Experimental Investigation On A Single Cylinder Diesel Engine With Cottonseed Oil Biodiesel With Additives

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Abstract-

Diesel engine is an utmost 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, as well as 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 precise near to diesel. Viscosity of biodiesel is higher and calorific values are lesser than that of diesel. Biodiesel produces required power through a higher emissions, especially smoke and nitrogen oxide. To decrease discharges quality of biodiesel will be equal or better than that of the diesel. To improve cetane amount of biodiesel and combustion quality some of the additives are added. In present work an additives called diethyl ether (DEE) with cottonseed oil biodiesel at 3%, 6% and 9% by volume and various mixes are evaluated on a single cylinder diesel engine to determine combustion, emission & functional properties. It is detected 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 like smoke, carbon monoxide, unburnt hydrocarbon as well as nitrogen oxide are lower than that of neat biodiesel.

Keywords : Cottonseed oil, additives, combustion characteristics, emission characteristics, performance characteristics

I. INTRODUCTION

1.1 General introduction

Diesel engine is a most versatile and robust in construction, being so largely these engines are used in industries, transportation, agriculture sector etc. Since its invention diesel fuel is explored continuously from the earth crust. The diesel fuel is limited in reserves and lack to last for next 35-45 years. 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, vegetable oils and their derivatives, liquid petroleum gas, hydrogen etc. Among these esters of vegetables oil called biodiesels. The biodiesels of Peanut oil, Jatropha oil, Pongamia oil, Mahua oil, Neem oil, etc. were successfully tested on diesel engine. Aside from benefits of using biodiesel as a diesel fuel, which include reduced sulphur as well as aromatic content, a greater flash point and lubricity & cetane number, there are also downsides.

To have the better performance and lower emissions sum additives are added to biodiesel. These additives includes cetane number of the biodiesel, low ignition temperature and wide flammability restrictions; high miscibility in diesel fuel; and renewed energy density for on-board stoned. In the literature reviews it is found that diethyl ether [DEE], propanol are used as additives with biodiesels. Engine performance as well as emissions were both improved when additives were used. Altogether 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 dataon potential additives with different biodiesel.

In this project an attempt is being made to characterized, cottonseed biodiesel with diethyl ether, additives and there combustion, emission as well as performance features evaluation on single cylinder DI diesel engine.

II.LITERATURE REVIEW

2.1 Performance and emission of biodiesel

Puneet verma et al.was taken vegetable oils identical to waste cooking oil, palm oil, coconut oil, jatropha oil and converted it into biodiesel by transesterification method and found act as well as emissions on 4-stroke single cylinder CI engine. BSFC was increased by increase in speed of engine and brake power as of lower heating value of the biodiesel than mineral diesel. By increase in blend percentage the BSFC was increasing. The BTE is decreased for all the biodiesels than diesel due to high viscosity and density of biodiesels. But for B20 blends of jatropha and palm oils the BTE has improved. From the overall experiment it shows the B20 blend biodiesel is the most reasonable blendfor the engine.

H.M.Dharmadhikari et al. performed the experiment on diesel enginewith karanja and neem biodiesel blends at changed injection pressures and associated by diesel as well as found that these biodiesels can be used directly without any changes. The BTE of blends were lesser than diesel because of high viscosity as well as poor volatility. But for B10 and B20 the BTE is closer to diesel and so found suitable. The BSFC with blends of biodiesel is high as linked by diesel because of low heating value as well as high density. Exhaust gas temperatures were increased by increase in blends concentration for all the biodiesels dueto low heat transfer rate. At a pressure of 200 bar optimum value of injection pressure wasobserved.

Ashok kumar yadav et al. were studied enactment as well as emissions features on a transportation engine by non-edible oil methyl esters of oleander,ground nut and kusum at many speeds as well as full load situations as well as found that these biodiesels were alternative resource for conventional fuels. Results presented that BTE of oleander methyl ester is high and BSFC is lower than other two oils.with the ground nut methyl ester. As a result, these biodiesel fuels may be used in engine without requiring any substantial modifications.

B.Deepanraj et al. With lower percentages of biodiesel, BTE is raised and BSFC is decreased, and emissions are reduced, on a straight ignition single cylinder 4 stroke diesel engine at continuous speed. Biodiesel derived from palm oil at a percentage of 20-40% may be utilised as a diesel substitute without need for any alterations.

U. Santhan Kumar et al. used corn oil biodiesel to conduct experiment on diesel engine and create that BTE is improved by increase in brake power and maximum for B15 than diesel because of better atomization as well as vaporization of fuel and BSFC is minimum for B15 than other blends and diesel due to development in combustion as well as less calorific value. The higher heat release rate is observed for B30 and maximum cylinder pressure for B60.

Soni S.Wirawan et al. choosed palm oil biodiesel to conduct performance and emissionson automotive diesel engine with the blends B10,B20,B30,B50 and B100.the results had shown that with higher blends of palm biodiesel the power and torque are increasing and the power with B100 is less than B10 and B20 and maximum torque was exerted by all the blends at a speed of 30 to 40 km.

2.2 Bio-diesel additives

The particular sorts of additives must to be combined in biodiesels to fulfill worldwide fuel regulations. Additives are mixed in specified proportion seeing type of feedstock oil and qualities like flash point, fire point, viscosity, density, calorific value as well as solubility etc. (Najafi 2018). Flame spread speed of methanol is high as it is an oxygenating additive which accelerates velocity of combustion process. It possesses high latent heat & high-octane number.

A neutral fuel (pH 7) that contains 34% more oxygen than ordinary gasoline, ethanol is also known as ethyl alcohol. A modest amount of ethanol has a noticeable effect on BTE (Mofijur et al., 2016). Auto-ignition temperature of diethyl ether, another oxygenating chemical, is lower (Imtenan et al., 2014). Biodiesel's calorific value is enhanced, and engine emissions are reduced significantly, due to fuel's strong flammability.

In order to improve engine performance and fulfil pollution control criteria, researchers have combined several additives in biodiesel. Different biodiesel feedstocks have varying levels of fuel additives and fuel characteristics. Cottonseed oil viscosity was reduced by up to 2.8 to 2.6 cSt when ethanol (5%) was added, according to Madiwale et al. (2017). C loud point dropped to about -22 and -24 degrees Celsius, and wax began to form. Calorific value is reduced by 3460 kJ/kg & flash point is lowered after 30 to 14 degrees Celsius. Also, density is reduced by 6 to 8 kg/m^3. When cottonseed oil is enriched with 5 percent diethyl ether (DEE), viscosity as well as density decrease& cetane number rise from 45.9 to 49.8, according to Malarmannan et al. (2016). There is no change in calorific value as a result of improved combustion quality.

2.3 Performances as well as emission of biodiesel blended with additives

Combustion qualities of diesel may be greatly improved by adding a little amount of additives. Adding ethanol to B20 cottonseed oil raises BTE by 7 to 12 percent, then reduced calorific content of mix reduces braking power marginally. When compared to clean diesel, air consumption rose by 60 to 70% but NOX emissions decreased. However, CO emissions are greater than diesel but lower than a B20 mix of gasoline.

Malarmannan et al., (2016) studied performance & combustion of cottonseed oil biodiesel by DEE; BTE enhances by rising blending proportion by 5 percent constant DEE addition. Because of poor thermal efficiency of cottonseed oil, BSFC rises. It is also observed that CO2 emission rise with an increasing load owing to increasing oxygen content. The CO emission displays rising behavior when blending ratio and DEE level rises owing to the greater heat of vaporization.

Kwanchareon P et al., At various temperatures and in varying proportions, we tested ethanol biodiesel as well as diesel blends. At increasing engine loads, CO & HC levels decreased knowingly, though NOx levels increased. , Biodiesel additives studied included methanol, ethanol, and carbon monoxide (CO) emissions. Engine emissions of NOx and PM are decreased while using gasoline additives. Increased carbon monoxide and hydrocarbon emissions were caused by use of alcohol. A CI engine using biodiesel & methanol as an addition was studied and evaluated by Cheng CH, et al. CO2, NOx, PM concentrations have been observed as less, according to the findings of the investigation. P. Bridjesh and colleagues. Constant speed engine was used for all of trials, which were run at varying loads.

III.OBJECTIVE OF STUDY

Main objective of proposed work is:

- To optimize biodiesel production of selected cottonseed oil biodiesel.
- To obtain the characteristics like performance, emission as well as combustion then related to that with the neat biodiesel as well as there its additive blends.
- To setup the cottonseed oil test ring for the experiment with diethyl ether,(DDE) additive and different biodiesel blends.
- To conduct the combustion, emission, as well as performance features of cottonseed oil biodiesel blends with 03, 06, 09% diethyl ether, additives by volume basis.
- To study effect of cottonseed oil biodiesel by 03.06.09% diethyl ether, additive on combustion, emission as well as performance features then related by that of neat biodiesel on normal engine.

3.1 Statement of the project

As mentioned in the objective an experimental is conducted on diesel engine usage of cottonseed oil biodiesel by diethyl ether, isobutanol and methanol additive and biodiesel blends on direct injection CI engine. Thus, obtained results are then compared with the neat cottonseed oil biodiesel and diesel on normal CI engine. The details are as follows.

- The cottonseed biodiesel is prepared and fuel properties are determined.
- The test is conducted for D100,BD100, BD97DEE03, BD94DEE06 and BD91DEE0 9on CI engine.
- Combustion characteristic like Pressure of cylinder by crank angle and net heat discharge rate by crank angle are evaluated.
- Emission characteristics of the different percentage of cottonseed oil biodiesel are evaluated

in terms of smoke, CO, HC and NO_X.

- Performance characteristics like BTE, and BSFC are evaluated.

3.2 Scope of the project

- Finding the characteristics of diesel, cottonseed oil biodiesel as well as its blends by diethyl ether.
- Conducting experiment on a single cylinder diesel engine to calculate combustion characteristics, emission features as well as performance features.
- To make biodiesel production a continuous process, apparatus must be set up such that cottonseed oil can be converted into biodiesel and fed into engine, and engine can operate continually.
- Finally, finding a suitable combination of cottonseed oil biodiesel as well as diethyl ether as an alternate fuel for CI engine.

IV. EXPERIMENTATION

4.1 Transesterification procedure

Transesterification is chemical process that takes place in order to produce biodiesel from oil or animal fats. It is possible to transesterify an ester with an alcohol by swapping ester's organic group R for alcohol's organic group R in organic chemistry. An alcohol is used to react oil or animal fat with a catalyst (often a strong base acid) to produce alkyl esters of fatty acid mixtures contained in the oil or animal fat in this reaction. E. Ducky and J. Patrick performed transesterification of oil in 1853, long before Rudolf Diesel's first LHR diesel engine was operational.

Figure 1 : Experimental setup of transesterification process

4.2 Procedure for preparation of biodiesel from cottonseed oil

- One litre of cotton seed crude oil is to be in use.
- Around 200-250 ml of methanol & 7.8 grams of NaOH (catalyst) is to be added to oil.
- This combination should be heated to between 65 and 70 degrees Celsius.
- The mixture should be kept at this temperature and constantly stirred for roughly two hours.
- After this reaction, mixture should be allowed to settle for 8 to 10 hours.
- There would be two layers to this settling reactant combination.
- Upper layer as bio diesel as well as traces of glycerine etc.
- Bottom layer as glycerine as well as gum etc.
- Open bottom tap on biodiesel preparation machine to remove glycerine.

- A separating funnel is used to collect pre-washed biodiesel.
- Two layers are separated after almost an hour of shaking biodiesel with hot water at around 50 °C and allowing it to settle.
- Above procedure is reiterated at least three times so that bits of glycerine as well as soap get distant.
- After washing method oil is heated up to 100 degree celsius to eliminate water particles.
- Biodiesel produced from cotton seed oil is ready for use.

4.3 Experimental setup

In continuous with previous chapter additive like diethyl ether additives identified to blend with cottonseed biodiesel. These different ratio of blends are set and verified on single cylinder DI engine, there combustion, emission as well as performance features are evaluated then presented in future chapter. In this chapter experimental setup and associated instrumentation were are presented.

Preparation of biodiesel and additives blends

Biodiesel and diethyl ether: Diethyl ether at 03%, 06% and 09% by volume is added to the cottonseed oil biodiesel the mixture is thoroughly stirred and prepared made ready for experimentation.

Table 1: Properties of Diesel, cottonseed oil methyl ester, diethyl ether

Sl.No	Characteristics	Diesel	CottonSeed oil Methyl Ester	DiethylEther (DEE)
01	Density (kg/m^3)	820	904.8	713
02	Calorific value (kJ/kg)	42500	39605	36840
03	Kinematic Viscosity at 40C	3.5	7.5	0.23
04	Flash point, C	68	204	45
05	Fire point, C	107	230	44

Direct ignition diesel engine

Kirloskar make single cylinder 5.2 kW at 1500 rpm cooled water by eddy current dynamometer is used for experimentation. Fig 2 shows schematic diagram and Fig.3 picture of investigational shows Table 2 displays requirement of diesel engine used in experimentation.

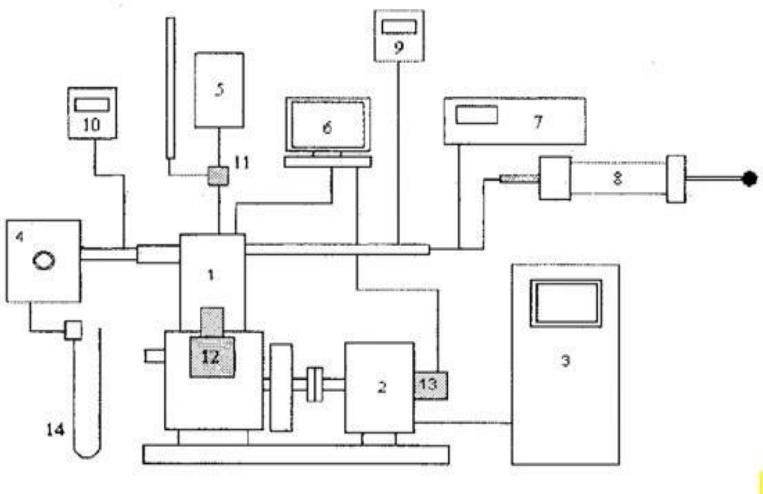

Figure 2: Schematic figure of experimental arrangement

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

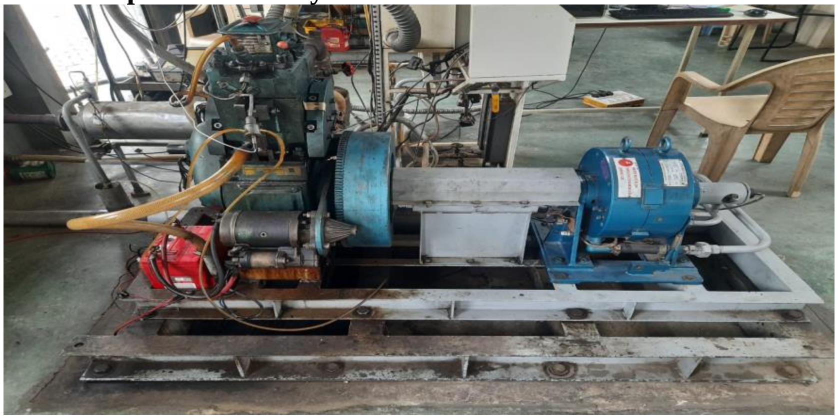

Figure 3: Photograph of experimental setup

Table 2: Specification of diesel engine

Manufacture	Kirloskar Oil Engines Ltd,India
Model	TV-SR II, naturally aspirated
Engine	Single cylinder, direct injection diesel engine
No. of strokes	4
Cylinder diameter	87.5mm
Connecting Rod Length	234mm
Stroke/compression(CR)	110mm/17.5:1
Orifice diameter	20mm
Dynamometer arm length	185mm
Rated power	5.2Kw
Speed	1500rpm,constant
Injection pressure/advance	200bar/23 degree before TDC
Dynamometer	Eddy current
Type of starting	Self starter
Exhaust gas temperature	RTD thermocouple
Fuel flow measurement	Burette with digital stopwatch
Governor	Mechanical governing
Sensor response	Piezo electric
Time sampling	4 micro seconds
Resolution crank	1 degree crank angle
Angle sensor	360 degree encoder with resolution of 1 degree

4.4 Monitoring and measurements

- Eddy current dynamometer

Output of engine may be measured using a DC electrical eddy current dynamometer. A statistical calibration is performed prior to usage of eddy current dynamometer. Dynamometers are reversible, meaning they may be used as both a monitoring and absorption tool. Adjusting field current allows you to regulate load. P rinciple of eddy current dynamometers is established on Fleming's right hand law (eddy current). Magnetic poles (stators) are positioned outside of dynamometer, by an opening, and are propelled by a prime mover. Magnetic pole is excited using a coil that is coiled in a circular fashion. Stators and a rotor generate a magnetic flux loop around exciting coil when electricity is sent through it. Eddy current travels from rotor to stator due to difference in density. This eddy current produces a magnetic force that is delivered in an opposite direction of rotating motion. Table 3 shows specification off eddy current dynamometer.

Table 3 Technical specification of eddy current dynamometer

Model	AG 80
Type of dynamometer	Eddy current Dynamometer
Make	Saj test plant private ltd
Cooling system	Water cooled
Load cell	Maywood load cell
Dynamometer	210mm

Gas analyzer

The fig 4 shows exhaust gas analyser. AVL DITEST MDS 480 exhaust gas analyzer 1000 modules is used for emission test. It is equipped with a wide range of high-tech sensors. Additional features include ability to store a vehicle as well as customer information, a radio-connected diesel measurement chamber, and possibility to create protocols to your specifications. D evice's durability and ease of use make it an excellent tool for doing in-depth analyses of emissions. This serves to educate, motivate, and influence behaviour. "IC engine soft" software and "automation and measurement" software are used to connect computer to engine used to regulator enginecycle operation and working.

Figure 4: AVL Exhaust gas analyzer

Engine software: Based on continuous monitoring, screening of pressuring the cylinder a pressure crank angle figure is drawn for an average of 10 cycles for a given load. Further using cylinder pressure with crank angle diagram, heat released rate and commutative heat released rate are evaluated based on ideal fluid and automatic ash calculated by engine software.

4.5 Experimental procedure

The experiments were conducted at 0, 03, 06, 09, and 12 KG 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 by 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 and oxide of nitrogen are recorded.

V. RESULT AND DISCUSSION

5.1 Introduction

There are three types of experimental analysis that are included in this topic: first, combustion characteristics like cylinder pressure and net heat release rate against crank angle; second, emission features such as smoke emission (N), CO, HC, and NOx, in contradiction of brake power; and third, brake thermal efficiency as well as brake specific fuel consumption compared to brake power are included in this section.

5.2 Diethyl ether additives with biodiesel

5.2.1 Combustion characteristics

- Variation of cylinder pressure by crank angle

Fig 5 displays difference of cylinder pressure by crank angle for full values at peak. The shape of pressure by crank angle diagram for all the fuels under test are similar. Maximum pressure are 76.06, 76.36, 76.26, 75.37 and 76.52 bar for diesel, biodiesel, BD97DEE03, BD94DEE06 and BD91DEE09 respectively. In all the cases the maximum pressure occurs at 10 after top dead centre.

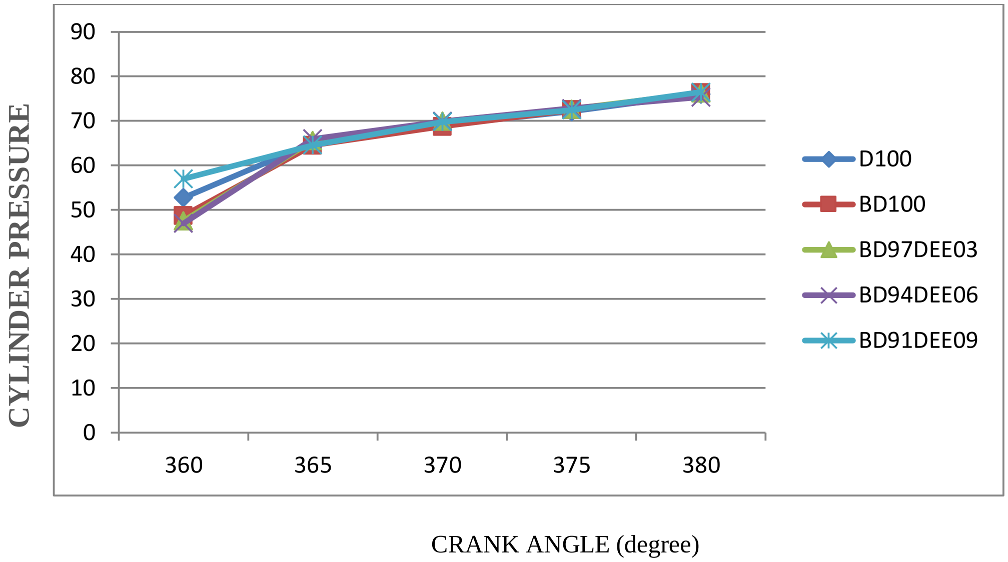

Figure 5 Variation of cylinder pressure with crank angle

Fig 6 displays difference of net heat discharge amount by respect to crank angle. Maximum heat released rate for all fuels are in collection of 35-40 J/deg. Among all the fuel under test blend with 09% diethyl ether is more uniform. This attributes to improvement in quality of the fuel cetane number due to diethyl ether additives.

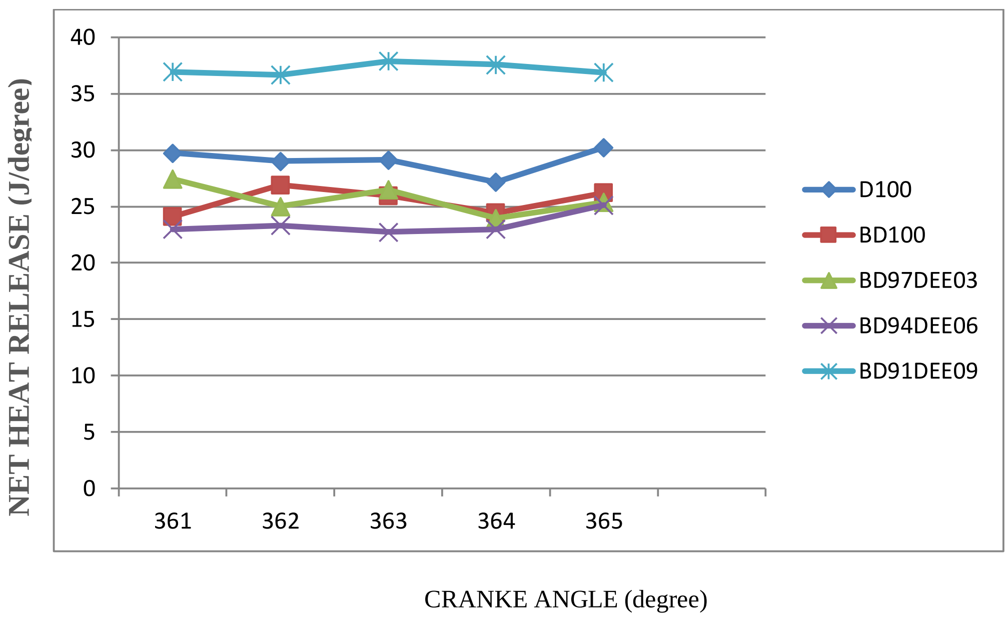

Figure 6: Variation of net heat release rate by crank angle

5.2.2 Emission features

- Variation of smoke opacity by brake power

Fig 7 displays the difference of smoke opacity by brake power. For all fuel under test smoke emission lower at lower load and it increases sharp at full weight. Maximum smoke release at full weight for D100, BD100, BD97DEE03, BD94DEE06 and BD85DEE09 are 19.4,9.5, 13.7, 19.3 and 19.3 % of opacity respectively. This attributes to maximum load more measure of fuel injected into cylinder, which indications reach mixture. From figure it can be detected smoke emission of BD100 is much lesser 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 smoke emission graduallyreduced and even becomes lower than that of diesel.

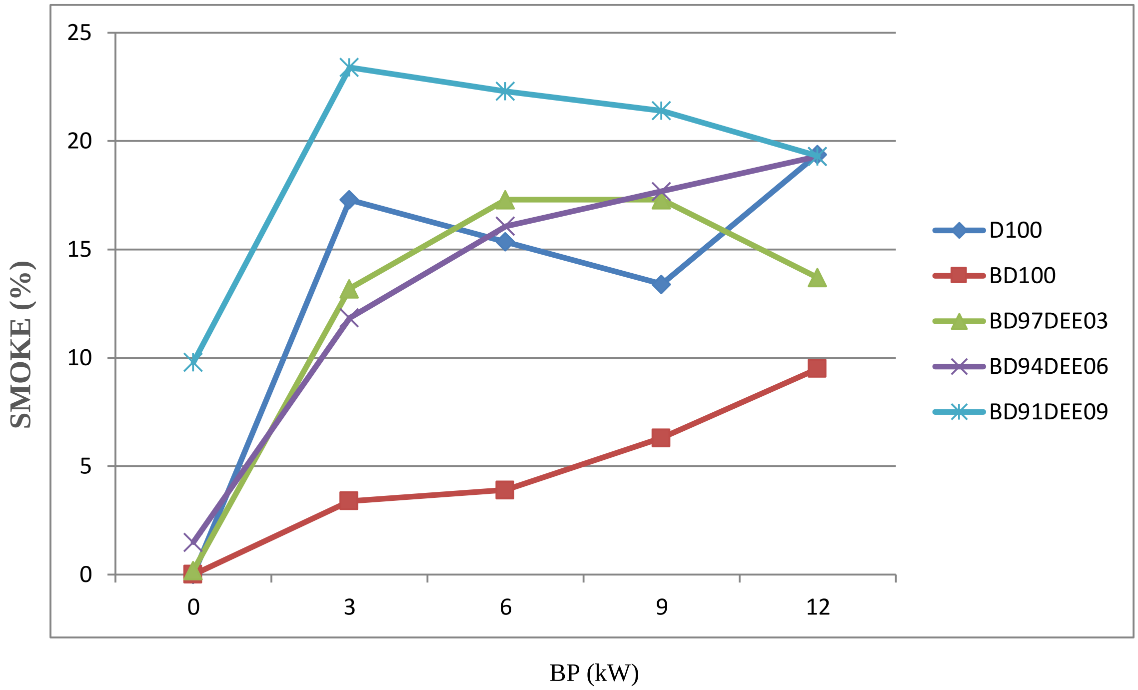

Figure 7: Variation of smoke opacity with brake power

- Variation of carbon monoxide emission with brake power

Fig 8 displays difference of carbon monoxide by respective brake power. It is found that carbon monoxide release of BD100 is lesser compare to that of D100. At extreme weight carbon monoxide emission of pure biodiesel is 0.46% against 0.56% of diesel. By adding diethyl ether the quality of biodiesel increases, carbon monoxide emission is of order of 0.10% which is much lower than that of neat diesel.

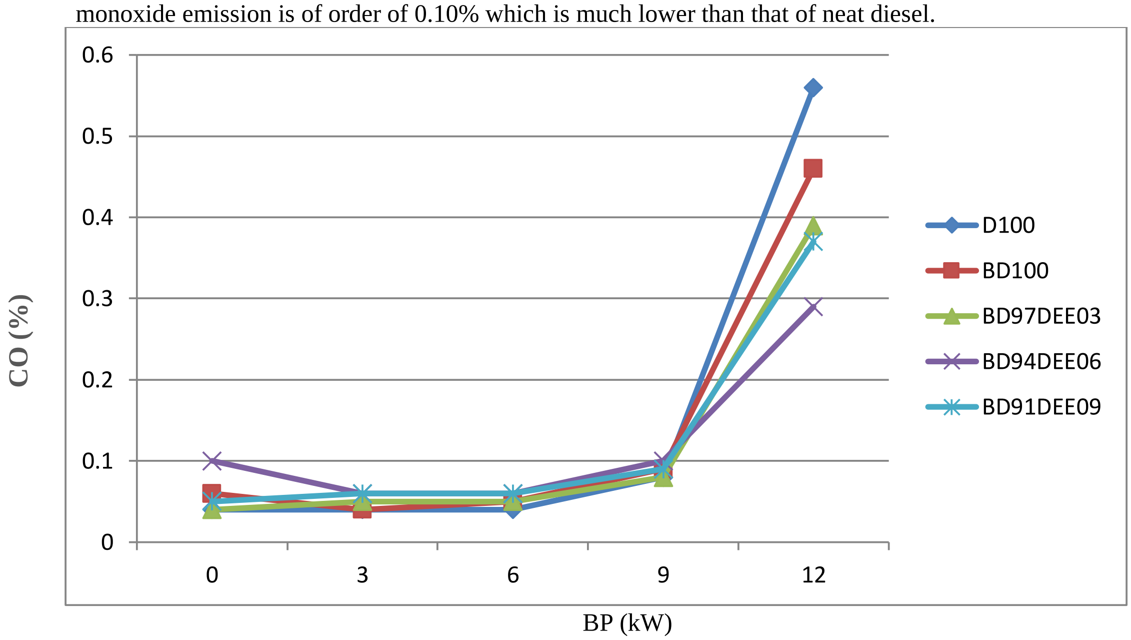

Figure 8: Variation of carbon monoxide emission with brake power

- Variation of unburnt hydrocarbon emission with brake power

Fig 9 displays the difference of HC emission by respective to brake power. At maximum load unburnt hydrocarbon emission for D100, BD100, BD97DEE03, BD94DEE06 and BD91DEE09 are 64, 47, 42, 38 and 50 ppm respectively. Unburnt hydrocarbonemission for pure biodiesel is lower because of higher viscosity of biodiesel with respective of diesel.

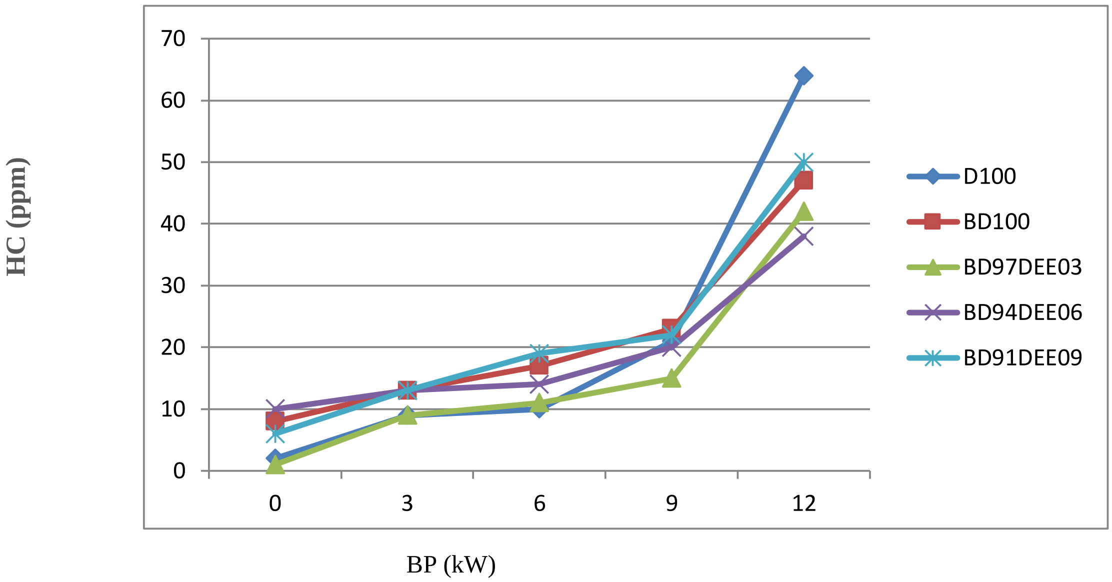

Figure 9: Variation of unburnt hydrocarbon emission with brake power

- Variation of nitrogen oxide emission with brake power

Fig 10 displays difference of oxide of nitrogen emission by 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 758 ppm at 60% load and then reduces. This attributes to oxygen present in biodiesel, which readily reacts with nitrogen of spitted air and forms of nitrogen oxides.

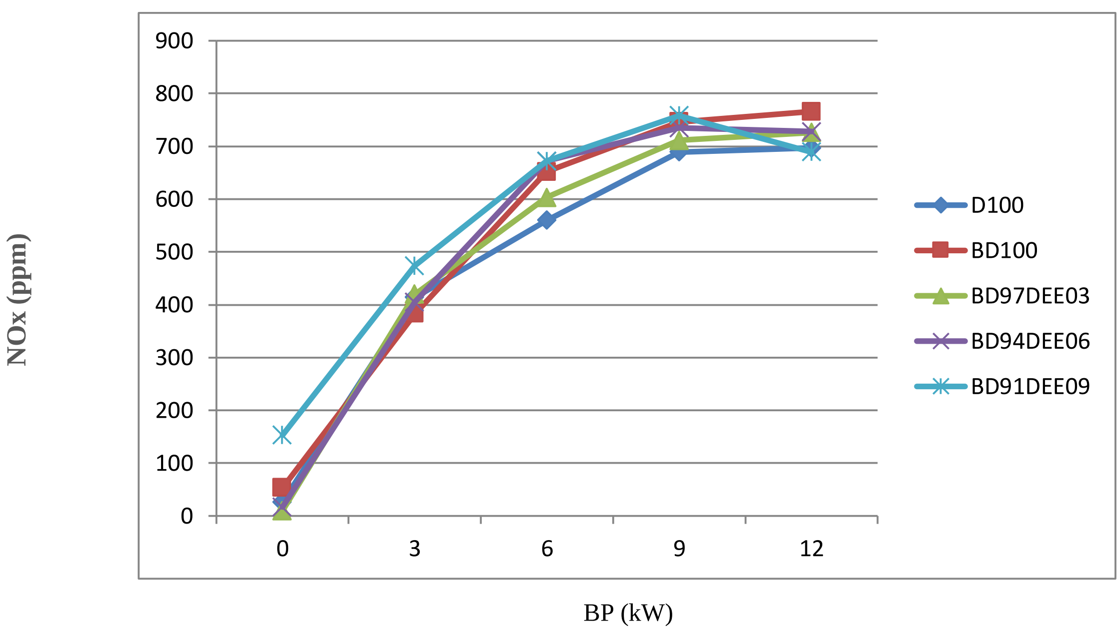

Figure 10: Variation of oxide of nitrogen emission with brake power

5.2.3 Performance characteristics

- Variation of brake thermal efficiency with brake power

Fig 11 displays difference 0f brake thermal effectiveness by respective to brake power. Thermal efficiency of all 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 lesser thanthat of diesel at all loads. At extreme load brake thermal efficacy of biodiesel is 19.44% against 18.46% diesel. This attributes to higher exhaust emission and upper viscosity of biodiesel. However brake thermal effectiveness of improve a lot by adding diethyl ether. As percentage of diethyl ether rises brake thermal effectiveness also rises. Maximum efficiency occurs for BD91DEE09 blend is order of 19.88% followed by 19.73%, 19.14% and 18.32% for BD94DEE06, BD97DEE03, and BD100 respectively. By increasing the quantity of diethyl ether improve cetane number of biodiesel.

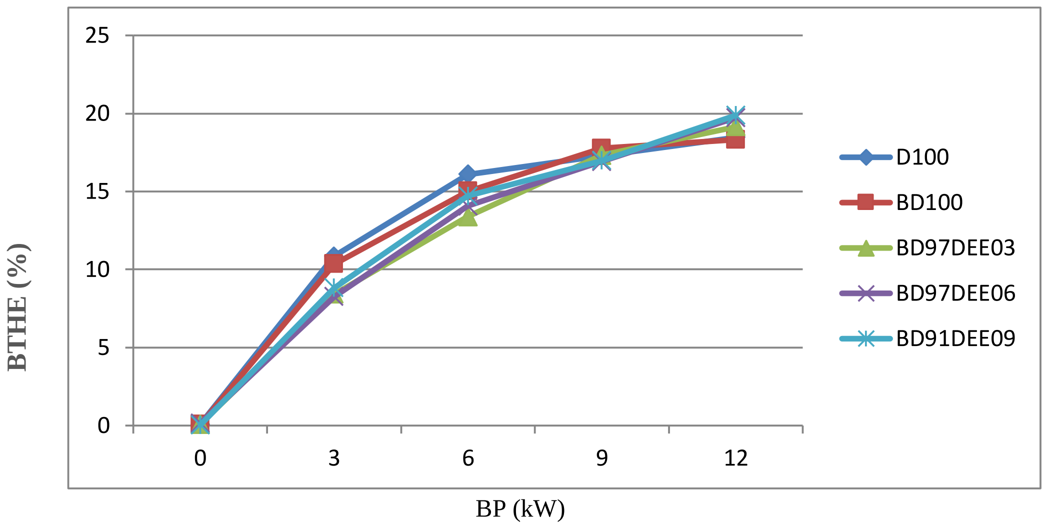

Figure 11: Variation of brake thermal efficiency (%) with brake power (Kw)

- Variation of brake specific fuel consumption with brake power

Fig 12 displays difference of brake specific fuel consumption by respective to brake power. Brake specific fuel consumption curve is a just reverse curve of brake thermal effectiveness. Minimum brake specific fuel consumption of biodiesel is 0.46 in contradiction of 0.49 kg/kW-h diesel. Adding diethyl ether increases quality of combustion as well as brake specific fuel consumptionis order of 0.42 kg/kW-h.

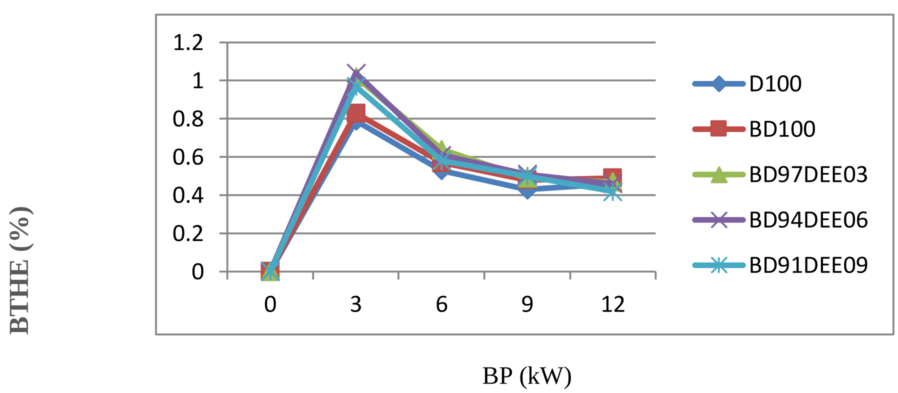

Figure 12: Variation of brake specific fuel consumption by brake power

VI.CONCLUSION

Subsequent conclusions are drawn from experimental project.

- Neat biodiesel produces more smoke, carbon monoxide, unburned hydrocarbon, & nitrogen oxide emissions than diesel. High viscosity causes larger droplets and lesser penetration, resulting in less efficient burning of biodiesel.
- By adding diethyl ether the fuel quality of biodiesel increases. Further reduces smoke, carbon monoxide, unburnt hydrocarbon and nitrogen oxide.
- Smog, carbon monoxide, unburnt hydrocarbons, and nitrogen oxide emissions fall as amount of diethyl ether in mixture rises. Brake thermal efficiency of BD91DEE09 is higher that is 19.88% which arises at 80% of load. Brake specific fuel consumption of BD91DEE09 is lower that is 0.42 kg/kW-h than that of neat biodiesel that is 0.49 kg/kW-h
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