Parametric assessment of single cylinder c.i. engine fuelled with diesel and jatropha seed oil blend

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***Abstract* - For more than a century, burning fossil fuels have generated most of the energy required to propel our cars. Even today; Oil, Coal, Gas provide about 80 percent of our energy needs And; we're paying the price for that, using conventional fuels for energy not only harming the environment but humanity, from 'Air pollution' to 'Global warming'. The utilization of oil which is not conventional like petroleum oil is the main objective of this research. Jatropha is the future of biodiesel. The aim of this paper is to do a comprehensive study on parametric optimization of diesel engine fuelled with a blend of Jatropha seed oil and diesel. For this there are various input parameters which are Intake air manifold diameter, Injection pressure, Blend ratio and Load. From the review of this study it is found that the validation table also stated that optimum sets which are obtained from performance of engine are appropriate for the engine. From experiments it is clear that load is affecting more on performance of Specific Fuel Consumption, Brake Thermal Efficiency and Mechanical Efficiency. Knocking has been seen during lean air-fuel mixture. Jatropha has the similarities with diesel fuel so we can also use Jatropha seed oil as fuel.**

***keywords* - Diesel engine, Jatropha, transesterification, Biodiesel**

I. INTRODUCTION:

Biodiesel is used throughout the world as an alternative fuel source for automobiles and other vehicles. Its supporters cite its positive impact on air quality as compared to traditional fossil fuels. Some also view biodiesel as a safer form of fuel due to the fact that it is less combustible than petroleum diesel. Globally, biodiesel assumes importance due to growing energy security and environmental concern.

However, for reducing the pollution and uses of the fossil fuel, it is more appropriate to make the use of the alternate fuels. Such promising liquid fuels in current use are ethanol, methanol, vegetable oils, non-edible oils and biodiesels (Acharya, Nanda, Panda, & Acharya, 2016). But biodiesel is considered as alternate fuel because of its renewable nature and environment friendly nature. The biodiesel has 12% less energy content than petroleum. The biodiesel has higher molecular weight, viscosity, flash point, etc. than diesel fuel (Patel & Sankhavara, 2017).

The biodiesel has its own advantages and disadvantages. The advantages like, produced from renewable resources, can be used in diesel engine, less greenhouse gas emission, non- toxic in nature, fuel economy are better, foreign oil import will be reduced, it will have more benefit to health. The disadvantages like, variation in quality, can't be used at low temperature, it will lead to increase in the fertilizers. (Dubey & Gupta, 2016).

Jatropha is the key of the future to use biodiesel as fuel because Jatropha has such similarities to the convention diesel oil. Jatropha are the plants which can be grown easily on wasteland, which require low amounts of water in the irrigation process. So the seed come from the Jatropha plants has the potential to produce oil from itself, this is called Jatropha oil which is non-edible oil.

The oil content is 25-30% in the seed. The oil contains 21% saturated fatty acids and 79% Unsaturated fatty acids. These are some of the chemical elements in the seed, which is poisonous and render the oil not appropriate for human consumption. Jatropha oil expelled from seeds and filtered through a filter press can replace kerosene or oil lamp. Jatropha oil can be used as liquid fuel for lighting and cooking. It will also be used in big Diesel engine based electricity generating sets, pump sets, heavy farm machinery, where the viscosity of oil is not an issue. (S.Antony Raja et al, (2011)

The greatest difference in using Jatropha oil as compared to diesel is the higher viscosity which could contribute to higher carbon deposit in the engines and also cause some durability problems. However, the high cetane number and calorific value that is approximately equal to diesel fuel make it possible to use Jatropha oil in diesel engines. (Subramanian K. et al, 2005)

II. JATROPHA SEED OIL AS FUEL:

Figure 1: Jatropha Seed (A. Antony, 2011)

Figure 2: Jatropha Curcas (GRIN, USDA, 2010)

Here are some reasons why Jatropha is so famous as source of biodiesel, Easy to cultivate, can grow in all climatic conditions and soil, provides higher rate of output, easy to maintain, plants can be grow on infertility soil, needs less maintenance and water. Early investigations report that biodiesel which is extracted from Jatropha oil by transesterification method has similar properties like diesel fuel. Jatropha biodiesel has higher quality combustion, making better use of its energy content.

Table 1: Chemical compositions (Momin, 2013)

Compositions	Percentage
Moisture	6.20%
Protein	18%
Fat	38%
Carbohydrates	17%
Fibre	15.50%
Ash	5.30%

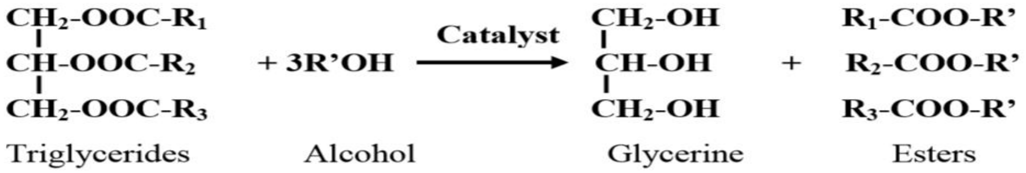
In table no. 1, Analysis of jatropha curcas seed shows all these chemical compositions.

Transesterification:

Transesterification Is the process of chemically reacting an oil with any alcohol in the presence of a catalyst (KOH/NaOH). Alcohol used is usually methanol or ethanol Catalyst is usually sodium hydroxide or potassium hydroxide. The main product of transesterification is biodiesel and the co-product is glycerine.

The reactor used for experiments was a 1000ml three necked round bottom flask. The flask is placed in a water bath. Centre neck is fitted with a stirrer. One of the two side necks is equipped with the condenser and the other is used for thermowell and for sample collection. A thermometer is placed in the thermowell for temperature measurement in the reactor. The motor is connected to a speed regulator for adjusting and controlling the stirrer speed.

In an experiment a known amount of Jatropha oil is charged to a round bottom flask. A known amount of catalyst (NaOH/KOH) based on weight percent of oil is mixed in excess mole percent of methanol. The mixture of sodium hydroxide in methanol is added to the Jatropha oil in the round bottom flask, while stirring the material of the flask. Required temperature is maintained by controlling the electrical heating till reaction is completed. After the addition of methanol-catalyst solution samples are drawn at regular interval to confirm the formation of methyl ester is checked by using TLC (Thin Layer Chromatography) technique.



$CH_2\text{-}OOC\text{-}R_1$ / $CH\text{-}OOC\text{-}R_2$ / $CH_2\text{-}OOC\text{-}R_3$ $+ 3R'OH \xrightarrow{\text{Catalyst}}$ $CH_2\text{-}OH$ / $CH\text{-}OH$ / $CH_2\text{-}OH$ $+$ $R_1\text{-}COO\text{-}R'$ / $R_2\text{-}COO\text{-}R'$ / $R_3\text{-}COO\text{-}R'$

Figure 3: Transesterification reactions (“Transesterification reactions,” 2011)

Above figure no: 3 shows the whole process of Transesterification reaction process, After the completion of methyl ester formation, a known amount of sulphuric acid in methanol is added to the methyl ester to neutralize the sodium hydroxide present in the ester. The main product coming from this process is biodiesel and the by-product comes from this process is glycerine.

Table 2: Properties of Jatropha Biodiesel

Parameter	**Unit**	**Result of Jatropha Biodiesel**
Density @15°C	kg/m^3	896
Calorific Value	kJ/kg	39100
Kinematic viscosity @40°C	Cp	14.69
Kinematic viscosity @100°C	Cp	9.82
Flash point	°C	135
Sulphur content	mg/kg	14
Carbon residue contents	% by mass	0.015
Sulphated ash content	ppm	26
Water content	mg/kg	1054
Total contamination	mg/kg	11
Copper strip corrosion @3HR @50°C	-	NILL
Cetane number	-	61.2
Acid value	mg KOH/gm	24
Methanol content	% by mass	0.14
Ethanol content	% by mass	0.18
Ester content	% by mass	98.11
Free glycerol content	mg/kg	152
Total glycerol content	% by mass	0.14
Oxidation stability @ 110°C	-	9
Iodin value	-	122
CCR (10% Bottom)	% by mass	0.040(100)
SOx	%	NILL
NOx	%	NILL
SPM	%	NILL
Gross Calorific Value	MJ/kg	39.10

III. EXPERIMENTAL SETUP:

Experimental setup consists of Fuel Preparation, Equipment and Materials and as shown in below narration.

Figure 4: Engine Test Rig

Figure 4 shows the experimental setup. It consists of a single cylinder, four stroke, multi-fuel, research engine connected to eddy type dynamometer for loading. The operation mode of the engine can be changed from diesel to Petrol or from Petrol to 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. The experimental setup consists of a single cylinder Diesel Engine, air metering unit, fuel measuring unit and thermocouples with temperature indication.

Table 3 shows the engine specifications which can be used in the calculations of the measured values.

Table 3: Engine specifications

Number of cylinder	Single Cylinder
Number of Stroke	4
Swept Volume	552.64 cc
Cylinder diameter	80 mm
Stroke length	110 mm
Connecting rod length	234 mm
Orifice Diameter	20 mm
Dynamometer Rotor Radius	141 mm
Fuel	Diesel
Power	5.2 kw
Speed	1500 rpm
Compression ratio range	12 to 18
Injection point variation	0 to 25 Before TDC

Figure 5 shows the eddy current dynamometer which is used for measuring the power of the engine.

Figure 5: Eddy Current Dynamometer

Table 4 shows the technical specifications of the engine eddy current dynamometer.

Table 4: Technical specifications of eddy current dynamometer

Model	AG10
Make	Saj Test plant Pvt. Ltd.
End flanges both side	Carbon shaft model 1260 type A
Water inlet	1.6 bar
Minimum kPa	160
Pressure IBF/in^2	23
Air gap mm	0.77/0.63
Torque Nm	11.5
Hot coil voltage max.	60
Continuous current amps	5.0
Cold resistance ohms	9.8
Speed max.	10000 rpm
Load	3.5 kg
Bolt size	M12*1.75
Weight	130 kg

IV. RESULT & DISCUSSION

This study includes results of experiment and discussion about those input Parameters. Results have been taken by using Minitab software for Taguchi analysis. The whole experiment is done by considering the Taguchi analysis method. Table 5 shows the table for experiment. This table is generated by Taguchi's method for doing an experiment.

This table can be generated by using flow chart steps. In this table four parameters as orifice diameter, blend ratio, injection pressure and load are taken and a mixed Taguchi method is used.

Table 5: Table for experiments

Sr. No	Intake Air Manifold Diameter	% Bio-Diesel	Injection Pressure (bar)	Load (kg)
1	10	0	160	1
2	10	0	180	5
3	10	0	200	9
4	10	50	160	5
5	10	50	180	9
6	10	50	200	1
7	10	100	160	9
8	10	100	180	1
9	10	100	200	5
10	20	0	160	1
11	20	0	180	5
12	20	0	200	9
13	20	50	160	5
14	20	50	180	9
15	20	50	200	1
16	20	100	160	9
17	20	100	180	1
18	20	100	200	5

Taghuchi Analysis for SFC:

Figure 6 shows the main effects plot for means for SFC. Figure gives data for various Intake Air Manifold Diameters, percentage of Biodiesel, injection pressure and load. As SFC of any engine should be as low as possible, so the lowest points on the graph will give the lowest value of SFC.

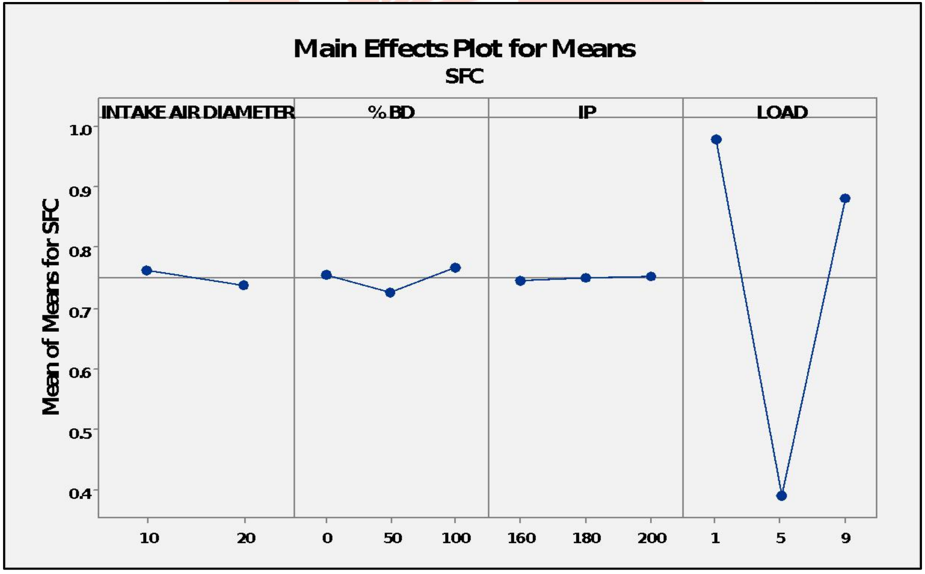


Figure 6: Main effect plot for means: SFC

Delta value of SFC is the average difference between maximum and minimum values on graph and rank is given based on the ascending order of delta values. It means the highest value will have 1st rank and lowest value will have last rank. Response table for means has the highest value of load that is 0.5901 and lowest value of injection pressure that is 0.0069. This indicates that load is affecting more on performance of SFC and injection pressure is affecting less on SFC.

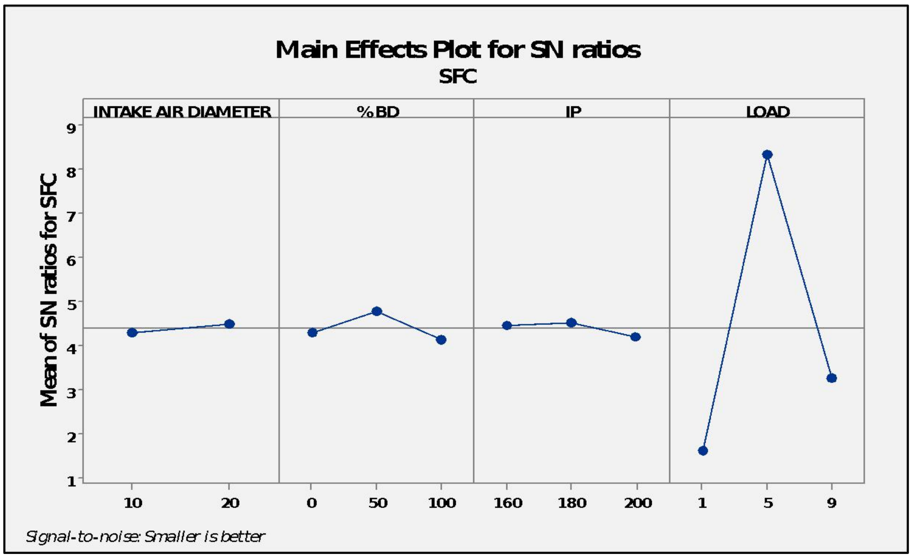


Figure 7: Main effects plot for SN ratio: SFC

In the SN, rank is given based on the ascending order of values means highest value will have 1st rank and lowest value will have last rank. Response table for means have highest value of load that is 6.707 and lowest value of Injection Pressure that is 0.326 this indicates that load is affecting more on performance of SFC and injection pressure affecting less on performance.

Table 6 shows the optimum set parameter for SFC. These values are obtained from the SN ratio graph. Highest values of parameters on that graph are taken as optimum values and based on that optimum values optimum set is generated. The optimum set for SFC is Intake Air Manifold Diameter of 20mm, blend ratio of 50% diesel and 50% biodiesel, low injection pressure i.e. 160 bar and load of 5 kg. For this set of parameters predicted value is 0.42 and experiment value is 0.43. These both values are closer to each other, so this set will give optimum results.

Table 6: Optimum set of parameters: SFC

Intake Air Manifold Diameter (mm)	% Bio-Diesel	Injection Pressure (bar)	Load (kg)	Predicted Value	Experiment Value
20	50	160	5	0.42	0.43

Taghuchi Analysis for Brake Thermal Efficiency:

Figure 8 shows the main effects plot for means for Brake Thermal Efficiency. Figure gives data for various Intake Air diameters, percentage of Biodiesel, injection pressure and load. As BTHE of any engine should be high, so highest points on the graph will give the highest value of BTHE. Those highest points in all parameters will give optimum sets of parameters. By considering this set of parameters for performance the values of BTHE will always be higher.

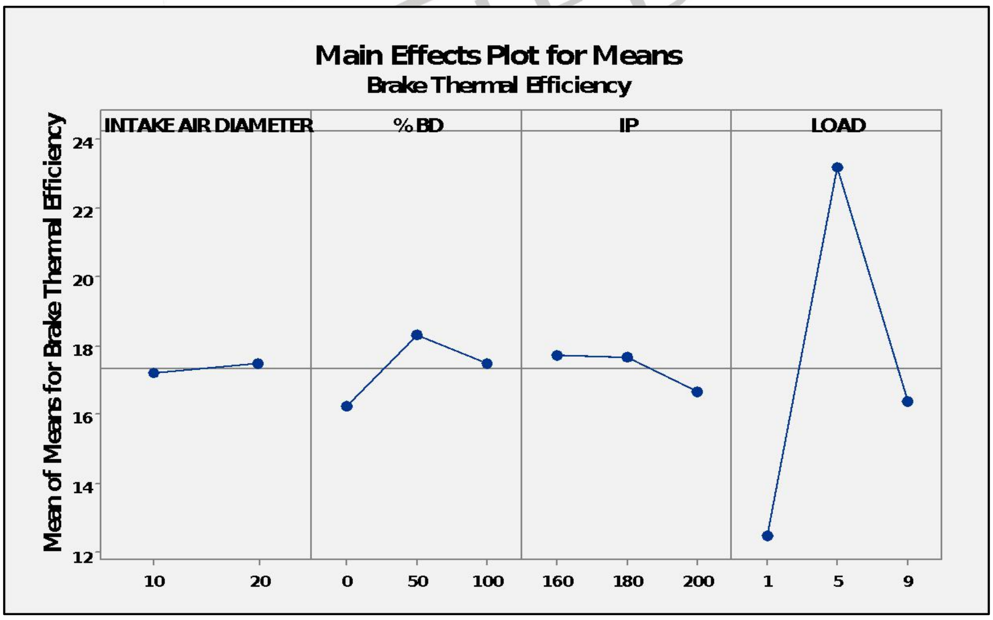


Figure 8: Main effects plot for means: Brake Thermal Efficiency

Delta is the average difference between different values and rank is given based on the ascending order of values means highest value will have 1st rank and lowest value will have last rank. Response table for means has the highest value of load that is 10.74 and lowest value is the percentage of Intake air manifold diameter that is 0.27. This indicates that load is affecting more on performance of BTHE and Intake air manifold diameter is affecting less on performance.

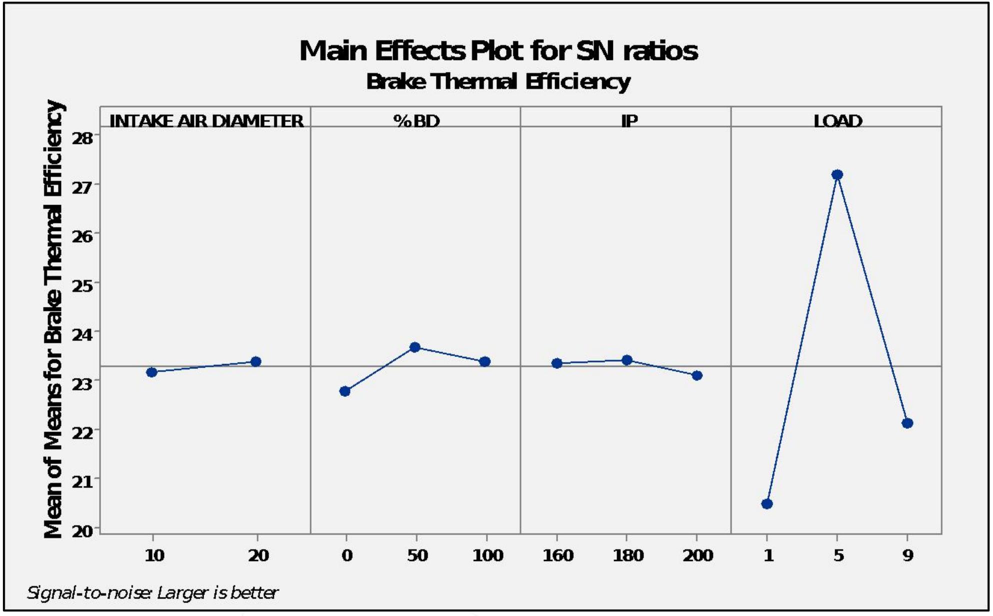


Figure 9: Main effects plot for SN ratio: Brake Thermal Efficiency

In the SN, As BTHE of any engine should be high, so highest points on graph will give the highest value of BTHE. Those highest points in all parameters will give optimum sets of parameters. By considering this set of parameters for performance the values of BTHE will always be higher.

Table 7 shows the optimum set parameter for BTHE. These values are obtained from the SN ratio graph. Highest values of parameters on that graph are taken as optimum values and based on that optimum values optimum set is generated. The optimum set for BTHE is Intake Air Manifold Diameter, blend ratio of 50% diesel and 50% biodiesel, injection pressure i.e. 160 bar and load of 5 kg. For this set of parameters the predicted value of is 19.70 and experiment value is 20.27. These values are closer to each other, so this set will give optimum results.

Table 7: Optimum set of parameters: Brake Thermal Efficiency

Intake Air Manifold Diameter (mm)	% Bio-Diesel	Injection Pressure (bar)	Load (kg)	Predicted Value	Experiment Value
20	50	160	5	19.70	20.27

Taguchi Analysis for Mechanical Efficiency

Figure 10 shows the main effects plot for means for mechanical efficiency. Figure gives data for various intake air manifold diameters, percentage of Biodiesel, injection pressure and load. The mechanical efficiency of any engine should be high, so the highest points on the graph will give the highest value of mechanical efficiency. Those highest points in all parameters will give optimum sets of parameters. By considering this set of parameters for performance the values of mechanical efficiency will always be higher.

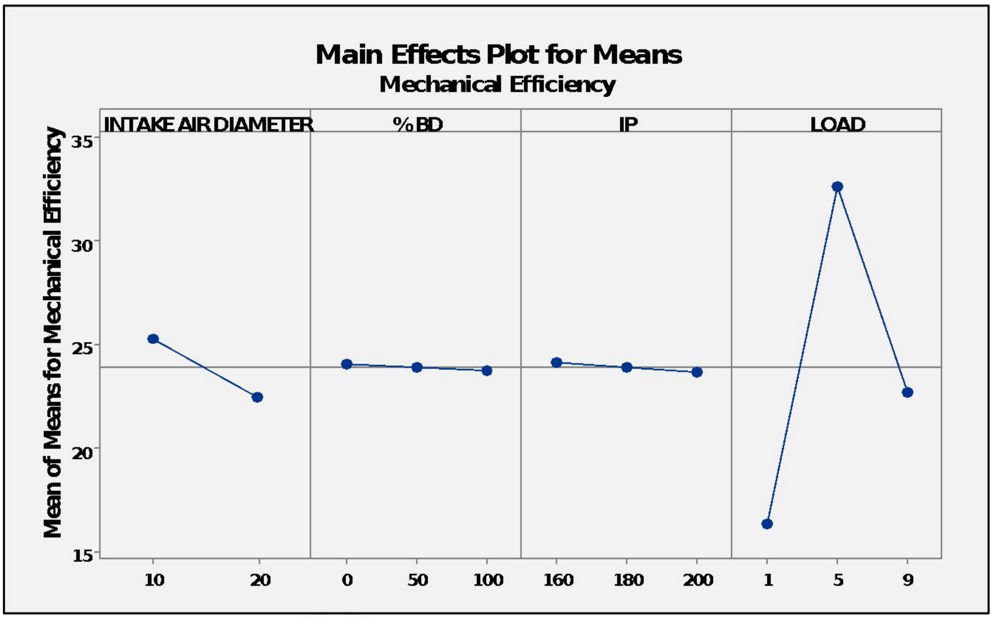


Figure 10: Main effects plot for means: Mechanical Efficiency

Delta is the average difference between different values and rank is given based on the ascending order of values means highest value will have 1st rank and lowest value will have last rank. Response table for means has the highest value of load that is 16.29 and lowest value of % Biodiesel that is 0.29. This indicates that load is affecting more on performance of Mechanical Efficiency and injection pressure is affecting less on performance.

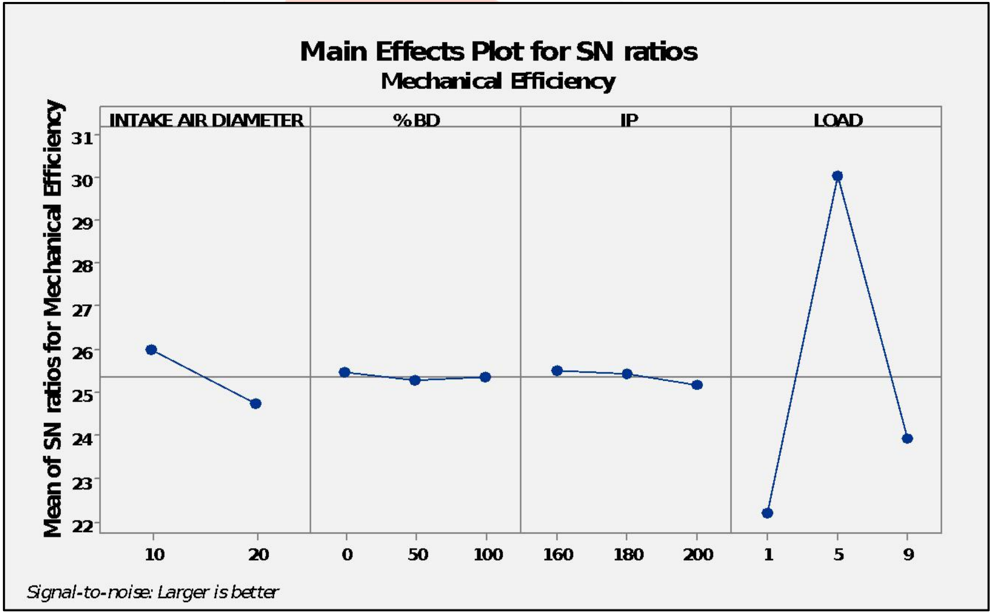


Figure 11: Main effects plot for SN ratio: Mechanical Efficiency

In the SN, delta value is the average difference between different values and rank is given based on the ascending order of values means highest value will have 1st rank and lowest value will have last rank. Response table for means has the highest value of load that is 7.82 and lowest value of % Biodiesel that is 0.20. This indicates that load is affecting more on performance of Mechanical Efficiency and injection pressure is affecting less on performance.

Table 8 shows the optimum set parameter for mechanical efficiency. These values are obtained from the SN ratio graph. Highest values of parameters on that graph are taken as optimum values and based on that optimum values optimum set is generated. The optimum set for mechanical efficiency is intake air manifold diameter, blend ratio of 100% diesel and 0% biodiesel, low injection pressure i.e. 160 bar and load of 5 kg. For this set of parameters predicted value is 27.90 and experiment value is 28.06. Predictive value and Experiment value for both sets are closer to each other, so this set will give optimum results.

Table 8: Optimum set of parameters: Mechanical Efficiency

Intake Air Manifold Diameter (mm)	% Bio-Diesel	Injection Pressure (bar)	Load (kg)	Predicted Value	Experiment Value
10	0	160	5	27.90	28.06

Validation Experiments:

Table 9 shows validation of experiment for different predicted values, experiment values and difference of two. All four results are derived from the best set of parameters. Which tells that the predictive value of the optimum set for SFC is

0.42 and for the same experiment value is 0.43, difference of that two is very is very minor. Predictive value for Mechanical Efficiency is 27.90 and for experiment it is 28.06 and difference is 2.50%. Predictive value for BTHE is 19.70 and experimental value is 20.27 and difference for that is 2.89%. This whole difference indicates that an optimal set of parameters gives better results in engine performance. Predicted value of optimum set for Mechanical Efficiency is 27.90 and for experiment it is 28.06 and difference is 2.50%. Predicted value for FC is 0.40 and experiment value is 0.41 and difference for that is 2.5. This whole difference indicates that an optimal set of parameters give better results in engine performance.

Table 9: Validation experiments

Response	Intake Air Diameter (mm)	Bio-Diesel (%)	Injection Pressure (bar)	Load (kg)	Predicted Value	Experiment Value	Difference (%)
S.F.C.	20	50	160	5	0.42	0.43	2.38
M.E.	10	0	160	5	27.90	28.06	2.50
B.T.H.E.	20	50	160	5	19.70	20.27	2.89

V. CONCLUSION

From the experiment the conclusions derived are as follows:

The optimal operation factors of high brake thermal efficiency and low SFC have been obtained for a diesel engine with diesel and biodiesel blends using orifice plate at engine with Taguchi's method. The Optimization performance of different parameters has also been compared with optimized engine and diesel engine. The authors conclude on the basics of the results and discussion as follows. The Taguchi method was a good method to find out the optimum combinations. The predictions using Taguchi's parameter design technique is in adequate agreement with the confirmation results, with a confidence interval of 90%, and this technique saves 75% of the time taken to perform the experiment in this research. Optimum set for specific fuel consumption of engine for 20 mm intake air diameter, Biodiesel blend for 50%, Injection pressure 160 bar and load 5 kg, This set has lowest value for SFC which is appropriate for engine. Optimum set for Brake thermal efficiency of engine for 20 mm intake air diameter, Biodiesel blend for 50%, Injection pressure 160 bar and load 5 kg, This set has highest value for BTE which is appropriate for engine. Optimum set for Mechanical efficiency of engine for 10 mm intake air diameter, Biodiesel blend for 0%, Injection pressure 160 bar and load 5 kg, This set has the highest value for ME which is appropriate for engine. From the result and discussion, it is found that Jatropha is a useful biodiesel instead of diesel. As some results generated are in fever of Jatropha biodiesel. So it would be appropriate to use Jatropha biodiesel. From experiments it is clear that load is affecting more on performance of SFC, Brake Thermal Efficiency and Mechanical Efficiency. Validation table also stated that optimum set which is obtained from performance of engine are appropriate for engine.

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