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Effect of Injection Pressure Variation on Performance Characteristics of CI Engine Fuelled with Dual Biofuel of Neem and Jatropha

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Abstract: The present work focuses on evaluation of the performance characteristics of single cylinder CI engine fuelled with dual biofuel of Neem (Azadirachta Indica) and Jatropha (Jatropha Carcus). Recent researches show that in an existing diesel engine when blending is done up to 20% of biofuels with neat diesel, no modifications are required. In current study, petroleum base diesel fuel is replaced by neem-jatropha-diesel blend. As jatropha and neem oil are non-edible oils, it can be used for blending purpose. Here, different B20 blends of neem and jatropha (i.e., N5J15D80, N10J10D80, N15J5D80) were made and evaluated on the basis of changing injection pressure (i.e., 160 bar, 180 bar and 200 bar) and load (i.e., 2 kg, 4 kg and 6 kg). Various performance parameters such as brake specific fuel consumption (BSFC), brake thermal efficiency (BTHE) was investigated. Minitab software was used for creating set of experiment as per Taguchi's approach. Experiments were performed and further Taguchi analysis carried out to find out an optimum set of parameters on basis of S/N ratio plot.

***Index Terms* - Dual biofuel, Neem biodiesel, Jatropha biodiesel, Injection pressure, Performance characteristics, Taguchi method.**

1. INTRODUCTION

The demand for petroleum has risen rapidly due to increasing industrialization and modernization of the world [1]. The increasing cost of petroleum is another concern for developing countries as it will increase their import bill. The world is also presently facing challenge with the twin crisis of fossil fuel depletion and environmental degradation. Increasing environmental concern, diminishing petroleum reserves and agriculture-based economy of our country are the driving forces to promote biofuel as an alternate fuel [2]. In recent years, many researchers have focused on the study of alternative fuels which enhances the combustion and emission characteristics of engine.

"Biofuels" are fuels produced from renewable resources and used in place of or in blend with, diesel, petrol or other fossil fuels for transport, stationary, portable and other applications. Various types of biofuels are: (1) Edible oil feedstock- palm oil, mustard oil, sunflower oil, rapeseed oil, soyabean oil etc. (2) non-edible oil feedstock- Jatropha, Karanja, Mahua, Neem, Castor, Pongamia etc. (3) Waste vegetable oil (4) Animal fats, fish oil etc. (5) Algae from sewage etc. Due to heavy demand of edible oil for food, non-edible feedstocks have been found promising for biodiesel production. Non-edible feedstocks like Jatropha, Karanja, Mahua, Neem, Castor, Pongamia etc. are not suitable for human consumption due to availability of toxic compounds in them [1].

2. OVERVIEW OF LITERATURE REVIEW

Sayyed *et al.* (2022) [3] have done experimental investigation for evaluating the performance characteristics of DICI engine fueled with dual biodiesel-diesel blends of Jatropha, Karanja, Mahua, and Neem. Six sets of dual biodiesel blends were prepared (i.e., 10 % Biodiesel and 90 % Diesel) by using these four biodiesels. Here average brake thermal efficiency, mechanical efficiency and volumetric efficiency is lower by 5.2 %, 9.79 % and 2.59 % respectively. In this study it can be concluded that dual biodiesel can be used as alternative fuels in diesel engines and hence it is recommended as alternative fuel for DICI engine.

Balasubramanian (2012) [4] analyzed the performance characteristics of various dual biodiesel blends (mixture of jatropha biodiesel and neem biodiesel) with diesel on a stationary single cylinder, four stroke direct injection compression ignition engine. Equal percentage of different blend of BB10, BB20, BB 40, BB 80 and BB 100 used for finding performance characteristics. It was concluded that blends of BB 10 (combination of Diesel 90% by volume, jatropha biodiesel 5% by volume and Neem biodiesel 5% by volume) and BB 20 (combination of Diesel 80% by volume, jatropha biodiesel 10% by volume and Neem biodiesel 10% by volume) gave better brake thermal efficiency and lower brake specific fuel consumption compare with other dual biodiesel blends (BB 40, BB 80 and BB 100). Here results show that, dual blended biodiesel will be a good substitute and it could replace diesel in future.

Rajan *et al.* (2020) [5] investigated the performance behavior of diesel engine operated with B20 blend of Neem oil methyl ester (NOME) with different injection pressure of 200 bar, 225 bar and 250 bar. By increasing fuel injection pressure, it increases the brake thermal efficiency and specific fuel consumption. It was concluded that performance characteristics of B20 blend of NOME at 225 bar is better than B20-200 bar and B20-250 bar. In diesel engine applications biodiesel from Neem oil is quite suitable as an alternative to diesel fuel. BTE of B20-225 bar (i.e.,29.54%) which is comparable with diesel (i.e.,30.45%). BSFC at maximum power for B20-225 bar (i.e.,0.26 kg/kWh) lower compared with B20-200 bar, B20-250 bar (i.e., 0.27 kg/kWh, 0.28 kg/kWh).

Karikalan *et al.* (2019) [6] were carried out experiment with combination of Neem biodiesel and diesel mixtures of N20 (Neem Biodiesel 20%+ Diesel 80%). The diesel and biodiesel blends were tested in single cylinder DI diesel engine at normal injection timing 270 BTDC, with compression ratio of 17.5 at varied fuel injection pressure of 180bar, 200bar, 220bar, 240bar. Purpose of experiment was to examine the characteristics like brake thermal efficiency, fuel consumption and combustion parameters for blends of N20 were tested with increased fuel injection pressure. BTE at 75% load increases by 3.05% and SEC at full load decreases by 12.26% at 240 bar compare to N20 at 200 bar. It was suggested that N20 biodiesel blend at 240 bar fuel injection pressure was optimal for the diesel engine performance.

Balaji *et al.* (2017) [7] investigated performance for variable compression ratio engine run with neat biodiesel (B100) obtained from Neem oil. In this experiment results were compared against the diesel fuel with standard pressure of 210 bar with neat biodiesel of NOME (B100) with various injection pressures viz 200 bar, 220 bar, 240 bar and 260 bar. By increasing in injection pressure, it increases the brake thermal efficiency and reduces brake specific energy consumption. BTE increases 2.06% while BSEC decreases 3.93% by increasing the injection pressure from 200 to 240 bar. It was concluded that optimum fuel injection pressure was found as 240 bar.

Jindal *et al.* (2010) [8] studied the effect of compression ratio and injection pressure in a direct injection diesel engine running on Jatropha methyl ester(B100). Experiments were conducted for three injection pressures (150, 200, 250 bar) and for each injection pressure, three different compression ratios (16, 17 and 18) were selected and compared against diesel as fuel for (210 IP and 17.5 CR). They found that the combined effect of increasing compression ratio and injection pressure increases the Brake thermal efficiency and reduces brake specific fuel consumption. For 250 bar IP and 18 CR BSFC improves by 10% and BTHE improves by 8.9%. It was concluded that compression ratio of 18 with injection pressure of 250 bar was optimum combination.

Some of the salient points from literature survey can be summarized as below:

- Researches show that minor or no modification is required in an existing diesel engine for blending up to 20 % of biofuels with neat diesel.
- Dual biofuel can be used as alternative fuel in diesel engine.
- Due to similar kind of properties to diesel fuel, biodiesel can be used as a renewable source of alternative fuel.
- Improvement in performance and emission characteristics can be achieved by increasing fuel injection pressure.
- Increase in fuel injection pressure improves the thermal efficiency and specific fuel consumption decreases.
- Thermal efficiency decreases for biodiesel blends and oil blends as compare to diesel fuel.
- SFC increases for biodiesel and oil blends compare to diesel fuel.

3. NEEM AND JATROPHA BIOFUEL

Neem and Jatropha biofuel prepared from Neem and Jatropha oil by using Transesterification process. Transesterification is the process of using a methanol in the presence of catalyst, such as potassium hydroxide, to chemically break the molecule of raw vegetable oil into ester of renewable oil with glycerol as byproduct [4]. Catalyst is used to increase the reaction rate so that the reaction can be completed in a relatively shorter time. Transesterification is used to lessen the oil viscosity. A successful transesterification reaction produces ester and glycerol.

Here two stage trans-esterification process is used for both neem and jatropha oil.

Step 1: Filter the oil and heated at 100 ˚C to remove any moisture content.

Step 2: Acid esterification: Mixture (300 ml oil + 125 ml methanol + 3 ml HCL) is heated at temperature 45-55 ˚C for 45 minutes with help of magnetic stirrer. Allow mixture to settle for 1 hour. Remove top layer of methanol-water fraction and remaining solution required for alkaline transesterification. Bottom layer is used in alkaline esterification process.

Step 3: Alkaline esterification: Mixture (300 ml oil mixture in acid esterification + 125 ml methanol + 3 gm KOH) is heated at temperature 55-60 ˚C for 1 hour with help of magnetic stirrer. Allow mixture to settle for 24 hours. Upper layer is biodiesel and lower layer contains glycerol and impurities.

Step 4: Washing of biodiesel: Water is added in biodiesel to remove remaining impurities. Repeat process 3-4 times. After washing heated to remove remaining water. After cooling it, Jatropha and Neem biodiesel can be used in pure form or in making blend with diesel.

After preparation of neem and jatropha biodiesel, its property was measured in laboratory. Here only performance point of view density and calorific value is useful in further calculations. In Figure 3.1 sample of Neem and Jatropha biodiesel was shown along with its properties in table 3.1 and based on calculation blend properties were shown in table 3.3.

Figure 3.1: Jatropha and Neem Biodiesel

Table 3.1: Density and calorific value of fuel

PROPERTIES	NEEM BIODIESEL	JATROPHA BIODIESEL	DIESEL
DENSITY (kg/m^3)	848	886	833
CALORIFIC VALUE (kJ/kg)	40180	39100	44800

Table 3.2: Fuel percentage in blend on volume basis

PERCENTAGE OF FUEL IN BLEND ON VOLUME BASIS	N5J15D80	N10J10D80	N15J5D80
NEEM BIODIESEL	5 %	10 %	15 %
JATROPHA BIODIESEL	15 %	10 %	5 %
DIESEL	80 %	80 %	80 %

Table 3.3: Density and calorific value of blend

PROPERTIES	N5J15D80	N10J10D80	N15J5D80
DENSITY (kg/m^3)	841.7	839.8	837.9
CALORIFIC VALUE (kJ/kg)	43667.27	43732.13	43797.29

4. Experimental Setup

The setup consists of single cylinder, four stroke, multi-fuel, water cooled computerized research engine in which loading has been provided by eddy current dynamometer.

Table 4.1: Engine specifications

Engine manufacturer	Kirloskar AV1
Engine type	Single cylinder four stroke engine
Type of cooling	Water Cooled
Rated RPM	1500
Power	5 BHP (3.7 kW)
Compression ratio	16.5:1 to 6:1
Engine capacity	0.553 L
Cylinder bore	80 mm
Stroke length	110 mm
Lubrication	Wet Sump Lubrication (SAE W40)
Fuel tank capacity	6.5 L

Figure 4.1: Experimental setup at LDCE, Ahmedabad

- **Injection pressure variation:** In fuel injector at upper part of plunger has adjustable screw. By adjusting screw position desirable injection pressure can be adjusted and checked with the help of injector tester as shown in figure 4.2.

Figure 4.2: Fuel injector along with its pressure variation

- **Experiment variables:** The variable parameters are neem biodiesel and jatropha biodiesel percentage variation in B20 blend, injection pressure and engine load listed in table 4.2.

Table 4.2: Variable parameters for experiment

Blend Ratio (B20)	N5J15D80 (5% Neem Biodiesel + 15% Jatropha Biodiesel + 80% Diesel) N10J10D80 (10% Neem Biodiesel + 10% Jatropha Biodiesel + 80% Diesel) N15J5D80 (15% Neem Biodiesel + 5% Jatropha Biodiesel + 80% Diesel)
Injection Pressure (bar)	160 180 200
Engine Load (kg)	2 4 6

In this experiment three fuels are mixed on volume basis as per their respective percentage at ambient condition with low mixing speed till they miscible with each other. Taguchi method is used in MINITAB 18 software to make set of design of experiment.

Table 4.3: Set of experiment by Taguchi method

Experiment No.	Neem Biodiesel %	Jatropha Biodiesel %	Injection Pressure (bar)	Load (kg)
1	5	15	160	2
2	5	15	180	4
3	5	15	200	6
4	10	10	160	4
5	10	10	180	6
6	10	10	200	2
7	15	5	160	6
8	15	5	180	2
9	15	5	200	4

Fuel tank was filled with required blend than engine was run on given injection pressure and load as per set of experiment. Injection pressure set for each set after one experiment of same blend is completed. Fuel consumption time recorded manually with the help of stopwatch. For all set readings were taken after the stabilization is achieved. Engine performance parameters such as brake power, brake specific fuel consumption, brake thermal efficiency found from the experiments.

5. Observations and Calculations

Different readings were taken for measurement of various parameters as per Taguchi's design of experiment. Here different biodiesel blend of B20 taken by using dual biofuel of Neem and Jatropha biodiesel. (i.e., N5J15D80, N10J10D80, N15J5D80). Here in table 5.1 for each experiment reading taken for fuel consumption and further calculation carried out as per below equations.

Torque (N.m): $T = (Load \times 9.81) \times Dynamometer\ arm\ length$ (1)

Where, Dynamometer arm length = 0.230 m

Brake Power (kW): $BP = \frac{2\pi NT}{60000}$ (2)

Where, N = RPM of the engine, and T = Torque

Fuel Consumption (kg/hr): $FC = \frac{20}{FC\ time(sec\ for\ 20\ ml)} \times 3600 \times \frac{Density\left(\frac{kg}{m^3}\right)}{1000000}$ (3)

BSFC (kg/kWh): $BSFC = \frac{FC}{BP}$ (4)

BTHE (%): $BTHE = \frac{BP\times3600\times100}{FC\times CV}$ (5)

Table 5.1: Observation and calculation table for set of experiment

Exp. No.	NBD %	JBD %	IP (bar)	LOAD (kg)	RPM	FC TIME (sec / 20 ml)	FC (kg/hr)	BP	BSFC (kg/kWh)	BTHE %
1	5	15	160	2	1476	84	0.721	0.697	1.035	7.97
2	5	15	180	4	1452	86	0.705	1.371	0.514	16.05
3	5	15	200	6	1428	98	0.618	2.023	0.306	26.98
4	10	10	160	4	1458	85	0.711	1.377	0.516	15.94
5	10	10	180	6	1424	92	0.657	2.018	0.326	25.27
6	10	10	200	2	1478	88	0.687	0.698	0.984	8.36
7	15	5	160	6	1430	91	0.663	2.026	0.327	25.12
8	15	5	180	2	1470	87	0.693	0.694	0.999	8.23
9	15	5	200	4	1448	90	0.67	1.368	0.49	16.77

6. Results and Discussions

Taguchi method helps in data analysis and prediction of optimum results. In order to evaluate optimal parameter settings, Taguchi method uses a statistical measure of performance called signal-to-noise ratio. The S/N ratio takes both the mean and the variability into account. The S/N ratio is the ratio of the mean (Signal) to the standard deviation (Noise). The ratio depends on the quality characteristics of the product/process to be optimized. In Taguchi's method signal-to-noise ratios (S/N), which are logarithmic functions of desired output; serve as objective functions in the optimization process [9].

The S/N ratio for minimum BSFC was coming under smaller-is-better characteristic. The S/N ratio for maximum BTHE was coming under larger-is-better characteristic.

Smaller is the better characteristic: n = -10 Log_{10} [mean of sum of squares of measured data] (6)

Larger is the better characteristic: n = -10 Log_{10} [mean of sum of squares of reciprocal of measured data] (7)

6.1 Experimental Result Analysis for BSFC:

- **Analysis of Main Effects Plot for S/N ratios of BSFC**

Main Effects Plot for S/N ratio for BSFC displays effect of blend proportion, injection pressure and load on BSFC on same scale base of BSFC.

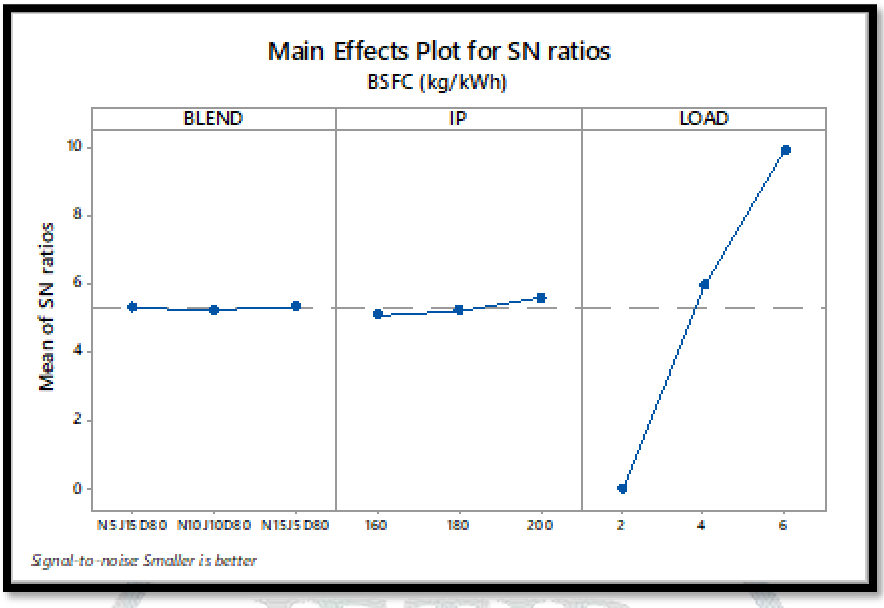

Figure 6.1: Main effects plot for S/N ratios of BSFC (kg/kWh)

Table 6.1: Response table for S/N ratios (smaller is better) of BSFC

LEVEL	BLEND	IP	LOAD
1	5.25583	5.05241	-0.05001
2	5.20758	5.17503	5.90794
3	5.30460	5.54058	9.91009
Delta	0.09702	0.48817	9.96009
Rank	3	2	1

The order of effectiveness of parameters are Load > Injection pressure > blend proportion. From the plot, it has been found that the optimum (minimum) BSFC is achieved when blend proportion = N15J5D80, injection pressure = 200 bar, and load = 6. It is also called optimum set of parameters.

Table 6.2: Predicted value for mean of S/N ratios plot of BSFC

OPTIMUM SET OF PARAMETERS			PREDICTED BSFC (kg/kWh)
BLEND PROPORTION	INJECTION PRESSURE	LOAD	
N15J5D80	200	6	0.2967

- **Validation of Experiment for Result and Error of BSFC**

For the validation of predicted results, experiments are carried out with optimum set of parameters and then the BSFC is measured.

Table 6.3: Validation of experiment for result and error of BSFC

BASIS	BLEND	IP	LOAD	PREDICTED BSFC (kg/kWh)	EXPERIMENTAL BSFC (kg/kWh)	|ERROR| %
S/N RATIO	N15J5D80	200	6	0.2967	0.3054	2.85%

For the validation of predicted results, experiments are carried out with optimum set of parameters and then Validation experiments results are very closer to predicted results. The error is less than 5%.

Hence, the optimum (minimum) BSFC is achieved when blend proportion = N15J5D80, injection pressure = 200 bar, and load = 6 kg. It is also called optimum set of parameters. The predicted value of BSFC with optimum set of parameters is 0.2967 kg/kWh.

The BSFC indicates the amount of fuel consumed by the engine to generate a unit amount of brake power. The lowest value of BSFC indicates that the engine is more efficient. Due to desirable parameters efficient combustion phenomenon obtained for low BSFC value. Here Lowest BSFC value obtained at high percentage of neem biodiesel in B20 blend, high injection pressure and at high load.

6.2 Experimental Result Analysis for BTHE:

- **Analysis of Main Effects Plot for S/N ratios of BTHE**

Main Effects Plot for S/N ratio for BTHE displays effect of blend proportion, injection pressure and load on BTHE on same scale base of BTHE.

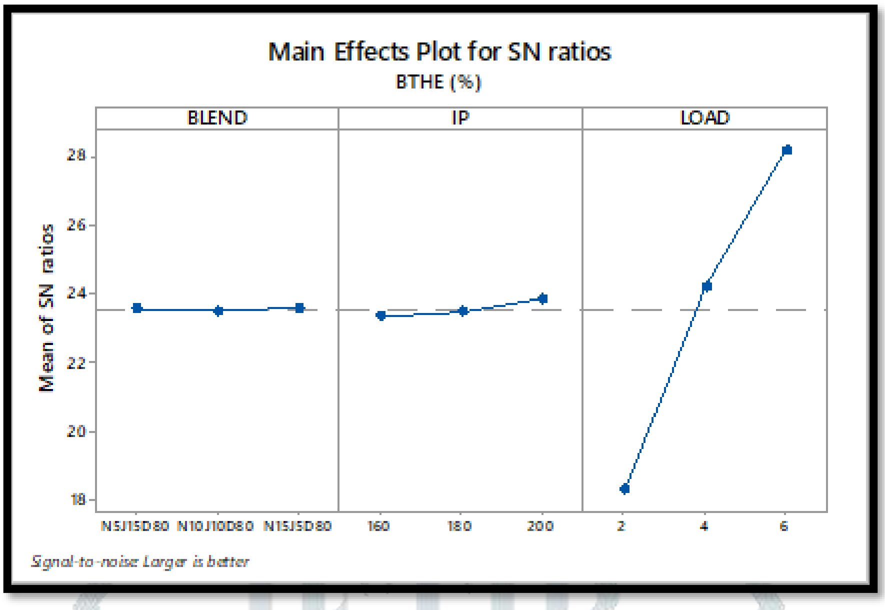

Figure 6.2: Main effects plot for S/N ratios of BTHE (%)

Table 6.4: Response table for S/N ratios (larger is better) of BTHE

LEVEL	BLEND	IP	LOAD
1	23.59	23.36	18.26
2	23.52	23.49	24.22
3	23.60	23.85	28.22
Delta	0.08	0.49	9.96
Rank	3	2	1

The order of effectiveness of parameters are Load > Injection pressure > blend proportion. From the plot, it has been found that the optimum (maximum) BTHE is achieved when blend proportion = N15J5D80, injection pressure = 200 bar, and load = 6. It is also called optimum set of parameters.

Table 6.5: Predicted value for mean of S/N ratios plot of BTHE

OPTIMUM SET OF PARAMETERS			PREDICTED BTHE (%)
BLEND PROPORTION	INJECTION PRESSURE	LOAD	
N15J5D80	200	6	26.38

- **Validation of Experiment for Result and Error of BTHE**

For the validation of predicted results, experiments are carried out with optimum set of parameters and then the BTHE is measured.

Table 6.6: Validation of experiment for result and error of BTHE

BASIS	BLEND	IP	LOAD	PREDICTED BTHE (%)	EXPERIMENTAL BTHE (%)	|ERROR| %
S/N RATIO	N15J5D80	200	6	26.38	26.91	1.97%

For the validation of predicted results, experiments are carried out with optimum set of parameters and then Validation experiments results are very closer to predicted results. The errors are less than 5%.

Hence, the optimum (maximum) BTHE is achieved when blend proportion = N15J5D80, injection pressure = 200 bar, and load = 6 kg. It is also called optimum set of parameters. The predicted value of BTHE with optimum set of parameters is 26.38%.

The BTHE indicates the amount of power taken by the engine crankshaft out of total power generated by fuel combustion. The highest value of BTHE indicates that the engine is more efficient. The BTHE is the ratio of the brake power at the engine crankshaft to the power generated by the fuel combustion. At optimum set of parameters efficient combustion phenomenon obtained for high BTHE value. Here highest BTHE value obtained at high percentage of neem biodiesel in B20 blend, high injection pressure and at high load.

Overall, for blend proportion = N15J5D80, injection pressure = 200 bar, and load = 6 kg, high BTHE and low BSFC obtained among all possible set of experiment. Also, it was validated experimentally as value was nearer to predicted value.

7. CONCLUSION

Performance characteristics of CI engine fuelled with diesel and dual biofuel of neem and jatropha for variation of injection pressure were investigated in this paper. Here blend percentage varies in proportion of (N5J15D80, N10J10D80, N15J5D80). Injection pressure was taken 160, 180 and 200 bar while load varies in proportion of 2, 4, and 6 kg. Taguchi's method used to find out optimum set of parameters on basis of S/N ratio plot for each response. The conclusion may be summarized as follows:

- Optimum Brake Specific Fuel Consumption (BSFC) observed for N15J5D80 Blend, 200 bar Injection pressure and 6 kg Load is 0.3054 kg/kWh. It means that lower BSFC can be achieved at higher injection pressure and higher load.
- Optimum Brake Thermal Efficiency (BTHE) observed for N15J5D80 Blend, 200 bar Injection pressure and 6 kg Load is 26.91 %. It means that higher BTHE can be achieved at higher injection pressure and higher load.
- The order of effectiveness of parameters for BSFC, BTHE, are Load > Injection pressure > blend proportion. It shows that load has higher effect as compare to injection pressure and blend proportion.

REFERENCES

[1] Takase M, Zhao T, Zhang M, Chen Y, Liu H, Yang L, and Wu X, "An expatiate review of neem, jatropha, rubber and karanja as multipurpose non-edible biodiesel resources and comparison of their fuel, engine and emission properties.", *Renewable and Sustainable Energy Reviews*. 2015, 43, 495-520, doi: 10.1016/j.rser.2014.11.049.

[2] Rao TV, Rao GP, and Reddy KH, "Performance and emission analysis of Pongamia, Jatropha and Neem methyl esters as biodiesel in a CI engine.", *International Journal of Mechanical Engineering and Robotics Research*. 2013, 2(3), 286-95.

[3] Sayyed S, Das RK and Kulkarni K, "Experimental investigation for evaluating the performance and emission characteristics of DICI engine fueled with dual biodiesel-diesel blends of Jatropha, Karanja, Mahua, and Neem.", *Energy*.2022, 238, 121787, doi: 10.1016/j.energy.2021.121787.

[4] Balasubramanian KA, "Dual Biodiesel Blends in Diesel Engine-Performance and Emission Analysis.", *European Journal of Scientific Research ISSN*.2012, 400-408.

[5] Rajan K, Sujith V, Ganesan M, Haroon MP, Mathivanan SD, and Elumalai R, "Performance and emissions characteristics of DI diesel engine using biodiesel blend with different injection pressures.", *Materials Today: Proceedings*.2020, 33, 4699-4702, doi: 10.1016/j.matpr.2020.08.348.

[6] Karikalan L, Chandrasekaran M, Vinod Kumar T, and Sridhar R, "Behaviour of CI engine performance, combustion and exhaust emission with neem biodiesel at varied fuel injection rates.", *International Journal of Ambient Energy*.2019, 40(7), 749-753, doi: 10.1080/01430750.2017.1423387.

[7] Balaji G, and Cheralathan M, "Experimental investigation of varying the fuel injection pressure in a direct injection diesel engine fuelled with methyl ester of neem oil.", *International Journal of Ambient Energy*. 2017, 38(4), 356-364, doi: 10.1080/01430750.2015.1111846.

[8] Jindal S, Nandwana BP, Rathore NS, and Vashistha V, "Experimental investigation of the effect of compression ratio and injection pressure in a direct injection diesel engine running on Jatropha methyl ester.", *Applied thermal engineering*. 2010, 30(5), 442-448, doi: 10.1016/j.applthermaleng.2009.10.004.

[9] Roy RK A Primer on the Taguchi Method; 2nd Edition, Society of Manufacturing Engineers, 2010, pp 49