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Compression Ratio Analysis of Bio Fuel Using Pongamiapinnata of CI Engine

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ABSTRACT
This review is started to enhance the degrees of boundaries, for example, pressure proportion, Injection tension and pongamiapinnata biodiesel mix % of single chamber direct infusion variable pressure proportion CI motor on the motor presentation. Taguchi and ANOVA procedures have been utilized to track down the ideal level and commitment of the boundaries on the brake warm productivity and break explicit fuel utilization. The outcomes induce that the pressure proportion is the most prevailing element affecting the brake warm effectiveness followed by biodiesel mix % and infusion pressure. It is seen that when the brake warm effectiveness is expanded with the expansion in pressure proportion and bio diesel mix while the brake explicit fuel utilization diminished with the increment in pressure proportion and bio diesel mix.
Watchwords: ANOVA, variable pressure proportion, CI motor, pressure proportion, infusion pressure, Pongamiapinnata biodiesel mix, brake warm productivity and brake explicit fuel utilization.

I. INTRODUCTION

Renewable energy plays a major role in solving the current energy requirement and biodiesel is a promising alternative fuel to tide over the energy crisis and conserve fossil fuels [1]. Biodiesel is gaining more and more importance as an attractive fuel due to the depleting fossil fuel resources [2]. Biodiesel has been considered as a potential alternative to petroleum diesel with the renewable origin for the existing compression ignition engine [3].Yüksek et al [4] investigated an optimum compression ratio by considering the friction loss and thermal efficiency of an engine. They reported that with increasing the compression ratio, indicated power and friction power of the test engine increased linearly. Mathur et al [5] estimated the highest brake thermal efficiency and lowest smoke capacity and carbon-monoxide emissions with the compression ratio of 17 and hence considered as the optimum compression ratio for variable compression ratio diesel engine.

Santhosh and Padmanaban [7] concluded that the brake thermal efficiency increases with increase in load for different blends and compression ratio and the BSFC decrease with increase in CR and also measured the emissions of exhaust gases. Alder et al [8] reported that pongamia biodiesel is environmentally friendly and rejects lesser CO_2, CO, HC, and *NOx* emissions in CI engine as an alternative fuel to diesel. Karanja biodiesel blends of 20% with fossil diesel fuel produce approximately 70% less pollution. The physical and chemical properties of biodiesel produced were found to be close to those of diesel fuel and also they meet the ASTM standard specifications for biodiesel. Ahmadetal [10] studied the commercial production of biodiesel on special grounds in the fuel sector for the future. Wail M. Adaileh1 and Khaled S. AlQdah [11] studied the combustion characteristics and emissions of compression ignition diesel engine using a biodiesel as an alternative fuel. Waste vegetable oil was found to be safe and efficient alternative fuel and has a low impact on the environment. Lower percent of blends (B5, B20) give a good improvement in the engine power. Jinlin Xueetal [12] studied the effect of biodiesel on engine power, economy, durability and emissions including regulated and non-regulated emissions and reported that biodiesel produced from renewable and often domestic sources, represents a more sustainable source of energy and will therefore play an increasingly significant role in providing the energy requirements for transportation.

Gaurav Dwivedi et al [14] reported that in recent years, biodiesel has been in focus as a part replacement component of petroleum diesel. Bio-diesel scores very well as an alternate fuel of choice as it helps in decreasing dependence on fossil – fuels and also as it has almost no sulphur. Paresh D. Patel et al [15] carried out a complete technical review on the use of bio-fuel (pure oil/blend with diesel/blend with diesel in the presence of additives) in CI engines based on performance and emission comparisons with diesel fuel. It is suggested to improve engine performance when fuelled with bio-fuels by changing engine operating parameters (injection timing, injection pressure & compression ratio). Mohamed Ibrahim and Udaya kumar [16] investigated the exhaust emissions by computational simulation during combustion in compression ignition engine with pongamia oil substitution. The model can also be applied for other biodiesels as well to predict the emission concentrations. Nidal H. Abu-Hamdeh [17] investigated the various performance parameters and emissions of a single cylinder diesel engine operating on almond biodiesel and compared them to the performance and emissions when the engine is operated on palm oil biodiesel and baseline diesel fuel. Almond biodiesel resulted in improved performance over the load range considered as indicated by lower brake specific fuel consumption, higher thermal efficiency, and higher exhaust gas temperature. Nantha gopal and Thundil Karupparaj [18] prepared bio-diesel from pongamia oil (PME 100) and tested on a diesel engine for different blends such as PME 20, PME40, PME 60 and PME 80. Comparison is made with diesel operation.

It is apparent that there is no clear understanding in the literature regarding the contribution of compression ratio, bio fuel blend and injection pressure on the brake thermal efficiency and brake specific fuel consumption of the engine. Hence this work aims to find the optimum compression ratio, injection pressure and percentage of pongamiapinnata bio-fuel blend on a diesel engine using Taguchi and ANOVA methods in attaining the highest brake thermal efficiency and lowest brake specific fuel consumption .

II. EXPERIMENTALPROCEDURE

Bio fuel was extracted employing Pyrolysis method. Pyrolysis was carried out using the bench made pyrolysis distillation apparatus shown in Fig.1. Glass made borosilicate furnace system in which the reaction temperature was maintained by a Proportional-Integral-Derivative (PID) controller. A condenser was attached at the outlet of reactor for condensing the vapours coming out of it and liquid was collected in a container.

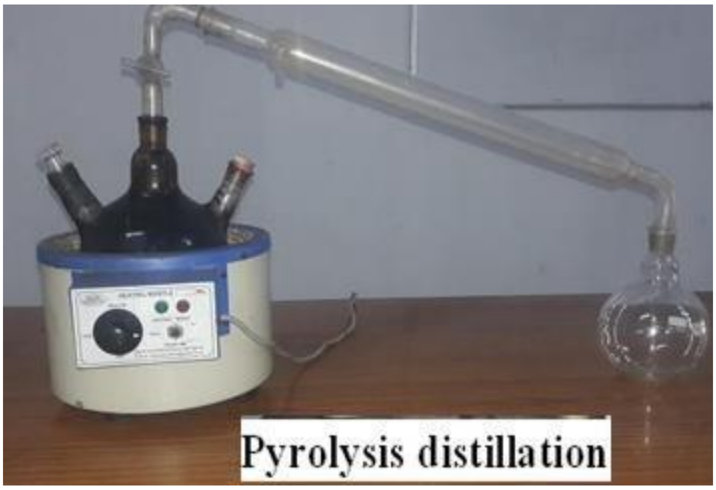

Figure1 Pyrolysisdistillationapparatus

Water when used as a cooling medium in the condenser and circulated continuously. The liquid product will have both bio-oil and oily water which consists of water and some dissolved hydrocarbons. Oily-water and bio-oil can be further separated by using decantation funnel. The properties of the used pongamia oil are compared with normal diesel and the values are presented in table1.

Table1 Properties of Fuel

S. No	Properties	Diesel	Pyrolyzed Bio-fuel
1.	Density in g/cc	0.825	0.910
2.	Calorific value in kJ/kg	45,000	38,700
3.	Flash point in ^{0}C	52	155
4.	Pour point in ^{0}C	-5	-1
5.	Ash Content % by mass	nil	0.07

The present study was done in a four stroke Variable Compression Ratio (VCR) engine shown in Fig. 2. Initially the engine was run on no load condition and engine speed was adjusted at rated rpm. The engine was tested at 20 Nm at rated rpm. Loading arrangement is provided with the Eddy current dynamometer, which is connected to the engine through a coupling. A specification of variable compression ratio engine is given in the Table.2. The engine was tested on both diesel and pongamia biodiesel and its blend combinations (B10,and B20) for each load conditions and for different compression ratios (CR 15:1, 18:1, 21:1) and injection pressures (160,180&200bar) respectively. The engine performance data were recorded after 20minutes.The parameters that were calculated were Brake Thermal Efficiency (BTHE), and Brake Specific Fuel Consumption (BSFC). Brake Thermal Efficiency can be defined as brake power of engine as a function of the heat supplied from the fuel. It is used to assess how well heat energy from a fuel is converted to mechanical energy. Brake Specific Fuel Consumption (BSFC) indicates the fuel efficiency of an engine with respect to thrust output.

Figure2 Variable Compression Ratio Multi Fuel Test Engine

Table2 Specification of Variable Compression Ratio Engine

S.NO	Description	Specification
1.	Stroke	Four
2.	Rated power	5HP
3.	Speed	1450-1600rpm
4.	No. of Cylinders	Single cylinder
5.	Compression ratio	5:1to22:1(variable)
6.	Bore	80 mm
7.	Stroke	110 mm
8.	Ignition	Compression ignition
9.	Loading	Eddy current dynamometer
10.	Load sensor	Strain gauge load cell
11.	Temperature Sensor	Type K–thermocouples
12.	Starting	Manual crank start
13.	Cooling	Water

III. TAGUCHIMETHOD

Taguchi method which was developed by Genichi Taguchi has been used to find the optimum levels of parameters affecting the process. It reduces the variation in a process through robust design of experiments. A large number of tests will have to be done when the number of process parameters increase. But Taguchi introduced orthogonal arrays to analyze the process parameters with only a small number of tests to find the optimum parameters which have an impact of performance of the process. It minimizes experimental runs, time and the cost. In addition to the S/N ratio, a statistical analysis of variance (ANOVA) can be used to find the contribution of process parameters on the response**.** In this study three variables such as compression ratio, Injection pressure and bio diesel blend were considered. The factors and levels are given in table3.

Table3 Factors and levels

Level	Compression ratio (A)	Injection Pressure (MPa) (B)	Bio Fuel Blend (%) (C)
I	15	160	0
II	18	180	10
III	21	200	20

Table4 ANOVA Analysis

S.NO	Factors			Measured Values		S/N ratio	
	CR	**IP**	**BLEND%**	**BThE %**	**BSFC (kg/kWh)**	**BThE**	**BSFC**
1	15	160	0	12.73	0.57	22.0966	4.88250
2	15	160	10	14.23	0.52	23.0641	5.67993
3	15	160	20	16.10	0.45	24.1365	6.93575
4	15	180	0	13.71	0.53	22.7407	5.51448
5	15	180	10	16.78	0.50	24.4958	6.02060
6	15	180	20	17.40	0.45	24.8110	6.93575
7	15	200	0	13.50	0.56	22.6067	5.03624
8	15	200	10	15.10	0.52	23.5795	5.67993
9	15	200	20	16.70	0.47	24.4543	6.55804
10	18	160	0	15.43	0.54	23.7673	5.35212
11	18	160	10	16.72	0.48	24.4647	6.37518
12	18	160	20	21.75	0.44	26.7492	7.13095
13	18	180	0	15.71	0.47	23.9235	6.55804
14	18	180	10	17.95	0.45	25.0813	6.93575
15	18	180	20	20.80	0.42	26.3613	7.53501
16	18	200	0	15.00	0.53	23.5218	5.51448
17	18	200	10	17.72	0.49	24.9693	6.19608
18	18	200	20	19.63	0.44	25.8584	7.13095
19	21	160	0	17.61	0.50	24.9152	6.02060
20	21	160	10	18.94	0.47	25.5476	6.55804
21	21	160	20	20.42	0.44	26.2011	7.13095
22	21	180	0	19.99	0.45	26.0163	6.93575
23	21	180	10	22.21	0.42	26.9310	7.53501
24	21	180	20	24.52	0.40	27.7904	7.95880
25	21	200	0	18.90	0.46	25.5292	6.74484
26	21	200	10	19.72	0.44	25.8981	7.13095
27	21	200	20	20.58	0.40	26.2689	7.95880

Table5 Response Table for Signal to Noise Ratios (Brake Thermal Efficiency)

Level	CR	IP	Blend
1	23.55	24.55	23.90
2	24.97	25.35	24.89
3	26.12	24.74	25.85
Delta	2.57	0.80	1.95
Rank	1	3	2

Table 6 Response Table for Signal to Noise Ratios (BSFC)

Level	CR	IP	Blend
1	5.916	6.230	5.840
2	6.525	6.881	6.457
3	7.108	6.439	7.253
Delta	1.192	0.651	1.413
Rank	2	3	1

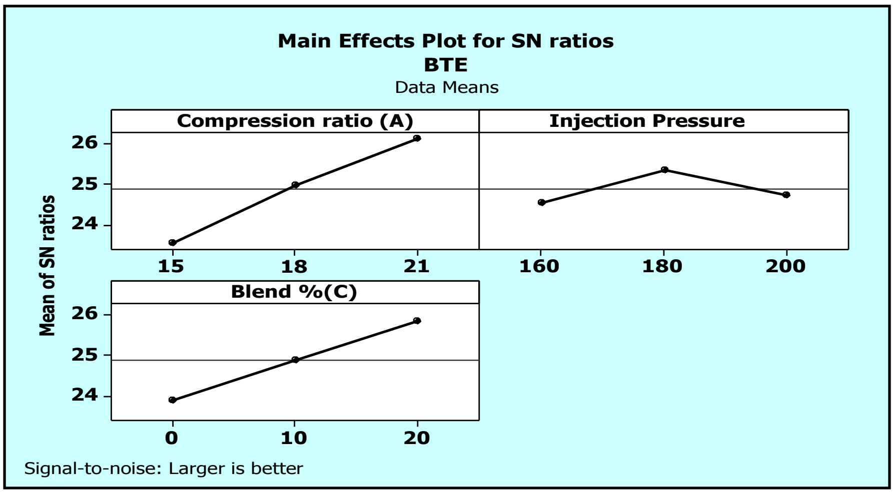

Figure3 Main effects plot for SN ratios (BTE)

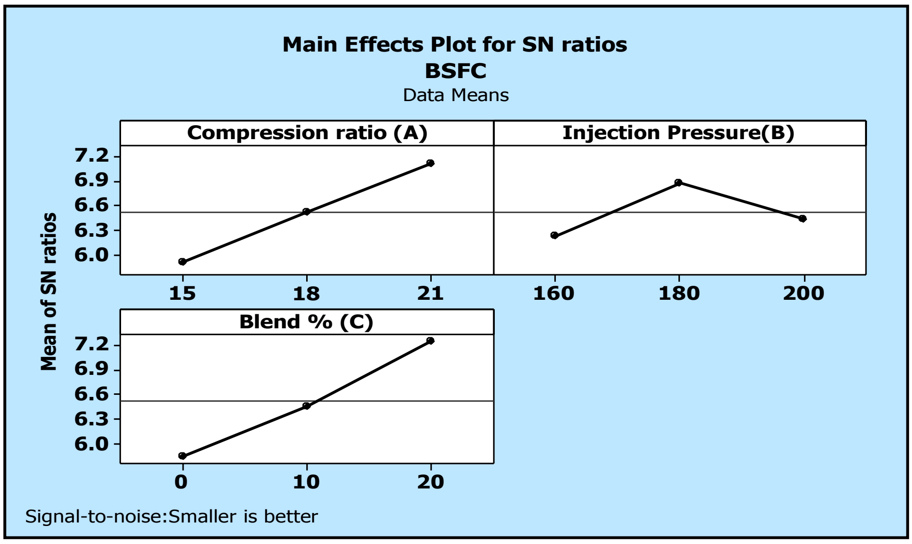

Figure4 Main effects plot for SN ratios (BSFC)

Table7 ANOVA ANALYSIS

Source	DF	SeqSS	AdjSS	Adj MS	F-Value	P-Value	Pc
BRAKE THERMAL EFFICIENCY							
CR	2	120.946	120.946	60.473	162.09	0.000	54.13
IP	2	14.336	14.336	7.168	19.21	0.001	6.41
Blend	2	69.362	69.362	34.681	92.96	0.000	31.04
CR*IP	4	7.754	7.754	1.938	5.20	0.023	3.47
CR*BLEND	4	2.491	2.491	0.623	1.67	0.249	1.11
IP*BLEND	4	5.564	5.564	1.391	3.73	0.054	2.49
Error	8	2.985	2.985	0.373			1.33
Total	26	223.437					100

BRAKE SPECIFIC FUEL CONSUMPTION (kg/kWh)							
CR	2	0.0193556	0.0193556	0.0096778	165.90	0.000	33.91
IP	2	0.0059556	0.0059556	0.0029778	51.05	0.000	10.43
Blend	2	0.0272889	0.0272889	0.0136444	233.90	0.000	47.82
CR*IP	4	0.0018222	0.0018222	0.0004556	7.81	0.007	3.19
IP*BLEND	4	0.0008889	0.0008889	0.0002222	3.81	0.051	1.55
CR*BLEND	4	0.0012889	0.0012889	0.0003222	5.52	0.020	2.25
Error	8	0.0004667	0.0004667	0.0000583			0.817
Total	26	0.0570667					100

DoF: Degrees of freedom; Seq.SS: sequential sums of squares; Adj.MS: Adjusted sums of Squares; Pc: percentage of contribution.

IV. RESULTS OF S/N RATIO

Measured values and corresponding S/N ratios are presented in Table.2. Taguchi method is used to identify the control parameters that reduce variability in a process by reducing the effects of uncontrollable parameters (noise factors) on the output. The selected control parameter with the highest S/N ratio gives the optimum quality with the least variance. Parameters were ranked based on signal to noise ratios for the Brake Thermal Efficiency of the Engine. It can be seen from the Response table.5 for signal to noise ratios for brake thermal efficiency, compression ratio was the dominant parameter followed by bio- fuel blend and injection pressure for the Brake Thermal Efficiency of the engine. From the response diagram of S/N ratio (Fig.3), it was found that the optimum parameters were Bio fuel blend (B20%), Compression ratio (21:1) and injection pressure (180bar).

Similarly, ranking of parameters was done using signal to noise ratios for the Brake Specific Fuel Consumption of the engine. It can be noted from the Response table.6, the Bio-fuel blend was the dominant parameter followed by compression ratio and injection pressure. It can be observed from the response diagram of S/N ratio (Fig.2) that the optimum parameters were Compression ratio (21:1), Bio fuel blend (B20%) and injection pressure (180bar).

V. RESULTSOFANOVA

ANOVA is a statistical analysis method which can be used to find the contribution of factors on the outcome. MINITAB16 statistical software was used to perform the ANOVA at the level of significance of 5%. P-value can be used to know whether the factor is significant or not on the performance of the process. In the ANOVA analysis Table7, It can be observed that P- value for all the three parameters have less than 0.05. Hence it can be concluded that they are highly significant at 95% confidence level for the specific fuel consumption and brake thermal efficiency of the engine.

It is observed from the Table 7 that the percentage contribution (Pc %) of each variable in the total variation indicating their degree of influence on the thermal efficiency of the engine. Compression ratio (54.13%) was the major contributing factor followed by Bio diesel blend (31.04%) and finally injection pressure (6.416%) influencing the thermal efficiency of the engine. Biodiesel blend (47.819%) was the major contributing factor followed by compression ratio (33.91%) and finally injection pressure (10.43%) influencing the specific fuel consumption.

VI. DISCUSSIONS

It can be noted from the Taguchi results, higher brake thermal efficiency and lower specific fuel consumption were found at a compression ratio of 21. Optimum compression ratio is the compression ratio of the cycle at which the cycle gives the maximum thermal efficiency and output. The maximum thermal efficiency can be attributed to the better combustion by inter mixing of the fuel and air at an optimum compression ratio. Theoretically, increasing the compression ratio of an engine can increase the thermal efficiency of the engine and provide more power output. Compression ratio is one of the major parameters which have about 54% contribution on the thermal efficiency of the engine. Higher compression ratio increases the air temperature at the end of the compression stroke which increases the combustion efficiency during the combustion. B20 provides the higher brake thermal efficiency and lower brake specific fuel consumption than B10 and pure diesel. Biodiesel blends have higher cetane value and oxygen content than that of normal diesel and it enhances the complete combustion process.

Injection pressure of 180 bars was found to be the optimum pressure, yielded lower BSFC and higher brake thermal efficiency. It can be concluded that 180 bar injection pressure enhances the fuel atomization and reduces the physical delay period. It can also be concluded that though a higher injection pressure makes very fine fuel spray, it tends to reduce the thermal efficiency and increased BSFC. It may be due to the less momentum and penetration ability of fuel droplets in the air stream. However, fuel injection pressure is having about 6-10% contribution on the performance of a diesel engine under the tested range of injection pressure.

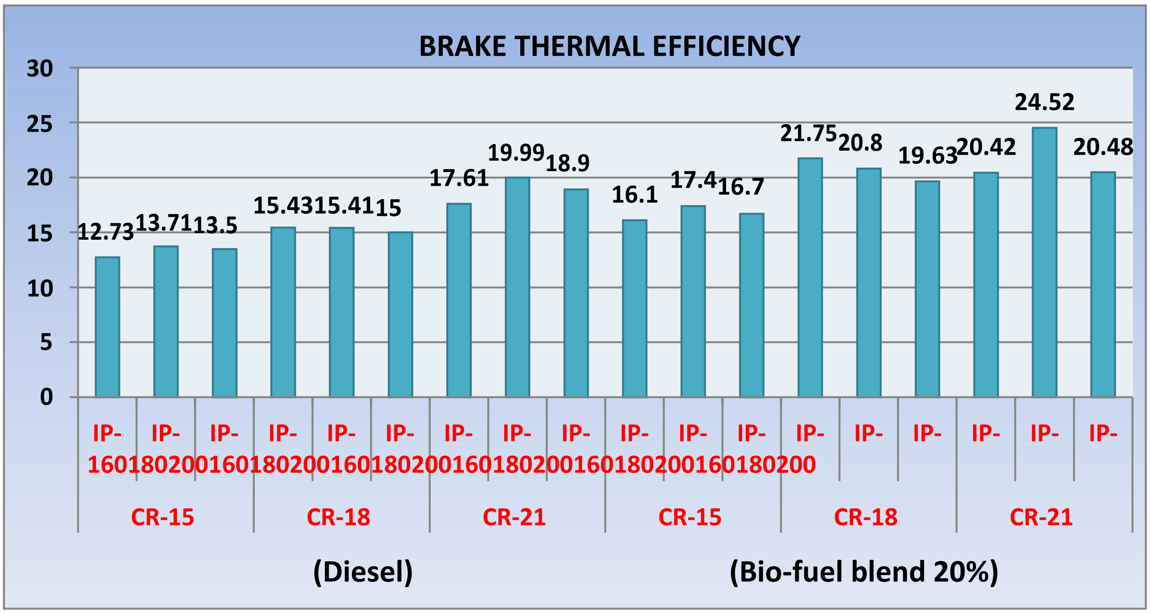

Figure5 Variation of brake thermal efficiency (BTE)

The variation of brake thermal efficiency (BTE) with respect to different compression ratios and injection pressures for diesel and B20 blend of pongamia oil is shown in Figure5. It shows that the BTE is increasing with increase in compression ratio. BTE of B20 increased from 17.4% to 24.52% when the compression ratio was increased from 15 to 21 at a injection pressure of 180 bar due to better mixing of fuel and air. It can also be observed from the table7 that bio-fuel blend has about 30% contribution on the BTE of a diesel engine. It can also be seen from the Figure 5 that B20 gives comparatively more BTE than diesel at all compression ratios.

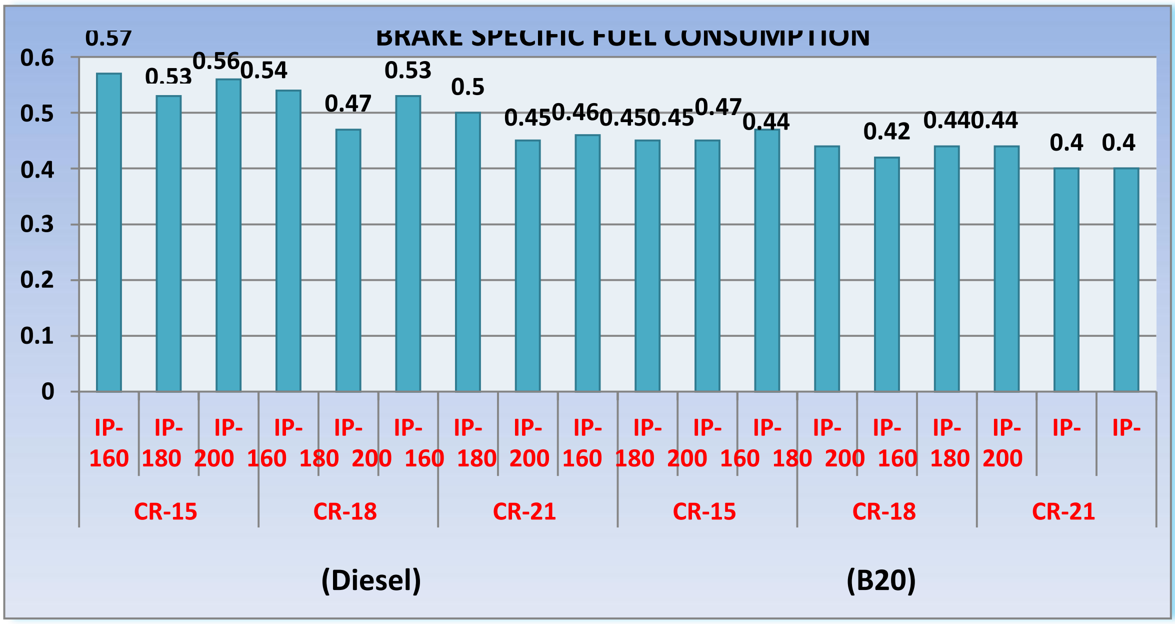

Figure6. variation of brake SFC (BSFC)

The variation of BSFC with three different compression ratios and injection pressures for diesel and B20 blend of Pongamia oil is shown in Figure 6. It can be inferred that the BSFC is decreasing with increase in compression ratio for both diesel and bio diesel. BSFC of B20 decreased from 0.45 to 0.40 when the compression ratio was increased from 15 to 21 at a injection pressure of 180 bar due to the better atomization of fuel at higher compression ratios. Lower injection pressure (160 bars) caused improper atomization of the fuel.

VII. CONCLUSIONS

The performance of single cylinder Variable Compression Ratio (VCR) engine fuelled with and pongamiapinnata oil its blends were analyzed and compared to the standard diesel fuel at various injection pressures (160, 180, 200 bar) and compression ratios (CR 15:1, 18:1, 21:1).Based on the experimental results the following conclusions were obtained.

The conclusions are summarized as follow:

From the Taguchi results, it was observed that the optimum levels were compression ratio (21:1), Bio fuel blend (20%) and Injection pressure (180 bars) in minimizing the brake specific fuel consumption and maximizing the thermal efficiency. It was noted that the BSFC tends to decrease with increase in compression ratio for both diesel and bio diesel. Blend B20 gives comparatively more Brake Thermal Efficiency than normal diesel at all compression ratios.

Injection pressure of 180 bar yielded lower Brake Specific Fuel consumption and higher brake thermal efficiency due to the better fuel atomization which lowers the physical delay period. From ANOVA analysis, it was found that, the compression ratio has 54.12% contribution of the total effect on the thermal efficiency, followed by the Bio fuel blend (31.04%) and the Injection pressure (6.416%). It was observed that the thermal efficiency increases with the increase in compression ratio and bio fuel blend. On the other hand Bio fuel blend has 47.87% contribution of the total effect, followed by the compression ratio (33.91%) and the Injection pressure (10.43%).

The results also clearly shows that the compression ratio and bio-diesel blend have significantly higher influence on thermal efficiency as compared to that of the injection pressure within the observed range.

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