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Parametric Optimization of Single Cylinder Diesel engine for Karanja Biodiesel & Diesel blend for Specific fuel Consumption using Taguchi method

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Abstract: *Practical study has been accomplished for Karanja Biodiesel blended with Diesel utilize in single cylinder 4 strokes Research Diesel engine. Karanja oil is made from Karanja seeds, then after its Biodiesel made using a trans-esterification process. Maximum possible proportion of Biodiesel helps to reduce the utilization of Petroleum fuel. In this Paper, the effects of Variables like Intake Air Supply, load, Blend rate and injection pressure are taken as a dominant variable for an optimization. As the requirement of a Practical, this selected four variables with three levels optimized simultaneously, so well-known Taguchi method of optimization is used in this Practical. Practical outcome shows that the half intake air supply, 50% blend ratio, 180 bar injection pressure and 9 kg engine load is an optimum set of parameter for the lowest SFC.*
Keywords*: Karanja Biodiesel, Trans-esterification, Taguchi method, SFC.*

I. Introduction

In recent view of the globe, energy crisis due to fast depletion of fossil fuel is the main problem. Energy utilization becomes more vital because of an augmentation of the globe's population, modified live hood standard, speedy evolution of private mobility, endlessly development of automobile sector and industrialization. Fossil fuels reverses drop down daily and its price becomes higher, so alternative fuel called Biodiesel appears to be a solution for the future. Taking substitute fuel as an alternate fuel of Diesel, novice Fieldworkers are tried discovering mid way solution which decrease the fossil fuel consumption and protect the globe from the significant effect of the pollution. The source used for the Biodiesel production is the eco-friendly and emit less emission. Several cooking (Castor and Cottonseed, sesame, and groundnut oil) and non-cooking oils (Jatropha, Neem, Karanja, Mahuva, etc.) and fats are feedstock of the Biodiesel and engine lubes. Biodiesel is decomposable. These Biodiesel utilized in most CI engines with smaller alteration in the ECU.
Nonlinear techniques are one of them. These methods such as Design of Experiments (DOE), fuzzy logic and neural network are capable to find the combined effects of Design variables. Optimization of the design variables for a present system can be found by experimental methods, but practical procedure will be take longer time, costly and involved fatigue long calculation when optimization is multivariate in order of 30, 40 etc., Such in case of IC engines. So in such condition, numerical modeling like Design of Experiment will be a very useful tool for the optimizing of these multivariate problems. Number of researches used DOE in them research field, the study of the combined effects between input Design variables like intake air supply (fully & partially), blend percentage, injection pressure, load on the efficiency, performance and Exhaust feature of the CI engine was not much more and gave Endeavour to study deeply,[2].

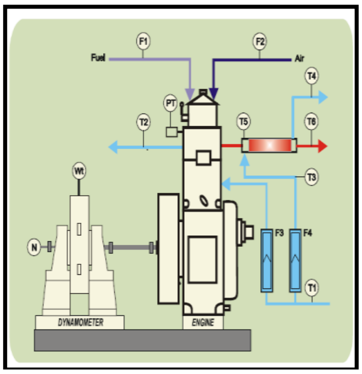
II. Literature Survey

Rao et al. used Jatropha biodiesel and additive in diesel engine and conclude that Multi-MD-32, Bio-additive possesses many attributes as Multi-Functional fuel additive. Its ability to reduce the surface tension between two or more interacting immiscible liquids helped the fuel to flow better through injector and better atomization of fuel, which improved the combustion and performance of the engine at all variable loads and also drastically down the emissions,[1]. **Joshi et al**. utilized Pyrolysis oil & Diesel blend to found mechanical efficiency using the Taguchi method and finding shows that the highest performance at set 5% blend ratio, engine load 20kg and injection pressure180 bar, which are an optimum parameter setting for highest mechanical efficiency, [2]. **Agarwal et al.** conducted Practical on Long-term storage oxidation stability of Karanja biodiesel with the use of antioxidants and terminated that to store the Karanja biodiesel with PY under dark storage condition without exposure to air and metallic surfaces. PY was observed to retain the oxidation stability specification limit of 6 h for longer period of time followed by PG. The biodiesel samples with 500, 700 and 1000 ppm of PY were able to retain the oxidation stability even after 4 months, [3]. **Patel et al.** Performed with

Pyrolysis Oil and Diesel Blend for Parametric Optimization of Single Cylinder Diesel Engine for Specific Fuel Consumption using Taguchi Method and the practical outcome shows that 22^o injection timing, injection pressure 200 bar, compression ratio 16 and engine load 20 kg are optimum parameter setting for lowest break specific fuel consumption. Engine performance is mostly influenced by engine load and is least influenced by Compression ratio,[4]. **Senthil Kumar et al.** performed with Karanja Biodiesel with Tyre Pyrolysis Blends to evaluate Performance, Emission and Combustion Characteristics of a CI engine and result revealed that KOMETPO80 gives the optimum result, compared to the other blends and the CO, HC and smoke emissions were lower by about 9.09%, 8.6% and 26% respectively at full load. Ignition delay for KOMETPO60 is almost equal to that of diesel at full load operation,[5]. **Trivedi et al**. utilize Diesel-sesame blend and conclude that at 160 bar injection Pressure, D90S10 blend and 10 kg load the Brake thermal efficiency is maximum. Response curve analysis by Taguchi method of S/N ratio shows that load has major effect and Injection Pressure and blend ratio has least effect on Brake thermal efficiency, [6]. **Patel et al.** was investigated Effect of Inlet Air Pressure and EGR Rate on the Diesel Engine Emission and conclude that NO_X reduce drastically and HC increases because of reduction of combustion temperature by increasing EGR rate,[7].

III. Experimental Set Up

The setup incorporates one cylinder, four strokes VCR engine as shown in figure-1. The Compression ratio can be varying in the running condition of the engine without modifying the combustion chamber design by the provision of tilting the cylinder block. The Eddy current type dynamometer is utilized to give the load on the engine. It is a multi-fuel type engine. The operation mode of the engine can be changed from diesel to Petrol or from Petrol to Diesel with some necessary changes. Figure-2 shows the provision for intake air supply.



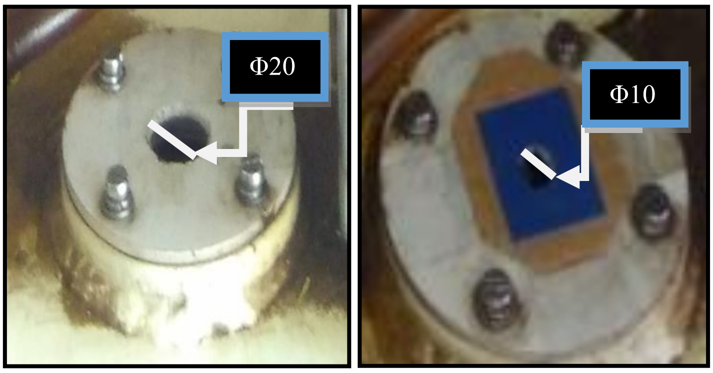


Fig.1: Engine test rig **Fig.2:** intake air supply (a) original **(b)** Modified

Table 1: Detail engine specification,[4]

Engine type	Single cylinder 4 strokes multi fuel water cooled Research engine
Rated power	3.5 kW @ 1500 rpm
Cylinder diameter	87.5 mm
Orifice diameter	20 mm
Stroke length	110 mm
Connecting rod length	234 mm
Dynamometer	Type eddy current, water cooled, with loading unit

IV. Methodology

Bi-fuelling is the easiest method for entering Composition of substitute fuel and crude diesel fuel into the Diesel engine. For this Propose, selected alternate fuel for the field work is blended with standard Diesel fuel in different rate on the weight basis. Before the practical start, biodiesel and its blends calorific value and Density are calculated. The lowest blend of Karanja Biodiesel is 5%. Other higher Blend like 10%, 15%, 20%, 25% Karanja Biodiesel with standard diesel fuel are also used, But one issue of using higher blend is the some existing system alteration which is not acceptable as per the economic consideration and also it require more time. The Best method for the simultaneous optimization called "Taguchi" was used in the practical for optimization of engine variables such as blend rate, injection pressure and different load condition.

4.1 Taguchi Method of Optimisation

Taguchi Method is developed by Dr. Genichi Taguchi. Generally a number of experiment based on a number of selected Parameters. Higher the number of Parameters means more the number of trials, which is time consuming. It is aid to modify the levels of Parameters include in the experiments. This method helps to reduce the number of trials by modifying the Parameters involved in the experiment so that less time require for the experiment and also not much more fatigue calculations. Experiment performs as per the flowchart depicted in figure-3.

The Taguchi method is an aggregation of numerical and statistical tools helpful for the parametric optimization and abstract thought of problems in which a response of interest is affected by various factors and the objective is to optimize this response. Taguchi method is utilized to find out the relationship between a response and a set of quantitative experimental variables,[8]. "Orthogonal array" is the Key factor of this method. Orthogonal array help to study a total number of variables by considering only a few trials. The recent paper utilizes four variables at three levels and so, L18 orthogonal array was taken for the building of Practical set up. So in the Minitab software, The L18 has the parameters such as Intake Air supply, blend rate, load, injection pressure is settled in the row 1, 2, 3& 4 and Table-2. As per this design, eighteen (18) experiments were conducted and trials were taken at random, for neglected systematic error creeping into the trials. For each and every experiment, the Specific Fuel Consumption was evaluated and utilize as a response variable. Signal to noise ratio (S/N) is one of the most useful Parameters for measuring the quality features. There are three kinds of signal to noise ratios are available among them as depicted in below Equation the lower-the-better S/N ratio was utilized in this practical study because this study is based on the lower SFC,[2]

$$\text{lower-the-better } S/N = -10 \, \text{Log}_{10} \, [\text{mean of sum of squares of measured data}]$$

4.2 Factors levels selection and orthogonal array

In this practical, four variables for three levels were taking into the account table-2. Design variables And its level are shown in table. L18 single orthogonal array shown in table-2 used for the Practical study. "smaller-the-better" is being taken as quality features, since the aim is to minimize response.

Table 2: Practical variables and their levels

Factors	Level 1	Level 2	Level 3
Intake air supply	Full	Half	-
Blend (%)	D100B0	D50B50	D0B100
Injection Pressure (bar)	160	180	200
Load (kg)	1	5	9

V. Result And Discussion

Trials were done for selected position of variables by Minitab software and find SFC for that position of parameters. SFC for those positions is given in the table-3.

Table 3: Result table for SFC

Experiment No.	Intake Air Supply	Blend (%)	IP (Bar)	Load (Kg)	SFC (kg/kwh)
1	Full	D100B0	160	1	1.45
2	Full	D100B0	180	5	0.45
3	Full	D100B0	200	9	0.34
4	Full	D50B50	160	5	0.41
5	Full	D50B50	180	9	0.30
6	Full	D50B50	200	1	1.37
7	Full	D0B100	160	9	0.33
8	Full	D0B100	180	1	1.45
9	Full	D0B100	200	5	0.44
10	Half	D100B0	160	1	1.41
11	Half	D100B0	180	5	0.45
12	Half	D100B0	200	9	0.34
13	Half	D50B50	160	5	0.41
14	Half	D50B50	180	9	0.31
15	Half	D50B50	200	1	1.32
16	Half	D0B100	160	9	0.33
17	Half	D0B100	180	1	1.31
18	Half	D0B100	200	5	0.48

5.1 Response Curve analysis

Response curve analysis is used for the evaluating effective variables and their optimum levels. It is graphical depicts of altering in performance features with the alteration in design variables. The curve shows an alteration of each variable and describes what the act on the system performance would be when a variable moves from level to level. Figure-4 shows valuable effects of entire design factor for three levels.

Now for the final optimization from the performance curve created by "Minitab software", take the lowest value of each factor in case of means curve as shown in figure-3.

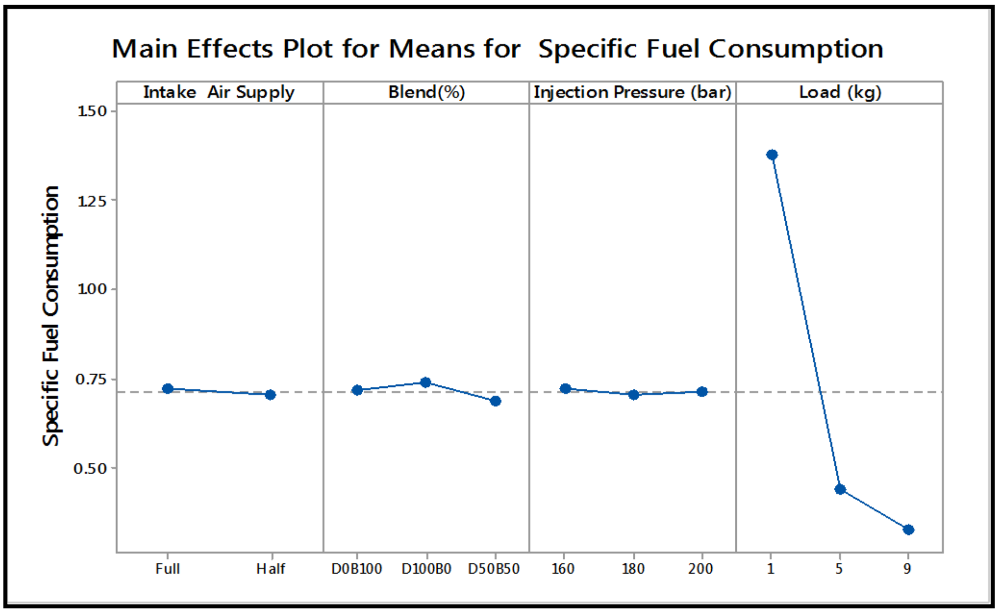


Fig.3: Main Effects Plot for Means of SFC

From above figure-3, mean is average measure for reading taken for specific variable. From graph, mean value is maximum (0.72) for full air supply and minimum (0.70) for half air supply. Mean value is maximum (0.74) for D100B0 blend and minimum (0.68) for D50B50 blend. Mean value is maximum (0.72) for 160 bar injection pressure and minimum (0.70) for 180 bar injection pressure. Mean value is maximum (1.37) for1 kg engine load and minimum (0.325) for 9 kg engine load.

Delta is difference of maximum value and minimum value. Delta value is high for load parameter (1.0533) and low (0.0156) for Full intake air supply. So that effect of load is maximum and effect of intake air supply is minimum on SFC.

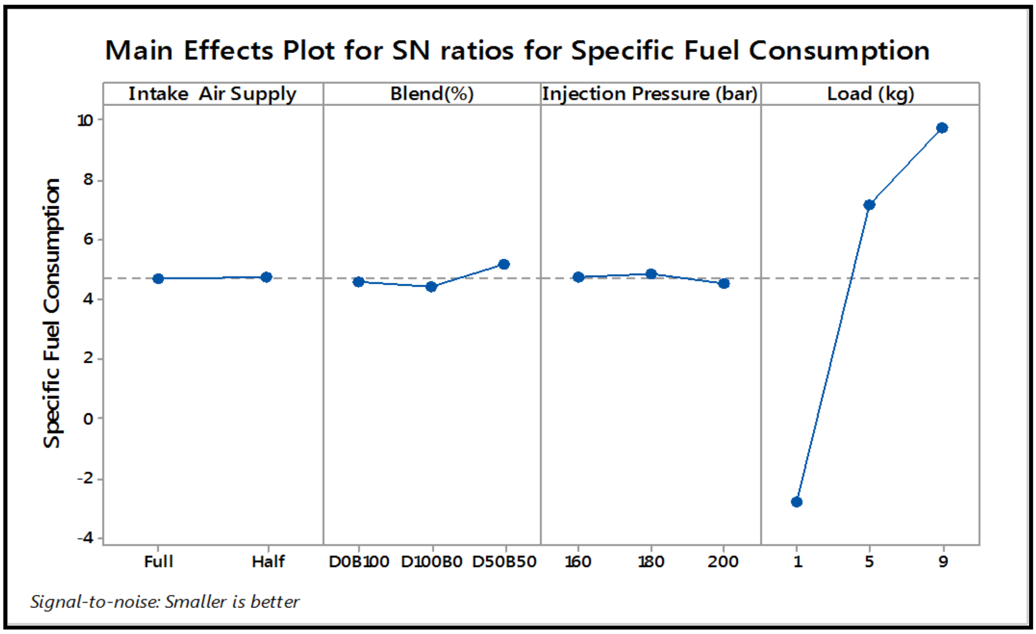


Fig.4: Main Effects Plot for S/N ratio of SFC

As depicted in figure-4 the response curve for S/N ratio, the highest S/N ratio was observed at half air supply (4.72), D50B50 Blend (5.16), 180 bar injection pressure(4.86)and9 kg engine loads(9.77) which are optimum parameter setting for better SFC. According to Delta values, it is maximum (12.553) for the Load and minimum (0.018) for intake air supply. So, engine load is most effective variable and intake air supply is least effective for better SFC.

5.2 Selecting optimum combination of parameter level

The main aim of the experiment is to get optimum set from the entire trial which give better performance (lowest SFC) among the all experiment run. This optimum combination is found by selecting the level with highest S/N ratio. As per the figure-4 and table-4, the response curve for S/N ratio, the better performance is at set Half intake air supply, D50B50 (50% Diesel & 50% Karanja Biodiesel) blend, 180 bar Injection Pressure and 9 kg engine load which is depicted in table-5. This combination gives the lowest SFC which is desirable for the Practical.

Table 4: Response Table for Signal to Noise Ratios

level	Intake air supply	Blend (%)	IP (bar)	Load (kg)
1	4.703	4.573	4.756	-2.781
2	4.721	4.400	4.862	7.144
3	-	5.162	4.517	9.772
Delta	0.018	0.762	0.345	12.553
Rank	4	2	3	1

Table 5: Optimum set of Parameters

Intake air supply	Blend (%)	IP (Bar)	Load (kg)
Half	D50B50	180	9

5.3 Predict performance at optimum setting

Using optimum set of parameters, which was achieved by response curve analysis was used for prediction by Minitab software. Minitab software gave the optimum set. Take this set and find this combination on the Taguchi Table (table-3). This combination of set gives 0.38 kg/kWh SFC and corresponding to SFC; S/N ratio is 10.3818 as shown in table-6.

Table 6: Predicted Value for SFC

SFC	S/N ratio
0.38	10.3818

5.4 validation of Taguchi result

Optimum Parameter set given by the Taguchi analysis is used to check the consistency of the method. For this purpose take the optimum set given by the Taguchi method to validate the outcomes. So, run the research engine by taking Half intake air supply, D50B50 (50% Diesel & 50% Karanja Biodiesel) blend, 180 bar Injection Pressure and 9 kg engine load which gives the value of SFC is 0.34kg/kWh .After that, evaluate the result as per the input data and compare with the Predicted result given by the Taguchi method. This comparison table-7 shows that experimental value was somewhat closer to the Predicted value.

Table 7: Comparison Table

Specific Fuel Consumption(kg/kWh)	
Predicted value	Experimental value
0.38	0.34

VI. Conclusion

The Practicability of using Taguchi method to optimize selected diesel engine parameter for more respectable public presentation was found using single cylinder, 4-stroke research diesel engine. The endings from this study are summarized as follows:

1) The Taguchi method was found to be an effective technique for measuring the issue of command Parameters.

2) The more dependable performance at set Half air supply, 50% blend ratio, engine load 9 kg, and injection pressure 180 bar, which are optimum parameter setting for the lowest SFC.
3) Engine load is most effective variable and intake air supply is least effective for better SFC & engine Performance.
4) Performance results obtained from the confirmation experiment using an optimum combination show excellent agreement with the predicted result.

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