Emission Analyses of Cottenseed Biodiesel by Taguchi Method

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Abstract

This paper is document the application of taguchi method. In this work we are analyses of cotton seed biodiesel and load effect on emission. Taguchi anova approach has been utilized to determine optimum operation parameter with using Minitab software. Taguchi design method is employed to investigate parameter L9 (3*4) means 9 no of experiment with linear curve and S/N ratio has control noise in experiment. It is conclude that Opacity, CO, CO2, HC, NOx, O2 gases has less emission when we use cotton seed biodiesel. Anova technique is also use for result confirmation and that also shows more effecting parameter for different gases with different combination of blend and load. In a nut shell, the use of cottonseed biodiesel decrees the emission adequately.

1. Introduction

Research on alternative renewable fuels has because very important worldwide due to concerns about the effect of fossil fuel usage to concerns about the effect of fossil fuel usage on global warning. Alternative fossil fuel usages such as biodiesel and bioethanol have been proposed as engine fuels. They can be made from renewable raw material and can offer reduction of fossil fuel consumption. Biodiesel is produced from renewable resources like vegetable oil or animal oil or blended with diesel in CI engines.

Decreases in fossil-fuel resources and global atmospheric pollution are becoming major problems throughout the World. Biofuel can provide a good alternative to fossil-fuels and they can reduce harmful emissions like carbon monoxide (CO), carbon dioxide (CO_2), unburned hydro carbon (HC) emissions, and soot. In diesel engines, biodiesel can potentially be used instead of mineral diesel fuel. Biodiesel can be made from different raw materials like canola oil, rapeseed oil, animal tallow, algae, and others. The raw material used influence the biodiesel properties that may be more or less similar to the one of mineral diesel. Biodiesel fuels typically consist of lower alkyl fatty acid, esters of short-chain alcohols, and methanol. Demirbas[1] and Torres et al. [2]. There is great variety of diesel using wide range of application, for example, automobile, truck, locomotive, marine, power generation and so on. However, diesel engine emits high level of emission. In addition more serious concern in public. As result researchers must find new ways of decreasing exhaust emission from engine and an alternative fuel solving these crises.

Experimentation as per taguchi method- As plan of experiments based on taguchi technique has been used to acquire the data. An orthogonal array, signal to noise (S/N) ratio, and analyses of variance (ANOVA) are employed to investigate the effect on emission by HC, NOx, CO, CO_2,CO.

The orthogonal array forms the basis for the experimental analysis in the taguchi method. The selection of orthogonal array is concerned with the total degree of freedom of process parameter. Total degree of freedom (DOF) associated with three parameter is equal to 6 (3*3). The degree of freedom for orthogonal array should be greater than or at least equal to that of process parameters. There by L9 orhogonal array having degree of freedom equal to (9-1=8) has been considered, But in present case each experiment is conducted three times, there for total dof (9*3-1=26).

1.1 Optimization

Apart from the studies on the suitability and efficiency of these alternate fuels, the main refer is the amount of modifications required in the existing engines. Though biodiesels can be directly applied in diesel engines, there are many issues related to optimum performance and emission, which need to be addressed. In order to decrease the cost of modification need in the existing engine designs, some optimization approach has to be followed so Algorithm (GA) [6] and Taguchi method. The simple method is found to be efficient for optimization without interaction effects but with inclusion of interaction effects, the method becomes computationally expensive and complex. In the case of response surface method, efficient engine control optimization could be achieved only if a response surface satisfying the prediction accuracy could be created [4]. When the response surface is subjected to multiple variables, accuracy degradation is observed and prediction accuracy degrades with increased interaction between the variables [5]. In the case of ANN and GA methods, the convergence is not always assured in the presence of interaction between multiple variables [6, 7]. Taguchi's technique has been popular for parameter optimization in design of experiments (DOE) for decades.

1.2 Software Analysis

MINITAB Release 16 is a powerful statistical software package that provides a wide range of data analysis and graphics capabilities; intuitive user interface; clean, clear output; procedure-specific statistical guidance; and extensive, context-sensitive online help. Whether used in industry, research, or teaching, MINITAB offers the ideal combination of power, accuracy, and ease of use to

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help you do your job better [3]. It is our view that an easy-to-use statistical software package is a vital and significant component of such a course. This permits the student to focus on statistical concepts and thinking rather than computations or the learning of a statistical package. The main aim of any introductory statistics course should always why we use of statistics rather than technical details that do little to stimulate the majority of students or, in our opinion, do little to reinforce the key concepts.

2. Material and Method

A test rig has been installed for experimentation to measure the NOx, CO, CO2, O2, HC, and Opacity of engine emission.

2.1 Engine Test

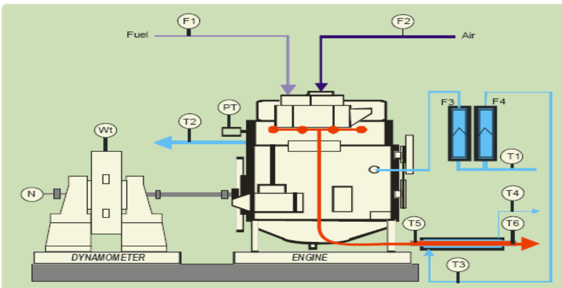

Fig: 1. Line Diagram of Single Cylinder Four Stroke Diesel Engine

F1 Fuel flow dp (differential pressure) unit

F2 Air flow dp (differential pressure) unit

F4 Calorimeter water flow kg/hr

T1, T3 Intel water temperature ^{0} K

T2 Outlet engine jacket water

T4 Calorimeter water outlet ^{0}K

T5 Exhaust gas to calorimeter inlet ^{0}K

T6 Exhaust gas from calorimeter ^{0}K

The setup consists of single cylinder in Fig 1, four stroke, VCR (Variable Compression Ratio) diesel engine connected to eddy current type dynamometer for Brake powering. The compression ratio can be changed without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement.

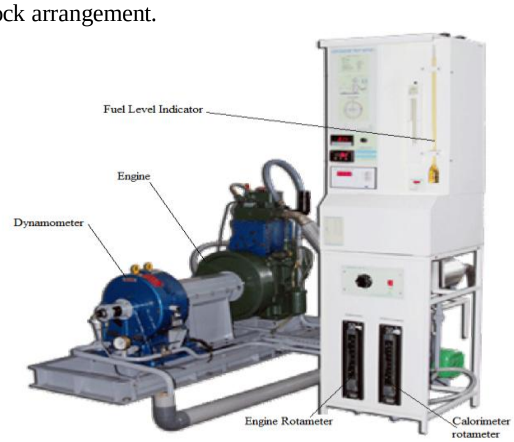

Fig: 2. Single Cylinder Four Stroke Diesel Engine Kirloskar 1 Cylinder Use in Biodiesel Testing

2.2 Engine Specification

Table: 1. Shows Engine Specification

Product (Computerized)	Engine test setup 1 cylinder, 4 stroke, Diesel
Engine Cooled	Make Kirloskar, Type 1 cylinder, 4 stroke Diesel, water
	power 3.5 kW at 1500 rpm, stroke 110 mm, bore 87.5 mm.
	661 cc, CR 17.5, Modified to VCR engine CR range 12 to 18.
Fuel tank	Capacity 15 lit with glass fuel metering column
Dynamometer	Type eddy current, water cooled, with loading unit
Software	"Engine soft LV" engine performance analysis software

2.3 Smoke Test

Preparation of Blend for Test

Blends of biodiesel and conventional hydrocarbon-based diesel are products most commonly distributed for use in the retail diesel fuel marketplace. Much of the world uses a system known as the "B" factor to state the amount of biodiesel in any fuel mix.

10%biodiesel, 90%diesel is.labeled-B10

20% biodiesel, 80% diesel is labeled-B20

30% biodiesel, 70% diesel is labeled- B30

Experiments of taguchi analyses for smoke test the level are divided. And test on AVL DIX smoke analyses on Fig. 2.

1-B10

2-B20

3-B30

For load

1-1. 6 K.g

2-2. 6 K.g

3-3. 6 K.g

This machine Fig. 3 AVL-DX shows the value of O_2, CO, PM, CO2, PM, NOx directly on screen. Then these values are analyzed by taguchi method.

Fig: 3. Emission Test Machine used in Bio Diesel Emission

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3. Result and Discussions

Taguchi parameter design research methodology allows one make product robust to noise factors and will also reduce the number of experiments to be carried out to arrive an optimized system. Taguchi developed multivariate experimental techniques using an orthogonal design array that allows one to isolate the effect of single parameter on particular variable. The different quantities of various variable parameters were taken.

Table: 2. Opacity Result

Blend	Load	Opacity	SNRA1
1	1	6.9	-16.7770
1	2	17.7	-24.9595
1	3	36.3	-31.1981
2	1	6.7	-16.5215
2	2	14.3	-23.1067
2	3	21.4	-26.6083
3	1	6.5	-16.2583
3	2	14.5	-23.2274
3	3	9.6	-19.6454

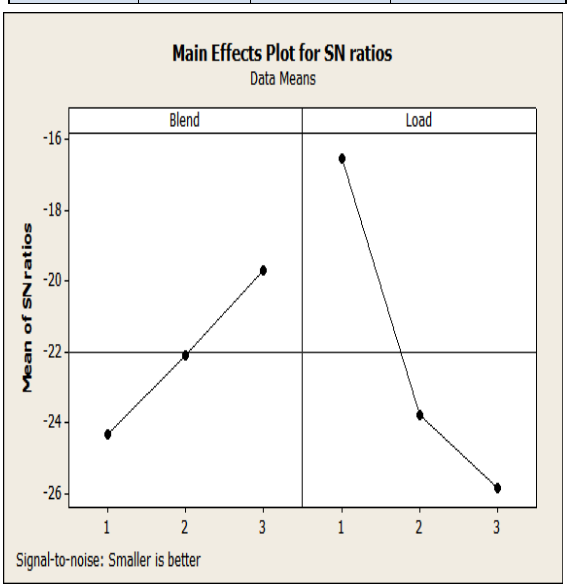

Fig: 4. Opacity S/N Ratio Curve

The average emission responses and S/N ratio have calculated for each blend and load respectively. The taguchi method has found to be more efficient for operating parameter on exhaust emission. Fig 4 shows that for blend point -3(B30) and load point -1 (1.6 Kg) load has minimum opacity. Analyze of variance (anova) was performed to identify the most significant control load is more affecting parameter on opacity compare to load.

Taguchi Analysis: Opacity versus Blend, Load

Response Table for Signal to Noise Ratio

Smaller is better

Level	Blend	Load
1	4.31	-16.52
2	2.08	-23.76
3	-19.71	-25.82
Delta	4.60	9.30
Rank	2	1

Main Effects Plot for S/N ratios

Two-way ANOVA: Opacity versus Blend, Load

Source	DF	SS	MS	F	P
Blend	2	155.509	77.754	1.48	0.330
Load	2	373.049	186.524	3.55	0.130
Error	4	209.898	52.474		
Total	8	738.456			

S = 7.244 R-Sq = 71.58% R-Sq (adj) = 43.15%

Apply taguchi analyses on NO with minimum is better condition. Table 3 show NO S/N ratio with blend and load with different experiment

Table: 3. Result of NO

Blend	Load	NO	SNRA1
1	1	101	-40.0864
1	2	288	-49.1878
1	3	403	-52.1061
2	1	101	-40.0864
2	2	157	-43.9180
2	3	311	-49.8552
3	1	309	-29.5424
3	2	174	-44.8110
3	3	150	-43.5218

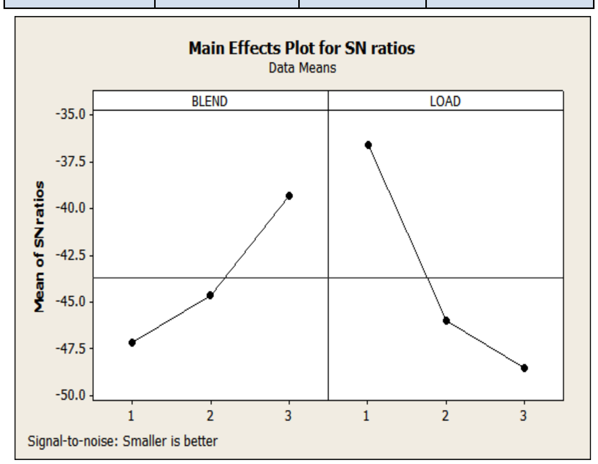

Fig: 5. S/N Ratio NO Graph

The average emission responses and S/N ratio have calculated **for each** blend and load respectively. The taguchi method has found to be more efficient for operating parameter on exhaust emission. Fig 5 shows that for blend point3 (B30) and load point -1 (1.6 Kg) load has minimum NO emission. Analyze of variance (anova) was performed to identify the most significant control load is more affecting parameter on NO emission compare to load.

Taguchi Analysis: NO versus A, B .Response Table for Signal to Noise Ratios

Smaller is better

Level	A	B
1	-47.13	-36.57
2	-44.62	-45.97
3	-39.29	-48.49
Delta	7.84	11.92
Rank	2	1

Table: 4. Result of CO S/N Ratio

Blend	Load	CO	SNRA1
1	1	0.06	24.4370
1	2	0.06	24.4370
1	3	0.05	26.0206
2	1	0.06	24.4370
2	2	0.07	23.0980
2	3	0.05	26.0206
3	1	0.06	24.4370
3	2	0.07	23.0980
3	3	0.07	23.0980

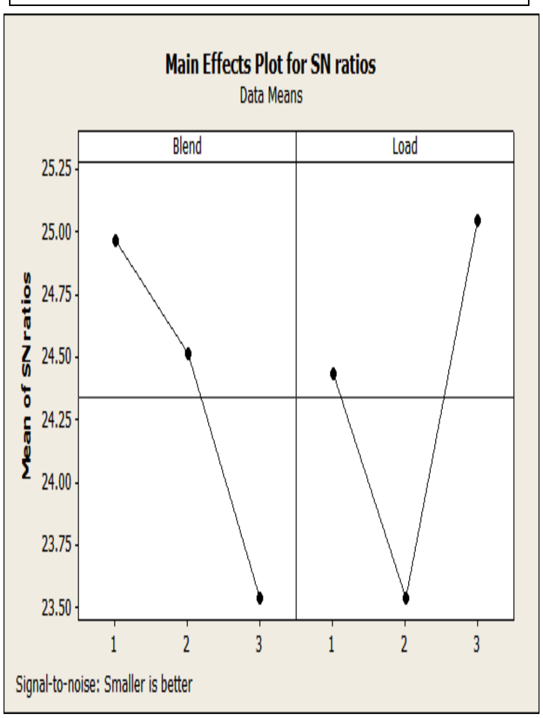

Fig: 6. CO S/N Ratio Curve

The average emission responses and S/N ratio have calculated for each blend and load respectively. The taguchi method has found to be more efficient for operating parameter on exhaust emission. Fig 6 shows that for blend point -3 (B30) and load point -2 (2.6 Kg) load has minimum CO emission. Analyze of variance (anova) was performed to identify the most significant control load is more Affecting parameter on CO emission compare to load.

Smaller is better

Level	A	B
1	24.96	24.44
2	24.52	23.54
3	23.54	25.05
Delta	1.42	1.50
Rank	2	1

Main Effects Plot for S/N ratios

Two-way ANOVA: CO versus A, B Variable

Source	DF	SS	MS	F	P
A	2	0.0001556	0.000077	1.75	0.284
B	2	0.0001556	0.000077	1.75	0.284
Error	4	0.0001778	0.0000444		
Total	8	0.0004889			

S = 0.006667 R-Sq = 63.64% R-Sq (adj) = 27.27%

Table: 5. Result of CO_2 Graph *S/N* Ratio

Blend	Load	CO 2	SNRA1
1	1	2.10	-6.4444
1	2	3.40	-10.6296
1	3	4.50	-13.0643
2	1	2.10	-6.4444
2	2	3.20	-10.1030
2	3	4.40	-12.8691
3	1	2.00	-6.0206
3	2	0.31	10.1728
3	3	2.40	-7.6042

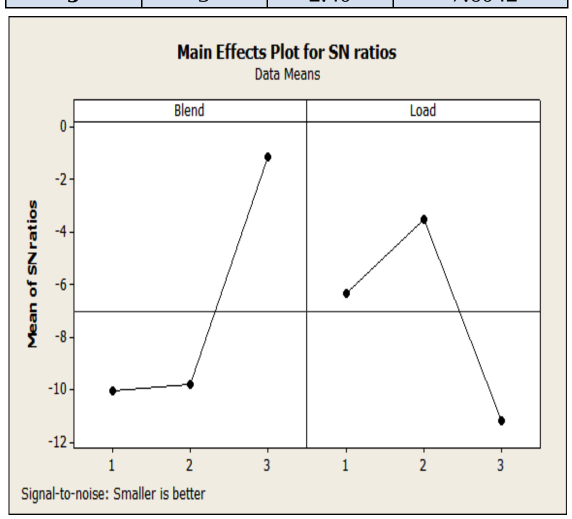

Fig: 7. CO_2 S/N Ratio Curve

The average emission responses and S/N ratio have calculated for each blend and load respectively. The taguchi method has found to be more efficient for operating parameter on exhaust emission. Figs 7 show that for blend point -3(B30) and load point -2 (2.6 Kg) load has minimum CO_2 emission. Analyze of variance (ANOVA) was performed to identify the most significant control load is more Affecting parameter on CO_2 emission compare to load.

Taguchi Orthogonal Array Design

Taguchi Analysis: C3 versus A, B

Response Table for Signal to Noise Ratios

Smaller is better

Level	A	B
1	-10.046	-6.303
2	-9.805	-3.520
3	-1.151	-11.179
Delta	8.895	7.659
Rank	1	2

Apply Taguchi method for O_2 that shows in table 5 For O_2 gas has to be maximizing for better combustion. So apply maximum is better in Taguchi analyses because that indicate better combustion.

Table: 6. Result of O_2 S/N Ratio

Blend	Load	O_2	SNRA1
1	1	17.89	25.0522
1	2	15.85	24.0006
1	3	14.15	23.0151
2	1	17.70	24.9595
2	2	16.23	24.2064
2	3	14.38	23.1552
3	1	18.18	25.1919
3	2	16.33	24.2597
3	3	17.34	24.7810

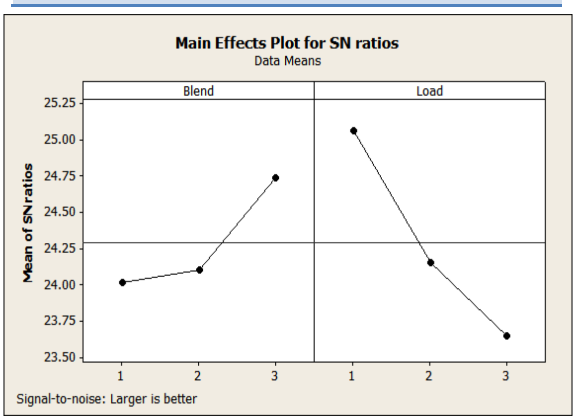

Fig: 8. O_2 S/N Ratio Curve

The average emission responses and S/N ratio have calculated for each blend and load respectively. The Taguchi method has found to be more efficient for operating parameter on exhaust emission and in Fig 3.5 shows that for blend point -3(B30) and load point -1 (1.6 Kg) load has minimum O_2 emission. Analyze of variance (ANOVA) was performed to identify the most significant control load is less affecting parameter on O2 emission compare to load.

Taguchi Analysis: O2 versus A, B

Response Table for Signal to Noise Ratios

Larger is better

Level	A	B
1	24.02	25.07
2	24.11	24.16
3	24.74	23.65
Delta	0.72	1.42
Rank	2	1

Main Effects Plot for SN ratios

Two-way ANOVA: O_2 versus A, B

Source	DF	SS	MS	F	P
A	2	3.1544	1.57720	1.84	0.271
B	2	10.8435	5.42173	6.34	0.058
Error	4	3.4209	0.85523		
Total	8	17.4188			

S = 0.9248 R-Sq = 80.36% R-Sq (adj) = 60.72%

Table 7 shows result of HC in biodiesel emission analyses. HC should be minimum so apply minimum is better to analyses less HC emission and also apply optimize condition for less HC.

Table: 7. Result of HC S/N ratio

Blend	Load	HC	SNRA1
1	1	30	-29.5424
1	2	30	-29.5424
1	3	35	-30.8814
2	1	30	-29.5424
2	2	32	-30.1030
2	3	24	-27.6042
3	1	23	-27.2346
3	2	29	-29.2480
3	3	25	-27.9588

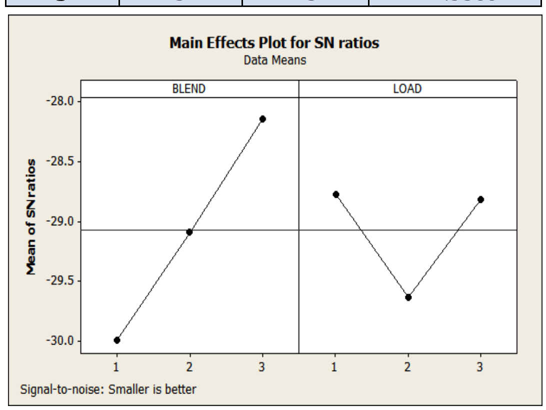

Fig: 9. HC S/N Ratio Curve

The average emission responses and S/N ratio have calculated for each blend and load respectively. The Taguchi method has found to be more efficient for operating parameter on exhaust emission and in Fig 3.6 shows that for blend point -3(B30) and load point -1 (1.6 Kg) load has minimum HC emission. Analyze of variance (Anova) was performed to identify the most significant control load is more affecting parameter on HC emission compare to load. Confirmation table of HC by using ANVOA Taguchi Analysis: HC versus A, B .Response Table for Signal to Noise Ratios Smaller is better

Level	**A**	**B**
1	-29.99	-28.77
2	-29.08	-29.63
3	-28.15	-28.81
Delta	1.84	0.86
Rank	1	2

4. Conclusions and Recommendations

The following emission analysis has been done for optimization of following emission element component for cotton seed biodiesel in Single cylinder four stroke Diesel engine using B10, B20 and B30 blends.

For hydrocarbon emission it was observed that the effect of blend on HC emission is less as compared to load. The least emission has been observed at B30 and 1.6 loads. Similarly for opacity, the effect of blend on opacity emission is less as compared to load. The least emission has been observed at B30 with 1.6 loads. For CO_2 emission, the effect of load on CO_2 emission is less as compared to blend. The least emission has been observed at B30 with 2.6 loads. Similarly For CO emission, the effect of blend on CO emission is less as compared to load. The least emission has been observed at B30 with 1.6 loads. For NO emission, the effect of blend on NO emission is less as compared to load. The least emission has been observed at B30 and 1.6 loads. Similarly for O_2, the effect of blend on O2 emission is less as compared to load. The least emission has been observed at B30 with 1.6 loads.

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