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COMBINED EFFECT OF DIFFUSER AT EXHAUST MANIFOLD AND WPO BLEND ON CI ENGINE USING TAGUCHI APPROACH AND PICK PRESSURE ANALYSIS

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Abstract-*Nowadays waste plastic is a big problem worldwide. To counter that problem pyrolysis process can be used, which is converting the waste plastic into the waste plastic oil. To use waste plastic oil as an alternative fuel is good option in place fossil fuel. Here study the effect of exhaust manifold on the performance of CI engine. Taguchi method is used to reduce the experiment run and it helps to get best result in short time. Experiments have been performed according to L18 orthogonal array were take 18 rows and 4 columns at 3 factors with 4 parameters.Selected parameters are Compression ratio, Blend, Load and Exhaust manifold, base on this parameter analyse the Brake thermal Efficiency, Specific Fuel Consumption, Fuel Consumption, Mechanical Efficiency. 10° exhaust manifold used with (18, 17, 16) compression ratio, (100D0B, 50D50B, 0D100B) Blend, (2, 7, 12) Load. Here get the best combination of the parameters which give the best result of Brake Thermal Efficiency, Specific Fuel Consumption, Fuel flow and Mechanical Efficiency.*

Keywords: *WPO, Taguchi method, exhaust manifold, blend, CI engine.*

Nomenclatures	
BTHE	Brake Thermal Efficiency
SFC	Specific Fuel Consumption
FC	Fuel Consumption
MECH EFF.	Mechanical Efficiency
S/N Ratio	Signal to Noise Ratio
WPO	Waste Plastic Oil
D.A	Draft Angle
D.O.E	Design of Experiment
100D0B	100% Diesel, 0% Waste Plastic Oil
50D50B	50% Diesel,50% Waste Plastic Oil
0D100B	0% Diesel, 100% Waste Plastic Oil

I. INTRODUCTION

The world is facing many big problems and one problem has the plastic waste. Plastic has some characteristics due to that it cannot be biodegradable and recycled easily. One major problem is fossil fuel quantity. Waste plastic can be utilized by the pyrolysis process to produce WPO. By using WPO reduces the environment pollution and reduces the amount of fossil fuel use [1]. The exhaust emission system significantly affects the engine performance. Exhaust emission system modification done by changing the design of the exhaust manifold. The Exhaust manifold is selected parameter for improving the exhaust emission system. Here use the 10° exhaust manifold use for better performance, gradually increase the area of exhaust manifold allow for more gas pass through the exhaust system and reduce the scavenging effect [2]. Compression ratio was another selected parameter which affected the performance of CI engine. By changing compression ratio, thermal efficiency also changes. By increasing the compression ratio, thermal efficiency also increases due to this engine performance increase [3]. The main goal is to study the effect of using exhaust manifold in CI engine.

II. LITERATURE REVIEW

Rana et al. have studied that WPO property was close to the diesel and can be used in diesel engine without modification. The blend gives batter brake thermal efficiency compared to the diesel. In the blend reduce the smoke opacity [4]. **Pappula et al.** Have studied that the Property of WPO and a blend of WPO have acceptable too used directly in CI engine. Brake thermal efficiency increases with increasing load for all blend and WPO, proper atomization and vaporization have done. 50% blend has higher brake thermal efficiency and lower hydrocarbon and carbon dioxide emission then the diesel [5]. **Tae et al.** have studied that some properties of blend such as viscosity, auto ignition and delay period improved. Due to higher viscosity in WPO help to get combustion stability [6]. **Rinaldini et al.** have studied that volumetric fuel rate has lower in the WPO. Specific Fuel Consumption has decreased at low speed and increase at high speed for the blend. WPO has lower density due to that BSFC also low [7]. **Choudhary et al.** have studied that the maximum cylinder pressure was obtained at 19.5:1 compression ratio. Combustion period is less at the highest pressure. Brake Thermal Efficiency increase with increase compression ratio. Exhaust gas temperature decreases with increase compression ratio. NO_x and unburned hydrocarbon emission was increased and carbon dioxide emission was decreased [8]. **Gupta et al.** have studied that the diesel engine has worked smoothly and successfully with biofuel. Brake Thermal Efficiency highest at blend 50% and at highest compression ratio. CO, HC and NO_x have been decreased and CO_2 has been increasing at blend 50% and compression ratio 20 [9]. **Zhou et al.** have studied that torque and BSFC have improved by increasing the compression ratio. The Compression ratio has influenced more NO_x with increase speed and load [10]. **Bhasker et al.** have studied that brake power and brake thermal efficiency increase with increasing compression ratio. Hydrocarbon emission has drastically decreased at compression ratio 12.5:1. CO_2 has decreased with an increase in compression ratio [11]. **Patel et al.** have studied Taguchi is one of the best methods for product and process. This has decreased the number of runs and save time [12].
Properties of WPO are shown in Table 1.

Table 1. Properties of waste plastic oil [12].

Parameter	Unit	Result
Density @ 15º C	kg/m^3	890
Kinematic viscosity @ 40º C	CP	14.12
Kinematic viscosity @ 100ºC	CP	9.55
Flash point	ºC	132

III. EXPERIMENT SETUP

Experiment setup shown in Figure1. Here the single cylinder engine has been used with variable load. This engine is working on both fuel (petrol and diesel). Compression ratio also can be varied in this setup. This setup is connected to the CI engine software.

Figure 1. Experiment setup [13]

Figure 2. Exhaust manifold

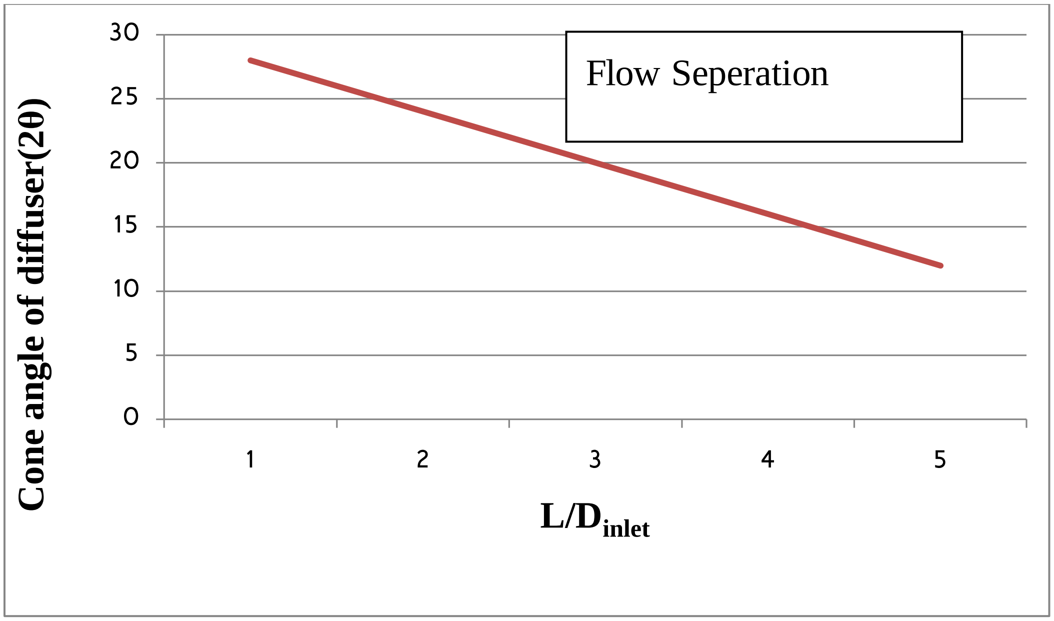

Figure 3. Cone angles of diffuser Vs L/Dinlet

Table 2 shows the specification of exhaust manifold and Table 3 shows the engine specification.

Table 2. Specification of exhaust manifold

Exhaust manifold	Conventional manifold	Diffuser shape manifold
Material	Cast iron	Stainless steel
Inlet diameter	28 mm	28 mm
Outlet diameter	28 mm	57.50 mm
Length	62.5 mm	84 mm
Thickness	5 mm	5 mm
Half cone angle	0°	10°

Table 3. Engine specification [13]

Number of Cylinders	Single cylinder
Number of Srtoke	4
Swept Volume	552.64 cc
Cylinder Diameter	80 mm
Srtoke length	110mm
Connecting Rod Length	234mm
Orific Diameter	20mm
Dynamometer Rotor Radius	141mm
Fuel	Diesel
Power	5.2 kW
Speed	1500rpm
Compression Ratio Range	12 to 18
Inj. Point variation	0 to 25BTDC

IV. METHODOLOGY

Taguchi method has been used for the optimization of the process. In the Taguchi method two types of input is used: 1. Control variable (design parameter) 2. Noise variable (value is hard to control during the process. Taguchi method is used only when factors are between in 3-50.

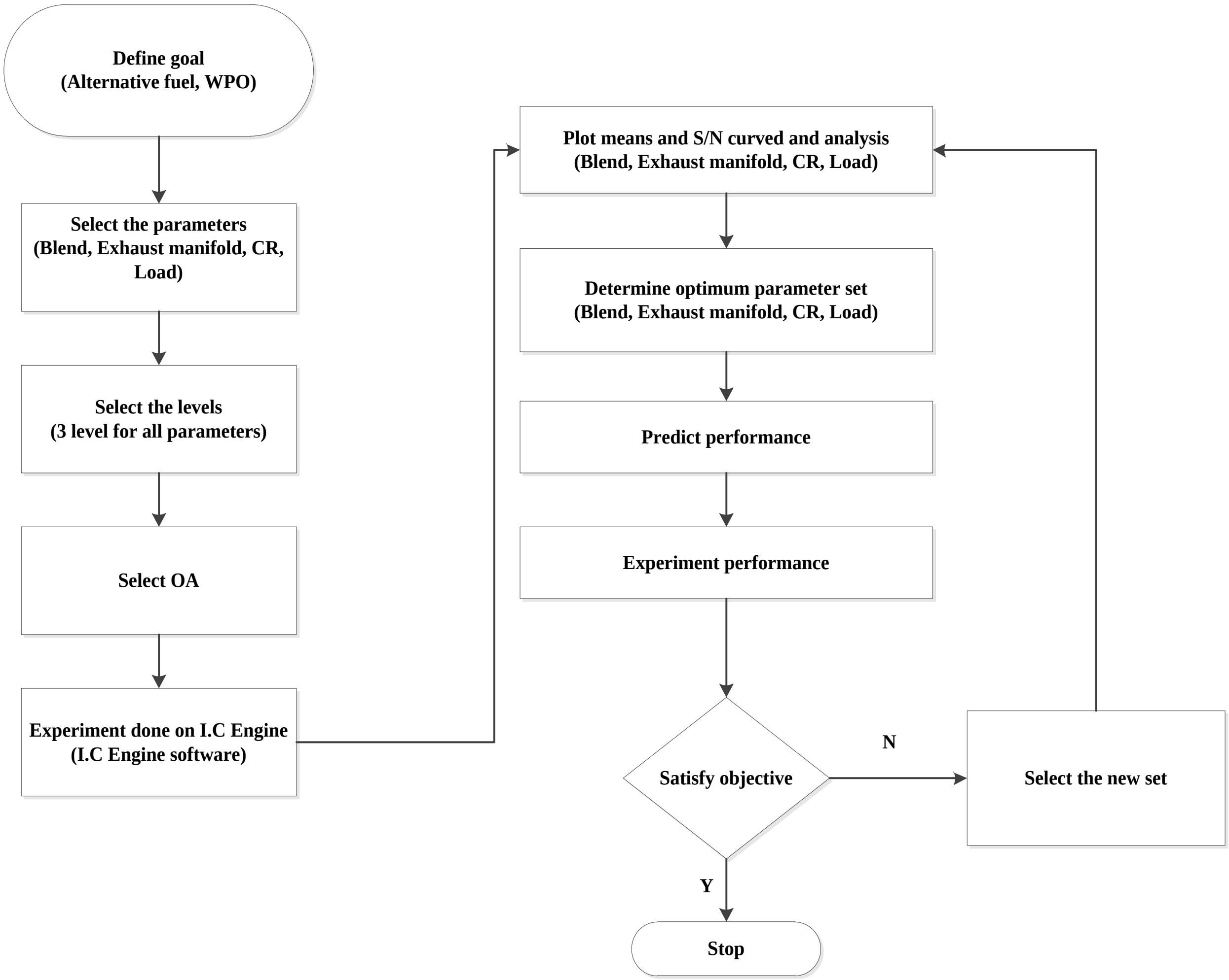

Figure 4. Flow chart of experiment

Firstly create Taguchi table L18 in minitab18 then experiment carried out on C.I. Engine collects the data and put in minitab18 after that got the S/N ratio and mean value graph.
S/N ratio, mean value and variation have been obtained by analyzing experiment data in minitab18. The S/N ratio has been taken instead of standard deviation, because of that standard deviation has been decreased with decreased in mean value and vice versa [14].

V. FACTORS AND LEVELS

Experiments have been performed according to L18 orthogonal array for exhaust manifolds, compression ratio, blend and load. In the experiment table take 18 rows and 4 columns at 3 factors. Those 3 parameters are shown in Taguchi Table 4.
The experiment has been done on the basis of the table and got the results, then after transferring the results into the S/N ratio and mean. For finding the optimum set of parameter, The Taguchi analysis has been used to analyze the optimum set which gave the predictive value.

Table 4. Factors and their levels

Factor	Level1	Level2	Level3
Compression Ratio	16	17	18
Blend%	100D0B	50D50B	0D100B
Load	2	7	12

VI. RESULT AND DISCUSSION

Table 5. Experimental results table

Sr. No	Diffuser	Compression ratio	Blend%	Load (Kg)	Brake Thermal Efficiency (%)	Mechanical Efficiency (%)	Fuel Consumption (Kg/H)	Specific Fuel Consumption (Kg/Kwh)
1	N	18	100D0B	2	18.62	12.55	0.27	0.43
2	N	18	50D50B	7	45.98	33.49	0.37	0.17
3	N	18	0D100B	12	57.55	48.59	0.48	0.14
4	N	17	100D0B	7	46.37	36.23	0.37	0.17
5	N	17	50D50B	12	57.08	49.79	0.48	0.14
6	N	17	0D100B	2	18.33	10.68	0.21	0.44
7	N	16	100D0B	12	52	47.9	0.53	0.15
8	N	16	50D50B	2	20.9	12.61	0.21	0.38
9	N	16	0D100B	7	44.71	34.8	0.37	0.18
10	Y	18	100D0B	2	21.86	11.79	0.21	0.37
11	Y	18	50D50B	7	50.31	34.68	0.32	0.16
12	Y	18	0D100B	12	55.4	47.05	0.48	0.14
13	Y	17	100D0B	7	42.56	35.97	0.37	0.19
14	Y	17	50D50B	12	52.8	49.85	0.48	0.15
15	Y	17	0D100B	2	22.36	15.77	0.21	0.36
16	Y	16	100D0B	12	54.04	51.25	0.48	0.15
17	Y	16	50D50B	2	22.43	15.22	0.21	0.36
18	Y	16	0D100B	7	50.7	37.94	0.32	0.16

Mechanical efficiency, brake thermal efficiency, fuel consumption and specific fuel consumption have been analyzed for each set of parameter using the IC engine software. Minitab18 offers Taguchi method in DOE. The graphs were created by putting all data in minitab18 and following the required steps. Based on those graphs the optimum set is gained. Putting that optimum set in minitab18 and following the steps and the predictive value has been obtained.

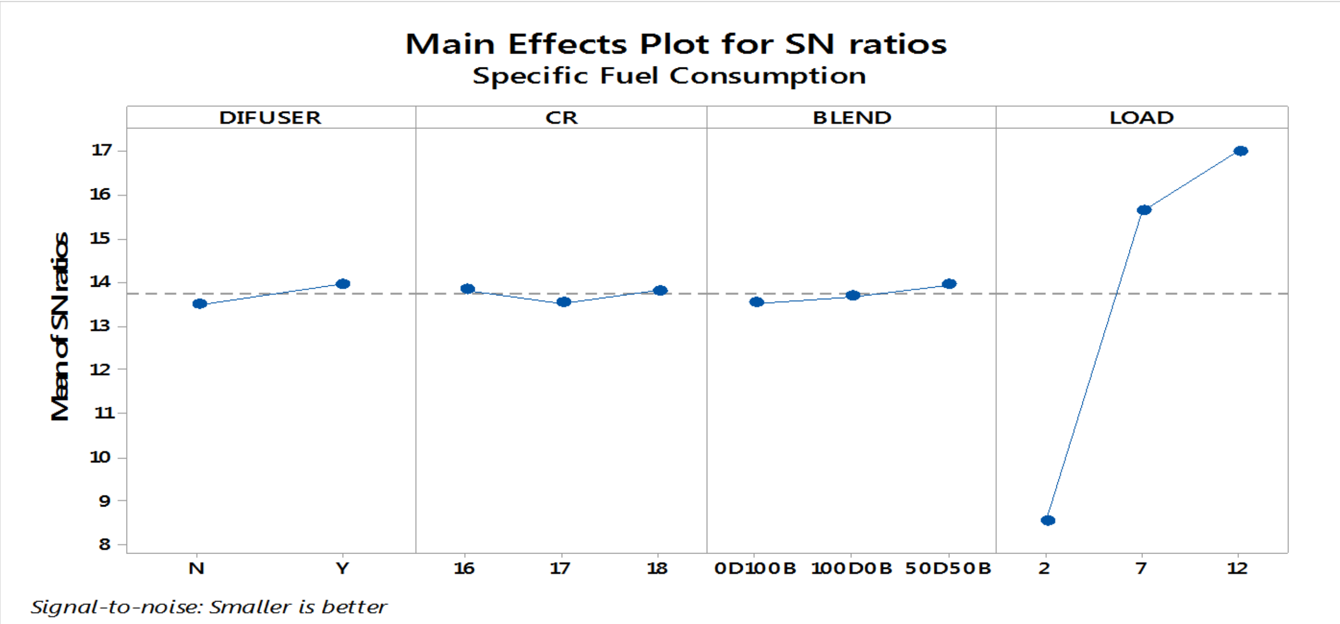

Figure 4. Main effect plot for SN ratio: Specific Fuel Consumption

Table 6. Main effects plot for SN ratio: Specific Fuel Consumption

Level	**Diffuser**	**Compression Ratio**	**Blend**	**Load**
1	0.2370	0.2218	0.2350	0.3754
2	0.2177	0.2351	0.2276	0.1656
3		0.2252	0.2195	0.1411
Delta	0.0193	0.0133	0.0155	0.2343
Rank	2	4	3	1

Table 6 show that the maximum value of the delta is 0.2343 (LOAD) and the minimum value is 0.0133 (CR). Specific Fuel Consumption performance more affected by load and less affected by compression ratio, because of load delta value has a maximum and compression ratio delta value has a minimum on Means result.

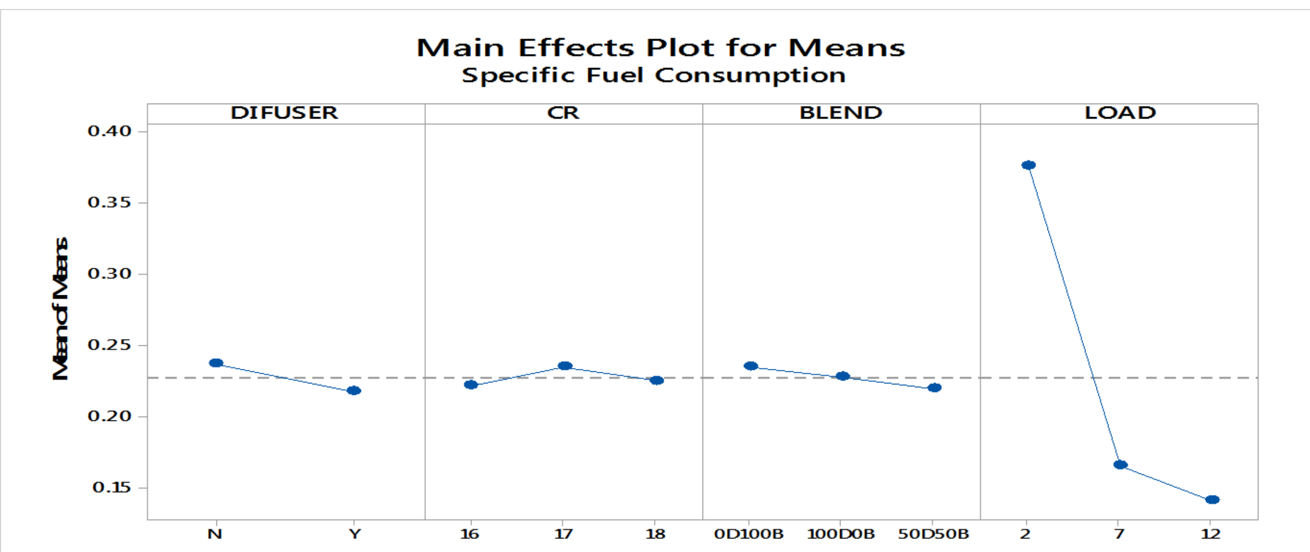

Figure 5. Main effect plot for means: Specific Fuel Consumption

Table 7. Main effects plot for means: Specific Fuel Consumption

Level	Diffuser	Compression Ratio	Blend	Load
1	31.84	32.18	31.58	26.89
2	32.31	31.88	32.36	33.98
3		32.16	32.29	35.36
Delta	0.47	0.30	0.77	8.47
Rank	3	4	2	1

Table 7 show that the maximum value of the delta is 8.47 (LOAD) and the minimum value is 0.30 (CR). Specific Fuel Consumption performance more affected by load and less affected by compression ratio, because of the load delta value has a maximum and compression ratio delta value has a minimum on the S/N ratio result.

Figure 9 and 10 shows the minimum and maximum value for all parameters. Take the maximum value from the above graph for the best value of Specific Fuel Consumption. The value was DA Y, CR16, BLEND50D50B and LOAD2. Predicted value gained by the putting Table value in minitab18, compare that value to the experiment value.

Table 8. Optimum set of parameters: Specific Fuel Consumption

Diffuser	Compression Ratio	Blend	Load	Predicted SFC	Experimental SFC	Error
Y	16	50D50B	12	0.11798	0.11808	0.0001

Table 8 show the Minimum Specific Fuel Consumption got at the draft angle Y, compression ratio16, Blend Ratio50D50B and Load12.

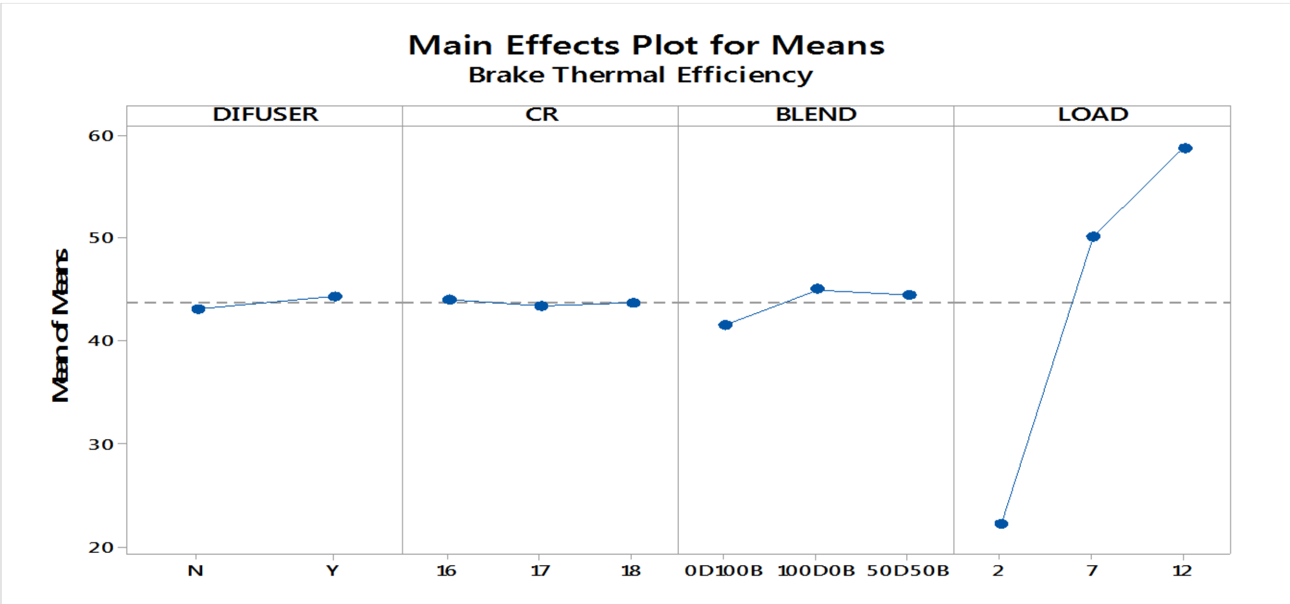

Figure 6. Main effect plot for means: BTHE

Table 9. Main effects plot for means: BTHE

Level	Diffuser	Compression Ratio	Blend	Load
1	43.01	43.93	41.55	22.21
2	44.29	43.36	44.97	50.10
3		43.66	44.43	58.64
Delta	1.29	0.57	3.42	36.44
Rank	3	4	2	1

Table 9 show that the maximum value of the delta is 36.44 (LOAD) and the minimum value is 0.57 (CR). BTHE performance more affected by load and less affected by compression ratio, because of load delta value has a maximum and Compression ratio delta value has a minimum on Means result.

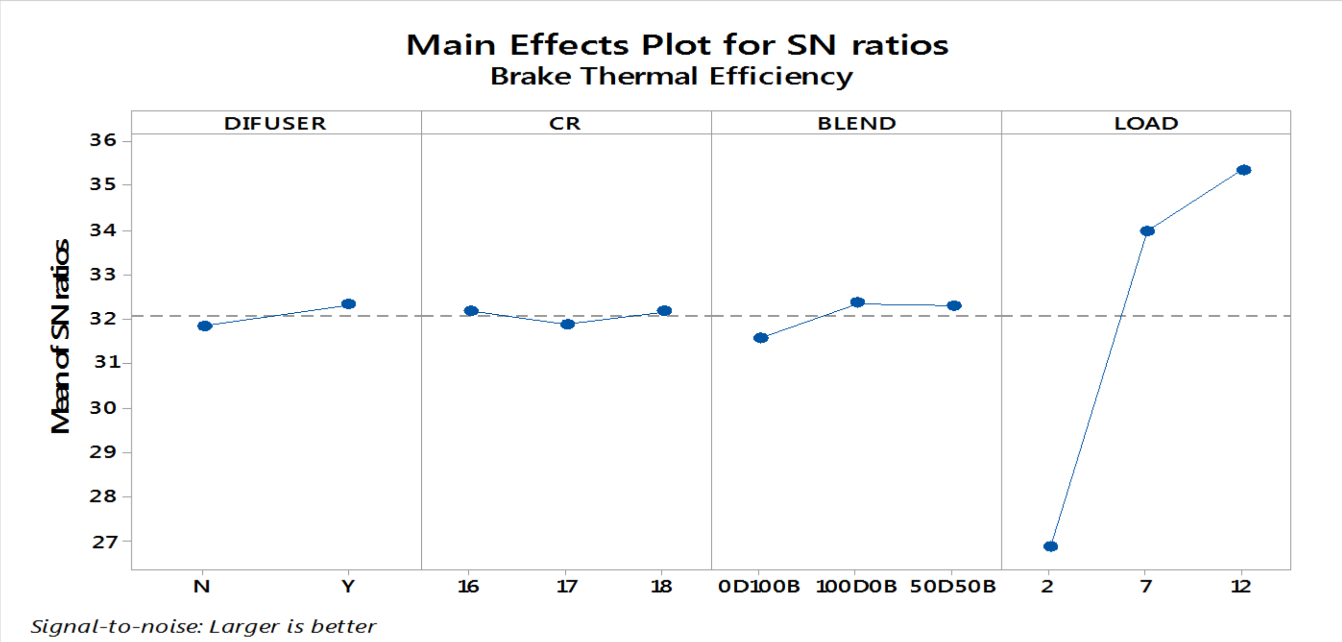

Figure 7. Main effect plot for SN ratio: BTHE

Table 10. Main effects plot for SN ratio: BTHE

Level	Diffuser	Compression Ratio	Blend	Load
1	31.84	32.18	31.58	26.89
2	32.31	31.88	32.36	33.98
3		32.16	32.29	35.36
Delta	0.47	0.30	0.77	8.47
Rank	3	4	2	1

Table 10 show that the maximum value of the delta is 8.47 (LOAD) and the minimum value is 0.30 (CR). BTHE performance more affected by load and less affected by compression ratio, because of the load delta value has a maximum and Compression ratio delta value has a minimum on the S/N ratio result.

Figure 3 and 4 shows the minimum and maximum value for all parameters. Take the maximum value from the above graph for the best value of BTHE. The value was DA Y, CR16, BLEND100D0B and LOAD12. Predicted value gained by the putting Table value in minitab18, comparing that value to the experiment value.

Table 11. Optimum set of parameters: BTHE

Diffuser	Compression Ratio	Blend	Load	Predicted BTHE	Experiment BTHE	Error
Y	16	100D0B	12	60.8870	60.024	0.863

Table 11 show the Best Brake Thermal Efficiency got at the draft angle 12.5, compression ratio18, Blend Ratio50D50B and Load12.

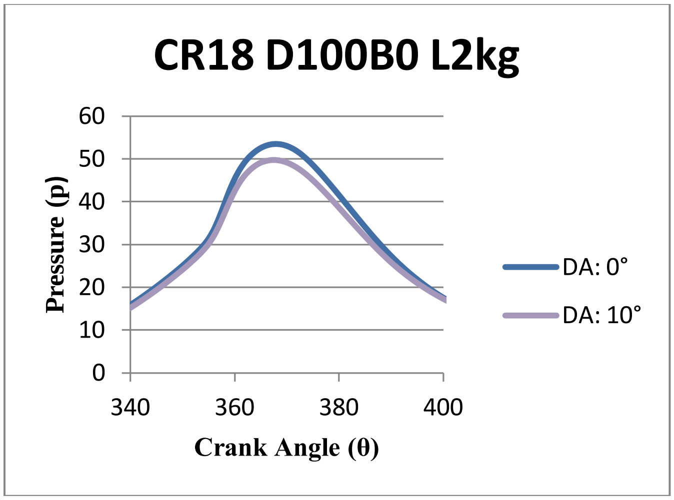

Figure 8 . p-θ for CR18 D100B0 L2

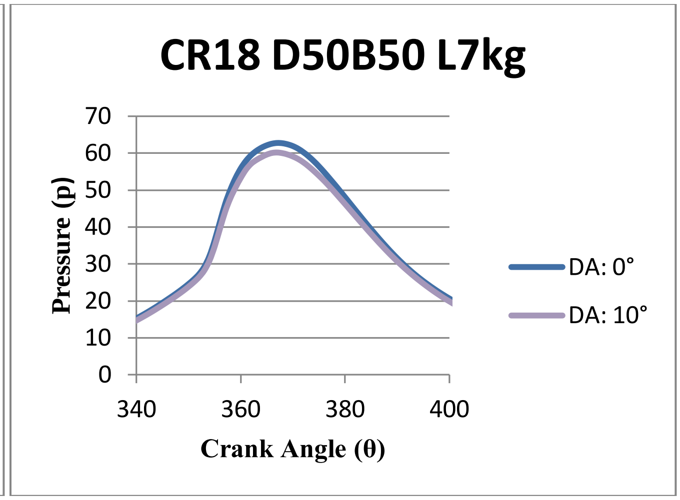

Figure 9 . p-θ for CR18 D50B50 L7

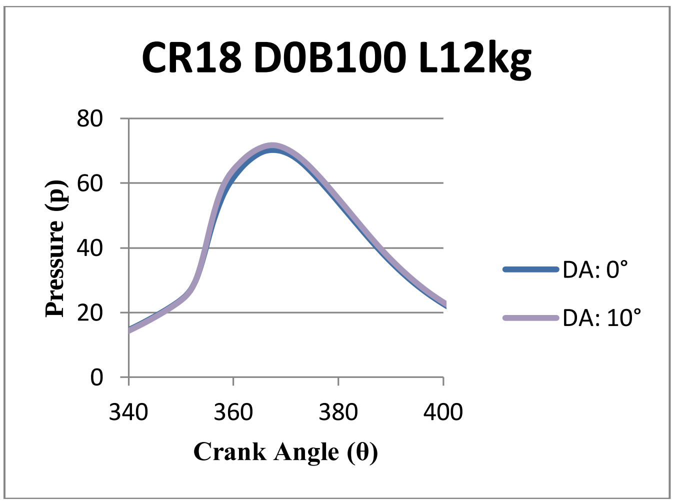

Figure 10 . p-θ for CR18 D0B100 L12

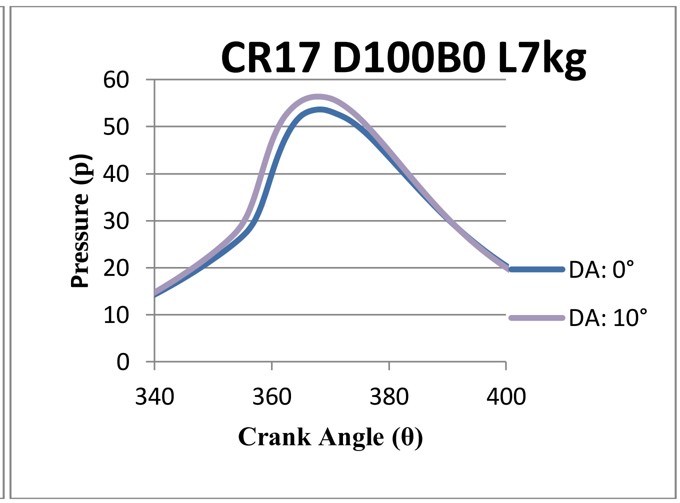

Figure 11 . p-θ for CR18 D100B0 L7

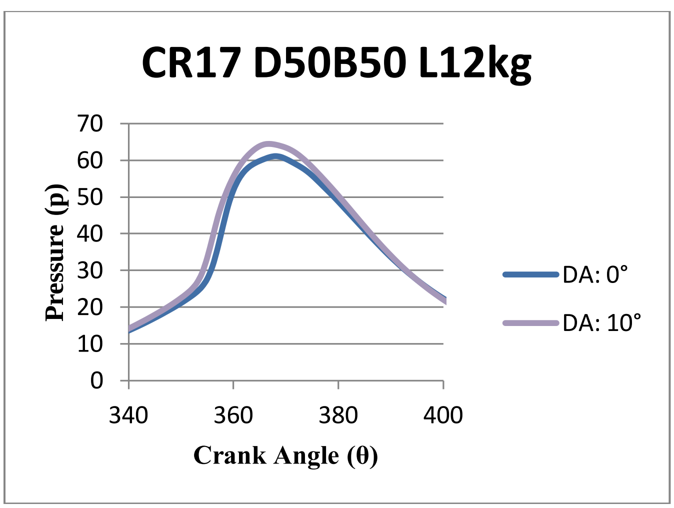

Figure 12 . p-θ for CR18 D50B50 L12

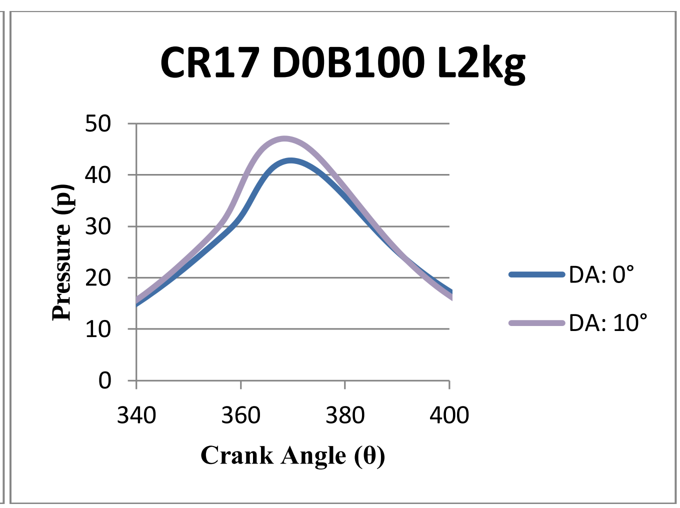

Figure 13 . p-θ for CR18 D0B100 L2

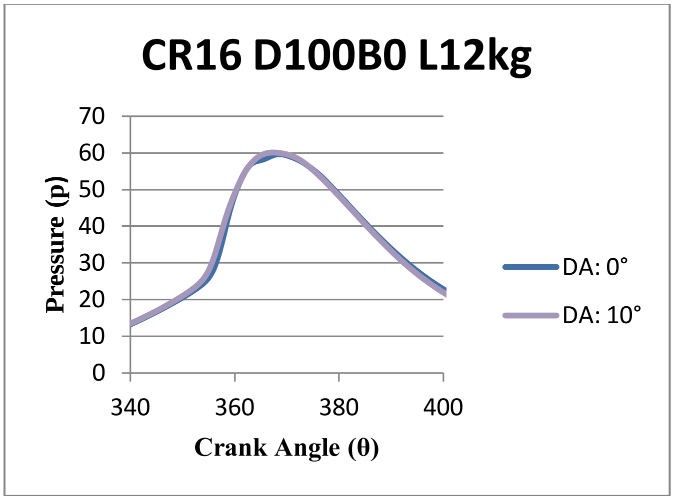

Figure 14 . p-θ for CR18 D100B0 L12

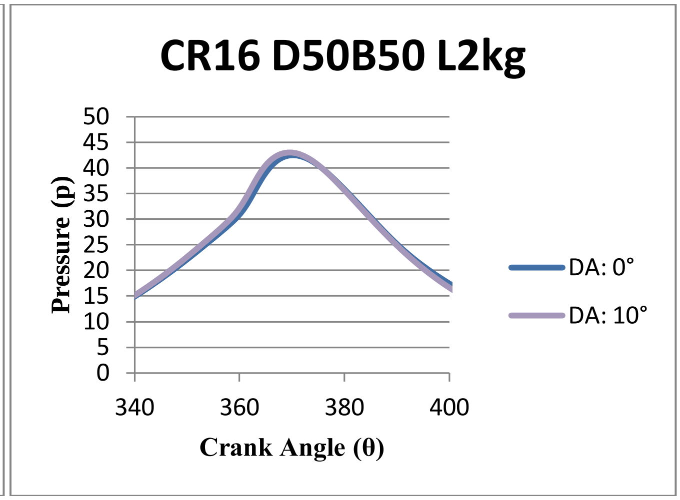

Figure 15 . p-θ for CR18 D50B50 L2

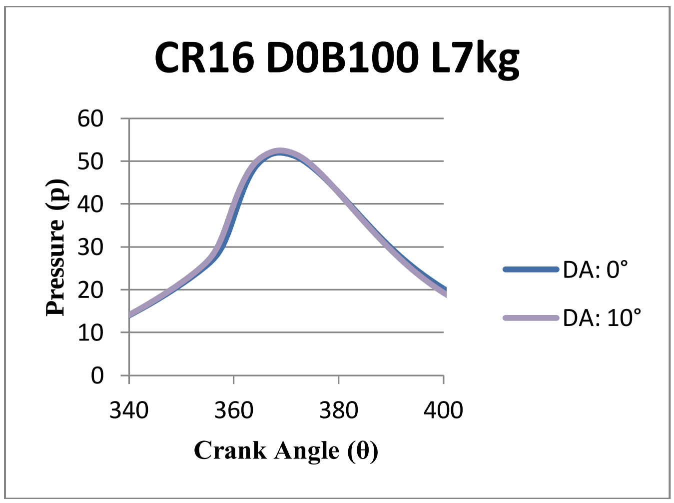

Figure 16 . p-θ for CR18 D0B100 L7

Figure 8 shows the p-θ diagram for CR18D100B0L2 at different DA that is 0° and 10°, that 0° DA gives the best result (53.47). Figure 9 shows the p-θ diagram for CR18D50B50L7 at different DA that is 0° and 10°, that 0° DA gives the best result (60.73). Figure 10 shows the p-θ diagram for CR18D0B100L12 at different DA that is 0° and 10°, that 10° DA gives the best result (71.75). Figure 11 shows the p-θ diagram for CR17D100B0L7 at different DA that is 0° and 10°, that 10° DA gives the best result (56.43). Figure 12 shows the p-θ diagram for CR17D50B50L12 at different DA that is 0° and 10°, that 10° DA gives the best result (64.49). Figure 13 shows the p-θ diagram for CR17D0B100L2 at different DA that is 0° and 10°, that 10° DA gives the best result (47.05). Figure 14 shows the p-θ diagram for CR16D100B0L12 at different DA that is 0° and 10°, that 10° DA gives the best result (60). Figure 15 shows the p-θ diagram for CR16D50B50L2 at different DA that is 0° and 10°, that 10° DA gives the best result (43.04). Figure 16 shows the p-θ diagram for CR16D0B100L7 at different DA that is 0° and 10°, that 10° DA gives the best result (52.47).Study included the analysis of combustion characteristics with diffuser with respect to various operating parameter. From Figure 8 to Figure 16 evolutes that parameter set CR18D0B100L12 is give optimum.

VII. CONCLUSION

From the experiment, it concluded that WPO and WPO blend can be used in CI engine as a fuel. Optimum set for Specific Fuel Consumption is Y Draft Angle, 16 Compression Ratio, 50D50B Blend and 12 Load. Optimum set for Break Thermal Efficiency is Y Draft Angle, 16 Compression Ratio, 100D0B Blend and 12 Load. This set gives the highest value of BTHE and SFC. As result analyze Y draft angle is give the best result for SFC and BTHE. SFC and BTHE are giving batter value at higher load. SFC and BTHE are performing well at higher compression ratio. Analyze the result and found that among the 4 parameter load is more affect to the BTHE and SFC, on the side compression ratio is less affect to the BTHE and SFC. From the experiment, it is deduced that WPO and WPO blend have little less brake thermal efficiency, specific fuel consumption. Analysis the result and found that at CR18D0L12 with diffuser gave the highest pressure because of this ignition delay reduce. Taguchi method save time by reducing experiment run and gives best optimum value for all parameter.

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