Scientific Journal of Impact Factor (SJIF): 5.71
e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 5, Issue 04, April -2018

EFFECT OF COMPRESSION RATIO ON PERFORMANCE OF CI ENGINE FUELLED WITH DIESEL-PALM SEED OIL BLENDS USING TAGUCHI'S DOE APPROACH.

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Abstract*-The use of fossil fuels is increasing day by day and it results into increasing pollution, to decrease the use of fossil fuels the use of alternative fuel is the good option. Palm seed oil is the oil which can be used as alternative fuel. The properties of both blends were estimated. The result showed that the fuel properties of the blends were very close to the diesel. There are many other oils available like waste plastic oil, jatropha, neem etc. so to reduce pollution, alternate fuel can be used as substitute. Three parameters compression ratio, load, and blend are variance and response like specific fuel consumption optimize completely. The experiments include use of palm seed oil blend such as 100D0B (100% Diesel 0% palm seed oil), 50D50B (50% Diesel 50% palm seed oil), 0D100B (0% Diesel and 100% palm seed oil) at different compression ratio. For mathematical and statistical analysis Taguchi's method is used.*

Keywords: *Palm seed oil, Taguchi, Compression ratio, blend, bio diesel, CI engine*

Nomenclature

BTHE	Brake Thermal Efficiency
SFC	Specific Fuel Consumption
FC	Fuel Consumption
S/N Ratio	Signal to Noise Ratio
D.O.E	Design of Experiment
100D0B	100% Diesel, 0% Biodiesel
50D50B	50% Diesel,50% Biodiesel
0D100B	0% Diesel, 100% Biodiesel

I. INTRODUCTION

Nowadays diesel engines are more popular and used in all over world because the price of petrol is increasing day by day and the problem is, pollution is increasing from gasoline engine's emission. All the problems can be solved by using an alternative fuel. A diesel fuel has no oxygen compound, it contains carbon and hydrogen arranged in straight chain structures [1]. Palm methyl ester was produced using an alkali catalysed transesterification process. Increasing industrialization, growing energy demands, limited reserves of fossil fuels and increasing environmental pollution are the factors to investigate possible alternative fuels [2]. Bio-diesel is fatty acid methyl ester made from virgin or used vegetable oils and animal fats. The property of Palm seed oil is very close to diesel. The viscosity of palm seed oil is 5-7 times more than that of diesel [3]. The use of bio-diesel in conventional diesel engines results in substantial reduction of unburned hydrocarbons, carbon monoxide and particulate matters. Bio-diesel is considered clean fuel since it has almost no sulphur, no aromatics and has about 10% built in oxygen, which helps it to burn fully. The higher cetane number improves the ignition quality even when blended in the petroleum diesel. As a liquid fuel, bio-diesel is simple to use and can be used in diesel engines without modifications. It also can be blended at any level with petroleum diesel to create a biodiesel blend [4].

II. LITERATURE REVIEW

For optimization of experiment run, The Taguchi method has been used. **Amin et al. (2017)** have studied that the properties of palm seed oil/ palm seed oil biodiesel blends have no difference in the properties of blends up to 30% volume of oil/ biodiesel of palm seed oil [5]. **Abed et al. (2017)** have studied that the exhaust emissions of CO and HC were reduced, where NOx emissions have increased. The thermal efficiency of palm seed biodiesel was lower compared to diesel, where specific fuel consumptions were higher [6]. **Nagi et al. (2008)** have studied that the palm seed biodiesel meets the combustion requirements of diesel engine combustion. Palm seed biodiesel contributes the source of green renewable energy to meet the demands of energy of the future [7]. **Ariyani et al. (2010)** have studied that the density of biodiesel has satisfied the quality standard, but not for kinematic viscosity [8]. **Yadav et al. (2016)** have studied that the emissions of CO and HC and smoke opacity of OOME, KOME and BGOME were slight less than that of diesel fuel. The engine could be operated without major modifications [9]. **Manoharan et al. (2015)** have studied that the blend ratio of 40% biodiesel (60% diesel) achieves optimal compromise between power loss and emission reduction as the power loss found around 5% and at the same time, HC and CO reduced around 73% and 46% compared to standard diesel [10]. **Choudhary et al. (2018)** have studied that the duration of combustion less in case of high compression ratio compared to other compression ratios. Exhaust gas temperature decreases when compression ratio increases [11]. **Bhasker et al. (2017)** have studied that the brake power output and brake thermal efficiency increases slightly with increasing compression ratio. The in-cylinder pressure increases with increase in compression ratio [12]. Properties of Palm seed oil shown in Table1.

Table 1 Properties of Palm Seed Oil [13]

Parameter	Unit	Result
Density @ 15℃	Kg/m^3	925
Kinematic viscosity@ 40℃	mm^2/sec	41
Flash Point	°C	260
Cloud point	°C	-
Fire point	°C	341
Iodine value	g/100g	44-51
Melting point	°C	35
Calorific value	KJ/kg	39849

III. EXPERIMENTAL SETUP

Experimental setup is shown in Fig.1. In this engine without stopping of engine the compression ratio can be varied. This engine is working on both fuels (petrol and diesel). The setup is connected with I.C. engine software. setup consists instruments for combustion pressure, diesel line pressure and crank angle measurements. The setup also observes VCR engine performances.

Figure1. Experiment setup [14]

Table 2 Engine specification [14]

Number of Cylinder	Single cylinder
Number of Stroke	4
Swept Volume	552.64 cc
Cylinder Bore	80 mm
Stroke	110mm
Connecting Rod Length	234mm
Orifice Diameter	20mm
Dynamometer Rotor Radius	141mm
Fuel	Diesel
Power	3.7 kw
Speed	1500rpm
Compression Ratio Range	12 to 18
Inj.Point variation	0° to 25° BTDC

IV. METHODOLOGY

Taguchi method has been used for the optimization of the process. In the Taguchi method two type of inputs are used: 1. Control variable 2. Noise variable. In the Taguchi method, one of the following condition is considered.

1. Larger is better.
2. Smaller is better.
3. On target minimum variation.

S/N ratio, mean value and variation have been obtained by analysing experiment data in minitab 18. The S/N ratio has been taken instead of standard deviation, because of that, standard deviation has been decreased with decrease in mean value and vice versa. Compression ratio is variable at three levels with high, low, and medium ranges of input parameters are selecting based on modification of engine. Advantage using design of experiment is evaluate variation of SFC with number of experiment [15].

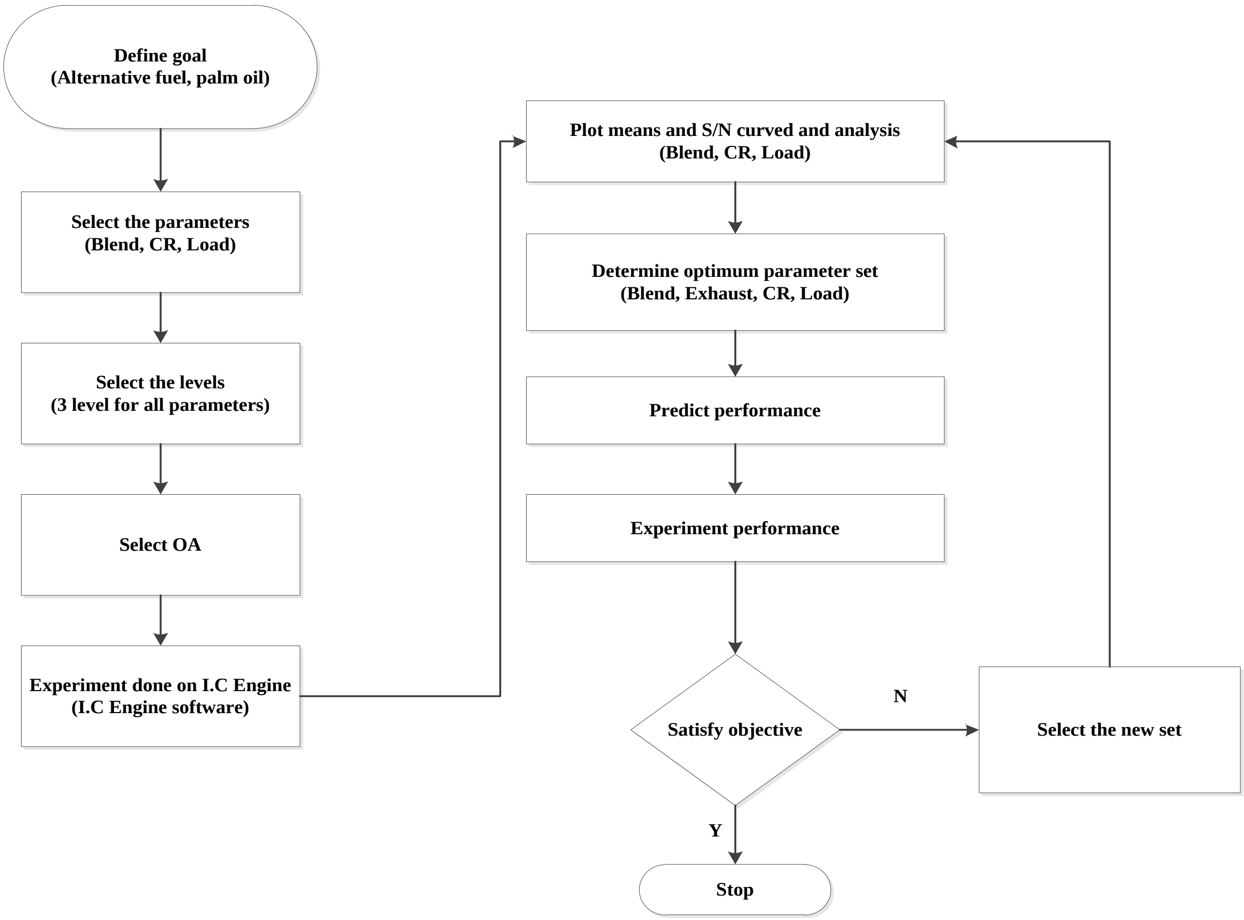

Figure2. Flow Chart Experiment [14]

V. FACTORS AND LEVELS

Experiments have been performed according to L9 orthogonal array for exhaust manifolds, compression ratio, blend and load. In the experiment table, take 9 rows and 3 columns at 3 factors. Those 3 parameters are shown in Taguchi Table 3.

Table 3 Factors and their levels

Factor	Level1	Level2	Level3
CR	14	16	18
BLEND	100D0B	50D50B	0D100B
LOAD	1	5	9

VI. RESULT AND DISCUSSION

Table 4 Experimental Results Table

Sr. No	Blend Ratio (%)	Compression Ratio	Load (kg)	BTHE (%)	Mechanical Efficiency (%)	FC (kg/h)	SFC (kg/kWh)
1	100D0B	18	1	5.7899	6.4989	0.44982	1.451032258
2	100D0B	16	5	19.1369	28.7937	0.64974	0.439013514
3	100D0B	14	9	23.7201	42.8330	0.89964	0.354188976
4	50D50B	18	5	15.4926	28.75	0.777	0.563043478
5	50D50B	16	9	22.0913	38.8632	0.999	0.39486166
6	50D50B	14	1	5.4137	8.0103	0.4995	1.611290323
7	0D100B	18	9	23.7909	41.4593	0.94932	0.379728
8	0D100B	16	1	4.6249	7.6487	0.5274	1.953333333
9	0D100B	14	5	20.6981	27.0018	0.63288	0.436468966

Mechanical efficiency, brake thermal efficiency, fuel consumption and specific fuel consumption were analysed for each set of parameters using I.C engine software. Minitab18 offers Taguchi method in DOE. These graphs were created by putting all data in minitab18 and by following the required steps.
Taguchi's analysis for BTHE by using different parameters compression ratio, blend and load.

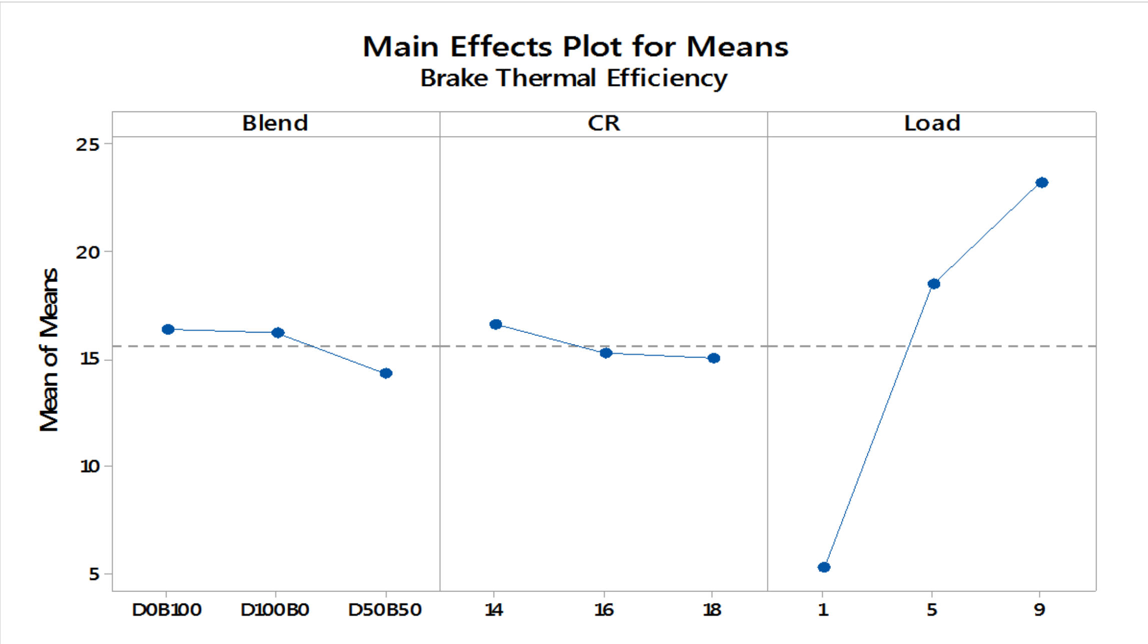

Figure 3. Main effect plot for means: BTHE

Table 5 Main effects plot for means: BTHE

Level	Blend	CR	Load
1	16.371	16.611	5.276
2	16.216	15.284	18.443
3	14.333	15.025	23.201
Delta	2.039	1.586	17.925
Rank	2	3	1

A table 5 show that the maximum value of the delta is 17.925 (LOAD) and minimum value is 1.586 (CR). BTHE performance more affected by load and less affected by compression ratio, because of load delta value has maximum and Compression ratio delta value has minimum on Means result.

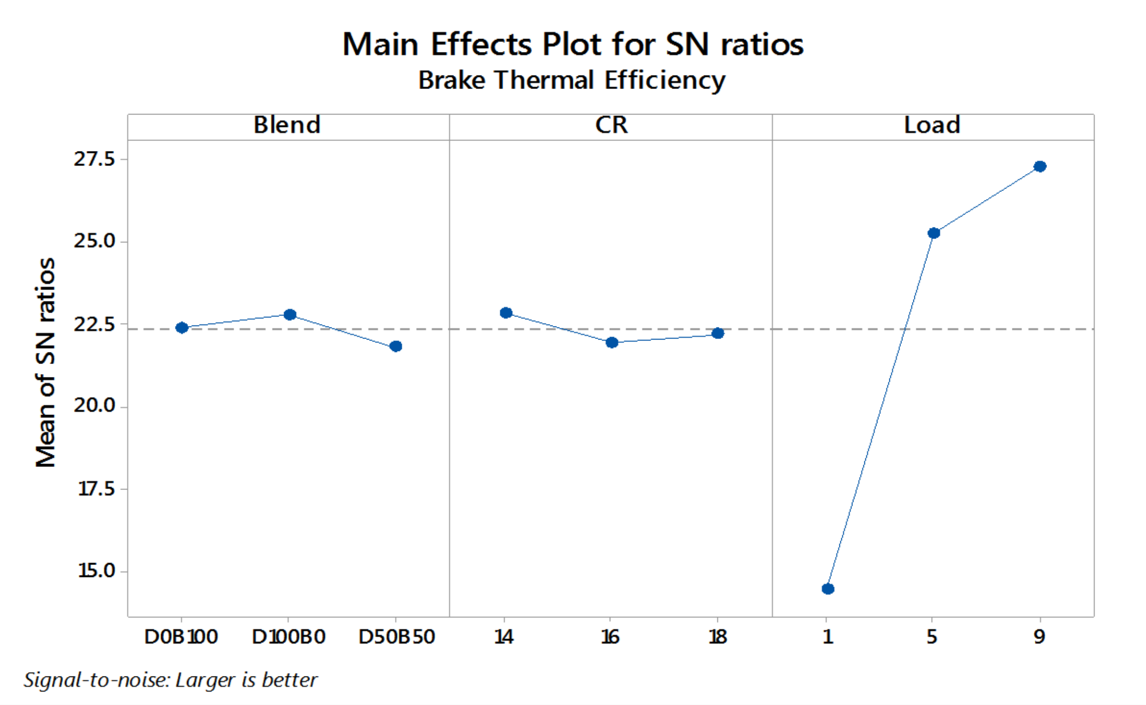

Figure 4. Main effect plot for SN ratio: BTHE

Table 6 Main effects plot for SN ratio: BTHE

Level	Blend	CR	Load
1	22.38	22.83	14.41
2	22.80	21.94	25.25
3	21.79	22.19	27.31
Delta	1.01	0.89	12.90
Rank	2	3	1

A table 6 show that the maximum value of the delta is 12.90 (LOAD) and minimum value is 0.89(CR). BTHE performance more affected by load and less affected by compression ratio, because of the load delta value has maximum and Compression ratio delta value has minimum on the S/N ratio result.
Fig. 3 and 4 shows the minimum and maximum value for all parameters. Take the maximum value form the above graph for the best value of BTHE. The value was CR14, BR D100B0 and LOAD9. Predicted value gained by the putting Table value in minitab18, comparing that value to the experiment value.

Table 7 Optimum set of parameters: BTHE

Compression Ratio	BLEND	LOAD	PREDICTIVE	EXPERIMENT	DEFFERENCE
14	D100B0	9	23.7201	24.7474	1.0273

Table 7 shows that Best Brake Thermal Efficiency got at compression ratio 14, Blend Ratio 100D0B and Load 9.

Taguchi's analysis for Mechanical Efficiency by using different parameters compression ratio, blend and load.

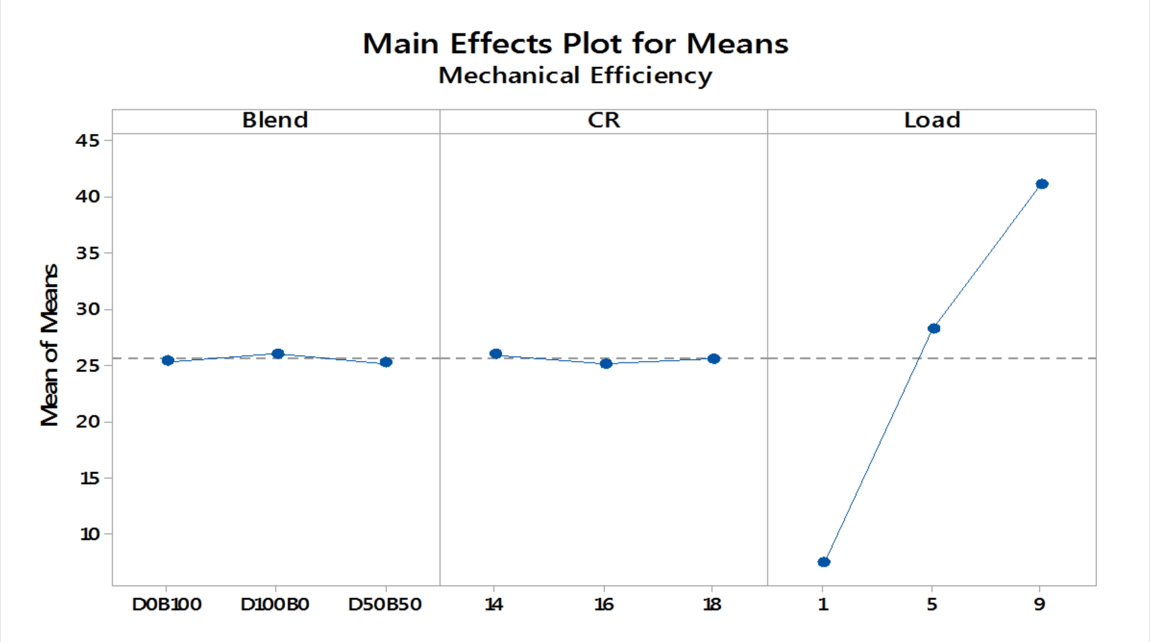

Figure 5. Main effect plot for means: Mechanical Efficiency

Table 8 Main effects plot for means: Mechanical Efficiency

Level	Blend	CR	Load
1	25.370	25.948	7.386
2	26.042	25.102	28.182
3	25.208	25.569	41.052
Delta	0.834	0.846	33.666
Rank	3	2	1

A table 8 shows that the maximum value of the delta is 33.666 (LOAD) and minimum value is 0.834 (BLEND). Mechanical Efficiency performance more affected by load and less affected by blend, because of load delta value has a maximum and blend delta value has minimum on Means result.

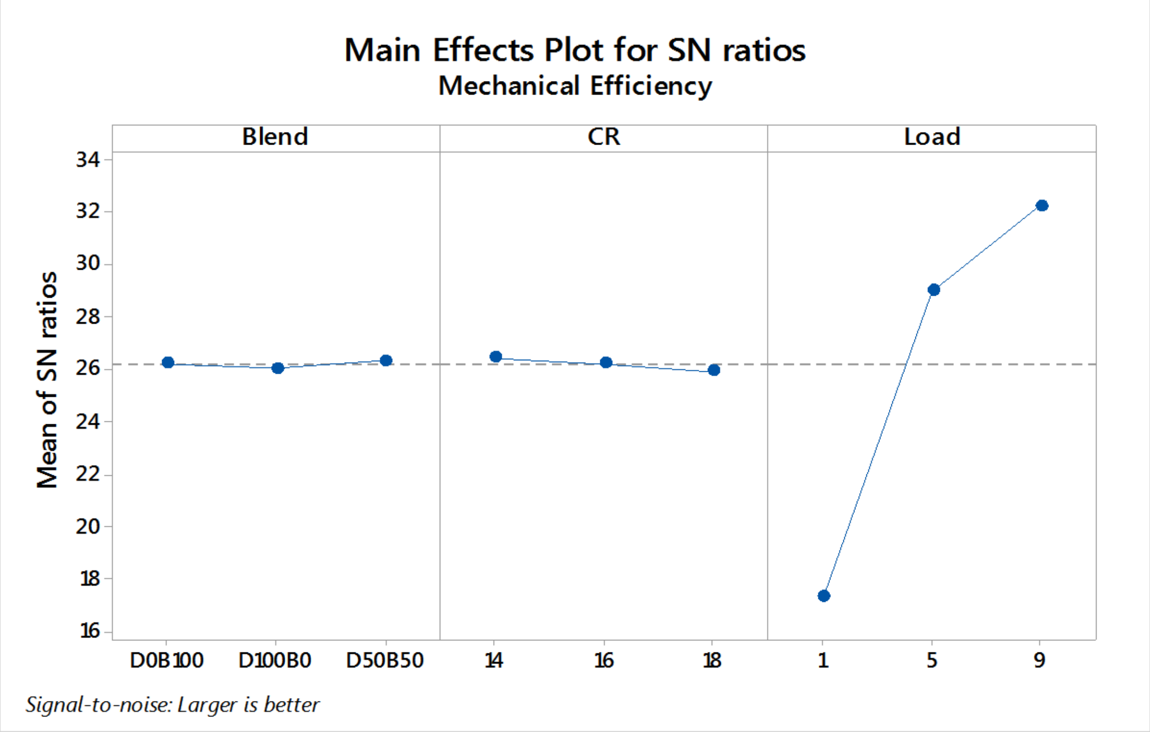

Figure 6. Main effect plot for SN ratio: Mechanical Efficiency

Table 9 Main effects plot for SN ratio: Mechanical Efficiency

Level	Blend	CR	Load
1	26.22	26.45	17.33
2	26.03	26.22	29.00
3	26.35	25.93	32.26
Delta	0.32	0.52	14.93
Rank	3	2	1

A table 9 shows that the maximum value of the delta is 14.93 (LOAD) and minimum value is 0.32 (BLEND). Mechanical Efficiency performance more affected by load and less affected by blend, because of load delta value has a maximum and blend delta value has minimum on the S/N ratio result.
Fig. 5 and 6 shows the minimum and maximum value for all parameters. Take the maximum value Form the above graph for the best value of Mechanical Efficiency. The value was CR14, BR D100B0 and LOAD9. Predicted value gained by the putting Table value in minitab18, compare that value to the experiment value.

Table 10 Optimum set of parameters: Mechanical Efficiency

Compression Ratio	**BLEND**	**LOAD**	**PREDICTIVE**	**EXPERIMENT**	**DEFFERENCE**
14	D100B0	9	42.8330	41.9624	0.8706

Table 10 shows that Best Mechanical Efficiency got at compression ratio14, Blend RatioD100B0 and Load9.

Taguchi's analysis for Specific Fuel Consumption with using different parameter compression ratio, blend and load.

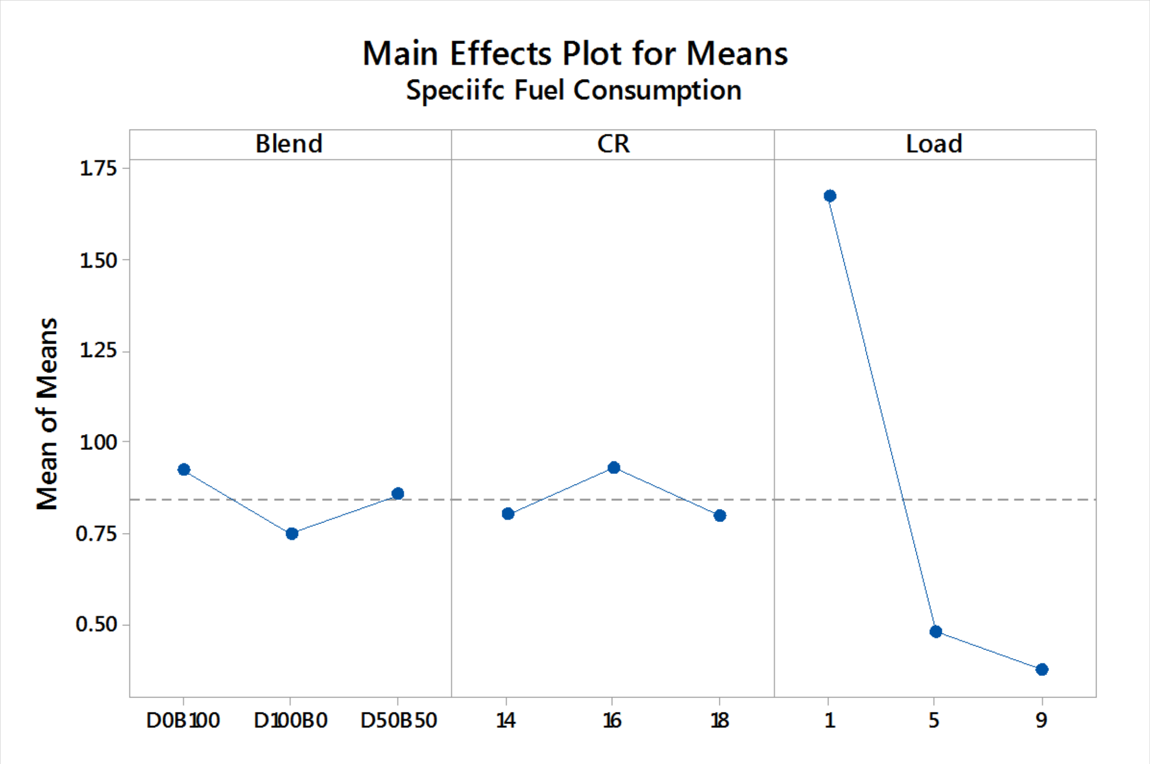

Figure 7. Main effect plot for means: Specific Fuel Consumption

Table 11 Main effects plot for means: Specific Fuel Consumption

Level	Blend	CR	Load
1	0.9232	0.8006	1.6719
2	0.7481	0.9291	0.4795
3	0.8564	0.7979	0.3763
Delta	0.1751	0.1311	1.2956
Rank	2	3	1

A table 11 show that maximum value of delta is 1.2956 (LOAD) and minimum value is 0.1311 (CR). Fuel consumption performance more affected by load and less affected by compression ratio, because of load delta value has maximum and compression ratio delta value has minimum on Means result.

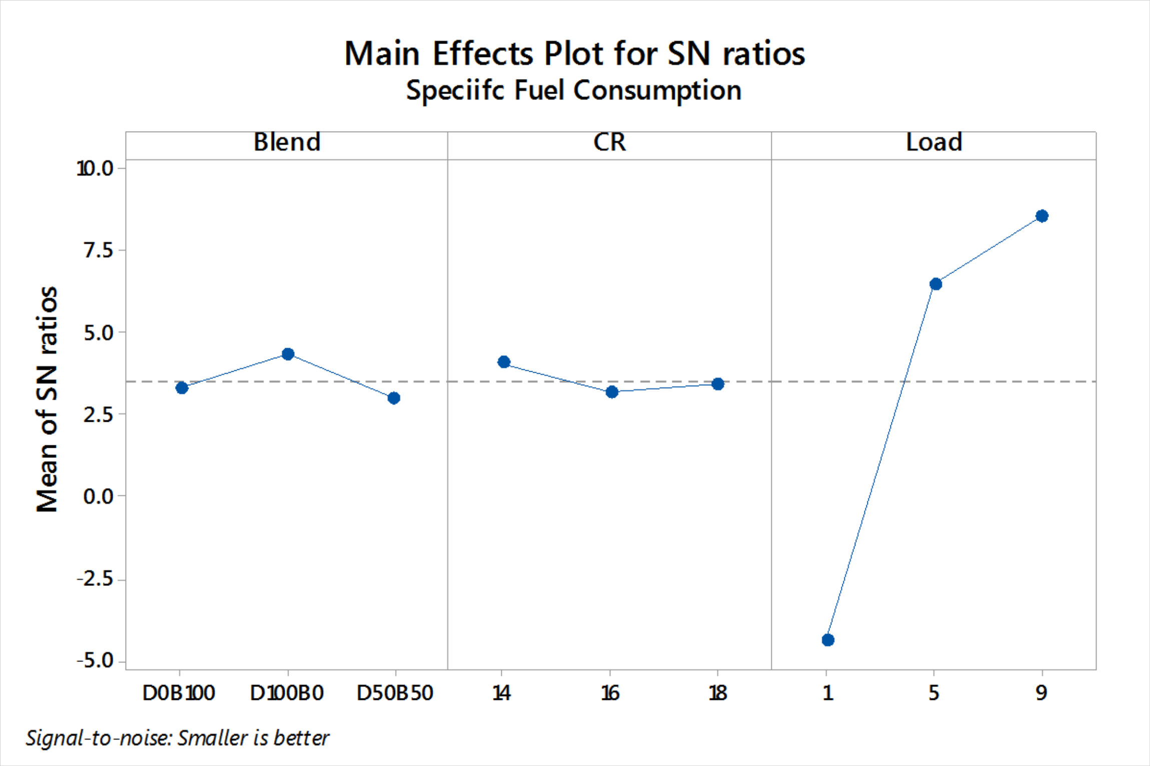

Figure 8. Main effect plot for SN ratio: Specific Fuel Consumption

Table 12 Main effects plot for SN ratio: Specific Fuel Consumption

Level	Blend	CR	Load
1	3.265	4.024	-4.398
2	4.311	3.135	6.447
3	2.972	3.389	8.499
Delta	1.338	0.889	12.896
Rank	2	3	1

A table 12 show that maximum value of delta is 12.896 (LOAD) and minimum value is 0.889 (CR). FC performance more affected by load and less affected by compression ratio, because of load delta value has maximum and Compression ratio delta value has minimum on S/N ratio result.

Fig. 7 and 8 shows the minimum and maximum value for all parameters. Take the maximum value Form the above graph for the best value of Fuel Consumption. The value was CR14, BR D100B0 and LOAD9. Predicted value gained by the putting Table value in minitab18, compare that value to the experiment value.

Table 13 Optimum set of parameters: Specific Fuel Consumption

Compression Ratio	**BLEND**	**LOAD**	**PREDICTIVE**	**EXPERIMENT**	**DEFFERENCE**
14	D100B0	9	0.354188976	0.239885	0.11430

Table 13 shows that Minimum Specific Fuel Consumption got at compression ratio14, Blend Ratio D100B0 and Load9.

Taguchi's analysis for Fuel Consumption with using different parameter compression ratio, blend and load.

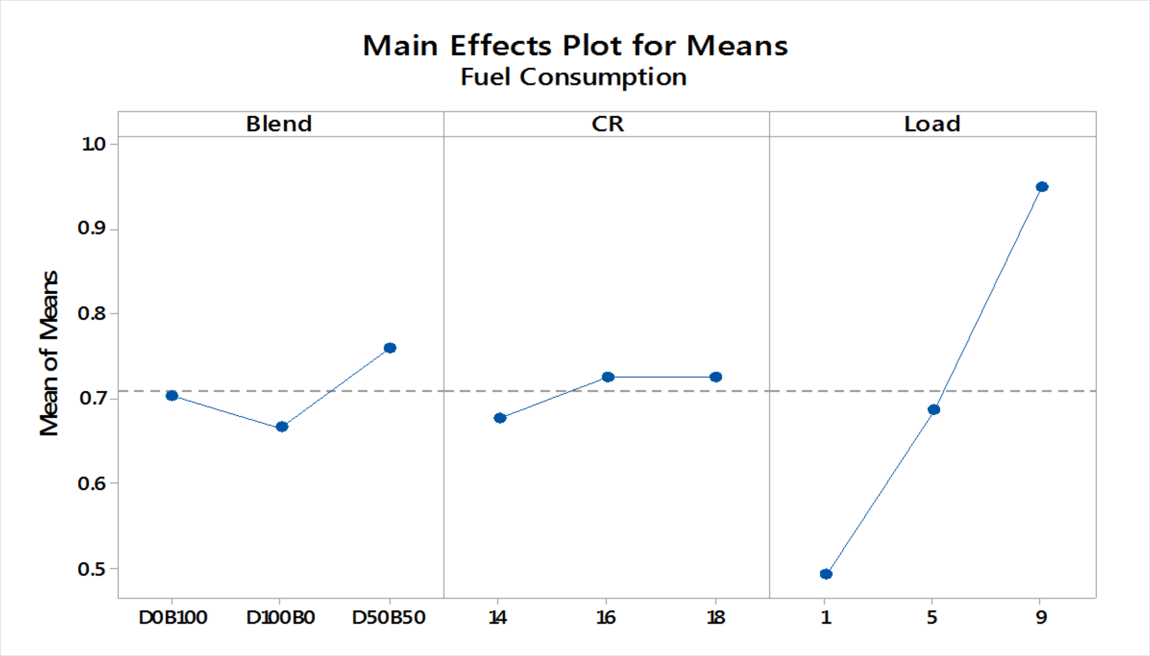

Figure 9. Main effect plot for means: Fuel Consumption

Table 14 Main effects plot for means: Fuel Consumption

Level	Blend	CR	Load
1	0.7032	0.6773	0.4922
2	0.6664	0.7254	0.6865
3	0.7585	0.7254	0.9493
Delta	0.0921	0.0480	0.4571
Rank	2	3	1

A table 11 show that maximum value of delta is 0.4571 (LOAD) and minimum value is 0.0480 (CR). Fuel consumption performance more affected by load and less affected by compression ratio, because of load delta value has maximum and compression ratio delta value has minimum on Means result.

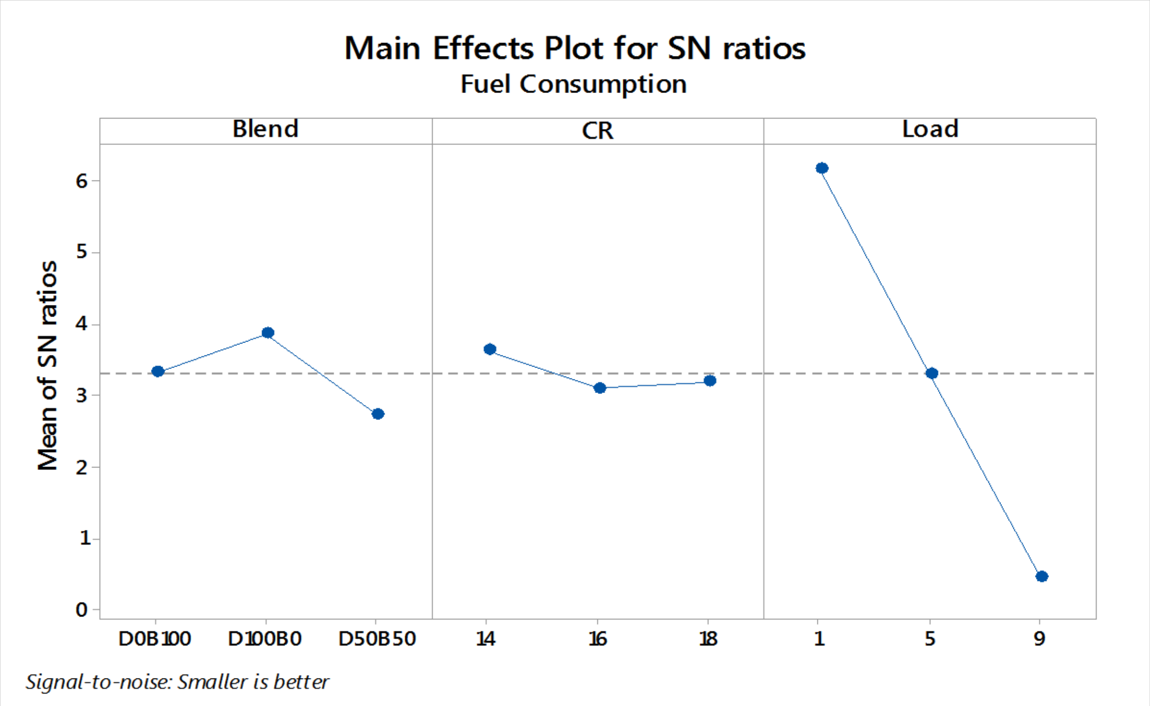

Figure 10. Main effect plot for SN ratio: Fuel Consumption

Table 14 Main effects plot for SN ratio: Fuel Consumption

Level	Blend	CR	Load
1	3.3275	3.6405	6.1752
2	3.8677	3.1037	3.3035
3	2.7432	3.1942	0.4597
Delta	1.1245	0.5368	5.7155
Rank	2	3	1

A table 12 show that maximum value of delta is 5.7155 (LOAD) and minimum value is 0.5368 (CR). FC performance more affected by load and less affected by compression ratio, because of load delta value has maximum and Compression ratio delta value has minimum on S/N ratio result.

Fig. 7 and 8 shows the minimum and maximum value for all parameters. Take the maximum value Form the above graph for the best value of Fuel Consumption. The value was CR14, BR D100B0 and LOAD1. Predicted value gained by the putting Table value in minitab18, compare that value to the experiment value.

Table 14 Optimum set of parameters: Fuel Consumption

Compression Ratio	**BLEND**	**LOAD**	**PREDICTIVE**	**EXPERIMENT**	**DEFFERENCE**
14	D100B0	1	0.39984	0.4172	0.01736

Table 13 shows that Minimum Fuel Consumption got at compression ratio1, Blend Ratio D100B0and Load1.

VII. CONCLUSION

Taguchi method helps to get the best results in minimum run of experiment. As per the experiment analysis & result palm seed oil and blend of palm seed oil can be used in CI engine. The best values of Brake thermal efficiency, Mechanical efficiency & Specific fuel efficiency are obtained, when compression ratio is 14, load is 9 and in pure diesel. Best value of fuel consumption is obtained, when compression ratio is 14, load is 1 and in pure diesel. The blend ratios of palm seed oil and diesel did not show better results as far as study is concern. From the study it is concluded that the palm seed oil is optimistic in CI engine at full load.

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