IOSR Journal of Mechanical and Civil Engineering (IOSR-JMCE)
e-ISSN: 2278-1684,p-ISSN: 2320-334X, Volume 14, Issue 2 Ver. II (Mar. - Apr. 2017), PP 81-90
www.iosrjournals.org

Combine Effect of Variable Compression Ratio and Diffuser at Exhaust Manifold for Single Cylinder CI Engine using Diesel and Palm Biodiesel

Kintesh D Patel[1*], Dr. Tushar M Patel[2], Gaurav P Rathod[3]
[1*]*M.E. Scholar, Mechanical Engineering Department, LDRP-ITR, Gandhinagar, India.*
[2]*Professor, Mechanical Engineering Department, LDRP-ITR, Gandhinagar, India.*
[3]*Lecturer, Mechanical Engineering Department, Govt. Polytechnic,Godhra, India.*

Abstract: *Ecological concern and accessibility of petroleum fuels have brought about interests in the search for substitute fuel for internal combustion engines. In conventional internal combustion (IC) engines, the compression ratio is fixed. One Basic problem is that drive units in the vehicles must successfully drive at varying speeds and loads and in different weather. If a diesel engine has a fixed compression ratio, a minimum value must be selected that can obtaina true self-ignition when starting the engine in cold start conditions. The combustion process in the internal combustion engine is changing cycle to cycle while changing load, speed,etc. It is difficult to obtain good fuel economy and decrease pollution emissions. Literature shows that the design of a taper, straight and lower thermal inertia exhaust manifold takes good mass conservation, fuel economy system and engine efficiency, Back pressure on engine having a powerful influence on engine efficiency and need to be decreased by using divergent shape exhaust manifold. In the experiment change the compression ratio 17, 18, 19 and also change the exhaust manifold. In this experiment engine using the pure diesel and palm biodiesel.An optimumset of Parameter find by using Taguchi method and Periodic value validation with Experiments value.*
Keywords: *Engine performance, Biodiesel, Compression ratio, Diffuser, Taguchi method, Exhaust manifold.*

I. Introduction

The brake thermal efficiency of the engine operating cycle is improved when compression ratio increase, and depends on the mechanical efficiency, which reduce when CR increase [8]. The key problem is that diesel engines do not run at the same loads.The engine in a truck, for example, sometimes play on full power along a highway or up the hill, and sometimes on idle speed at low loads. Diesel engines in general also have to be able to take of start at any temperature range, for example, below zero. For conventional diesel engine with a constant compression ratio, the CR has to be set so high that a dependent self-ignition can always be receive even when starting the engine or when working on very low load with little amount of fuel injected into the cylinder. There is a limit to very high pressures in the cylinder when diesel engine runon full load. Consequently, a high CR additionally impediment the measure of diesel fuel that can be injected at full payload [13]. In the VCR diesel engine, we could expand the compression ratio at start-up and low power and apply it to get steady start and lower the compression ratio when full power is required with a specific end goal to have the capacity to burn more fuel and make more power, yet at the same time having a reliable ignition. [10]. Therefore, the concept of VCR engine is a powerful means for increasing low load engine thermal efficiency and for making it possible to maximize engine power with high pressure-charge. The main objective for these Experiment was to know the impact of compression ratio on the efficiency and emission propertyof the diesel engine at changingloads and variable Compression ratio.

II. Literature review

In the recent year many research on the Engine Exhaust system. There are different exhaust manifold available like as nozzle, diffuser.Iqbal et al. (2013)was studied that performance and emission characteristics of diesel engine running on blended palm oil. Engine performance testing as well shows that the palm oil blends have lower brake thermal efficiencies(BTHE) and higher brake specific fuel consumption(BSFC) agree with BTHE similar to diesel [5]. J. Galindo et al. (2004) carried out experimental work on dual wall airgap exhaust manifold and conventional exhaust manifold. they concluded that dual wall air gap exhaust manifold improve transient performance of an engine due to saving exhaust energy by reducing heat loss to increase catalyst temperature by 50 °C, increase in torque 6.6 % and volumetric efficiency [2]. Patil et al. (2014) Experimental work carried out at engine output condition is 5 kg load and 1500 rpm constant speed and found the result of fuel consumption rate is inversely proportional to the diffuser volume of exhaust manifold. Pressure at outlet of diffuser type exhaust manifold is directly proportional to the diffuser volume of exhaust manifold, which reduces the back pressure [9].Patil et al. (2015) conclude that the increase in inlet cone angle increases the pressure of the flow which leads to reduce the recirculation zones. Installation of the EDS – II increases the brake thermal efficiency and decreases the backpressure [10]. Patel et al. (2013) has been carried out for pyrolysis oil blended with diesel used in single cylinder diesel engine. The results of the Taguchi experiment identifies that 220 injection timing, injection pressure 200 bar, compression ratio 16 and engine load 3 kg are optimum parameter setting for lowest break specific fuel consumption [6]. Parikh et al. (2016) has been carried out palm biodiesel blended with diesel. As a result Mechanical efficiency was high in D60P40 and P100 blend as compared to theconventional diesel fuel [12].A. Karnwak et al. studied on the Taguchi strategy and get ideal numerous performance attributes of a diesel engine with various blends. He infer that the BSFC, BET and EGT of diesel engine depend on the biodiesel-diesel mix, compression ratio, nozzle opening pressure and injection timing and engine parameter give ideal numerous performance for various engine stacking condition [3]. Ramesha et al. studied on the mechanized 4-stroke, single chamber, steady speed, direct injection diesel engine worked on fish oil-biodiesel of various mix. He conclude 20% mix of fish oil with diesel fuel was observed to be the best mix concerning performance and combustion contrast with all other blend [4].

III. Palm bio-diesel

Evaluation of the carbureting quality of vegetable oils requires the determination of their physical and chemical characteristic, such as: calorific value, Cetane level, distillation curve, viscosity, cloud point etc. In Table 1 compares the physical-chemical properties of palm biodiesel to that of petroleum diesel. It is observed that the trans-esterification reaction reduces the calorific value of palm biodiesel, as well as its density, cloud point, sulphur content and carbon residue as compared petroleum diesel. Palm biodiesel has a lower calorific value, however, the higher Cetane level compensates for this disadvantage, i.e., palm biodiesel has higher quality combustion, making maximum use of its energy content.

Table 1: The fuel Properties of Palm seed oil and Diesel

Property	**Palm biodiesel**	**Diesel**
Kinematic viscosity at 40°c (cSt)	4.8	3.0
Density@15°c kg/m3	876	833
Flash point(°c)	130°c	74°c
Fire point(°c)	171°c	120°c
Cetane number	62.8	49
Calorific value(kJ/kg)	38600	42850
Pour point(°c)	17°c	-25°c

IV. Exhaust manifold

The environment which a contending exhaust system, and specially engine head, must survive. It can only be described as a brutal combination of temperatures, stresses, corrosion and vibration. The exhaust technology can help decrease the problems and help to increase the potential gains of the system. There are two separate components to the exhaust event. The first is the removal of exhaust gasses from the cylinder, which occurs as a pulse of hot gas exiting the cylinder and flowing down the header primary tube. The second is the (much faster) travel of the pressure wave in the port created by the pressure spike which occurs when the exhaust valve opens, and the various reflections of that wave. Taking suitable advantage of these pressure waves (component two) can create dramatic improvements in clearing the cylinder (component one) and can powerfully assist the inflow of fresh charge [7]. In automotive engineering, an exhaust manifold gains the exhaust gases from multiple cylinders into one tube. Exhaust manifolds are usually constructed from cast iron or stainless steel units which gain engine exhaust gas from multiple cylinders and deliver it to the exhaust pipe. The high pressure head is development by the high pressure distinction between the exhaust in the burning chamber and the atmospheric pressure outside of the exhaust Arrangement [11]. The immediate pressure advancement forced by the manifold at the exhaust valve depends basically on the design and measurements of the pipes, so that an adequate design of the manifold dimension can improve the engine power, efficiency, and decrease the emissions of pollutants.

Figure 1 Shows Diffuser A, It was made from cast iron. It has outer diameter (61.50mm), inner diameter (31.50mm), length (58mm), and angle with center axis (14.5°).

Figure 2 Shows Diffuser B, It was made from aluminum. It has outer diameter (60.50mm), inner diameter (33.50mm), length (79.50mm), and angle with center axis (10°).

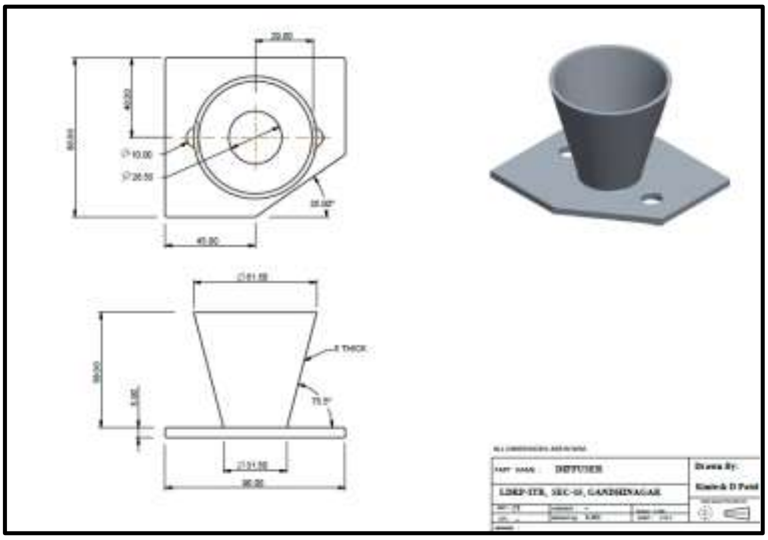

Fig 1: 2D-3D Drawing of Diffuser A

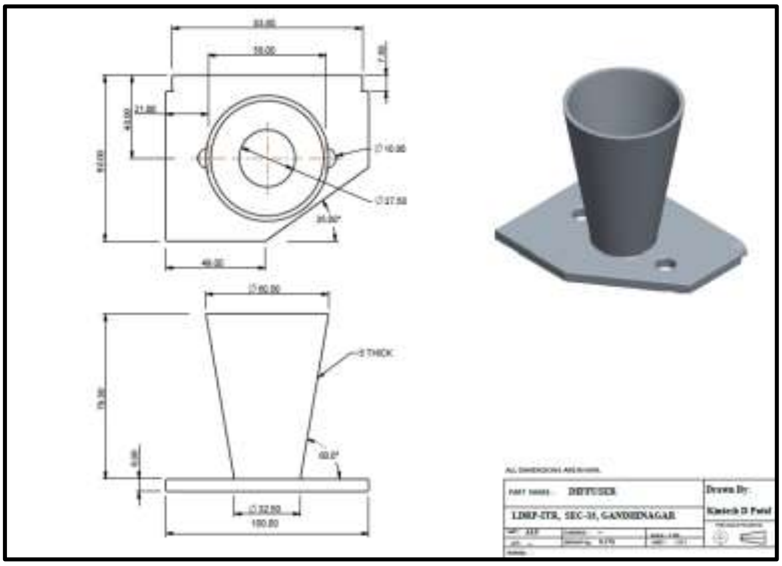

Fig 2: 2D-3D Drawing of Diffuser B

V. Experiment set up

In this experiment, single cylinder IC Engine is used and attached with the eddy current dynamometer with the help of flywheel shaft, varies the load on the engine or load remain constant. Exhaust Gas analyzer is used to find the emission characteristic of exhaust gas from engine. The reading takes by varying the load on the engine using the dynamometer. The mode of operation in this engine can be changed from diesel to Petrol or from Petrol to Diesel with some needed changes. In both operation modes the compression ratio can be changed without stopping the engine and no other changes needed for the geometry of combustion chamber by specially designed tilting cylinder block arrangement. Different other instruments are provided to interface are airflow, fuel flow, temperatures and load measurement devices. For cooling water and calorimeter water flow measurement Rota meter is provided. For auto start of engine a battery, starter and battery charger is provided. Analysis software Engine-soft is provided for on line performance evaluation and lab view based Engine Performance. The test engine used in this experiment is as shown in figure 3.

Different engine performance parameters such as Brake power, indicated power, specific fuel consumption etc. and emission contents such as CO, CO_2, NO_X and HC found from the experiments. In this experiment first engine performance and emission is measured by only using diesel as a fuel. After that the engine performance and emission is measured by diesel with diffuser type exhaust manifold.Then same reading taking with palm biofuel. Compare the results coming out for different exhaust manifold with the only used diesel as a fuel. Than the analysis is being made for which exhaust manifold and biofuel have a best optimized performance and emission characteristics for particularly used diesel engine compared to diesel fuel. Engine Specification as shows in table 2.

Table 2: Engine setup specifications[IC Engine Manual]

Engine manufacturer	Apex Innovations (Research Engine test set up)
Software	Engine soft Engine performance analysis software
Engine type	Single cylinder four stroke multi fuel research engine
No. of cylinder	1
Type of cooling	Water cooled
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

Fig. 3: Engine setup with diffuser.

VI. Observation table and result table

The observed data find out by experiment on diesel engine by using pure diesel and palm biodiesel as a working fuel for variable compression ratio is given in table 3.

Table 3: Observation Table for Variable Compression Ratio

For Diesel fuel, Density: 833 kg/m^3, Calorific value : 42850 kJ/kg Parameter : Compression ratio, Load						**For Palm Biodiesel fuel, Density: 876 kg/m^3, Calorific value : 38600 kJ/kg Parameter : Compression ratio, Load**					
Ex. No	**Diffuser**	**CR**	**Load (kg)**	**RPM**	**FC (cc/min)**	**Air (mmwc)**	**O_2 (%)**	**CO_2 (%)**	**HC (ppm)**	**CO (%)**	**NO_X (ppm)**
1	No	18	1	1528	8	59.09	19.15	0.9	35	0.06	69
2	No	17	6.99	1492	13	56.5	19.18	0.92	38	0.062	67
3	No	16	12.9	1448	20	52.65	17.22	2.1	31	0.03	647
4	diffuser-A	18	7.21	1497	15	57.55	14.32	4.1	40	0.05	890
5	diffuser-A	17	12.96	1453	19	52.58	13	4.3	63	0.09	1080
6	diffuser-A	16	1	1520	8	62.28	18.43	1.3	42	0.2	27
7	diffuser-B	18	11.63	1439	19	51.66	11.8	5.4	43	0.09	2400
8	diffuser-B	17	1.06	1519	8	62.81	11.69	1.7	25	0.16	18
9	diffuser-B	16	7.11	1487	13	59.59	14.76	3.1	37	0.11	420
10	No	18	1.04	1530	8	58.79	19.08	0.9	25	0.06	26
11	No	17	6.97	1505	15	57.12	18.1	1.5	30	0.04	113
12	No	16	12.97	1447	21	51.33	17.18	2.1	35	0.04	488

13	diffuser-A	18	7.16	1475	13	57.04	14.9	3.6	37	0.07	731
14	diffuser-A	17	12.75	1464	21	55.16	11.89	6.3	69	0.08	1813
15	diffuser-A	16	1.22	1501	9	60.08	18.63	0.8	22	0.06	72
16	diffuser-B	18	12.98	1502	23	53.44	11.27	6.3	50	0.11	223
17	diffuser-B	17	1.09	1557	9	65.21	17.47	1.9	41	0.2	106
18	diffuser-B	16	7.25	1504	16	59.04	14.6	4.1	56	0.12	520

The result data obtained from the observed data for pure diesel and palm biodiesel fuelled in diesel engine for variable compression ratio is given in table 4.

Table 4: Result Table for Variable Compression Ratio

Ex. No.	**Load (kg)**	**Torque (Nm)**	**IP (kW)**	**BP (kW)**	**FP (kW)**	**ITHE (%)**	**BTHE (%)**	**Mech. eff. (%)**	**Vol. eff. (%)**	**SFC (kg/kWh)**	**FC kg/hr.**	**Air kg/hr.**
1	1	1.81	3.7	0.29	3.41	77.72	6.1	7.84	70.33	1.38	0.4	25.03
2	6.99	12.68	5.23	1.98	3.25	67.58	25.62	37.91	70.43	0.3	0.65	24.48
3	12.9	23.49	6.93	3.55	3.38	58.25	29.83	51.21	70.06	0.28	1	23.63
4	7.21	13.09	5.9	2.05	3.85	77.72	6.1	34.76	70.84	0.3	0.65	24.7
5	12.96	23.51	6.7	3.58	3.12	59.26	31.65	53.41	69.77	0.27	0.95	23.61
6	1	1.82	3.43	0.29	3.14	72.08	6.08	8.44	72.59	1.38	0.4	25.7
7	11.63	21.12	6.16	3.18	2.98	54.5	28.15	51.65	69.83	0.3	0.95	23.41
8	1.06	1.93	3.59	0.31	3.28	75.4	6.46	8.57	72.94	1.3	0.4	25.81
9	7.11	12.91	5.25	2.01	3.24	67.91	26.03	38.33	72.48	0.32	0.65	25.14
10	1.04	1.89	3.88	0.3	3.58	81.57	6.37	7.81	69.24	1.32	0.42	25.27
11	6.97	12.65	5.52	1.99	3.53	65.34	23.59	36.1	31.22	0.4	0.79	24.61
12	12.97	23.53	7.13	3.57	3.56	60.18	30.13	50.07	69.22	0.31	1.1	23.33
13	7.16	13	5.17	2.01	3.16	70.49	27.41	38.89	71.58	0.34	0.68	24.6
14	12.75	23.15	6.89	3.55	3.34	58.18	29.98	51.54	70.93	0.31	1.1	24.19
15	1.22	2.21	3.44	0.35	3.09	67.75	6.86	10.12	72.2	1.36	0.47	25.24
16	12.98	23.57	7.26	3.71	3.55	56.62	28.06	51.05	68.04	0.33	1.21	23.81
17	1.09	1.97	4.4	0.32	4.08	86.71	6.34	7.31	72.51	1.47	0.47	26.3
18	7.25	13.15	5.79	2.07	3.72	64.18	22.97	35.8	71.42	0.41	0.84	25.02

VII. Result and discussion

In the experiment, four parameters is consider like as fuel (Diesel and Palm Biodiesel), Diffuser (No, Diffuser A, Diffuser B), compression ratio (18, 17, 16) and Load (1, 7, 13).From this parameter to Discuss Brake thermal efficiency, specific fuel consumption and NO_X emission. This result discuss from the Minitab software Then Validation of Optimum set of Parameter.

7.1 Taguchi Analysis for Brake Thermal Efficiency

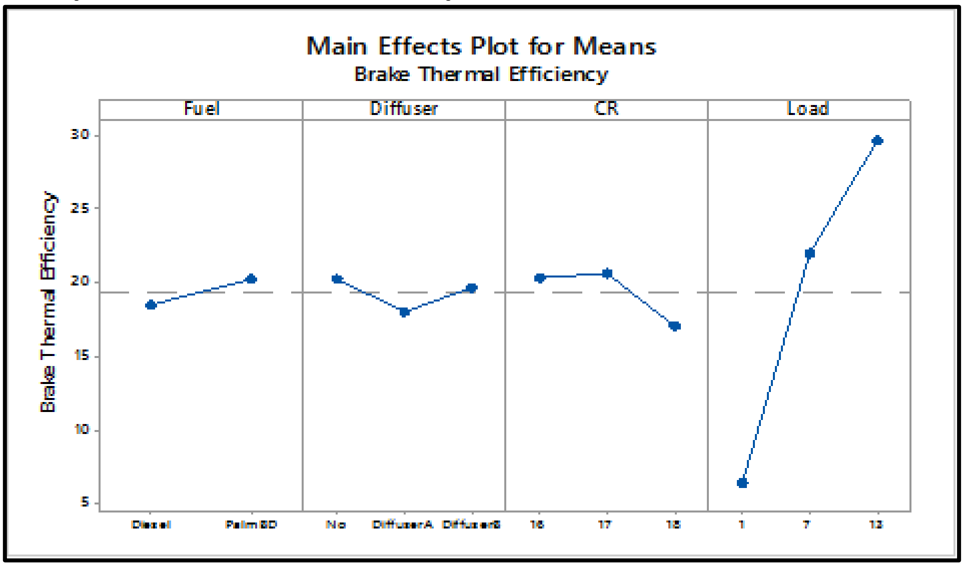

Fig. 4: Main Effects Plot for Means of Brake Thermal Efficiency

Table 5: Response Table for S/N Ratios of Brake Thermal Efficiency

Level	Fuel	Diffuser	CR	Load
1	23.14	24.41	24.50	16.07
2	24.29	22.74	24.57	25.94
3	-	24.29	22.37	29.43
Delta	1.34	1.68	2.02	13.35
Rank	4	3	2	1

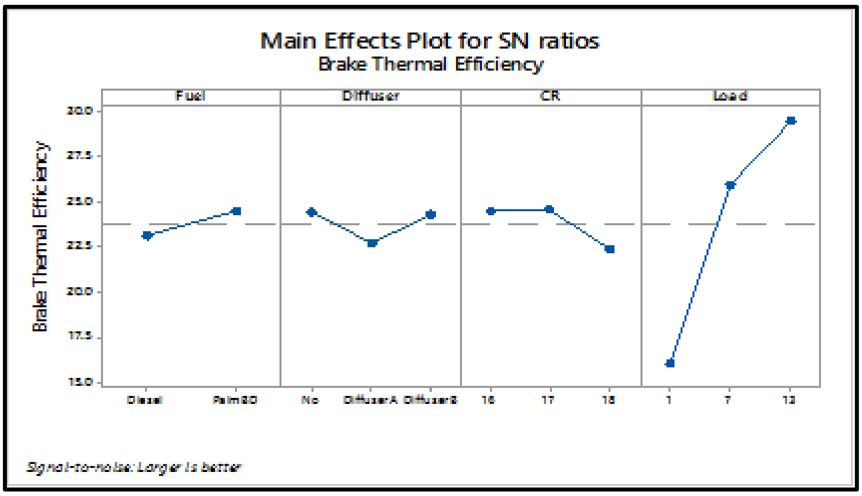

Fig. 5: Main Effects Plot for S/N ratios of Brake Thermal Efficiency

Response curve analysis is aimed at determining influential parameter and their optimum set of control parameters. Figure shows response at each factor level. The S/N Ratio for the different performance responses were is calculated at each factor. The S/N Ratio for different performance response were calculated at each factor level and the average effect were determined by taking the total of each factor level and divided by the number of data points in the total. The greater difference between S/N ratio values the levels, the parametric influence will be much. The parameter level having the highest S/N ratio corresponds to the sets of parameters indicates highest performance.

The term optimum setting is reflects only optimal combination of the parameters defined by this experiment. The optimum setting is determined by choosing the level with the highest S/N ratio. Referring (figure 5) the response curve for S/N ratio, the highest S/N ratio was observed at Palm Biodiesel Fuel, Engine Load (13 kg), No Diffuser and Compression ratio (17), which are optimum parameter setting for highest Brake thermal efficiency. From delta values as mention table 5, maximum (13.35) for engine load and minimum (1.34) for fuel. Parameter engine load is most significant parameter and fuel is least significant for Brake Thermal efficiency. Optimum parameter set as shown in table 6.

Table 6: Optimize Set of Parameter for Brake Thermal Efficiency

Fuel	Diffuser	CR	Load	BTHE (%)	SN Ratio
PalmBD	No Diffuser	17	13	31.6333	30.7441

Experiment has been carried out using optimum set of parameter. Experimental brake thermal efficiency for optimum set of parameter is 30.20 %. This experimental value is nearer to predicted value 31.6333 %as shown in table 7.

Table 7: Validation Results for Brake Thermal Efficiency

Predicted Value	Experimental Value	% Variation
31.633%	30.20%	4.7

7.2 Taguchi Analysis for Specific Fuel Consumption

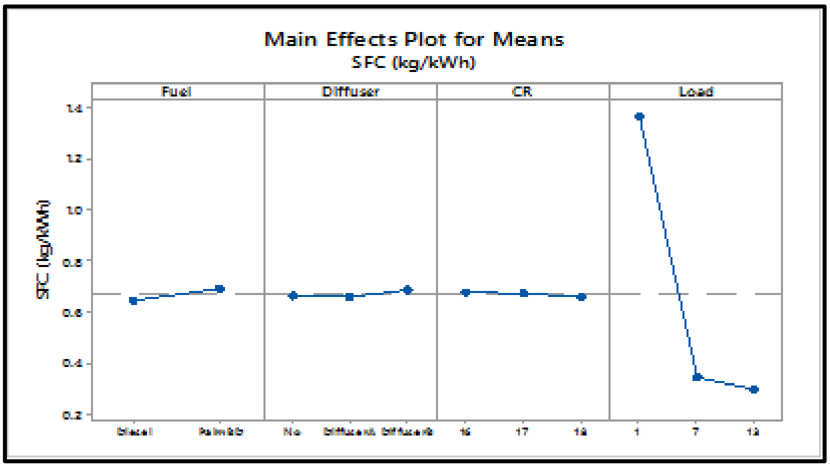

Fig. 6: Main Effects Plot for Means ofSpecific Fuel Consumption

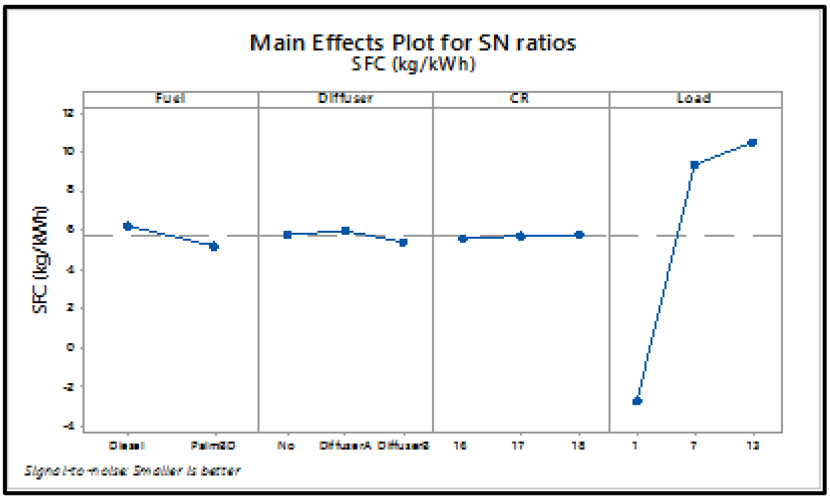

Fig. 7: Main Effects Plot for S/N ratios of Specific Fuel Consumption

Table 8: Response Table for S/N Ratios of Specific Fuel Consumption

Level	Fuel	Diffuser	CR	Load
1	6.023	5.739	5.567	-2.717
2	5.180	5.984	5.723	9.314
3	-	5.351	5.784	10.477
Delta	1.023	0.634	0.217	13.194
Rank	2	3	4	1

The term optimum setting is reflects only optimal combination of the parameters defined by this experiment. The optimum setting is determined by choosing the level with the largest S/N ratio. Referring (figure 7) the response curve for S/N ratio, the largest S/N ratio was observed at Diesel fuel, Engine Load (13 kg), Diffuser A and Compression ratio (18), which are optimum parameter setting for Smaller Specific fuel Consumption. From delta values as mention table 8, maximum (13.194) for engine load and minimum (0.217) for fuel. Parameter engine load is most significant parameter and Fuel is least significant for Specific fuel Consumption. Optimum parameter set as shown in table 9.

Table 9: Optimize Set of Parameter for Specific fuel Consumption

Fuel	Diffuser	CR	Load	SFC (kg/kWh)	SN Ratio
Diesel	Diffuser A	18	13	0.269	11.22

Experiment has been carried out using optimum set of parameter. ExperimentalSpecific fuel consumptionfor optimum set of parameter is 0.28 kg/kWh. This experimental value is nearer to predicted value 0.269 kg/kWh as shown in table 10.

Table 10: Validation Results for Specific fuel Consumption

Predicted Value	Experimental Value	% Variation
0.269 kg/kWh	0.28 kg/kWh	3.9

7.3Taguchi Analysis for NO_X Emission

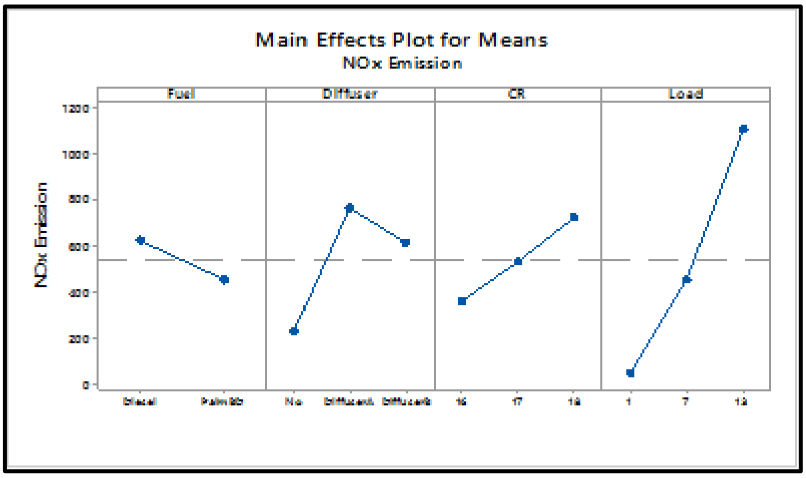

Fig. 8: Main Effects Plot for Means of NO_X Emission

Table 11: Response Table for S/N Ratios of NO_X Emission

Level	Fuel	Diffuser	CR	Load
1	-47.00	-42.11	-47.09	-32.74
2	-47.17	-51.31	-44.84	-50.11
3	-	-47.83	-49.32	-58.40
Delta	0.17	9.21	4.48	25.66
Rank	4	2	3	1

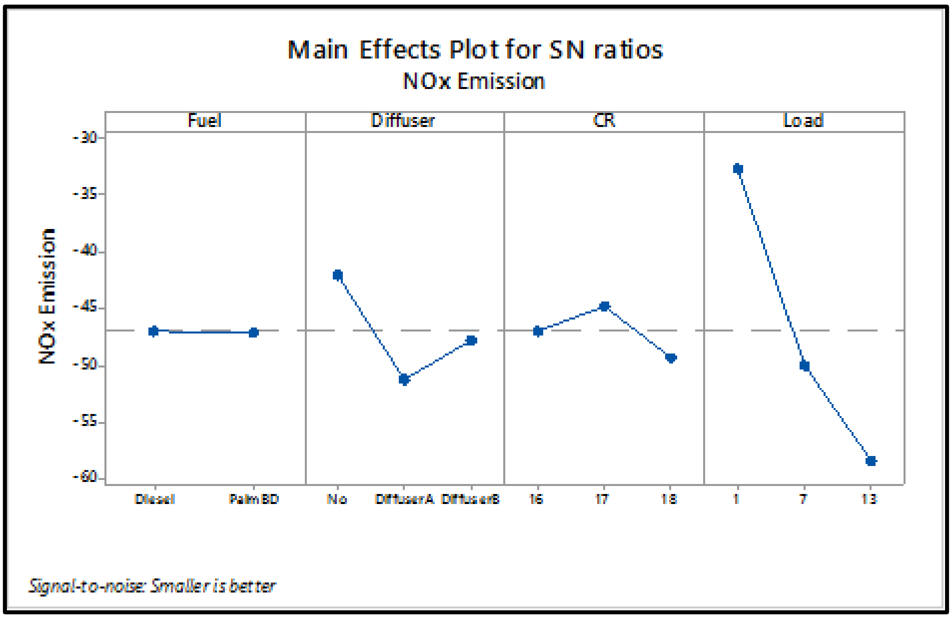

Fig. 9: Main Effects Plot for S/N ratios of Specific Fuel Consumption

The term optimum setting is reflects only optimal combination of the parameters defined by this experiment. The optimum setting is determined by choosing the level with the largest S/N ratio. Referring (figure 9) the response curve for S/N ratio, the largest S/N ratio was observed at Diesel Fuel, Engine Load (1 kg), No Diffuser and Compression ratio (17), which are optimum parameter setting for Smaller NO_X Emission. From delta values as mention table 11, maximum (25.66) for engine load and minimum (0.17) for fuel.

Parameter engine load is most significant parameter and Fuel is least significant for NO_X Emission. Optimum parameter set as shown in table 12.

Table 12: Optimize Set of Parameter for NO_X Emission

Fuel	Diffuser	CR	Load	NO_X Emission (ppm)	SN Ratio
Diesel	No Diffuser	17	1	232	26.58

Experiment has been carried out using optimum set of parameter. ExperimentalNO_X Emissionfor optimum set of parameter is 250 ppm. This experimental value is nearer to predicted value 232 ppm as shown in table 13.

Table 13: Validation Results for NO_X Emission

Predicted Value	Experimental Value	% Variation
232 ppm	250 ppm	7.2

VIII. Conclusion

The Taguchi method was found to be an efficient technique for quantifying the effect of control parameters. Result discuss below,

- For Brake Thermal efficiency, Palm Biodiesel Fuel, No Diffuser and Compression ratio (17) and Engine Load (13 kg), which are optimum parameter. This experimental value 30.20% which nearer to predicted value 31.6333%.
- For Specific fuel Consumption, diesel Fuel, Diesel fuel,Diffuser A, Compression ratio (18) and Engine Load (13 kg) which are optimum parameter. This experimental value 0.28 kg/kWh which nearer to predicted value 0.269 kg/kWh.
- For NO_X Emission, Diesel Fuel, No Diffuser, Compression ratio (17) and Engine Load (1 kg) which are optimum parameter. This experimental value 250 ppm which nearer to predicted value 232 ppm.

References

[1] World energy consumption by source, 1990-2040

[2] J. Galindo , J.M. Lujan , J.R. Serrano , V. Dolz , S. Guilain, “Design of an exhaust manifold to improve transient performance of a high-speed turbocharged diesel engine” Experimental Thermal and Fluid Science 28 (2004) 863–875.

[3] A. Karnwal, M.M Hasan, N. Kumar, Z.A. Khan (2011) Multi-Response Optimization of diesel engine performance parameters using thumba biodiesel-diesel blends by applying the taguchi method.

[4] Ramesha, D. K., Thimmannachar, R. K., Simhasan, R., Nagappa, M., &Gowda, P. M. (2012). A Study on Performance, Combustion and Emission Characteristics of Compression Ignition Engine Using Fish Oil Biodiesel Blends. Journal of The Institution of Engineers (India): Series C, 93(3), 195–201. https://doi.org/10.1007/s40032-012-0030-4

[5] Iqbal, A. M., Zainal, Z. A., Mazlan, M., Al-Bakri, A. M. M., &Salim, M. S. (2013). Performance and Emission Characteristics of Diesel Engine Running on Blended Palm Oil. 2nd International Conference on Sustainable Materials, 795(August 2015), 164–169.

[6] Patel, K. B., Patel, T. M., & Patel, S. C. (2013). |Parametric Optimization of Single Cylinder Diesel Engine for Pyrolysis Oil and Diesel Blend for Specific Fuel Consumption Using Taguchi Method, |6(1)|, 83–88.

[7] Exhaust System Technology: Science and Implementation of High Performance Exhaust Systems.

[8] Modi, M. A., Patel, T. M., &Rathod, G. P. (2014). Parametric Optimization Of |Single Cylinder Diesel Engine For Palm Seed Oil & Diesel Blend| For Brake Thermal Efficiency Using Taguchi Method, |4(5)|, 49–54.

[9] Patil, A. A., Navale, L. G., &Patil, V. S. (2014). Experimental Investigation and Analysis of Single Cylinder Four Stroke CI. Engine Exhaust System, 3(1), 1–6.

[10] Patil, D. D., Kumbhare, S., & Thakur, K. K. (2015). CFD Analysis of Exhaust System and Effect of Back Pressure on Engine Performance, 1(1), 1–9.

[11] Dole, N. B., &Bhangale, J. H. (2016). A review on effect of backpressure on exhaust system, 3(1), 163–168.
[12] Parikh, H. Y., Patel, T. M., Rathod, G. P., & R, P. P. (2016). Performance Investigation of the Single Cylinder Diesel Engine Fueled with the Palm Biodiesel-Diesel Blend, IOSR Journal of Mechanical and Civil Engineering 13 (2), 22-28.
[13] Rao, P., Abdulrahman, G. A., &Mahmood, S. (2016). Parametric Optimization through Numerical Simulation of VCR Diesel Engine. Journal of The Institution of Engineers (India): Series C, (x). https://doi.org/10.1007/s40032-016-0298-x