect plot for nitrogen oxides

The figure shows the mean effect plot for Nitrogen oxide against various factor levels load and IOP. With increase in load there is sharp increase in Nitrogen oxides. Because of that only E.G.T. also increases with increase in load and blend ratio. But as increase in IOP there is slight decrease in NOX level.

Table No.3.19: Analysis of Variance for NOX

SOURCE	SS	DF	MS	F
IOP	433	2	216.5	1.3834
Load	1271344	3	423748	2707.65
Residual	939	6	156.5	
Total	1272716	11		

10. Optimization of Taguchi Design:

Starting Point

IOP = 190

LOAD = 4

Global Solution

IOP = 210

LOAD = 8.24242

Composite Desirability = 0.928600

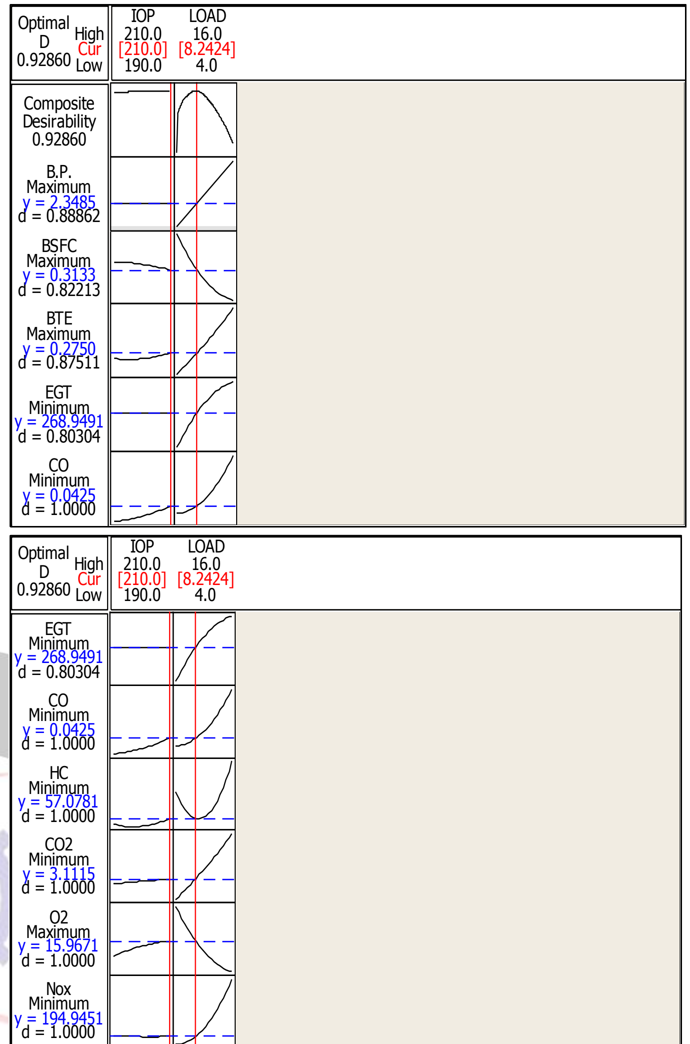

Figure No.3.20: Optimization plot of Taguchi Design

IV. CONCLUSION

This paper illustrates the application of the parameter design (Taguchi method) in the optimization of Blends used. The following conclusions can be drawn based on the above experimental results of this study:

- We can say that Niger seed oil can be used as new source for biofuel i.e. biodiesel. And its oil can be blend with neem biodiesel and forms new blend of biodiesel (in proportion of 50% neem & 50% niger). Also by varying the injection pressure of fuel we can run the internal combustion engine fueled with different blends of biodiesel with different injection pressure. But up to certain limit of increase in injection pressure can shows better results than lower injection pressure in internal combustion engine.
- Taguchi's Method of parameter design can be performed with lesser number of experimentations as compared to that of full factorial analysis and yields similar results.

• Taguchi's method can be applied for analyzing any other kind of problems as described in this paper.

• It is found that the parameter design of the Taguchi method provides a simple, systematic, and efficient methodology for optimizing the process parameters.

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