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PERFORMANCE AND EMISSION CHARACTERISTICS OF A CI ENGINE FUELLED WITH DIETHYL ETHER BLENDED PONGAMIA BIO FUEL

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This study was initiated to find the effect of Di Ethyl Ether (DEE) on the performance and emission characteristics of Pongamia Pinnata 20% biodiesel blend (B20) fuelled single cylinder direct injection variable compression ratio CI engine. DEE was blended with the bio diesel in different percentages upto15% (by volume). Performance tests were carried out in the engine at a predetermined engine speed 1500 rpm. The results infer diethyl ether (DEE) can be utilized as a fuel additive for the CI engines. The brake thermal efficiency (BTE) of 10% DEE with B20 blend is 28.1%, while for B20 blend is 24.52% at a maximum load of 20 Nm. The brake specific fuel consumption of the engine fuelled with 10% DEE + B20 pongamia blend is reduced by 53% compared to B20 pongamia biodiesel. DEE can be added up to 10% with B20 biodiesel to reduce the exhaust emission significantly.

Keywords: Di Ethyl Ether, Pongamia Pinnata bio diesel, Variable Ratio Compression ignition engine, emission

1. Introduction

The energy necessities are escalating rapidly worldwide. Particularly fuel crisis is one of the biggest problems that have triggered interest to search for alternative fuels from bio-origin like vegetable based edible and non-edible oils. Growth of automobile vehicles in recent years created a greater demand for fossil fuels. Various investigators have carried out research work on the performance and emission of compression ignition engines using vegetable based biofuels as an alternative fuel owing to potential properties of the bio fuel [1,2] . Vegetable oil does not have sulfur, aromatic hydrocarbons and metals. Based on the weather and soil environment, researchers are seeking suitable bio fuels as a substitute for standard diesel fuels [3]. Vegetable oils cannot straightaway be chosen as a fuel in CI engines because of superior viscosity. High viscosity oil would obstruct the fuel passages which may lead to incomplete combustion, engine deposits in addition to contamination of lubricants. This can be overcome by employing various methods, such as pyrolysis, dilution, emulsification and transesterification. Vegetable oils are triglycerides of long chain fatty acids which comprise triglycerides with small

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quantities of mono and di glycerides. Bio fuel is long chain fatty acid that could be selected as a substitute fuel in compression ignition engine. Viscosity of hazelnut oil is almost eleven times more than that of standard diesel and hazelnut oil has 27% lower heating value than standard diesel [4].

Various researchers have done research on the CI engine using both edible and non-edible oils such as waste cooking oils, rapeseed, soybean, palm, cotton seed, sesame, sunflower, rubber seed oil, mahua, Pongamia and jatropha [5 ,6].Gaurav Dwivedi et al [7] reviewed the impact of biodiesel on engine performance. The Indian economy is expected to grow and energy demand to rise to 166 MT (Million Tons) of crude oil by 2019 and 622 MT by 2047. Ahmad et al [8] studied the marketability of bio fuel in the fuel sector for the future. Pongamia seeds yield 35% oil by weight. Properties were contrast with biodiesel standards of ASTM. Jinlin Xue et al [9] studied the result of bio fuel brake power, robustness and exhaust emission and reported that bio fuel extracted from renewable sources would provide the energy requirements for transportation. Siddalingappa R. Hotti and Omprakash D. Hebbal [10] studied about the production and characterization of bio fuel from sugar apple oil and reported that the bio fuel yield was 95% at the optimal process conditions. Biodiesel properties were very close to the standard diesel and in accordance with ASTM standard. Asokan et al [11] investigated the characteristics of compression ignition engine operated using diesel with papaya and watermelon bio fuel blends. Performance of the engine fuelled with B20 was very close to that operated with diesel. B20 is the most suitable blend which lessens the diesel expenditure by 15-20%. Yüksek et al [12] investigated to find the optimum compression ratio in view of the friction loss and thermal efficiency of the engine. Modern emission control methods are being employed to CI engines to attain the low fuel consumption. Frictional energy loss is becoming a vital factor for increasing the fuel efficiency. Compression ratio which is a major factor increases the cylinder pressure and exerts load on the engine components. Indicated power and friction power increased linearly with increasing the compression ratio. Mathur et al [13] optimized the value of compression ratio of a variable Compression ratio compression ignition engine. The highest brake thermal efficiency, lowest smoke capacity and CO emissions were obtained with the compression ratio of 17 and it was considered as the optimum compression ratio for the CI engine.

Khandal et al [14] demonstrated emissions of a four stroke, common rail injection system (CRDI) engine operated with honge biodiesel by varying the injection timing, injection pressure and exhaust gas re circulation. The experiments were conducted as per full factorial design. Mathematical models based on response surface methodology were employed to find the correlation among the parameters and its characteristics. Hirkude and Padalkar [15] investigated of the impact of compression ratio on the engine fueled with fried biofuel blend. It was noticed that a higher compression ratio enhances the engine thermal efficiency and reduces BSFC. The results inferred that CO and particulate matter emission declined whereas NOx emission increased with compression ratio.

Nagaraja et al [16] investigated the effect of compression ratio over the performance and emission characteristics of a variable compression ratio engine fueled with preheated palm oil - diesel blends. The blend B20 is found to give maximum mechanical efficiency at higher compression ratio (20:1) and it is 14.6% higher than diesel where as indicated mean effective pressure (IEMP) of the engine fuelled with blend B20 is lower than diesel at higher compression ratio (20:1).

Diethyl ether (DEE) could be identified to be a fuel as it is extracted from ethanol by means of the dehydration method. DEE has a number of encouraging properties for CI engines, which holds low ignition temperature, higher cetane value and energy density, a wide-ranging flammability, high O_2 and volatility. DEE is a renewable fuel and act as a fuel additive. It can be used as cold-start aid for engines. It is in liquid condition at normal pressure states which makes it easy for fuel handling. On the other hand DEE tends to oxidize and forms peroxides in storage. It has high cetane value of about 125. [17]. Sendilvelan and Bhaskar [18] studied the combustion as well as pollutants of a diesel engine through the use of polymer based additives with standard diesel. Additive reduces the exhaust smoke and slightly increases NOx. Sivalakshmi and Balusamy [19] reported that the when DEE level increases the cetane value, which results in shorter ignition delay. Rakopoulos et al [20, 21] analyzed the performance of a CI engine operated with DEE and diesel fuel. It was reported that the NOx emissions seem to be reducing when the engine operated with DEE+diesel blend. Kapilan et al [22] examined the impact of DEE additive on the engine performance. Oxygenated fuel additives are widely reported to enhance the engine performance as well as cleanliness. Experimental results showed performance improves drastically with the addition of DEE to diesel fuel. However smoke, CO and HC emission were slightly reduced. Patil and Thipse [23] investigated the combustion of CI engine using DEE–kerosene–diesel blends. The presence of oxygen in diethyl ether improves the combustion which reduces generation of particulate matter. Lee and Kim [24] investigated the engine fueled with DEE and diesel blended fuel. DEE is used in CI engines because of its exceptional cetane value. Sezer [25] investigated the use of DEE and dimethyl ether (DME) in CI engines as alternative fuels. Performance of the engine operated with di methyl ether and diethyl ether extensively enhances. But more amount of fuel is required ,about 64% for DME and 32% for DEE. The lower CO_2 is obtained by DME and DEE at all conditions, while CO and NO_X are slightly higher at equal equivalence ratio condition. Senthil et al [26] used pongamia and eucalyptus along with addition of 10% of diethyl ether. Results demonstrated that pollutants except NOx were lesser than standard diesel. Patnaik et al [27] investigated the impact of $FeCl_3$ and DEE as additives on CI engine emissions. DEE15% diesel blend indicates an increase in the brake thermal efficiency, 29.4% which is more than diesel. Purushothaman and Nagarajan [28] reported that the diethyl ether was supplied into the inlet manifold in fine droplets form which increases smoke, carbon monoxide, hydrocarbon and drop in NOx. Ibrahim [29] investigated the impact of using DEE in engine and the results inferred that diethyl ether can be employed like an oxygenated supplementary fuel for CI engines. Qi et al. [30] engine operated with DEE blended fuel provides lower BSFC and NOx compared to ethanol blended fuel. The addition of oxygenated and volatile fuels, like DEE and ethanol can be utilized in existing CI engines with no modifications. Srihari et al [31] assessed the engine operated with DEE-bio fuel-diesel blends. Addition of DEE with normal diesel reduces the combustion temperature and NOx level. As percentage of DEE increases, significantly decreases the NOx emission. It is primarily caused by the increase in latent heat with the increasing DEE in blend. Limited attempts have been made to investigate the performance and emission characteristics of variable compression ratio (VCR) ignition engine using Pongamia bio diesel and diethyl ether blend. Hence this work aims to find the optimum level of diethyl ether in Pongamia bio fuel blend using Taguchi and ANOVA methods in attaining the better performance and lower emission of the engine.

2. **Materials and Methodology**

2.1 Pyrolysis process

Pyrolysis process was employed to lower the viscosity of Pongamia oil to use in the compression ignition engine. Karanja (Pongamia pinnata) seeds were collected and healthy seeds were identified, deshelled and finally dried for moisture removal. It is a medium-size, with an average height of between 10-18 m. Pongamia pinnata fruits get matured within 4–8 years. They are elliptical in shape and flat pods with size three to six cm long and two to three cm wide. Seed kernels have about 40% of oil which is in dark brownish color, bitter flavor, and unpleasant smell. It can yield about 9000 kilograms per hectare. It is non-edible oil which is currently being under-utilized.

Fig.1. Pyrolysis distillation apparatus

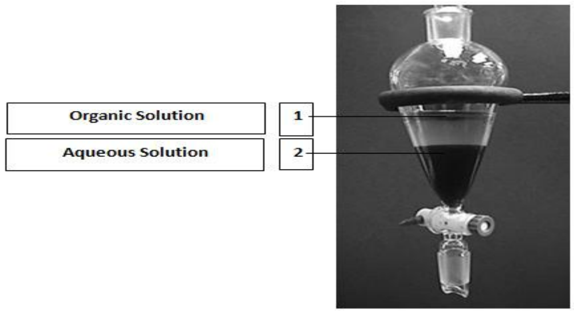

Fig.2. Decantation process

A glass made borosilicate furnace and the bench made pyrolysis distillation apparatus was employed as shown in Fig.1. After collecting the Pongamia Pinnata raw oil, impurities were cleaned by filtration. Pongamia oil was introduced in to the reactor where heating is done in a closed environment with no oxygen. The reaction temperature was kept at 400°C. A water cooled condenser has been attached for condensing the vapors coming out of it. The condensed liquid will have two substances namely Aqueous and Organic. With help of decantation method (Figure.2) aqueous solution was separated and finally bio fuel was extracted. Properties of diesel, Pyrolyzed Pongamia oil and diethyl ether are indicated in table 1.

Table. 1.

Properties of Fuel

S.No	Properties	Diesel	Pyrolyzed Pongamia oil	Di Ethyl Ether (DEE)
1.	Density in kg/m^3 @25^{0}C	825	910	713
2.	Kinematic Viscosity (@40^{0}C) cst	2.77	6.10	0.34
3.	Calorific value in kJ/kg	45,400	36,700	33,800
4.	Ash Content in gm's	nil	0.02	nil
5.	Cetane number	49	43.2	121

2.2 Variable Compression Ratio Compression Ignition Engine

The engine employed in this experiment is 4 stroke, direct injection, a single cylinder variable compression ratio multi fuel engine (Fig.3). Initially engine was operated on without load conditions and its speed was regulated at the rated 1500 rpm. It was tested at full load i.e. 20 Nm. The engine specifications are presented in the table 2.

Fig.3.Variable Compression Ratio Compression Ignition Engine

Table.2.

Specifications of Engine

S.No	Description	Specification
1.	Stroke	Four
2.	Rated power	5 HP
3.	Engine Speed	1500rpm
4.	No of Cylinders	Single cylinder
5.	Compression ratio	21:1
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 medium	Water

2.3 Exhaust Gas Analyzer

The exhaust pollutants like carbon monoxide, CO (% vol.), HC (ppm vol.), and nitrogen oxide, NO_X (ppm vol.) were recorded for each load at a constant speed (1500rpm) by using AVL 444 gas analyzer which is approved by ARAI (Automotive Research Association of India) and OIML class1/Cε/ISO3930:2000/PTB (Europe). Specifications of AVL 444 exhaust gas analyzer is displayed in table 2.1.

Table 2.1

Specifications of AVL 444 exhaust gas analyzer

Parameter	Measurement	Resolution
CO	0-10% Vol.	0-0.01% Vol.
HC	0-20000 ppm Vol.	1ppm(0-2000ppm) 10ppm(>2000ppm)
NO_2	0-5000 ppm Vol.	1ppm Vol.

The engine was operated and CO, HC and NOx emission were recorded for each test after 10 minutes. During the test, the fuel lines were cleaned before testing each blend and the VCR engine was operated for fifteen minutes to reach the stable state.

3 Experimental Procedure

The fuel tank was filled with diesel/ bio diesel blends and the engine was set to run. The engine maintains a stable speed of 1500 rpm. Compression ratio of 21:1, Injection timing of 23°bTDC and fuel Injection pressure of 180 bar were chosen. Ambient inlet air temperature was 27°C and the relative humidity (RH) was 55%. Loads were applied to the engine through an eddy current dynamometer. DEE was blended with the bio diesel in different percentages till 15% (by volume) on the behaviour with respect to performance as well as emission of the VCR engine.

4. Results and Discussion

4.1 Brake Thermal Efficiency

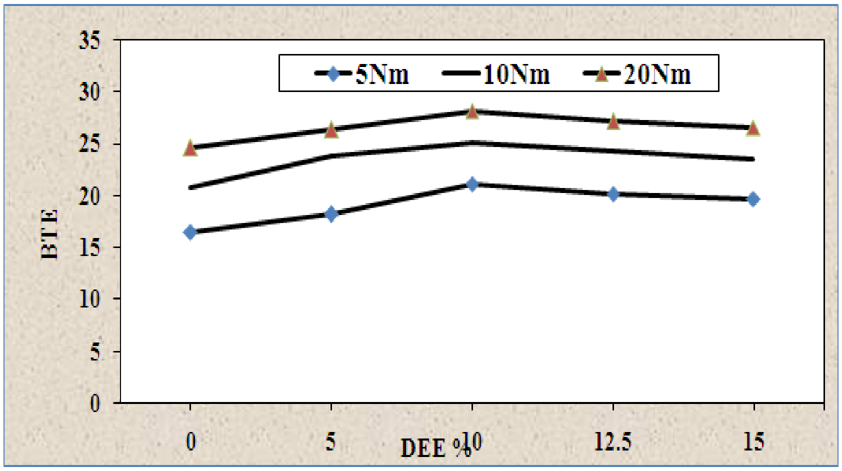

Fig.4. Variation in brake thermal efficiency with DEE fraction at different loads

Fig. 4 shows the variation in BTE with load for various percentages of DEE with B20 biodiesel. Thermal efficiency of the engine operated with 10% DEE+ B20 blend and 15% DEE+ B20 blend were found to be 28.1% and 26.5% respectively at 20 Nm load. It can be noted that BTE of the engine operated with 10% DEE+ B20 blend is more than that of B20 biodiesel and 15% DEE+ B20 blend. This rise in BTE of the engine caused by the existence of oxygen in DEE which decreases the surface tension and enhances the better atomization of the fuel. This can also be the fact that better cetane value of di ethyl ether even though the calorific value of the DEE blended bio fuel is low. On the other hand brake thermal efficiency tends to decrease when the concentration of DEE exceeds 10% owing to lesser heating value of blend. As DEE concentration increases in B20 blend, the heating value of the blend tends to decrease. Hence 10% DEE can be blended with B20 to enhance the BTE of the engine. As load increases on the engine, thermal efficiency tends to increase irrespective of the fuel tested. It is in line with other researchers [32].

4.2 Specific Fuel Consumption

The brake specific fuel consumption (BSFC) is described as the fuel consumed (1kg) to produce 1 kW power in an hour. Figure 5 elucidates the results of BSFC of the engine attained with and without diethyl ether for B20 bio diesel. It is seen that engine operated with 10 %DEE+ B20 at 20Nm yielded lower BSFC value, 0.26 kg/kWh. DEE is an oxygenated substance with high cetane value assisted B20 biodiesel to undergo complete combustion due to higher flammability.

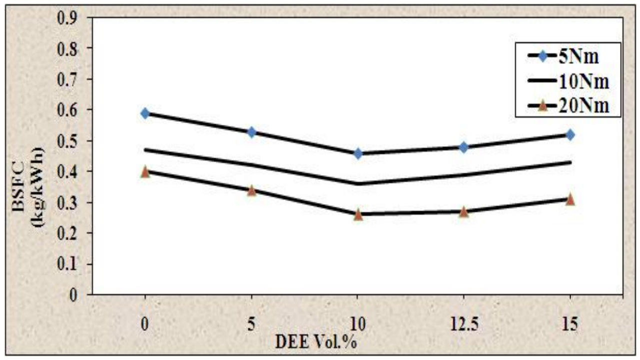

Fig.5. Variation in brake-specific fuel consumption with DEE fraction at different loads

Hence oxygenated additives could be better substitute for bio diesel. As DEE content increases beyond 10% in B20 biodiesel, brake specific fuel consumption tends to increase. The BSFC decreased when the engine was run with 10% DEE blend compared to B20 biodiesel and 15% DEE+B20 blend. The brake specific fuel consumption of the engine fuelled with 10% DEE + B20 blend and 15% DEE + B20 blend were 0.26 and 0.31 kg/kWh respectively, while for B20 biodiesel was 0.4 kg/kWh at full load. The brake specific fuel consumption of the engine fuelled with 10% DEE + B20 blend is reduced by 53% compared to B20 biodiesel. It can be concluded that the DEE can be added up to 10% with B20 biodiesel to reduce the brake specific fuel consumption considerably.

4.3 Carbon Monoxide Emission

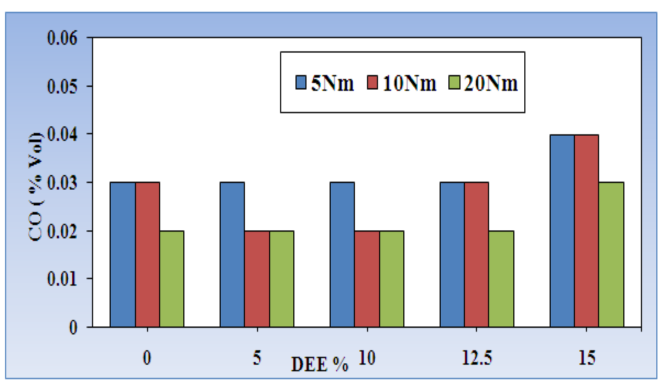

Fig.6. Variation in carbon monoxide emission with DEE fraction at different loads

Fig. 6 shows the results of CO emission of the engine obtained with DEE fraction at different loads. CO emission indicates the incompleteness in combustion process. For load 20Nm the CO emission is lower at all % of DEE. The CO emission of the engine tends to increase when DEE concentration beyond 10% in B20 biodiesel at all loads. It may be the result of the presence of more O_2 molecules in the DEE which enhances the complete burning causing lesser CO emission at max. load compared with B20 biodiesel. Conversely, when DEE% increased above 10% with B20 bio diesel, the mixture turns out to be lean and leads to poor burning by latent heat of vaporization (hfg) of DEE. The CO emission of the engine fuelled with 10% DEE + B20 blend and 15% DEE + B20 blend were 0.02 and 0.03 respectively, while for B20 biodiesel was 0.02 at full load. It can be concluded that the DEE can be added up to 10% with B20 biodiesel to reduce the CO emission significantly.

4.5 Hydrocarbon emission

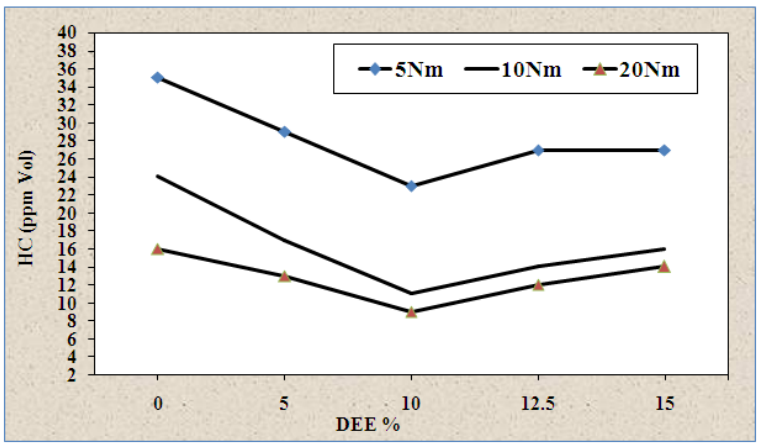

Fig.7. Variation in hydrocarbon emission with DEE fraction at different loads

Fig. 7 shows the results of hydrocarbon emission attained with DEE fraction at different loads and without DEE as an oxygenate fuel for B20 biodiesel. As displayed in Fig. 7, the HC emission decreases by increasing load, consequently the increase in combustion temperature. It can be noted that HC emission is maximum at 5Nm, while lower HC values are obtained at 10Nm and 20Nm loads at stable engine speed of 1500rpm. At full load condition, all blends display lesser HC emissions as compared to diesel caused by the superior cetane value of DEE blends. Also, the excess oxygen molecules present in biodiesel as well as DEE reduces the HC emission drastically. At full load condition, HC emissions of 5% DEE + B20 and 10% DEE+ B20 were found to be 8ppm and 7ppm respectively. Engine operated with B20 Bio diesel emits 10ppm of HC emission which is more compared to

5%DEE + B20 and 10%DEE+ B20 blends. Higher cetane number reduces auto ignition delay and premixed combustion duration but increases the mixing-controlled combustion during which the HC combustion becomes more complete and hence lower HC values are registered. Similar results have been reported by Sivalakshmi and Balusamy [19].

4.6 Nitrogen Oxide (NOx) emission

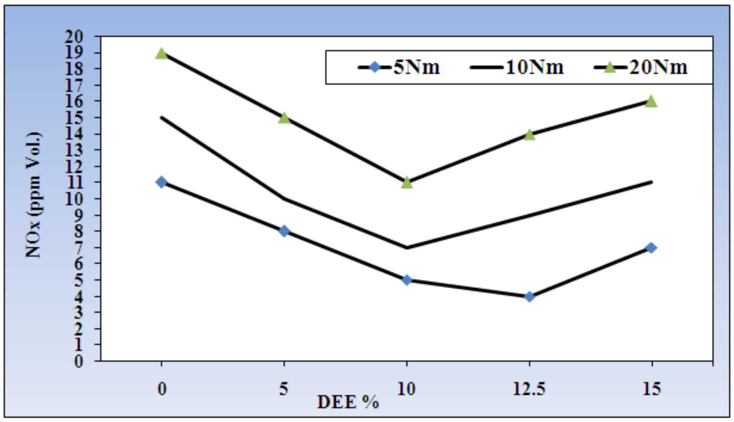

Fig.8. Variation in NO_X emission with DEE fraction at different loads

Fig. 8 elucidates the results of NO_X emission (ppm Vol.) attained with DEE fraction at different loads and without DEE as an additive in B20 biodiesel. The oxides of nitrogen emission increasing with increasing content of DEE more than 10% with B20 biodiesel blend. Figure 8 also demonstrates NOx emission tends to increase by load. The temperature of the combustion chamber increases when load is increased on the engine. At full load condition, NOx emission of the engine operated with 5%DEE + B20and 10%DEE+ B20 were found to be 16 and 11 respectively. NOx emission of the engine operated with B20 blend and 10% DEE+ B20 were found to be 21 and 11 respectively. NOx emission of 10% DEE+B20 blend is decreased by 48% compared to B20 biodiesel at 20Nm. Hence NOx emission is considerably reduced when 10 % of DEE added with B20 blend. One of the most harmful emissions is nitrogen oxides which can be reduced by blending oxygenated additive DEE in bio fuel. However addition of DEE exceeds 10% by volume, NOx emission increased drastically. This can be attributed to the fact that oxygen available in DEE increased the cylinder temperature during the combustion and that can be clearly proved in heat release rate and exhaust gas temperature of the engine (33). It was observed that highest exhaust temperature was recorded (133°C) when the engine was running with bio fuel blended with DEE 12.5% by volume compared to bio fuel blended with DEE 10%.

5. Taguchi and ANOVA Analysis

Taguchi method which was introduced by Genichi Taguchi method was applied to know the optimal levels of parameters affecting the process. It brings down the difference in a process by DoE (Design of Experiments) concept. While the process parameters increase, the number of tests will also increase. But Taguchi introduced orthogonal arrays to analyze the process parameters with only a small number of tests to select the optimum level of parameters which have an impact of performance of the process. It minimizes experimental runs, time and the cost. ANOVA method can be used to know the contribution of parameters on the response. L9 Taguchi orthogonal array was used to have two process factors and each with three levels for the experimental plan. Each test was repeated twice and mean values were considered. Selected process factors along with their levels were: Load (5Nm, 10Nm, and 20Nm); DEE blend in B20 biodiesel (0%, 5%, 10%).

Table 3

Process parameters with their values at three levels

Level	Load (Nm) (A)	DEE % (B)
I	5	0
II	10	5
III	20	10

Table 4

Measured values and S/N ratios

Exp.No	Load (Nm) (A)	DEE % (B)	Measured values		Signal/Noise Ratio	
			BTh%	BSFC (kg/kWh)	BTh%	BSFC
1	5	0	16.45	0.59	24.32332	4.58296
2	5	5	18.18	0.53	25.19188	5.514483
3	5	10	21.10	0.46	26.48565	6.744843
4	10	0	20.78	0.47	26.35291	6.558043
5	10	5	23.87	0.42	27.55705	7.535014

6	10	10	25.12	0.36	28.00039	8.87395
7	20	0	24.52	0.40	27.79041	7.9588
8	20	5	26.31	0.34	28.40242	9.370422
9	20	10	28.10	0.26	28.97413	11.70053

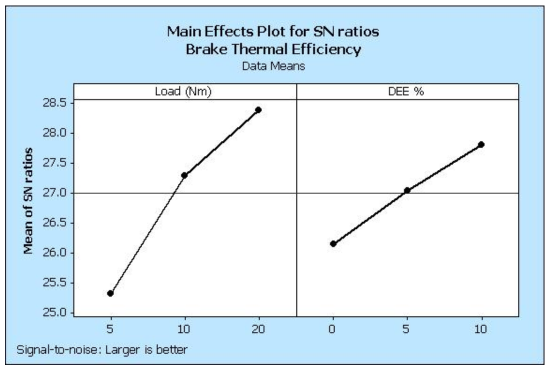

Fig.9. Main effects plot for SN ratios (Brake thermal efficiency)

Table 5 shows that delta values for the load and DEE % were 3.06 and 1.66 respectively. Load was the dominant factor followed by DEE % for the Brake thermal efficiency of the CI engine.

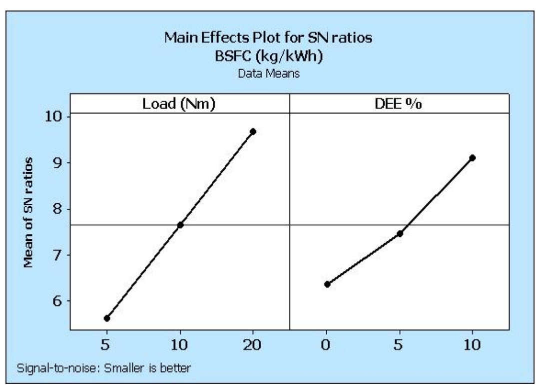

Fig.10. Main effects plot for SN ratios (Brake Specific Fuel Consumption)

Table5

Response Table for Signal to Noise Ratios (Brake thermal efficiency)

Level	Load (Nm)(A)	DEE% (B)
1	25.33	26.16
2	27.30	27.05
3	28.39	27.82
Delta	3.06	1.66
Rank	1	2

Table 6

Response Table for Signal to Noise Ratios (BSFC)

Level	Load (Nm)(A)	DEE% (B)
1	5.614	6.367
2	7.656	7.473
3	9.677	9.106
Delta	4.062	2.740
Rank	1	2

Table 6 shows that delta values for the load and DEE % were 4.062 and 2.740 respectively. Load was the dominant factor followed by DEE % for the BSFC of the CI engine .

5.1 Results of S/N ratio

S/N (Signal/Noise) ratio is expressed in a decibel, determined from the quadratic function. Measured values and corresponding S/N ratios are given in Table.4. Signal indicates the mean value and noise indicates the variance (undesirable) for the outcome of the process. This method is employed to classify the controllable factors that reduce the consequence of the uncontrollable (noise) factors on the output response. The selected factor having maximum S/N ratio tells the desired quality with the least difference. Ranking of factors was prepared by means of S/N ratios and given in the table 5 and table 6 for the BTE and BSFC respectively. For both the cases, Load on engine was the dominant parameter followed by DEE %. From the response diagrams (Fig.9 and 10), it was noted that the optimal level of parameters were Load (20Nm) and DEE content (10%). The obtained results depend on the fuel characteristics and the operating conditions.

Table 6

ANOVA results for BTE and BSFC

Factors	DoF	BTE %				BSFC (kg/kWh)			
		SS	F	P value	Pc%	SS	F	P value	Pc%
Load (Nm) (A)	2	91.030	168.59	0.001	76.8	0.056422	461.64	0.000	69.8
DEE% (B)	2	26.358	48.81	0.002	22.24	0.024156	197.64	0.000	29.88
Error	4	1.080			0.91	0.000244			0.30
Total	8	118.467			100	0.080822			100

5.2 Results of ANOVA

ANOVA can be used to find the contribution of factors on the outcome. ANOVA was done by using MINITAB16 software for a level of significance of 5% and analysis is presented in Table 6. It can be noted that P- value for load and DEE content, were less than or equal to 0.05, factors may be considered as significant at 95% confidence level for BTE and BSFC of the engine. It can also be noted from the Table 6 that Load (76.8%) was the vital factor followed by DEE content (22.24%) influencing the BTE of the engine. Load (69.8%) was the vital factor followed by DEE content (29.88%) influencing the BSFC of the engine.

6. Conclusions

Based on this present investigation, the following conclusions have been summarized.The brake thermal efficiency of 10% and 15% DEE with B20 blend is 28.1% and 26.5%, respectively, while for B20 blend is 24.52% at a maximum load of 20 Nm. On the other hand brake thermal efficiency tends to decrease when the concentration of DEE exceeds 10% caused by lesser heating value of DEE blend. The brake specific fuel consumption of the engine fuelled with 10% DEE
+B20 blend and 15% DEE + B20 blend were 0.26 and 0.31 kg/kWh respectively, while for B20 biodiesel was 0.4 kg/kWh at full load. The brake specific fuel consumption of the engine fuelled with 10% DEE + B20 blend is reduced by 53% compared to B20 biodiesel. When DEE% increased above 10% with B20 bio diesel, the mixture turns out to be lean and leads to poor combustion by reason of high latent

heat of vaporization (hfg) of DEE. It can be concluded that the DEE can be added up to 10% with B20 biodiesel to reduce the brake specific fuel consumption considerably. It can be concluded that the DEE can be added up to 10% with B20 biodiesel to reduce the CO emission significantly. At full load conditions, HC emissions of 5%DEE + B20 and 10%DEE+ B20 were found to be 8ppm and 7ppm respectively. Engine operated with B20 Bio diesel emits 10ppm of HC emission which is more compared to 5%DEE + B20 and 10%DEE+ B20 blends. NOx emission of 10% DEE+B20 blend is decreased by 48% compared to B20 biodiesel at 20Nm. Hence NOx emission is considerably reduced when 10 % of DEE added with B20 blend. One of the most harmful emissions is nitrogen oxides which can be reduced by blending oxygenated additive DEE in bio fuel. However when the addition of DEE exceeds 10% by volume, the NOx emission increased drastically.

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