Combined Effect of Injector Opening Pressure and Injection Timing on Diesel Engine Performance- An Experimental Exploration

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Abstract— The application of dairy scum oil methyl ester (DSOME) in diesel engine is highly marked as it reduces the emissions and foreign fuel dependency. To realize the full potential use of biodiesel in diesel engine slight modifications are made in injection timing (IT) and injector opening pressure (IOP). The study, explored the combined effect of IOP and IT on diesel engine performance. From the experimental results it is revealed that operation-B (IT: 26.deg.bTDC, IOP: 230 bar) has shown the improved performance, combustion and emission characteristics when compared to operation-A (IT: 23.deg.bTDC, IOP: 210 bar).

Keywords—Dairy scum biodiesel, Diesel engine, Injector opening pressure, Injection timing, Performance

I. Introduction

The applications of diesel engines are more as they have greater thermal efficiency and output power but theirs harmful emission effects the environment. In this aspect looking to alternative fuels which promise desired properties as of conventional diesel are highly pronounced. In this regard biodiesel derived vegetable oil or animal fat oils can be consider as substitute fuels for diesel engines as they are renewable, nontoxic, locally available and less emissions profiles. In this direction inherent oxygen content biodiesels with butanol and ethanol may joins hands to reduce the engine emissions [1]. The biodiesel production and utilization in diesel engine will provide the job security as well lesser emission when compare to convention diesel fuel [2]. The emissions of the diesel or petrol engines can be controlled by using particulate filters (PF) [3]. The optimized engine parameters like IT and fuel injection angle could enhance the engine performance and reduces the emissions of the diesel engine operated with biodiesel [4]. Biodiesel production from the dairy iste scum would give the viable solutions to the disposal problems and the produced biodiesel properties are within ASTM standards hence it can use in diesel engine [5-7]. Varying fuel injection strategies such as long boot length and high boot pressure injections would help to reduce the NOx and soot emissions in diesel engine when operated with biodiesel [8]. The engine performance and emissions can be optimized by advancing fuel injection timing with DMM (diesel-dimethoxymethane) blends operation in engine [9]. The pre-injection strategies cause negligible thermal losses and exegetic efficiencies [10, 11]. The increased injection pressure of the fuel will improve the performance, combustion and emission characteristics as it provides better atomization and air–fuel mixing rate for complete combustion in the cylinder [12, 13].

The problems associated to the higher viscous problem is a major challenge to use this in existing engines, somehow this problems can be reduce with optimized engine parameters namely Injector opening pressure IOP), advanced injection timing (IT), compression ratio (CR), preheating of biodiesel, use of bio-additives etc. In this view investigation aimed to study the combined effect of influence of injector opening pressure (IOP) and injection timings (IT) on diesel engine performance operated with dairy scum biodiesel.

2. MATERIALS AND METHODS

2.1. Biodiesel Properties

In the present study transesterified dairy scum biodiesel and its blends (Fig.1) are selected for experimental investigations. The properties of DSOME (dairy scum oil methyl ester) and its blends such as viscosity, calorific value, density and flash point and fire point are determined as per ASTM- 6751 standards [5-7, 10, 11]. Table1 shows the properties of biodiesel. The density of biodiesel blends are measured using a hydrometer at a temperature of 30 ⁰C. Flash points of the fuels are computed by using Pensky–Martens apparatus in 40–250 ⁰C temperature range. The calorific value of biodiesel and its blends is measured in a bomb calorimeter. The Redwood viscometer is used to calculate the kinematic viscosity of the biodiesel at a 40⁰ C temperature.

Fig.1 Photographic view of fuel blends.

Table 1 Properties of dairy scum biodiesel blends.

Properties	Methods IS 1448	Diesel	B20
Density (kg/m³)	P:16	830	840
Viscosity at 40⁰ C (cSt)	P:25	2.9	2.98
Calorific value (kJ/kg)	P:6	43000	40890
Flash Point (⁰C)	P:69	50	58
Fire point (⁰C)	P:69	60	68

2.2 Experimental Setup

Kirloskar, 3.5 kW (TV1) diesel engine (Fig.2 & Fig.3) is used to conduct the experiments. The standard engine specifications are given in Table 2. Instruments used for the defined work are diesel engine-test rig, ECU, Exhaust gas analyzer, burette and stopwatch, digital manometer, Chromel Alumel (K-Type) thermocouples. "Engine soft LV" software is employed for online combustion analysis. The combustion pressure at various crank angles is determined with using Piezosensor (Fig.4) and crank angle sensor. Temperature sensors are provided for the measurement water jacket temperature, calorimeter water temperatures. The fuel and air flow rates are determined using flow sensors. Baseline engine readings are recorded for the pure petroleum diesel. Average of three readings is considered for the examination and comparative study. Airrex Automotive Emission Analyzer HG-540 (Fig.5) is used to measure the exhaust emissions such as Hydrocarbons (HC), Carbon Monoxide (CO) and Oxides of Nitrogen (NOx). The experiments are carried on diesel engine at various loads such as 0, 20, 40, 60, 80 and 100 % load. Slight engine modifications are made in the fuel injection pressure and fuel injection timing using provided arrangement (as shown in Fig.6 & 7) and studied their effect on the performance of the diesel engine operated with B20.

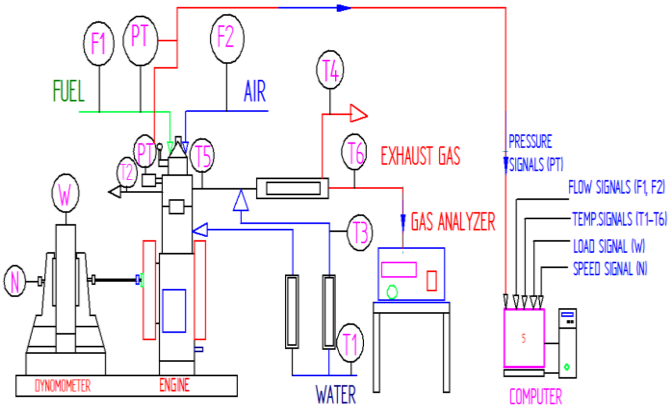

Fig.2. Schematic diagram of experimental set up.

F1 & F2: Flow sensor for fuel and air, PT: Cylinder pressure and injection pressure sensor, W: Load sensor, N: Engine speed sensor, T1-T6: Temperature sensors

Fig.3. Photographic view of experimental test rig.

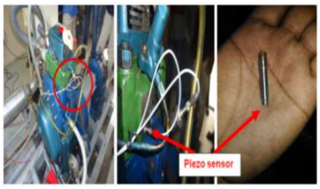

Fig.4. Piezo sensor

Fig.5. Exhaust gas analyzer

Table 2 TV1engine specifications.

Parameters	Specifications
Engine suppliers	Apex Innovations Pvt. Ltd
Type	TV1 (Kirloskar made)
Cubic capacity	661 cc
Bore and stroke length	87.5 mm X 110 mm
Injector opening pressure	210 bar
Rated power	3.5 kW
Injection timing	23⁰ bTDC (diesel)
No. of cylinder/stroke	One/Four
Compression ratio	17.5
Dynamometer	Eddy current
Software used	Engine soft

Fig.6. Injection pressure setting

Fig.7 Injection time setting

3. RESULTS AND DISCUSSION

Basic performance and emission characteristics of a diesel engine run with DSOME-B20 blend is carried to study the consequence of IT and IOP on diesel engine performance. The standard engine parameters like engine speed 1500 rpm, 3 hole nozzle, compression ratio of 17.5 are kept constant throughout the experimentation. Experiments are carried for different ITs (in step of 3 degree such as 20.deg.bTDC, 23.deg.bTDC 26.deg.bTDC and 29.deg.bTDC) and IOPs (in step of 10 bar like 210 bar, 220 bar, 230 bar and 240 bar) at different loads to study their effect on diesel engine performance, combustion and emission characteristics.

3.1 Optimization of Fuel Injector Opening Pressure (IOP) and Injection Timing (IT)

The variation of BTE with brake power is shown in Fig.8. BTE is increased as the IOP increased, the reason might be the improved atomization, vaporization; better air-fuel mixing leads better combustion at higher IOP. 230 bar IOP has shown highest BTE of 30.55% among other IOPs at full load however it is lesser than diesel (31.32%) fuel as it has higher viscosity and lower calorific value than diesel. The 220 bar IOP and 210 bar IOPs are shown BTE of 29.63% and 29.94% at full load respectively. Whereas in case of 240 bar IOP, least BTE of 27.97% is observed when compared to other IOPs, which is attributed to too increased IOP would reduce the fuel droplet size too smaller and finer particles, hence too finer fuel droplets could have lesser momentum and relative velocity leads poor combustion, hence BTE would decreases as IOP increased beyond certain limits [14-17].

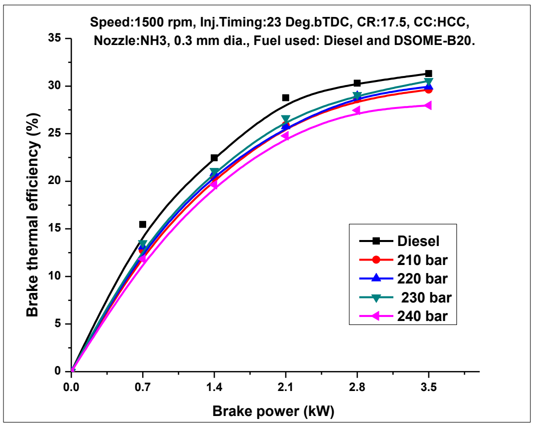

Fig.8. Brake thermal efficiency verses brake power.

Variation of BTE with BP for different injection timings are represented in Fig.9. The BTE increases with the increase in engine loads. As the IT advanced BTE is increased with increased ignition delay period results more time availability in the combustion chamber for physical processes like, fuel–air mixing, heating, evaporation process and combustion process [10, 11]. Whereas by retarding the IT from 23.deg.bTDC to 20.deg.bTDC will reduce the ignition delay hence improper mixing of fuel and air which is associated to shorter delay leads lower BTE and HRR. From experimental study it is revealed that BTE values for Diesel-23.deg.bTDC, 20.deg.bTDC, 23.deg.bTDC, 26.deg.bTDC and 29.deg.bTDC are 31.32, 28.21, 30.55 31.03 and 29.15% respectively for the B20 operation at full load. For B20, 26.deg.bTDC is considered as the optimum injection timing as it has BTE of 31.03% near to Diesel BTE of 31.32%. It is attributed to combination of low mass flow rate and volatility. Based on BTE values 26.deg.bTDC IT is the optimum for B20 operation.

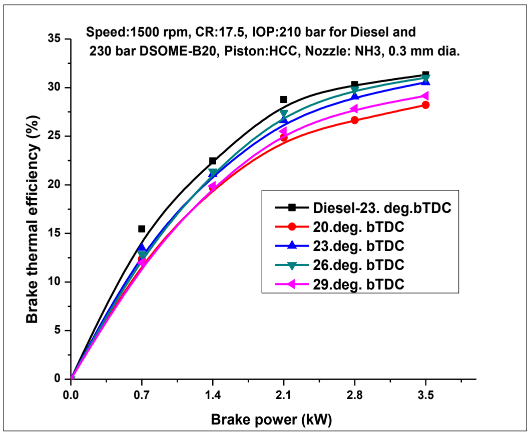

Fig.9. Brake thermal efficiency verses brake power.

3.2. Combined Study of Effect of IOP and IT on Diesel Engine Performance

3.2.1 Brake Thermal Efficiency

Variation of BTE with BP for different operations is represented in Fig.10. The BTE increases with the increase in engine loads. From the study it is noticed that diesel fuel has shown highest BTE than B20 at operation A and B this could be due to its higher heating value and lower viscosity led improved combustion with increased combustion efficiency. The operation-B with increased IOP and advanced IT has resulted grater BTE than operation-A because improved performance with better atomization and sufficient time availability for air-fuel mixing by increased IOP and advanced IT respectively [10,11, 13-16]. The decreased BTE for operation-A might be due to lower burning of B20 fuel with higher viscosity leads poor combustion. The BTE values for diesel, Operation-A and operation-B are found to be 31.32, 29.93 and 31.03% respectively at maximum load.

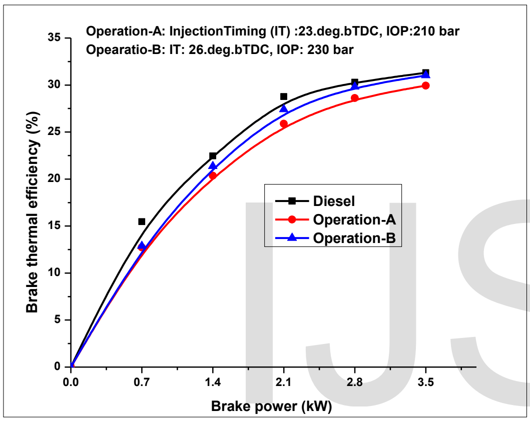

Fig.10. Brake thermal efficiency verses brake power.

3.2.2. Brake Specific Fuel Consumption

Fig.11 illustrates the distinction of BSFC with brake power for different operations at different loads. For both the fuels as load increased, the BSFC gradually decreased. The BSFC values of B20 fuel blend are higher for all loads in comparison with petroleum diesel (0.290 kg/kW.hr) it could be due to lower heating value biodiesel fuels will required more quantity of fuel to generate same power as of diesel. The BSFC for operation-B is lower than operation-A as it has improved atomization and faster evaporation leads better combustion with improved fuel conversion efficiency. The operation-B has resulted lower BSFC of 0.300 kg/kW.hr as compared operation-A of 0.320 kg/kW.hr.

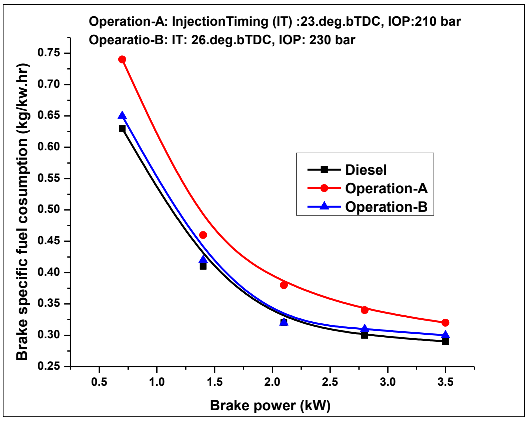

Fig.11. Brake specific fuel consumption verses brake power.

3.2.3. Hydrocarbons Emission

Fig.12 depicts comparison of HC emissions for different engine operation namely operation-A and operation-B at various engine loads at full load. The graph raveled that HC emission is lower for B20 when compared to conventional diesel, because biodiesel fuels have inherent oxygen content hence improve the chemical oxidation and faster burning with utilizing all the air-fuel mixture (charge) which is present in the combustion chamber therefore reduces the HC emission. The higher HC emission is exhibited by conventional diesel of 45 ppm than B20 biodiesel fuel blend the reason could be diesel has higher hydrocarbons and lesser oxygen presence in comparison with biodiesel blended fuels. Whereas operation-B has resulted lower HC of 37 ppm than operation-A which attributed to increase fuel droplet velocity with reduced droplet size and more time availability for air-fuel mixing hence ensured the better air-fuel mixing to enhance the combustion rate.

3.2.4. Carbon Monoxide Emission

Fig.13 represents the variation of CO emissions with brake power for different engine operations. Initially as load increased from no load condition to medium load condition CO emission decreases, while as the load increased from medium to maximum level CO emission increased for both A and B operation the reason may introduction of more amount fuel into the cylinder. With B20, CO is the least for operation-B at all loads compared to operation-A because of its increased air-fuel mixing with rapid evaporation led more heat release hence higher cylinder temperature and pressure with improved combustion, BTE and conversion of CO into CO_2 by taking additional oxygen molecules which are present in B20 and use of more leaner fuel air mixtures as. The operation-B has lowest CO emission of 0.067% than operation-A of 0.06% the reason could be due to higher cylinder temperature and pressure with operation-B influences the faster oxidation of CO during combustion hence results lower CO emission. Diesel fuel operation has resulted higher CO emission of 0.089% than among operation-A and operation-B operated with B20 biodiesel blend.

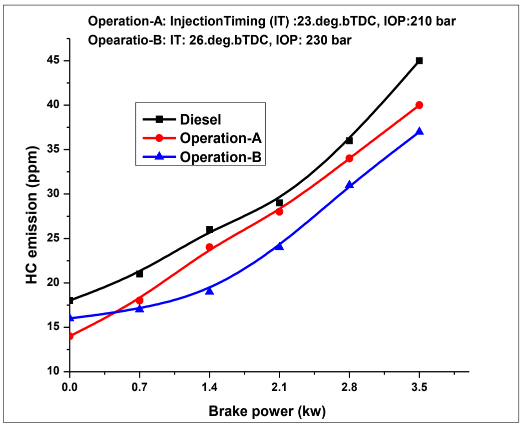

Fig.12. HC emission verses brake power.

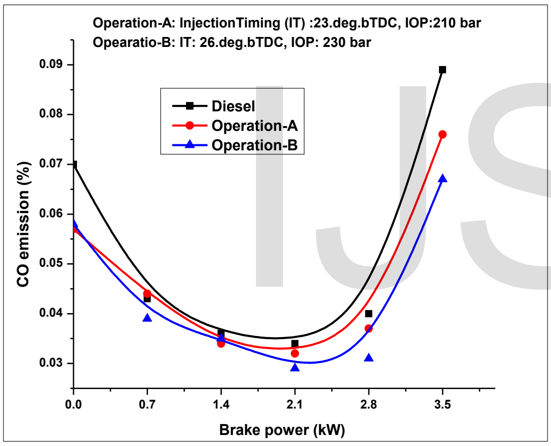

Fig.13. CO emission verses brake power.

3.2.5. Oxides of Nitrogen Emission

Fig.14 describes the distinction of NOx with BP for various engine operations (A and B). As the biodiesels have more oxygen content and increased air-fuel mixing rate with increased IOP and advanced IT exhibits higher NOx emissions than petroleum diesel since. The diesel operation has lesser NOx emission of 961 ppm among operation-A and B as it has lesser oxygen content and reduced cylinder temperature than B20 fuel. The increased NOx of 1124 ppm is observed at higher load for operation-B as it released more rates of heat with superior cylinder temperature and pressure with burning more quantity of fuel. Where as in case of operation-A reduced NOx of 978 ppm compare to operation-A is monitored as it provides lesser cylinder temperature and leas heat release.

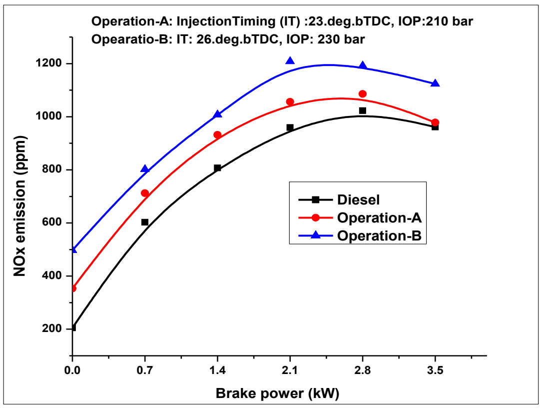

Fig.14. NOx emission verses brake power.

3.2.6. Cylinder Pressure

Distinction of cylinder pressure with crank angle at maximum load fueled B20 at different engine operations are shown in Fig.15. B20 has fewer trace of pressure waves and also the variation of gas pressure is smoother at maximum load when the engine is run at operation-B. The cylinder pressure results for diesel, operation-A and operation-B are found to be 53.63, 52.29 and 53.33 bar respectively at full load. Among above threes operations diesel has highest cylinder pressure of 53.63 bar followed by operation-B. The higher cylinder pressure of operation-B than operation-A is attributed to better mixing of air molecules with fuel leads better oxidation and combustion hence releases more chemical and heat energy hence cause the more cylinder pressure.

3.2.7. Heat Release Rate

The deviations of HRR for different engine operations (A& B) at full load are represented in Fig.16. In the beginning a slender negative HRR is observed during ignition delay period which is due to cooling effect of vaporization of the B20 blend and loss of heat from cylinder walls and later on it turns into positive when combustion starts. The HRR for biodiesel operation is lower than pure diesel as the diesel as more calorific value and lesser viscosity releases more heat than lower and higher viscous biodiesel fuels. In case of operation-B improved HRR of 57.85 J/crank angle is observed in comparison with operation-A of 57.13 J/crank angle. This might be due to better atomization of fuel and faster air-fuel mixing during diffusion phase releases more heat and pressure. The diesel fuel operation has shown highest HRR of 65.43 J/crank angle when compared to biodiesel operation.

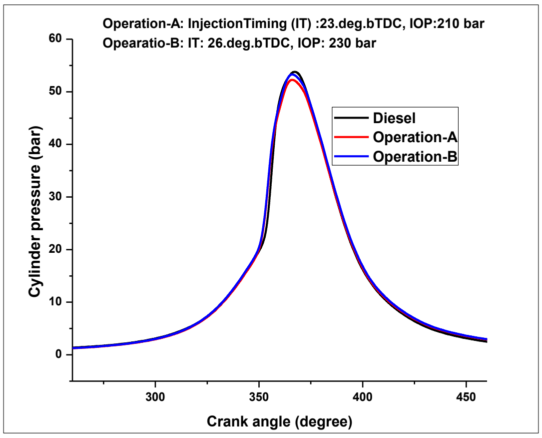

Fig.15. Cylinder pressure verses crank angle at full load.

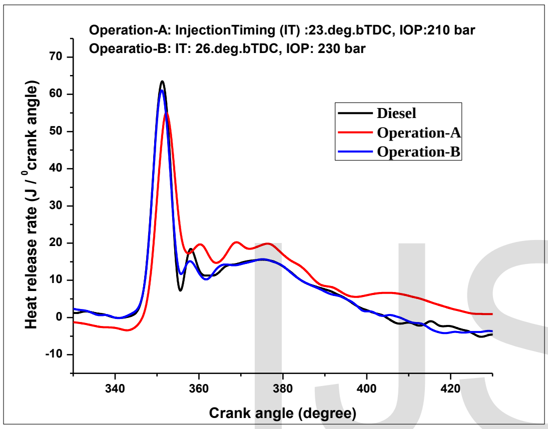

Fig.16. Heat release rate verses crank angle at full load.

4. CONCLUSION

The tests are conducted on single cylinder kirloskar TV1 diesel engine to appraise the engine performance with slight modifications in the diesel engine. From the experimental results it is observed that operation-B has shown increased BTE of 3.54% and reduced BSFC of 6.25% when compared to operation-A. There is decreased HC of 7.5% and CO of 11.84% are observed, while 12.98% of NOx emission is increased with operation-B. 1.24% of HRR increased with operation-B when compared to operation-A.

On whole, it conclude that combined increased IOP and advanced IT results improved performance, combustion and emission characteristics of the diesel engine when it is fueled with B20 fuel blend. It could be attributed to improved fuel atomization, enhanced air-fuel mixing rate, evaporation and complete combustion in the cylinder.

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