Parametric Optimization of C.I. Engine for Specific Fuel Consumption using Diesel-Sesame Blend

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ABSTRACT: An effort is made towards finding such biodiesel, which can replace and solve present problem of depleting crude oil. In this paper sesame seed is investigated as an alternative source of energy, but due to high viscosity, it cannot be used directly. Thus Diesel sesame blend is used in the Single cylinder C.I. Engine and performance is measured. Taguchi Method for parametric optimization is used in this experiment. An optimum condition of Injection pressure and the blend is evaluated for minimum specific fuel consumption and maximum brake thermal efficiency and maximum Mechanical Efficiency. The result of Taguchi Method identified that minimum specific fuel consumption is obtained by when Diesel is blended with sesame in 10 % and operated at an injection pressure of 160 bar at 10 kg load.
Key words: C.I. Engine, Parametric optimization, Sesame oil, Specific fuel consumption, Taguchi method

I. INTRODUCTION

The depletion of crude oil and its harmful effect on the environment is the major problem in today's age. The use of biodiesel engines is necessary in the recent years for energy efficient and environmentally friendly environment. The world is facing the problem of depletion of natural resources of fossil fuel and lead to degradation of the environment. There is an urgent need to explore new alternatives which reduces dependency on the export of oil. Many alternative fuels are recently discovered which are having potential to be used in diesel engines. Experts believe that by the year 2070, the world will be exhausted of fossil fuels. So there is an urgent need of replacing these fossil fuels with alternative fuels. Basically the major part of energy consumed worldwide comes from the fossil fuels (Petroleum, Coal, Natural gas) which are not only nonrenewable but also a major cause of atmospheric pollution. Meanwhile, alternative fuels are renewable and also address many issues like global warming and air pollution. This report discusses in a general and comparative aspects such as fuel properties, performance environmental effects and exhaust emissions. To deal with this issue a lot of research is going on for development of alternate fuel, which is compatible with the present engine system and to get lower emission than traditional fuel. Now days, India is importing more than 80% of its fuel demand and its spending a huge amount of foreign currency on fuel." Biofuels" are produced from biomass such as trees, grasses, food processing waste, forestry and animal residue and municipal solid waste. Biodiesel has become more attractive recently because of its environmental benefits.

II. LITERATURE REVIEW

Shailaja et al did research on Performance Evaluation of a Diesel Engine with Sesame Oil Biodiesel and its Blends with Diesel. Blends used are B10, B20, B25, B30, B40 and the results show that brake thermal efficiency and mechanical efficiency increase with increase in load, B25 and B60 give maximum brake thermal efficiency and mechanical efficiency respectively. Highest indicated thermal efficiency is obtained for B100 [1].Prof Bhave et al in his paper entitled performance and emission of sesame oil methyl ester in compression ignition engine shown the result of his experiment performed by using sesame methyl ester prepared by transesterification process. Various blends of different proportions of Sesame Oil Methyl Ester (SOME) and diesel ranging from 20% to 100% were used to run this single cylinder engine. BSEC is found to decrease with increase in load. The specific fuel consumption of ester was generally higher than diesel, mainly due to low volatility and high fuel flow rates due to the high density of SOME [2]. Şehmus et al presented study of the comparison of engine performance and exhaust emission characteristics of sesame oil–diesel fuel mixture with diesel fuel in direct injection diesel engine which shows that the engine power and torque of the mixture of sesame oil–diesel fuel are close to the values obtained from diesel fuel and the amounts of exhaust emissions are lower than those of diesel fuel [3]. Banapurmath et al in his article performance and emission characteristics of a DI compression ignition engine operated on Honge, Jatrpoha and sesame oil methyl esters showed results that Engine performance in terms of higher brake thermal efficiency and lower emissions (HC, CO, NOX) with sesame oil methyl ester operation was observed compared to methyl esters of Honge and Jatropha oil operation [4].

III. PROPERTY OF VARIOUS OILS

Table 1. Properties of Various oils [9]

Oils	Kinematic Viscosity (m^2/s at 40° C)	Density (kg/m^3)	Calorific Value (MJ/kg)	Flash Point (° C)	Cetane Number
Diesel	2.75	835	42.25	66	47
Sesame	35.5	913	39.34	260	40.2
Linseed	27.2	923	39.3	241	34.6
Palm	39.6	918	36.5	271	42
Corn	34.9	909	39.5	277	37.6
Thumbs	31.52	905	39.78	201	45
Babassu	30.3	946	-	150	38
Tallow	-	-	40	201	-
Jatropha	49.9	921	39.7	240	40-45
Karanja	46.5	929	38.8	248	40
Rapeseed	37	911	39.7	246	37.5
Neem	57	938	39.4	295	47
Sunflower	33.9	916	39.6	274	37.1
Soybean	32.6	914	39.6	254	38
Coconut	27.7	915	37.1	281	52
Cotton Seed	33.5	914	39.4	234	42
Rice Bran	28.7	937	38.9	200	30
Peanut	39.6	902	39.7	271	42

Table 1 shows property of various oils. In this research work, sesame seed was investigated as an alternate source of biofuels, although cost of sesame oil is high but can be cultivated. If beneficial results are found, then sesame seed can be cultivated and production cost can go down.

IV. METHODOLOGY

In this experiment three parameters were selected Injection Pressure, different blend proportion and loading condition. For parametric optimization here Taguchi Method is selected. Taguchi Method is a process/product optimization method that is based on 8-steps of planning, conducting and evaluating results of matrix experiments to determine the best levels of control factors.

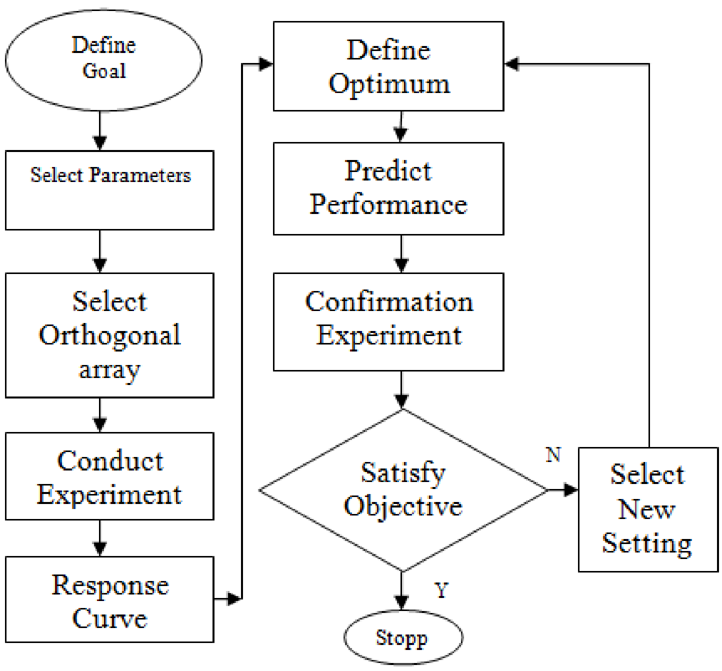

Fig 1: Flow Chart of Taguchi Method [5]

Fig 1 shows flow chart for the process and in which first of all goal is defined, then parameters are selected based on that orthogonal array in our case L16 array is selected. After that an experiment is conducted and response curve is generated using Minitab Software. Final results are predicted for optimum condition.

In Taguchi Method the word "optimization" implies "determination of the finest levels of control factors". In turn, the BEST levels of control factors are those that maximize the Signal-to-Noise ratios. The Signal-to-Noise ratios are log functions of desired output characteristics. The experiments, that are conducted to determine the BEST levels, are based on "Orthogonal Arrays", are balanced with respect to all control factors and yet are minimum in number. This in turn implies that the resources (materials and time) required for the experiments are also minimum [7].

Taguchi method divides all problems into 2 categories – static or dynamic. While the Dynamic problems have a signal factor, the Static problems do not have any signal factor. In Static problems, the optimization is achieved by using 3 Signal-to-Noise ratios - smaller-the-better, larger the better and nominal-the-best. In Dynamic problems, the optimization is achieved by using 2 Signal-to-Noise ratios - Slope and Linearity [7].

V. EXPERIMENTAL SETUP

Engine setup available is a single cylinder, four stroke, multi-fuel, research engine connected to eddy type dynamometer for loading. The operation mode of the engine works on two different modes i.e. petrol and diesel with some necessary changes. In both modes the compression ratios can be varied without stopping the engine and without altering the combustion chamber geometry by specially designed tilting cylinder block arrangement.

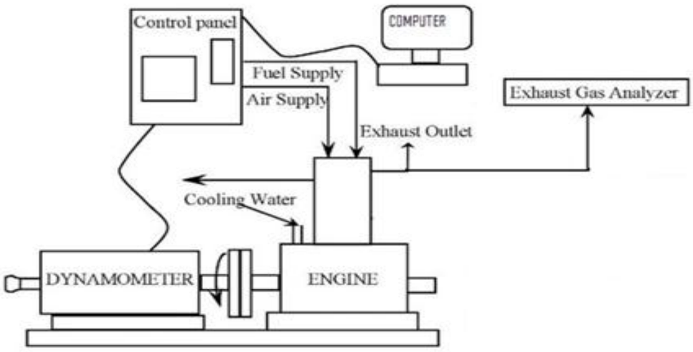

Fig 2: Experimental Setup[5]

The injection point and spark point can be tented for research tests. Setup is provided with necessary instruments for combustion pressure, Diesel line pressure and crank-angle measurements. These signals interface with computer for pressure crank-angle diagrams. Instruments are provided to interface airflow, fuel flow, temperatures and load measurements. The setup has a stand-alone panel box consisting of air box, two fuel flow measurements, process indicator and hardware interface. Rotometers are provided for cooling water and calorimeter water flow measurement. A battery, starter and battery charger provides for engine, electric start arrangement [6].

Engine Parameters are listed below which shows the overall dimensions of the Engine apparatus.

Engine Parameters:

Various engine parametes are described such as number of cylinder , number of strokes, cylinder diameter , stroke length, connecting rod length, orifice diameter, dynamometer arm length, fuel, power speed, Compression ratio range, Injection point variation are described below.

Table 2. Engine Parameters [8]

Sr No.	**No. of Cylinders**	**1**
1	No. of strokes	4
2	Cylinder Diameter	87.5 mm
3	Stroke Length	110 mm
4	Connecting rod Length	234 mm
5	Orifice Diameter	20 mm
6	Dynamometer arm Length	185 mm
7	Fuel	Diesel
8	Power	3.5 kw
9	Speed	1500 rpm
10	CR Range	12:1 to 18:1
11	Injection point variation	0 to 25 ^{o} BTDC

Table 2 shows different engine parameters. The setup enables study of VCR engine performance for brake power, indicated power, frictional power, BMEP, IMEP, brake thermal efficiency, indicated thermal efficiency, Mechanical efficiency, volumetric efficiency, specific fuel consumption, A/F ratio, heat balance and combustion analysis. Lab view based Engine Performance Analysis software package “Engine soft” provides for online performance evaluation [8].

VI. OBSERVATIONS

An experiment was performed selecting set of parameters. A software Minitab is used to generate tables for parameters. Below Table 3 shows L16 Orthogonal array. Table 3 shows the L16 orthogonal array which is generated using the Minitab software and value of specific fuel consumption obtained for the given input parameter of blend ratio , injection pressure and load.

Table 3. L_{16} Orthogonal array

Sr. No.	Blend Ratio	Injection Pressure (bar)	Load (kg)	Specific Fuel Consumption (kg/kwh)
1	B00D100	160	1	1.3
2	B10D90	160	4	0.22
3	B20D80	160	7	0.32
4	B30D70	160	10	0.26
5	B00D100	180	4	0.41
6	B10D90	180	1	1.32
7	B20D80	180	10	0.26
8	B30D70	180	7	0.28
9	B00D100	200	7	0.32
10	B10D90	200	10	0.29
11	B20D80	200	1	1.14
12	B30D70	200	4	0.44
13	B00D100	220	10	0.27
14	B10D90	220	7	0.32
15	B20D80	220	4	0.43
16	B30D70	220	1	1.33

VII. RESULT AND DISCUSSION

An analysis of the result is generated with the help of Minitab software. As the difference between two levels is greater, the parametric level, having the highest S/N ratio corresponds to the parameters setting indicates highest performance.

Main effects plot for various parameters such as injection pressure, Load and Blend proportion is being plotted against the Mean of Means of the specific fuel consumption using the Minitab Software as well as the effect of all these parameters were also plotted using the same software for the S/N ratio. Then the results are compared for the optimization of Specific fuel consumption.

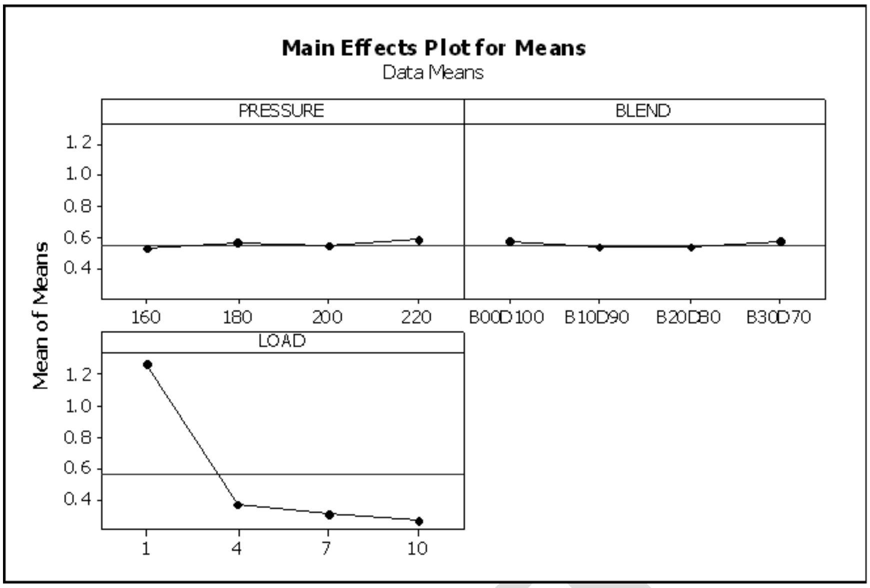

Fig 3: Main effects Plot for Means of Specific Fuel Consumption

From above Fig-3 the mean is an average value for reading taken for a particular parameter. From the graph, mean value is the maximum (0.5875) for 220 bar Injection Pressure and minimum (0.525) for 160 bar injection pressure similarly mean value is maximum (0.5775) for 30% blending and mean value is minimum (0.5375) for 10 and 20% blend, the mean value is the maximum (1.2725) for 1kg load and a minimum (0.27) for 10kg engine load.

Table 4 Response Table for Mean of means of specific fuel consumption

Level	Injection Pressure (bar)	Blend Ratio (%)	Load (kg)
1	0.525	0.575	1.2725
2	0.5675	0.5375	0.375
3	0.5475	0.5375	0.31
4	0.5875	0.5775	0.27
Delta	0.0625	0.04	1.0025
Rank	2	3	1

Table 4 shows the value of mean of means of specific fuel consumption. Three parameters are considered hereby namely injection pressure, blend ratio and Load. Delta is the difference from maximum value and minimum value of means of means for a particular parameter. The highest difference suggests that particular parameter has a greater effect. From the table it can be seen that Load has maximum effect after that Injection pressure and lastly Blend ratio of specific fuel consumption.

Similarly, main effect plots for SN ratio is generated using Minitab software as shown in Figure 4. Figure 4 shows the response curve for S/N ratio, the lowest S/N ratio was observed at 220 bar Injection Pressure. It shows that without blending, S/N ratio is minimum and next minimum value for specific fuel consumption is when sesame oil is blended 30% with diesel.

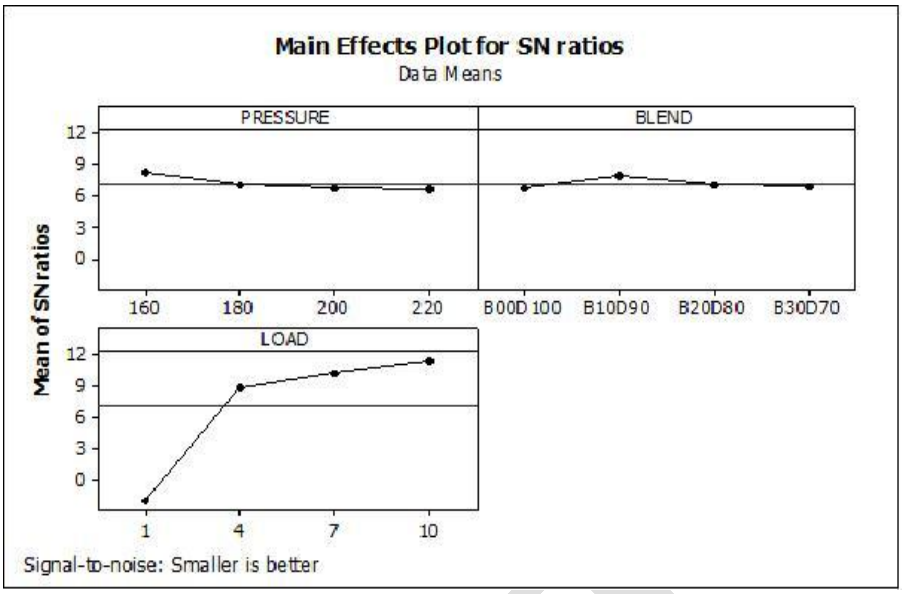

Fig 4: Main effects Plot for Means of SN Ratio

It also shows that at a load of 1 kg, S/N ratio is minimum that shows condition for lowest specific fuel consumption.

Table 5. Response Table for Signal to Noise Ratios Smaller is better

Level	Injection Pressure (bar)	Blend Ratio (%)	Load (kg)
1	8.118	6.684	-2.076
2	7.023	7.847	8.839
3	6.66	6.948	10.187
4	6.531	6.853	11.381
Delta	1.587	1.163	13.458
Rank	2	3	1

As per Table 5, Delta is the difference between the maximum value and minimum value. Rank denotes the maximum and minimum effect of the parameters. It shows that the effect of load is maximum whereas the effect of Injection Pressure is minimum on Specific Fuel consumption.

Table 6. Predicted Values for Minimum Specific Fuel consumption

Injection Pressure (bar)	Blend Ratio	Load (kg)	Signal to Noise Ratio	Specific Fuel Consumption (kg/kw-hr)
160	B10D90	10	13.1806	0.21875

In Table 6 an optimum set of parameters has been achieved by response curve analysis generated with the help of Minitab software. Minitab software for Taguchi method of optimization suggested Signal to Noise (S/N) ratio to be maximum for minimum specific fuel consumption. The result suggests that minimum specific fuel consumption is obtained when the engine is operated at 160 bar injection pressure at 10 kg Load and sesame is blended with 10%.

Table 7. Comparison of SFC for different Loading condition

Blend Ratio	Injection Pressure (bar)	Load (kg)	Specific Fuel Consumption (kg/kw-hr)
B10D90	160	1	1.22125
B10D90	160	4	0.32375
B10D90	160	7	0.25875
B10D90	160	10	0.21875

Table 7 shows comparision of the value of Specific fuel consumption for different load condition at Fixed Injection Pressure and blend ratio. This shows minimum values of specific fuel consumption under varying load. These shows minimum specific fuel consumption for a particular load when operated under different injection pressure or blend proportion as the effect of load is maximum on specific fuel consumption.

VII. CONFIRMATION EXPERIMENT

After this a confirmation experiment was done in order to check the value of optimum parameters obtained through the Taguchi analysis. Below table shows a comparison of computing value and Experimental Value. Considering optimum parameter for minimum specific fuel consumption that is at 160 bar Injection Pressure when blended with 10% sesame oil at different load condition.

Table 8. Comparison of Predicted value and Experimental Value

Blend Ratio	Injection Pressure (bar)	Load (kg)	Predicted value of Specific Fuel Consumption (kg/kw-hr)	Experimental value of Specific fuel consumption (kg/kw-hr)	Difference in percentage (%)
B10D90	160	1	1.221	1.238	2
B10D90	160	4	0.323	0.307	2
B10D90	160	7	0.258	0.258	0
B10D90	160	10	0.218	0.210	1

Table 8 shows a comparison between result of specific fuel consumption as obtained from Taguchi analysis with the result obtained from confirmation experiment. The Experimental result shows fluctuation of about 0 to 2 % as compared to the predicted value.

IX. CONCLUSION

Above experiment shows that specific fuel consumption is minimum when blend of sesame with diesel is done in 10%, Injection pressure is 160 bar and load is 10kg.Signal to noise analysis shows that load has maximum effect on specific fuel consumption after that Injection Pressure and blend ratio has least effect.

REFERENCE

[1] Shailaja.M, A. Aruna Kumari, A V Sita Rama Raju." Performance Evaluation of a Diesel Engine with Sesame Oil Biodiesel and its Blends with Diesel" *International Journal of Current Engineering and Technology*.

[2] Bhave, Nikhil A., Vivek M. Ugare, and Amol M. Andhare. "Performance and Emission Studies of Sesame Oil Methyl Ester in Compression Ignition Engine."

[3] Altun, Şehmus, Hüsamettin Bulut, and Cengiz Öner. "The comparison of engine performance and exhaust Emission characteristics of sesame oil–diesel fuel mixture with diesel fuel in a direct injection diesel engine." *Renewable Energy33.8 (2008): 1791-1795.*

[4] Banapurmath, N. R., P. G. Tewari, and R. S. Hosmath. "Performance and emission characteristics of a DI compression ignition engine operated on Honge, Jatropha and sesame oil methyl esters." *Renewable energy 33.9 (2008): 1982-1988*.

[5] Patel, Mr Krunal B., Tushar M. Patel, and Mr Saumil C. Patel. "Parametric Optimization of Single Cylinder Diesel Engine for Pyrolysis Oil and Diesel Blend for Specific Fuel Consumption Using Taguchi Method." *IOSR Journal of Mechanical and Civil Engineering 6.1 (2012): 83-88.*

[6] Raut, R. L., Naik, B. N., Thakare, S. D., & Gawali, A. A. EMISSION ANALYSIS OF BIO-DIESEL BLENDS ON VARIABLE COMPRESSION RATIO ENGINE.

[7] https://www.ee.iitb.ac.in/~apte/CV_PRA_TAGUCHI_INTRO.htm

[8] http://shodhganga.inflibnet.ac.in/bitstream/10603/10168/14/14_chapter%202.pdf