EXPERIMENTAL INVESTIGATION ON A SINGLE CYLINDER DIESEL ENGINE WITH COTTONSEED OIL BIODIESEL WITH ADDITIVES

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Abstract - *Diesel engine is a most versatile, robust and largely used machine in industry, transportation, and agriculture sector. Diesel fuel is continuously explored since invention of diesel engine. The diesel fuel is limited in reserves and likely to last for next 3 decades. On other hand diesel engine emits smoke, unburnt hydrocarbon, carbon monoxide, carbon dioxide, and nitrogen oxides. 70% of these gases come from transportation sector. The stringent environmental regulation forced to find an alternative liquid fuel for diesel. Among the many alternatives, vegetable oil and there derivatives that is biodiesel are proven suitable alternative to diesel due to its properties which are very close to diesel. The viscosity of biodiesel is higher and calorific values are lower than that of diesel. Biodiesel produces the required power with a higher emissions, especially smoke and nitrogen oxide. To reduce the emissions the quality of biodiesel shall be equal or better than that of the diesel. To improve the cetane number of biodiesel and combustion quality some of the additives are added. In present work an additives called diethyl ether (DEE), isobutanol (IB) and methanol (M) is blended with cottonseed oil biodiesel at 5%, 10% and 15% by volume and these blends are tested on a single cylinder diesel engine to evaluate combustion, emission and performance characteristics. It is observed that addition of the additives into the biodiesel improve the quality of fuel and there brake thermal is better than that of neat diesel and biodiesel. Emission such as smoke, carbon monoxide, unburnt hydrocarbon and nitrogen oxide are lower than that of neat biodiesel. However methanol additives increase nitrogen oxide emission at higher percentage of additives.*

Key Words*: *Additives; Biodiesel; Emission…

1. INTRODUCTION

Diesel engine is a most versatile and robust in construction, being so largely these engine are used in industries, transportation, agriculture sector etc. Since its invention diesel fuel is explored continuously from the earth crust. The diesel fuel are limited in reserves and lack to last for next 35-45 years [1]. On other hand diesel engines emits green houses, which are determinate to flora and fauna. Apart from this the diesel reserves are available in limited part of the world (midlist), so has politically disturbances which effects there continuous supply. All these necessitated to find an alternative fuel to the diesel. Many researches worked on alternative fuel such as alcohols [2], vegetable oils and their derivatives [3], liquid petroleum gas [4-5], hydrogen etc. Among these esters of vegetables oil called biodiesels. The biodiesels of Peanut oil, Jatropha oil [6], Pongamia oil [7], Mahua oil [8], Neem oil [9], etc. were successfully tested on diesel engine. The advantages of biodiesel as diesel fuel are minimum sulphur and aromatic content and higher flash point, lubricity and cetane number there disadvantages includes higher viscosity, lower calorific value and volatility. Performance of diesel engine with 20 % addition of biodiesel that is (B20) is a most acceptable worldwide. Emission of HC and CO with (B20) are reduced NO_X emission are higher than that of diesel [10].

To have the better performance and lower emissions sum additives are added to biodiesel. These additives includes cetane number of the biodiesel, renew energy density for on-board stoned, high oxygen content, low auto ignition temperature, broad flammability limits and high miscibility in diesel fuel. In the literature reviews it is found that methanol [10], n-butanol [11], ethanol [11], diethyl ether [11], propanol are used as additives with biodiesels. The use of additives showed improvement in engine performance and reduction in emissions. All biodiesels are not tested and reported in open-end literature. The limited research work is published of sum of biodiesel. There is a need to collect huge amount of data on potential additives with different biodiesel.

In this project an attempt is being made to characterised, cottonseed biodiesel with diethyl ether, isobutanol and methanol additives and there combustion, emission and performance characteristics evaluation on single cylinder DI diesel engine.

2. EXPERIMENTATION

2.1 Introduction

In continuous with previous chapter additive like diethyl ether, isobutanol and methanol additives identified to blend with cottonseed biodiesel. These different ratio of blends were prepared and tested on single cylinder DI engine, there combustion, emission and performance characteristics are evaluated and presented in future chapter. In this chapter experimental setup and associated instrumentation were are presented.

Table 1: Properties of diesel, cottonseed oil methyl ester diethyl ether, isubutanol and methanol

Properties	Diesel	Cottonseed biodiesel	Diethyl ether	Isubutanol	Methanol
Calorific value (KJ/KG)	42500	39605	36840	32500	19700
Density (kg/m^3)	820	904.8	713	809	790
Kinematic viscosity (mm^2/s)	3.5	7.5	0.23	2.26	0.59

2.2 Direct ignition diesel engine

Kirloskar make single cylinder 5.2 Kw at 1500 rpm water cooled with eddy current dynamometer is used for experimentation. Fig 1 shows schematic diagram and fig 2 photograph of experimental shows table 2 shows specification of diesel engine used in experimentation.

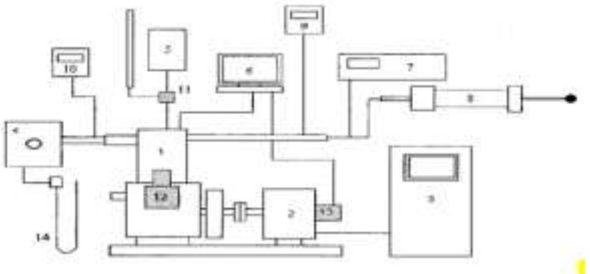

Fig 1: Schematic diagram of Experimental setup

Nomenclature:

1	Diesel Engine	8	Exhaust gas Calorimeter
2	Eddy current Dynamometer	9	Exhaust temperature indicator
3	Dynamometer Control	10	Air inlet temperature
4	Anti-pulsating drum	11	two way valve
5	Fuel Tank	12	Fuel injection pump
6	Computer with DAQ	13	Crank angle encoder
7	Smoke meter	14	Manometer

2.3 Experimental procedure

The experiment were conducted at 0, 20, 40, 60, 80 and 100% load. Fuel flow, air flow and water flow by measured and fit to the engine software to determine thermal efficiency, brake specific fuel consumption, exhaust gas temperature, pressure with crank angle diagram, heat released rate, cumulative heat released rate.

At different load using 5-gas analyser emission of smoke opacity, unburnt hydrocarbon, carbon monoxide, oxide of nitrogen and carbon dioxide are recorded.

3. REULTS AND DISCUSSION

3.1 Diethyl ether additives with biodiesel

3.1.1 Combustion characteristics

Fig 3.1 shows the variation of cylinder pressure with crank angle for at peak respectively. The shape of pressure with crank angle diagram for all the fuels under test are similar. Maximum pressure are 68.73, 68.05, 70.71, 60.88 and 67.53 bar for diesel, biodiesel, BD95DEE5, BD90DEE10 and BD85DEE15 respectively. In all the cases the maximum pressure occurs at 10° after top dead centre.

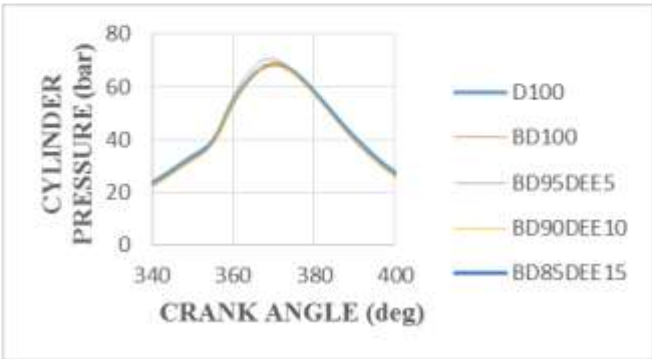

Fig 3.1: Variation of cylinder pressure with crank angle

Fig 3.2 shows the variation of net heat release rate with respect to crank angle. The maximum heat released rate for all fuels are in the range of 25-30 J/deg. Among all the fuel under test blend with 15% diethyl ether is more uniform. This attributes to improvement in quality of the fuel cetane number due to diethyl ether additives.

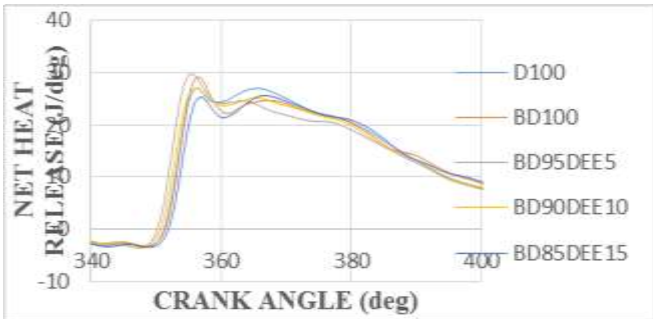

Fig 3.2: Variation of net heat release rate with crank angle

3.1.2 Emission characteristics

Fig 3.3 shows the variation of smoke opacity with brake power. For all the fuel under test smoke emission lower at lower load and it increases sharp at full load. The maximum smoke emission at full load for D100, BD100, BD95DEE5, BD90DEE10 and BD85DEE15 are 98.9, 97.4, 90.5, 86.8 and 93.1 % of opacity respectively. This attributes to maximum load more amount of fuel injected into the cylinder, which leads the reach mixture. From the figure it can be observed smoke emission of BD100 is much higher compare to D100, this could be due to higher viscosity of oil which makes size of the droplets higher and leads to poor combustion. As the percentage of diethyl ether increases the smoke emission gradually reduced and even becomes lower than that of diesel.

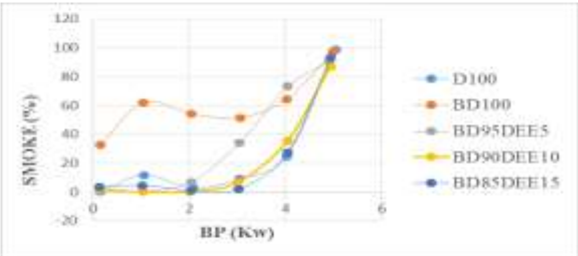

Fig 3.3: Variation of smoke opacity with brake power

Fig 3.4 shows variation of carbon monoxide with respective brake power. It is found that carbon monoxide emission of BD100 is higher compare to that of D100. At maximum load carbon monoxide emission of pure biodiesel is 0.92% against 0.1% of diesel. By adding diethyl ether the quality of biodiesel increases, carbon monoxide emission is of order of 0.06% which is much lower than that of neat diesel.

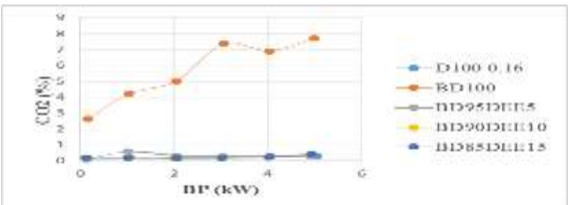

Fig 3.4: Variation of carbon monoxide emission with brake power

Fig 3.5 shows the variation of oxide of nitrogen emission with respective to brake power. It is observed that additives of diethyl ether into the biodiesel reduces nitrogen oxide emission. However nitrogen oxide emission for pure biodiesel is first increases up to 258 ppm at 60% load and reduces. This attributes to oxygen present in biodiesel, which readily reacts with nitrogen of spitted air and forms oxides of nitrogen.

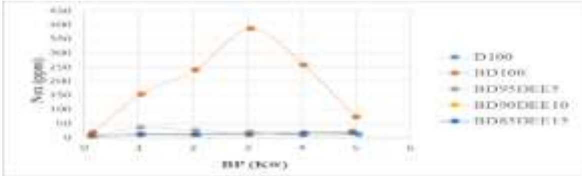

Fig 3.5: Variation of oxide of nitrogen emission with brake power

3.1.3 Performance characteristics

Fig 3.6 shows the variation 0f brake thermal efficiency with respective to brake power. Thermal efficiency of all the fuel under test increases as load increases. It reaches maximum at 80% of load and reduces a little at maximum load. Efficiency of biodiesel is lower than that of diesel at all loads. At maximum load brake thermal efficiency of biodiesel is 19.93% against 20.42% diesel. This attributes to higher exhaust emission and higher viscosity of biodiesel. However brake thermal efficiency of improve a lot by adding diethyl ether. As the percentage of diethyl ether increases the brake thermal efficiency also increases. The maximum efficiency occurs for BD85DEE15 blend is order of 27.1% followed by 25.36%, 25.35% and 23.3% for BD90DEE10, BD95DEE5, and BD100 respectively. By increasing the quantity of diethyl ether improve cetane number of biodiesel

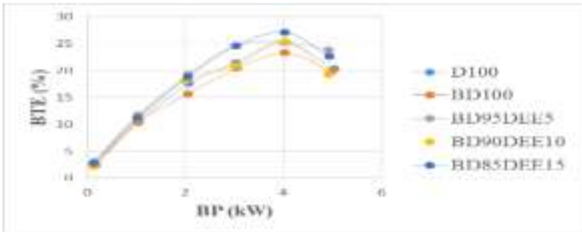

Fig 3.6: Variation of brake thermal efficiency with brake power

3.2 Isobutanol additives with biodiesel

3.2.1 Combustion characteristics

Fig 3.7 the variation of cylinder pressure with respective crank angle for value at peak respectively. The shape of pressure with crank angle diagram for all the fuel test are similar. Maximum pressure are 68.73, 68.05, 70.59, 68.68 and 67.53 bar for diesel, biodiesel, BD95IB5, BD90IB10 and BD85IB15 respectively. In all the cases the maximum pressure occurs at 10̊ top dead center.

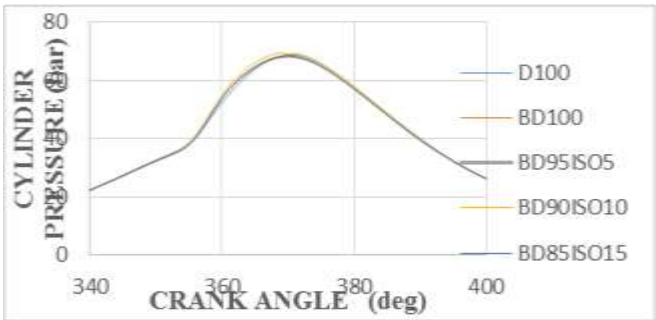

Fig 3.7: Variation of cylinder pressure with crank angle

Fig 3.8 shows the variation of net heat release rate and its close value at the top dead centre respectively. The maximum heat released rate for all fuels are in the range of 25-30 J/deg. Among all the fuel under test blend with 15% IB is more uniform. This attributes to improvement in quality of the fuel, cetane number due to isobutanol additives.

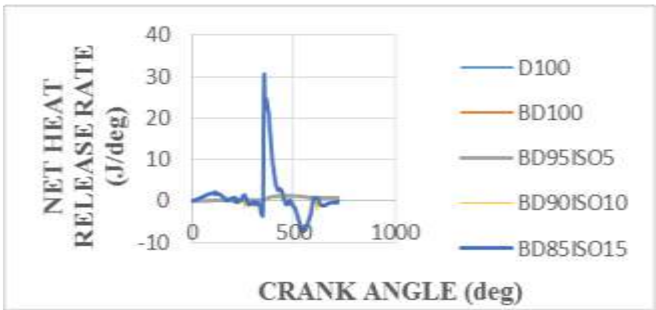

Fig 3.8: Variation of net heat release rate with crank angle

3.2.2 Emission characteristics

Fig 3.9 shows the variation of smoke opacity with brake power. Soot content in the exhaust gas is indicated the smoke opacity. Smoke is mainly formed due to incomplete combustion of hydrocarbon fuel and the composition of smoke generally depends on engine operating condition and type of fuel. The maximum smoke emission at full load for D100, BD100, BD95IB5, BD90IB10 and BD85IB15 are 98.9, 97.4, 42.0, 60.8 and 98.9 % of opacity respectively. This attributes maximum load more amount of fuel injected into the cylinder, which leads the reach mixture. From the figure it can be observed by smoke emission of BD100 is much lower compare to D100, this could be due to lower viscosity of oil makes size of the droplets lower and which leads to pure combustion that of diesel. As the percentage of isobutanol increases the smoke emission gradually reduced and even becomes lower than that of diesel.

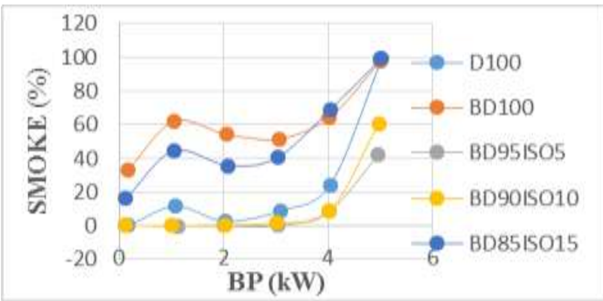

Fig 3.9: Variation of smoke opacity with brake power

Fig 3.10 shows variation of carbon monoxide with respective brake power. Carbon monoxide forms during combustion with rich air fuel mixture regions because insufficient oxygen available to completely oxidize all carbon monoxide content in the fuel. It is found that carbon monoxide emission of BD100 is higher compare to that of D100. At maximum load carbon monoxide emission of pure biodiesel 0.92% against 0.1% of diesel. By adding Variation isobutanol the quality of biodiesel increases, carbon monoxide emission is of order of 0.02% which is much lower than pure diesel.

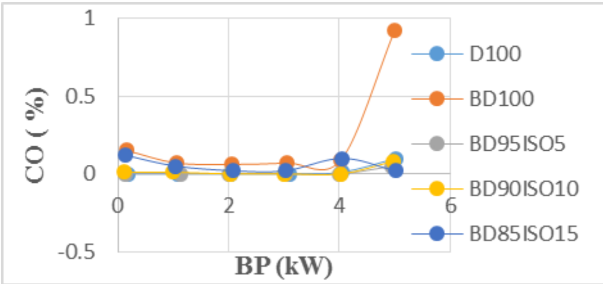

Fig 3.10: of carbon monoxide emission with brake power

Fig 3.11 shows the variation of oxide of nitrogen emission with respective brake power. It is observed that additives of isobutanol into the biodiesel reduces nitrogen oxide emission. However nitrogen oxide emission for pure biodiesel is first increases up to 258ppm at 60% load and reduces. This attributes to oxygen present in biodiesel, which readily reacts with nitrogen oxide of spitted air and forms oxide nitrogen.

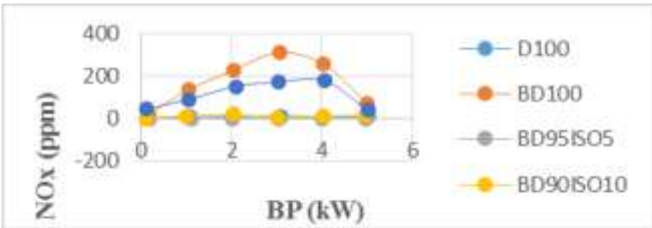

Fig 3.11: Variation of oxide of nitrogen emission with brake power

3.2.3 Performance characteristics

Fig 3.12 shows the variation 0f brake thermal efficiency with respective brake power. Thermal efficiency of all the fuel under test increases load increases brake thermal efficiency increases. It reaches maximum at 80% of load and reduces a little at maximum load. Efficiency of biodiesel is lower than that of diesel at all loads. At maximum load brake thermal efficiency of biodiesel is 19.93% against 20.42% diesel. This attributes to higher exhaust emission and higher viscosity of biodiesel. However brake thermal efficiency of improve a lot by adding isobutanol. As the percentage of isobutanol increases the brake thermal efficiency also increases. The maximum efficiency occurs for BD85IB15 blend is order of 24.42% followed by 23.98%, 23.9% and 21.89% for BD90IB10, BD95IB5, and BD100 respectively.

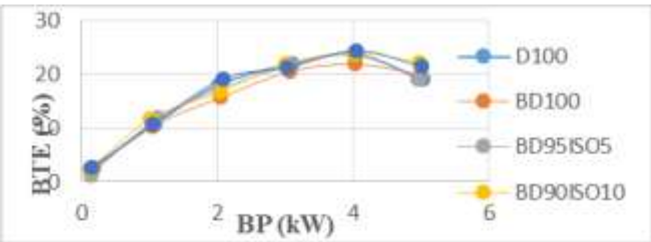

Fig 3.12: Variation of brake thermal efficiency with brake power

3.3 Methanol additives with biodiesel

3.3.1 Combustion characteristics

Fig 3.13 shows the variation of cylinder pressure with crank angle value of peak respectively. The shape of pressure with crank angle diagram for all the fuel test are similar. Maximum pressure are 68.73, 68.05, 67.63, 67.22 and 66.97 bar for D100, BD100, BD95M5, BD90M10 and BD85M15 blends respectively. In all the cases maximum pressure occurs at 10° after top dead center.

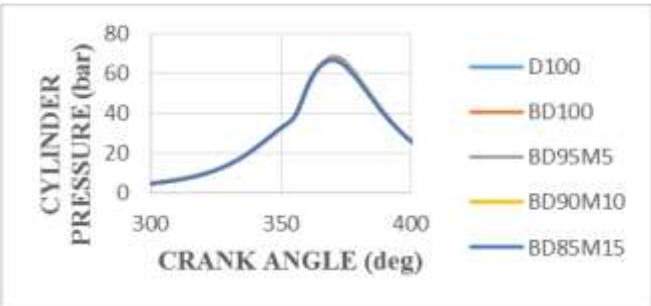

Fig 3.13: Variation of cylinder pressure with crank angle

Fig 3.14 shows variation of net heat release rate for a full stroke and its close value at the top dead centre respectively. Average net heat release rate during premixed combustion is higher for biodiesel followed by diesel, 5% methanol, 10% methanol and 15% methanol blend. It indicates that temperature of the gas during first phase of combustion is higher for biodiesel followed by diesel, 5% methanol, 10% methanol and 15% methanol blend. Among all the fuel under test biodiesel with 15% methanol blend is more uniform.

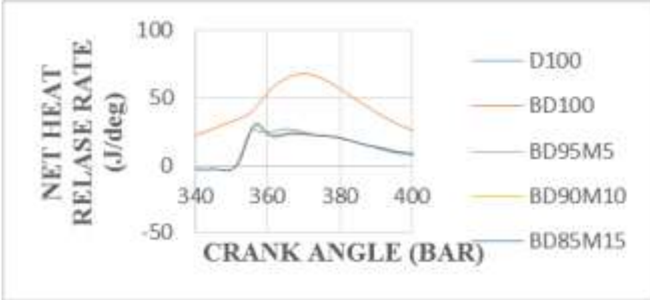

Fig 3.14: Variation of net heat release rate with crank angle

4.3.2 Emission characteristics

Fig 3.15 shows variation of smoke emission with brake power. It is observed that emission of the smoke for biodiesel is much higher than that of diesel. This attributes to higher viscosity of the biodiesel which increases the droplets sizes and reduced the spray penetration, which leads to improper combustion. However by adding 15% methanol to the biodiesel improves the cetane number of biodiesel and combustion ability. At full load smoke emission of 15% methanol mix is 75.52% against diesel is 98.9%, biodiesel is 97.4%, BD95M5 is 99.6% and BD90M10 is 77.01%.

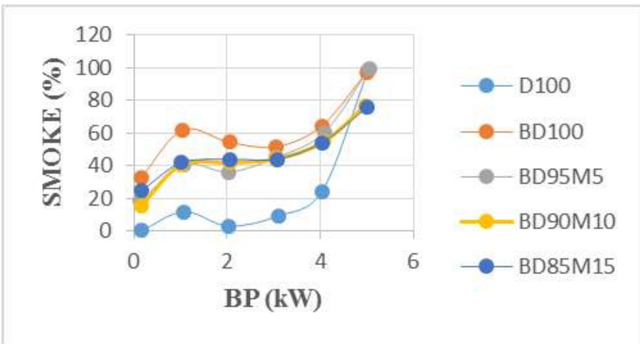

Fig 3.15: Variation of smoke emission with brake power

Fig 3.16 shows variation of nitrogen oxide emission with brake power. Emission of nitrogen oxide for biodiesel is higher than that of diesel. The maximum nitrogen oxide emission occurs at 60% of load 258 ppm against 13 ppm of diesel. This attributes to higher cylinder gas temperature and inbuilt oxygen present in the biodiesel. Both are favourable commodities for formation of nitrogen oxide. However of adding of 5% methanol blend well compare to diesel.

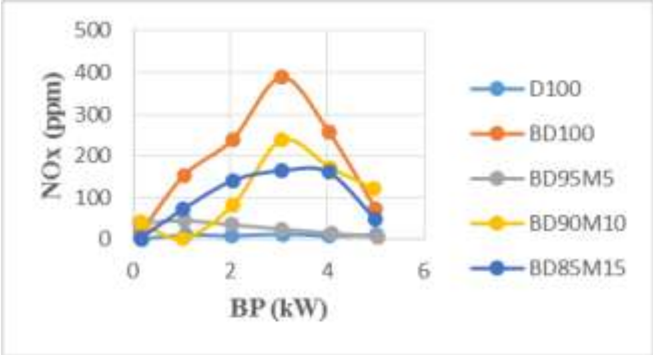

Fig 3.16: Variation of nitrogen oxide emission with brake power

4.3.3 Performance characteristics

Fig 3.17 shows variation of brake thermal efficiency with brake power. Brake thermal efficiency of biodiesel is lower than that of diesel at all loads. However brake thermal efficiency of 15% methanol blend is higher than that of diesel at maximum loads. The maximum efficiency of 15% methanol blend is 24.84% followed by 23.7, 23.61 and 23.3% for BD90M10, BD95M5 and BD100 respectively. By adding more percentage methanol increases the efficiency.

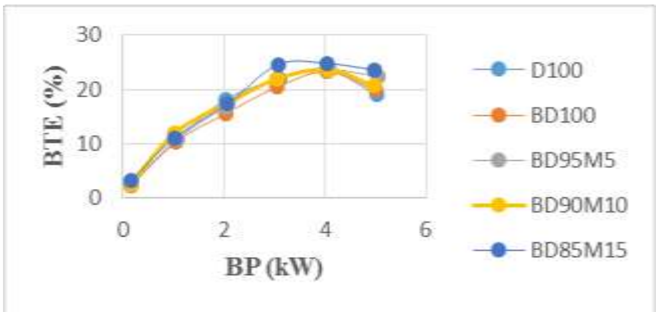

Fig 3.17: Variation of brake thermal efficiency with brake power

4. CONCLUSIONS

The following conclusions are drawn from the experimental project.

- Smoke, carbon monoxide and nitrogen oxide emissions are higher for neat biodiesel compare to that of diesel. This attributes to poor combustion of biodiesel due to higher viscosity which leads to higher droplet and lower penetration.
- By adding diethyl ether the fuel quality of biodiesel increases. Further reduces smoke, carbon monoxide and nitrogen oxide.
- As the percentage of diethyl ether in the blend increases emission of smoke, carbon monoxide and nitrogen oxide decreases. Brake thermal efficiency of BD85DEE15 is higher that is 27.1% which occurs at 80% of load. The brake specific fuel consumption of BD85DEE15 is lower that is 0.32 kg/kW-h than that of neat biodiesel that is 0.39 kg/kW-h.
- Smoke emission for additives isobutanol in biodiesel reduces smoke emission compare to that of neat biodiesel. However smoke emission at 5, 10, and 15% of isobutanol is higher than that of diesel. As the percentage of isobutanol increases smoke emission increases.
- Carbon monoxide and unburnt hydrocarbon emission with isobutanol addition to the biodiesel reduces.
- Nitrogen oxide emission is lower that of the biodiesel methanol blends. However by increasing the percentage isobutanol in the blend emits considerably amount of nitrogen oxide. This attributes to inherent oxygen content in the additives of isobutanol.
- Brake thermal efficiency of 15% additives of isobutanol with biodiesel is higher than that of biodiesel and diesel. The maximum thermal efficiency of IB15% is 24.42% against 21.89% of neat diesel.
- Smoke emission with the additives of methanol to the biodiesel is considerably higher. This attributes to low cetane number of methanol.
- Carbon monoxide emission of methanol blend higher than that of diesel and lower than that of neat biodiesel. Further unburnt hydrocarbon is little higher than that of neat diesel.
- Nitrogen oxide emission of methanol blends with biodiesel is higher than diesel but lower than that of neat biodiesel. As the percentage of methanol is increased nitrogen oxide emission increased, this attributes to oxygen molecular available in methanol. Which radially reacts with nitrogen quality in combustion and form nitrogen oxide.
- Brake thermal efficiency of methanol blends is better than that of biodiesel. The maximum brake thermal efficiency for 15% methanol blend is 24.84% at 80% load.

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