



EFFECT OF INJECTOR OPENING PRESSURE ON DAIRY SCUM BIODIESEL OPERATED DIESEL ENGINE

Manjunath Channappagoudra*1., Ramesh K² and Manavendra.G³

^{1,2}Department of Mechanical Engineering, U.B.D.T College of Engineering, Davangere, Karnataka, India

³Department of Mechanical Engineering, B.I.E.T, Davangere, Karnataka, India

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ABSTRACT

The applications of diesel engines are more as they have more output power and thermal efficiency. But their emissions effect the environment and human being health. Hence there is a lot of scope to search for alternative fuels which promise better performance and emission behaviors of internal combustion (IC) engines. In this regard dairy scum oil methyl ester (DSOME) is a promising sustainable substitute fuel for conventional diesel engines. The standard diesel engine parameters are optimum for diesel but not for DSOME. The present investigation made a effort to use dairy waste scum as a potential source of alternative fuel for diesel engine. In first phase of work, different blends of DSOME (B10, B20, B30 and B100) are prepared and studied their effect on diesel engine performance and emission characteristics. From the study it's observed that DSOME-B20 exhibits improved performance and emission characteristics among other blends hence it is optimized and carried for further investigation. In second phase of work injector opening pressure (IOP) of the standard engine is modified from 210 bar to 240 bar in step of 10 bar (210, 220, 230 and 240 bars) to study the performance, emission and combustion characteristics of the diesel engine. From the experimental results it's revealed that increasing the IOP from 210 bar to 230 bar with DSOME-B20, brake thermal efficiency (BTE) is increased while brake specific flue consumption (BSFC), CO, and HC emissions are reduced however, NOx (oxides of nitrogen) is increased marginally. The combustion parameters namely heat release rate (HRR) and cylinder pressure are enhanced significantly with DSOME-B20 at 230 bar IOP. Based on experimental results it's conclude that 230 bar IOP is the optimum for DSOME-B20 fuel blend operation in diesel engine.

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INTRODUCTION

Diesel engines are the most efficient prime movers. Development of alternative fuels with comparable properties to diesel is in need to protect the environment and energy security [1]. As the oil and gas resources are going to end in few decades, crop based oils are the key alternative fuels to conventional petroleum fuels. The use of Biohydrogen in IC engines will play the key role in upcoming days [2]. Dependency on fossil fuels can be reduced by using biodiesel and its blends in diesel engine [3]. Biodiesel is renewable, non-hazardous and has good lubrication properties. But have some draw backs like higher specific gravity, viscosity and lower heating value compare to petro-diesel [4]. Biodiesel production could be increased with proper utilization of raw material resource at precise time with additional care [5]. The properties of used palm oil biodiesel are within ASTM standards.

Hence used palm oil biodiesel and its blends can be used as a substitute fuel in direct injection (DI) diesel engine [6]. There is a lot of scope for research for automotive manufacturers as the biodiesel has higher viscosity and density hence investigations on effect of fuel spray, combustion and pollution formation is highly pronounced as the higher viscosity of biodiesel tends to alter the injection spray characteristics, resulting in fuel hits on the piston bowl surfaces [7]. The utilization of biodiesel in engines could consequences the considerable reduction in particulate matter, HC and CO emissions except NOx [8]. For biodiesel run engine GHG emissions are lower [9]. The diesel engine offers greater power output, thermal efficiencies and longer life when compared to the SI engine, whereas diesel engine emissions will affect on human health by providing polluted air. Therefore search for ecco-friendly fuels are highly marked for diesel engines [10].

Challenges associated with biodiesel industry development, biodiesel policy and biodiesel utilization in automobile sector could be resolved, biodiesel will be the future fuel and it can be applied widely in automobile sector and it will be more convenient fuel [11].The biodiesel can be produced by various

*Corresponding author: **Manjunath Channappagoudra**
Department of Mechanical Engineering, U.B.D.T College of Engineering, Davangere, Karnataka, India

vegetable oils and animal fat oils like, animal tallow, castor oil, algae oil, cashew nut oil, Camelina sativa Oil and they can utilized in the conventional diesel engine with no engine modification. The emissions levels such as CO, HC Smoke, CO₂ are less compare to petro-diesel engine hence biodiesel and its blends can be considered as suitable substitute fuel for standard diesel with reduced air pollution [12-18]. There will be reduction in HC and Soot and Nox in engines operated with biodiesel [19]. The physical properties of biodiesel are quite similar to the conventional diesel fuel [20]. The smoke concentrations are less with biodiesel operation than diesel. But lower No emissions can be achieved with the application of exhaust gas recirculation operated with biodiesel, but it is not for diesel operation. [21]. As the injection pressure increase soot emissions are decreased but NOx emissions increased for biodiesel and its blends compare to diesel. EGR (exhaust gas recirculation) and injection timing variation could be beneficial to reduce NOx not for CO, THC [22]. At higher compression ratio of 18 operated with 100% biodiesel will exhibits the reduction in HC and CO compares to the diesel [23]. The oxides of nitrogen can be decreased injecting water into the combustion cavity of diesel engine [24]. The application of additive in biodiesel blends reduced the emission and improved the combustion and performance of the engine [25]. The amide-functionalized MWCNTs-CeO₂ catalyst with diesel/biodiesels blends can substitute the pure diesel without any adverse effect in the engine performance [26]. Mustard oil methyl ester with magnetite ferrofluid will give the positive impact by enhancing engine performance and reducing HC, CO, NOx and smoke. [27]. 4% ethanol addition to the diesel increases the output power and efficiency while decreases the fuel consumption in addition the higher compression ratio of 21 improved the engine efficiency [28]. CO, HC and smoke emissions are loared for all test fuels with the coated and uncoated piston. However, NOx emissions are raised when engine is coated. The noise decreased is observed with ceramic coating. Heat releases are close to each other in both coated and uncoated engines. [29]. As the biodiesel share is increased there is reduction in performance, ignition delay and peak pressure but improves the emissions. Hence biodiesel is the alternative to the diesel. [30]. However, NOx and CO₂ emission are enhanced in the coated engine. The lower blends of dual biodiesel (pongamia pinnata and neem oil) result in better engine performance and slightly higher in comparison petro- diesel. [31].

Different engine parameters can be modified to enhance engine performance. Various researchers are studied the performance of the engine with varying different engine parameters to improve the performance and emissions. The higher injector opening pressure of 240 bar improved the performance and emissions of the diesel engine operated with linseed methyl ester [32]. Guide vanes are installed at intake manifold to improve the engine performance and to reduce emissions with biodiesel run engine [33]. Engine alterations with different parameters like injector opening pressure (IOP), injection timing (IT) and compression ratio (CR) are auspicious to use biodiesels in engines to have improved performance [34]. The cylinder pressure HRR affected by water injection through inlet manifold with no adverse effect on fuel consumption [35]. Engine performance and exergy are improved with optimized heat exchanger designs [36]. Turbulence in cylinder could be increased with guide vane and tumble device for higher viscous biodiesels. [37]. The

biodiesel production from the non-edible oils will improve rural economy, energy security and sustainable development and also these biodiesels operated engine efficiency can enhanced with aid of preheating of biodiesel using hot exhaust gases [38]. At maximum load, with increased blending ratio and higher compression ratio there would be decreament in CO, HC emission. Lower blended with preheated palm oil can substitute the diesel fuel [39]. For 20⁰ bTDC retarded injection timing (IT) NOx, HC, CO are reduced while BTE and smoke enhanced when compared to baseline injection timing of the engine. [40]. 20% Annona biodiesel run engine with increased CR and IT had resulted enhanced BTE and reduced BSFC, CO and HC emissions [41]. The fast combustion is resulted when the IOP is increased and there is serious reduction of soot at part and low engine speeds but there will be considerable increment in NOx it can be controlled by EGR [42]. The engine power can be increased by increasing the IOP hence there is reduction in smoke and BSFC [43]. The higher IOP 230 bar had shown improved performance and reduced emissions namely HC, CO and smoke operated with used transformer oil (UTO) when compared to 200 bar IOP [44].

Dairy scum waste a source of alternative fuel

Biodiesel production cost and disposal problem of dairy waste scum can be solved by producing biodiesel prom dairy waste scum. The properties of scum biodiesel are within ASTM standards thus it can be productively used in diesel engines [45]. Biodiesel properties like specific gravity, kinematic viscosity, calorific value, flash point are determined using Fourier Transform Infrared Spectroscopy (FTIR) and they are within ASTM standard limits hence dairy scum biodiesel can be used in the diesel engine [46, 47].

The performance and emission behaviors of diesel engines depends on various parametrs like, IT, IOP, Piston bowl shape, different holes nozzle, fuel spray formation, air swirl, organic or nano additive, piston surface coating, EGR application, compression ratio, injection timing, water injection (in intake manifold, direct injection into combustion cavity and emulsification with water), etc. The biodiesel operated diesel engine performance can also be improved by providing better swirl with desired combustion chamber geometry [53]. Higher atomization can be attained when the injection pressure increased in engine injection system. From the literature it is found that there are limited investigations on diesel engine operated dairy scum biodiesel. Hence it's directed to investigate effect of different injector opening pressure (210, 220, 230 and 240 bar IOP's) on diesel engine performance, combustion and emission characteristics with DSOME-B20 biodiesel blend operation at constant speed.

MATERIALS AND METHODS

Dairy scum biodiesel production

White color and semisolid dairy waste scum (Fig.1) is collected from diary effluent treatment unit and heated it up to 50-60⁰ C to converting (melting) into liquid and permitted to settle down to remove lower unwanted aqueous phase. Upper layer of oil is separated and filtered to remove dissolved wastes from the scum oil.



Fig 1 Dairy scum and scum oil biodiesel.

Schematic flow diagram of dairy scum biodiesel production plant is shown in Fig.2. Dairy scum oil, methanol and potassium hydroxide are the used main raw materials for biodiesel production with different equipments namely stirrer, electric heater, thermostat, stainless steel reactor, biodiesel and glycerin tanks, flow control valves and control panel.

The separated dairy scum oil is transesterified using transesterification method where scum oil is mixed with methanol and KOH (potassium hydroxide) catalyst in a reactor with agitator (stirrer) for 2 hours at 60⁰ C and then it is kept for 12 hour to obtain biodiesel and glycerin. Then bottom settled glycerin is collected in a glycerin tank. Three times produced crude biodiesel is washed with water to remove acids, soaps and residual catalyst. At the end, transesterified biodiesel is heated to 110⁰ C to remove the dissolved water particles which are present in the biodiesel. The procedure is repeated until getting clear biodiesel.

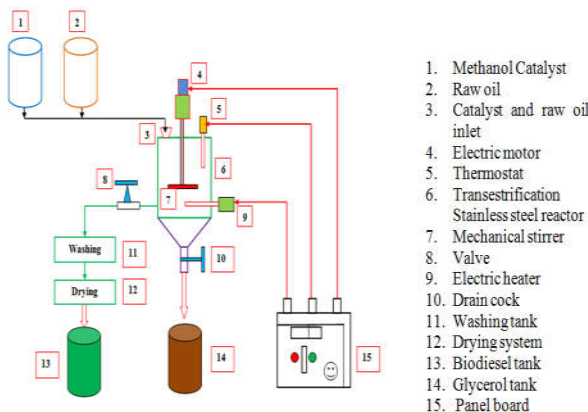


Fig 2 Biodiesel production process

Biodiesel properties

Efficient use of fuel in diesel engines can achieve by selecting right fuel with right proportion. In this study, dairy scum biodiesel and its different blends like B10, B20, B30 and B100 are used for experimentation. The properties of biodiesel and its blends are determined as per ASTM-6751 standard. Hydrometer is used to determine the specific gravity of the fuel and bomb calorimeter is used to determine heating value of fuel blends. To measure the viscosity of the fuels Redwood viscometer is used. Pensky–Martens equipment is used to determine the Flash and fire points of the different fuel blends in the laboratory.

Table 1 Properties of biodiesel fuel blends.

Properties	Methods IS 1448	Diesel				
		Diesel	B10	B20	B30	B100
Density (kg/m ³)	P:16	830	833	840	844	870
Viscosity at 40 ⁰ C (cSt)	P:25	2.9	2.94	2.98	3.15	4.36
Calorific value (kJ/kg)	P:6	43000	42935	40890	40012	38012
Flash Point (°C)	P:69	50	55	58	62	130
Fire point (°C)	P:69	60	66	68	75	142

Experimental setup

The experiments are conducted on Kirloskar (TV1) single cylinder, 4 strokes, diesel engine (Fig.3 & Fig.4). The engine specifications are given in Table 2. The experimental set up consist of a diesel engine, ECU, Exhaust gas analyzer, burette and stopwatch, digital manometer, data acquisition system, Chromel Alumel (K-Type) thermocouples. “Engine soft LV” software is used for online combustion analysis. Piezosensor and crank angle sensors which are mounted into the engine head and flywheel are used to measure the combustion pressure. An orifice fitted to air box is used to measure amount of air flow. The test engine is coupled to an electric dynamometer and overheating of dynamometer is prevented using water circulation. Speed of the engine is maintained constant as 1500 rpm throughout the work. The engine is operated with pure diesel to have baseline readings. There after engine is fueled with different DSOME blends to conduct the experiments then average of three readings are considered for analysis. Optimization of fuel blend is made in first phase and optimization of injection timing is made in second phase of work. Then optimized fuel blend from first phase is carried to second phase of experimental work to study the effect of IOP on engine performance. In this work IOP of standard engine (210 bar) is modified and experiments are carried out for different injector opening pressures at different loads. At the end of experiment the DSOME-B20 fuel is replaced with diesel and engine is kept running for some time to remove DSOME-B20 fuel from injection system before turn off. Airrex Automotive Emission Analyzer HG-540 is used to determine the exhaust emissions, like Hydrocarbons (HC), Carbon Monoxide (CO), and Oxides of Nitrogen (NO_x).

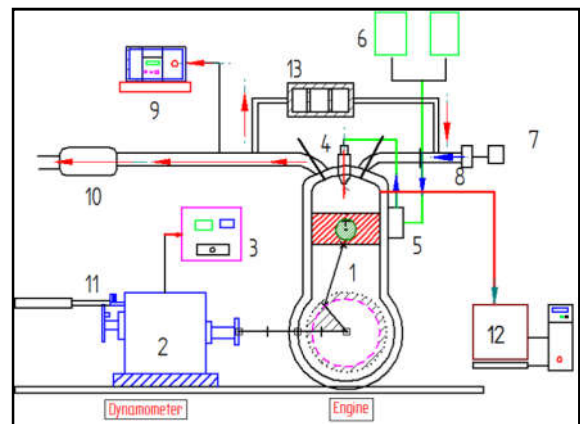


Fig 3 Schematic diagram of diesel engine test rig.

1. Kirloskar TV1 engine, 2. Eddy Current Dynamometer, 3. Control Panel, 4 Fuel Injector, 5. Fuel pump, 6. Fuel tank, 7. Air filter, 8. air stabilizing tank 9. Exhaust gas analyzers, 10. Exhaust gas silencer, 11. Crank encoder, 12. Data acquisition system



Fig.4 Photograph of experimental set up.

Table 2 Engine specifications.

Parameters	Specifications
Engine suppliers	Apex Innovations Pvt. Ltd
Type	TV1 (Kirloskar)
Cubic capacity	661 cc
Bore and stroke length	87.5 mm X 110 mm
Injector opening pressure	210 bar
Rated power	3.5 kW at 1500 rpm
Injection timing	23°bTDC (diesel)
No. of cylinder/stroke	one /four
Compression ratio	17.5
Dynamometer	Eddy current
Software used	Engine soft

The standard engine IOP (210 bar) is varied from 210 bar to 240 bar in step of 10 bar (210, 220, 230 and 240 bar) and aimed to optimize and study the effects of IOP on diesel engine performance, combustion and emission characteristics of diesel engine fueled with optimized fuel blend. The experiments are conducted from zero to full load conditions in steps of 0, 20, 40, 60, 80 and 100 % loads. Manufacturer specified parameters injection timing (23.deg.bTDC), Compression ratio (CR-17.5), nozzle geometry (3 hole, 0.3 mm diameter) and piston shape (Hemispherical) are kept same throughout the experimental work. In this present study engine performance (BTE, BSFC), combustion (heat release rate, peak pressure, cumulative heat release rate and rate of pressure rise) and emissions (HC, CO and NOx) are determined and compared with standard diesel.

RESULTS AND DISCUSSION

Phase-1: Optimization of DSOME blend

In this first phase of work experiments are carried to optimize the best blend ratio in B10, B20, B30 and B100 and optimized blend among above is carried for further investigations.

Brake thermal efficiency

Fig.5 shows the comparison of BTE with brake power for petroleum diesel and different dairy scum biodiesel blends. From the test results it is noticed that BTE of dairy scum is lesser than pure diesel for all loads it could be due to lower heating value, higher specific gravity and higher viscosity of the dairy scum biodiesel. BTE reduces when biodiesel percentage is increased with diesel it is attributed to reduced heating value of biodiesel blends.

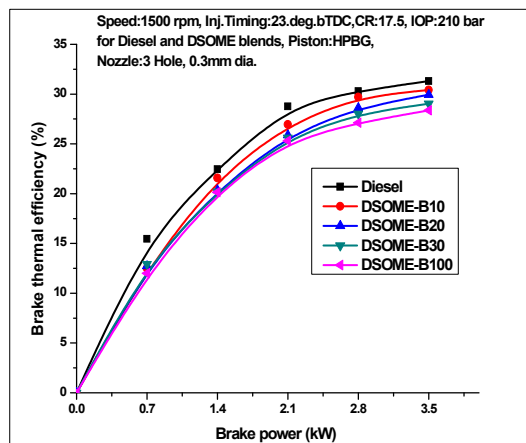


Fig 5 Brake thermal efficiency versus brake power.

From the experimental results is seen that the blend B10 has BTE of 30.42% and B20 has BTE of 29.93% respectively at

maximum load and they are closer when compared to BTE of B30 (29.04%) and B100 (28.37%). Compare to blend B30 and B100, B20 blend has higher BTE hence it is optimized

Brake specific fuel consumption

Fig.6 represents the variations of BSFC with brake power. The trend shows that the BSFC increases with the biodiesel blend ratio in diesel. This may be attributed to the lower heating values of and higher viscosity of the biodiesel. The BSFC for neat diesel is lesser among all blends it may be attributed to higher calorific value and lower viscosity and specific gravity of the diesel fuel contributes complete combustion. The blends B30 and B100 have higher fuel consumption when compared to B10 and B20. The reason may be admission of more fuel into cylinder to produce same out power of diesel as the biodiesel blends have lower heating value, higher viscosity and density leads slow and incomplete combustion. BSFC results for Diesel, B10, B20, B30 and B100 are found to be 0.29, 0.304, 0.320, 0.341, and 0.352 kg/kW.hr respectively at maximum load. The BSFC of B20 (0.320 kg/kW.hr) is closer to blend B10 (0.304kg/kW.hr) among other blends.

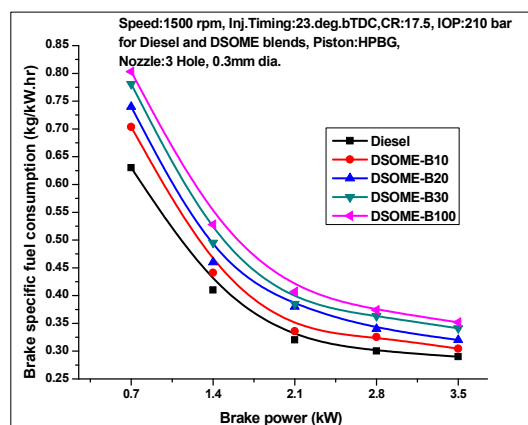


Fig 6 Brake specific fuel consumption versus brake power.

Hydrocarbons emission

Fig.7 shows the distinction of HC emission with brake power for petro diesel and different dairy scum biodiesel blends. The HC emission is lower for dairy scum biodiesel operation when compared to petroleum diesel. The reason may be more oxygen content in biodiesel contributes the better combustion.

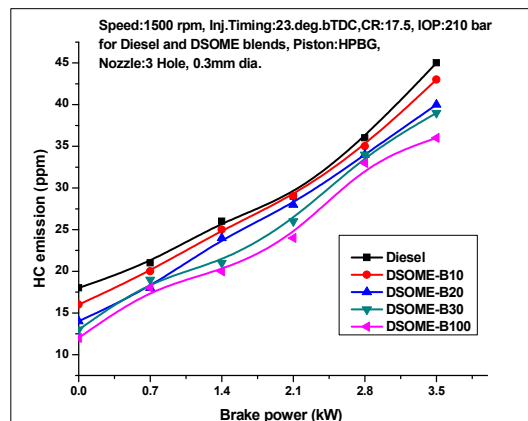


Fig 7 HC emission versus brake power.

At maximum load the blends B100 and B30 shown the lesser HC emissions of 36 ppm and 39 ppm among other blends it could be due to more inherent oxygen presence in the higher

proportion of biodiesel tends improved and clean burning. Study reveals that B10 has higher HC emissions of 43 ppm than B20 HC emission of 40 ppm at maximum load.

Carbon monoxide emission

The comparison of CO emissions with brake power for neat diesel and dairy scum biodiesel blends are depicted in Fig.8. Biodiesel and their corresponding blends have lower CO emission than the conventional diesel as they have more oxygen content leads better oxidation and improved combustion as compared to diesel. It can be seen from graph that at beginning CO decreased with increasing load because of at zero load temperature of cylinder might be too less and later increased stridently up to maximum load. At full load CO emissions for Diesel, B10, B20, B30 and B100 are 0.089, 0.081, 0.076, 0.069, and 0.062% respectively. The result clears that CO decrease with increased biodiesel blend concentration. The B100 and B30 have lower CO emissions followed by DSOME-B20. From the above results it's clear that B20 blend has lesser CO of 0.076% when compared to B10 of 0.081%.

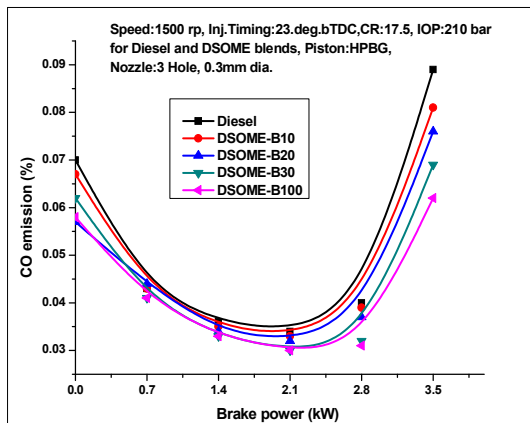


Fig 8 CO emission verses brake power.

Oxides of nitrogen emission

Fig.9 shows the variations of oxides of nitrogen with brake power for standard Diesel and dairy scum biodiesel blends. Comparatively NOx is higher for biodiesel blends than petrodiesel over the entire load range. It may be due to higher temperature and HRR during premixed combustion phase as biodiesel blends have more oxygen content compare to diesel leads improved combustion. The NOx level is higher for B100 compared to B10, B20 and B30 blends. The reason may be better combustion rate due to more homogeneous air-fuel mixing rate tends to better combustion at power stroke. From the study results, it could be seen that the blend B100 generated the highest nitrogen oxides when compared to other blends. At 100% load, NOx emissions for Diesel, B10, B20, B30 and B100 are found to be 961, 976, 1006, 1021, 1085 ppm respectively.

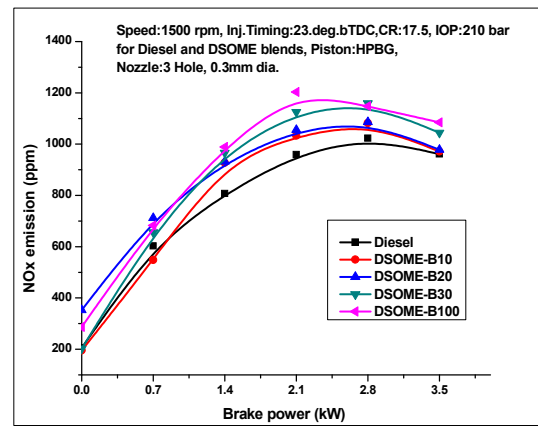


Fig 9 NOx emission verses brake power.

Phase-2: Optimization of Injector opening pressure

Brake thermal efficiency (BTE)

The variation of BTE with brake power is shown in Fig.10. BTE is increased as the IOP increased the reason might be the improved atomization, vaporization; better air-fuel mixing leads better combustion [52]. At 230 bar IOP enhanced air fuel mixing is observed during higher loads at compression process leads maximum BTE however it is lesser than diesel. This might be higher viscosity, low volatility, improper atomization and lower calorific value of DSOME-B20 than that of diesel. The maximum BTE of DSOME-B20 at 230 bar pressure is 30.55% and it is near to the petro-diesel (210 bar) BTE of 31.32% at full load condition. However DSOME-B20 with 240 bar IOP BTE decreased compared to 230 bar IOP for all loads. The reason might be, too increased IOP will reduced the fuel droplet size, hence too finer (very small size) fuel droplets have lower momentum and relative velocity leads incomplete combustion by its own combustion products. And also Higher IOP has low depth penetration, delayed ignition and more fuel consumption at full load because of their smaller droplet size [44, 48, 49, 50]. However, if the IOP is too high ignition delay becomes shorter hence probability of air-fuel mixing rate will be lower leads decreased burning rate and increased emissions in the engine [51]. The BTE for Diesel, IOP 210 bar, 220 bar, 230 bar and 240 bars are found to be 31.32, 29.63, 29.94, 30.55, and 27.97% respectively at full load condition.

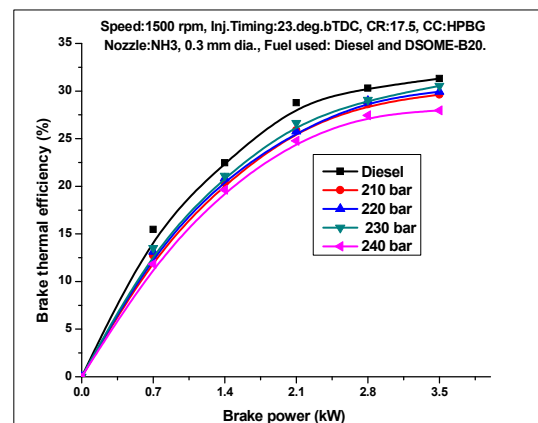


Fig.10 Brake thermal efficiency verses brake power.

Brake specific fuel consumption (BSFC)

The BSFC with brake power for different IOP operated with DSOME-B20 is shown in Fig.11. From study it is noticed that at full load the BSFC is decreased with an increase in IOP. The BSFC of DSOME-B20 is higher than diesel it may be due to the lower calorific value of biodiesel. From the experimental results it revealed that at full load the BSFCs for Diesel, 210 bar, 220 bar, 230 bar, and 240 bar IOP's are 0.290, 0.320, 0.310, 0.30 and 0.330 kg/kW.h respectively. With an increase in IOP from 210 to 240 bar, the BSFC is increased from 0.320 to 0.33 kg/kW-hour fueled with DSOME-B20 which is attributed to lower calorific value and lesser momentum of smaller size fuel droplets hence reduction of fuel-air mixing rate in the burning leads incomplete combustion. The BSFC for 230 bar IOP is 0.30 kg/kW.hr which is near to diesel and lower than 210 bar, 220 bar and 240 bar IOP. Hence 230 bar IOP for is optimized for DSOME-B20.

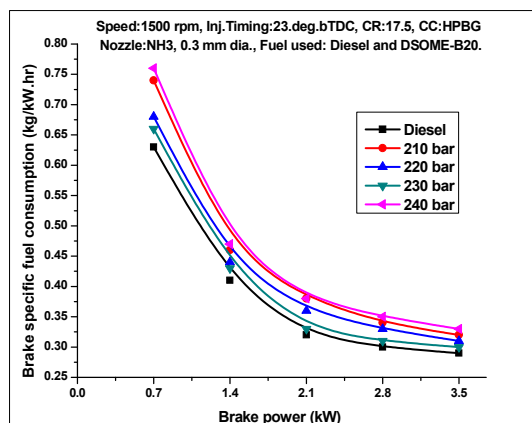


Fig 11 Brake specific fuel consumption versus brake power.

Hydrocarbons (HC) emission

Fig.12. depicts the distinction of HC emissions with brake power. The HC emission for conventional diesel operation had shown higher for all loads compare to the DSOME-B20 because of lower oxygen content in diesel compare biodiesel. For DSOME-B20 as the IOP increases the HC emission decreases, this may be attributed to improved atomization leads better air-fuel mixing rate and also the more availability of oxygen presence in biodiesel effects better oxidation and complete combustion. From study it is observed that HC emission for 230 bar IOP with DSOME-B20 is lower than the petroleum diesel for all loads, as diesel has higher hydrocarbons in it will increase HC emissions whereas presence of oxygen in DSOME-B20 might be advances the combustion process leads lowering the HC emissions. DSOME-B20 at 230 bar IOP HC emissions are minimum levels of 38 ppm whereas at 240 bar IOP an increase in HC levels of 43 ppm which may associated to local rich regions and some of the occupation of fuel droplet at crevice volume, finer spray, which reduces fuel droplet momentum resulting in poor combustion. [44, 48, 49]. The HC at full load reduces from 41 to 38 ppm when IOP is increased from 210 bar to 230 bar. From the study the results revealed that the HC emissions for Diesel, 210 bar, 220 bar, 230 bar and 240 bar IOP's are found to be 45, 41, 40, 38, and 43 ppm respectively at full load.

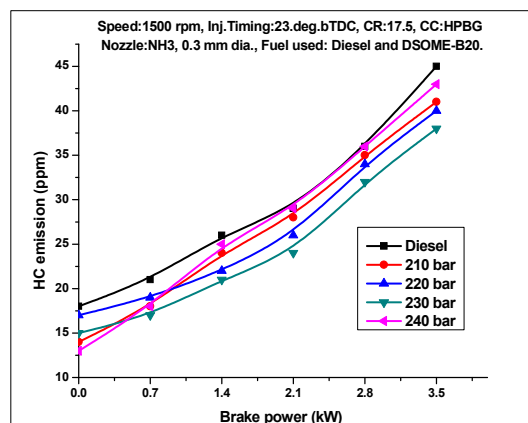


Fig 12 HC emission verses brake power.

Carbon monoxide (CO) emission

The deviation of CO emissions with brake for different IOP's is shown in Fig.13. The higher combustion temperature would enhance the oxidation of carbon monoxide to form carbon dioxide hence results less CO emission. However indecent mixing of fuel with air and ineffective burning of fuel may results higher CO emission. Generally CO emission is lower for biodiesel fueled diesel engine it could be attributed to higher temperature and oxygen presence in biodiesel [16]. The CO emissions for diesel and DSOME-B20 fuels are lesser in lower engine loads and increased at higher engine load. This might be due to shorter oxygen with more fuel introduction into cylinder at higher loads. Whereas CO reduces with lower and medium loads because of rich oxygen and higher IOP [48, 49]. It is noticed that IOP of 230 bar with DSOME-B20 had resulted lesser CO emission as it has sufficient oxygen and improved fuel atomization led improved burning process. Hence there will be improved oxidation process as there is rapid mixing of air-fuel mixing and atomization in cylinder led to better combustion. At 240 bar IOP there appears to be an increase in CO which could be due to the too finer fuel spray leads reduced momentum of the fuel droplets results lower combustion, even at higher IOP higher boiling compounds may not break up [44, 48, 49]. The study shown the CO emission values for Diesel, 210 bar, 220 bar, 230 bar and 240 bar IOPs are 0.089, 0.076, 0.073, 0.071 and 0.078 % respectively. From above results it is concluded that the CO of 230 bar IOP is lower than diesel and other IOPs.

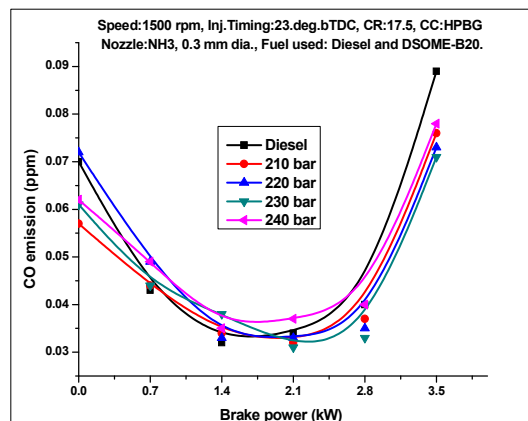


Fig 13 CO emission verses brake power.

Oxides of nitrogen (NOx) emission

Fig.14. represents the variation of NOx emission with different IOP. From the graph it clears that NOx emission is increased when the IOP is increased. This is attributed to dominant premixed combustion phase and complete combustion leads to increase in peak cylinder pressure and gas temperature inside the combustion chamber. The higher dairy scum biodiesel blend proportion with petro-diesel results higher NOx levels for all IOPs as they are rich in oxygen results improved burning [16, 48, 49]. The study revealed the nitrogen oxides for diesel, 210 bar, 220 bar, 230 bar and 240 bar IOPs are 961, 978, 983, 1021, 1014 ppm respectively. Study revealed that NOx emission for 230 bar is higher than diesel and other IOPs

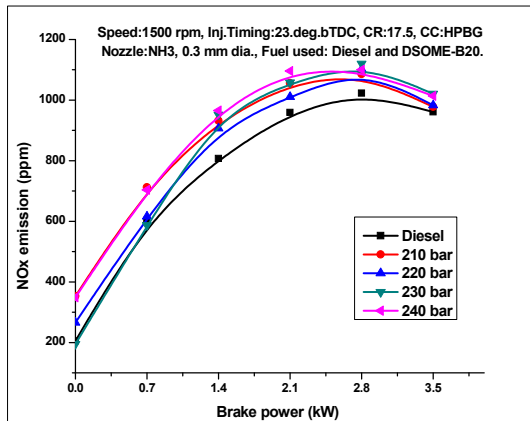


Fig 14 NOx emission verses brake power.

Cylinder pressure

Fig.15. depicts the deviation of cylinder pressure with crank angle for different IOP's at maximum load operated with DSOME-B20. Cylinder Pressure curve for different IOPs follow the trend same as Diesel pressure curve at rated 210 bar IOP. The cylinder pressure is highest with Diesel followed by DSOME-B20 at 230, 220, 210 and 240 bar IOP [48, 49]. As IOP increases combustion rate will be increased which leads in higher cylinder pressure. At 230 bar IOP pre mixed combustion phase is improved because of better fuel atomization, rapid vaporization, and fuel-air mixing in turn improved combustion. From study it's observed the peak pressure for Diesel, 210 bar, 220 bar, 230 bar and 240 bar IOP are found to be 53.63, 49.67, 49.81, 50.81 and 49.70 bar respectively. The peak pressure value of 230 bar IOP is greater than other IOPs but lower than diesel.

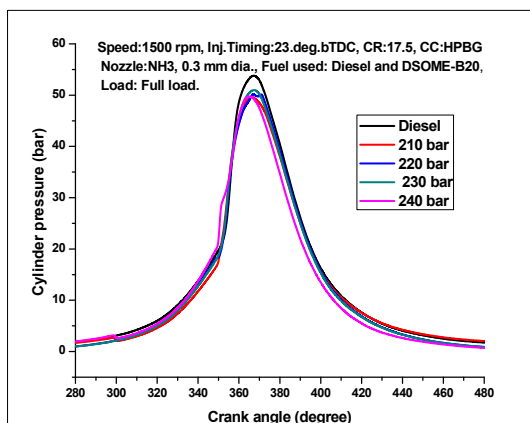


Fig.15 Cylinder pressure verses crank angle at 100% load.

Heat release rate (HRR)

Fig.16. demonstrates the comparison of HRR with crank angle for different IOP's fueled with Diesel and DSOME-B20 at full load. It is observed that with DSOME-B20 the value of HRR for all IOPs are lower than neat diesel which might be attributed lower heating value, volatility and higher viscosity of DSOME-B20. Improved premixed heat release rates is noticed when the IOP is increased from 210 bar to 230 bar IOP which is due to improved fuel atomization and air-fuel mixing leads improved combustion. It is noticed that HRR increased as IOP increased from 210 bar of 57.14 J/crank angle to 230 bar of 62.22 J/crank angle. The HRR for Diesel, 210 bar, 220 bar, 230 bar and 240 bar injector opening pressures are 65.43, 57.14, 58.48, 62.22 and 54.83J/crank angle respectively at maximum load. From the experimental results it's clear that the 230 bar IOP resulted in higher heat release rate when compared to other IOPs whereas it is lesser than standard diesel.

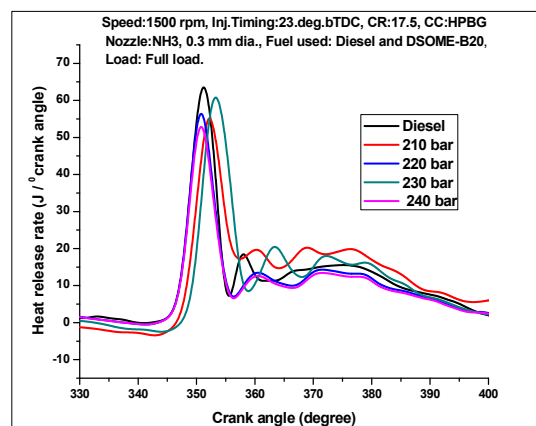


Fig 16 Heat release rate verses crank angle at 100% load.

CONCLUSION

In this study different DSOME blends are prepared (B10, B20, B30 and B100) and studied at different loads. Based on experimental results fuel blend is optimized and optimized fuel blend is carried further to study the influence of fuel IOP on performance, combustion and emission characteristics of diesel engine. IOP is varied from 210 to 240 bars in steps of 10 bar such as 210 bar, 220 bar 230 bar and 240 bar. The conclusions drawn from the study are summarized as below.

1. The B20 blend shows the improved BTE, BSFC among other blends except B10. BTE of B10 is higher and BSFC is lower when compared B20 whereas B10 HC, CO emissions are higher than B20. The B20 blend has lower HC and CO emissions than B10 and also its BTE is closer to B10. Hence B20 (DSOME-B20) is optimized and carried to the optimization of injector opening pressure.
2. When the IOP of engine is increased from 210 bar (manufacturer specified for diesel) to 230 bar (modified for diesel) the BTE is increased from 29.63% to 30.55% while BSFC reduced from 0.320 kg/kW.h to 0.300 kg/kW.h respectively at maximum load.
3. From the emission study it is observed that, HC lowered from 41 ppm to 38 ppm and CO reduced from 0.076 to 0.071% whereas NOx increased from 978 to 1021ppm at full load.

4. From the combustion study it's noticed that as the IOP increased from 210 bar to 230 bar an improvement occurs in the HRR, cylinder pressure. For 230 bar IOP peak pressure increase from 49.67 to 50.81 bar and HRR from 57.14 J to 62.2 J/crank angle when compared with standard engine IOP of 210 bar.

On whole, the blends of dairy scum biodiesel with diesel significantly reduced the HC and CO emissions whereas slightly increases the NO_x. Among all blends B20 exhibits the improved performance and emission characteristics. It could be concluded that 230 bar IOP with DSOME-B20 is the best IOP as it revealed better performance and emission, combustion characteristics as compared to 210, 220 and 240 bar IOP's. For 240 bar IOP BTE, HRR and cylinder pressure are decreased while emissions like HC, CO are increased when compared to 230 bar IOP it might be due to lesser fuel particle momentum and improper fuel distribution with too smaller fuel droplets leads poor combustion. From study it is concluded that 230 bar IOP with DSOME-B20 operation improves the engine performance, combustion and lowers the HC, CO emissions. Hence 230 bar IOP is optimum for DSOME-B20 blend.

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