IOP Conference Series: Materials
Science and Engineering

PAPER • OPEN ACCESS

Effect of Nozzle Hole Number on Diesel Engine Using Diesel and Biodiesel Blends

To cite this article: S Sabareesh Kumaran and P Raghu 2020 *IOP Conf. Ser.: Mater. Sci. Eng.* **912** 042007

IOP Conf. Series: Materials Science and Engineering **912** (2020) 042007 doi:10.1088/1757-899X/912/4/042007

Effect of Nozzle Hole Number on Diesel Engine Using Diesel and Biodiesel Blends

S Sabareesh kumaran[1] and P Raghu[1]
[1]Department of Mechanical Engineering, Sri Venkateswara college of Engineering, Pennalur, Sriperumbudur, Tamilnadu, pincode-602117, India.

E-mail: kumaransabareesh@gmail.com

Abstract. In this work the experiment was carried out to investigate the performance, combustion and emissions by changing the number of nozzle holes of the injector such as 3 hole, 4 hole and 5 hole by maintaining the hole diameter as 0.25mm. The experiments are executed on Kirloskar 4-stroke computerized single cylinder air cooled and electrical dynamometer coupled DI diesel engine with diesel, Rubber seed methyl ester and B20 Blend as fuels at 1500 rpm, with the injection timing of 23.4°BTDC with an injection pressure of 240 bar maintained constant throughout the experiment. It is found that 4 hole nozzle gives higher brake thermal efficiency, lower specific fuel consumption, CO, HC, for Diesel, Biodiesel and B20 Blend compared with other two nozzle holes. However the NO_X got increased which is more for all the tested fuels by varying a number of nozzle hole diameter.

1. Introduction

In a CI engine the diesel is inoculated into an extremely pressurised gas. The pressure and temperature of the gas makes the diesel to self-ignite. Certain time period is essential for self-ignition as the reactions of combustion does not takes place instantly. Hence, the preliminary stage of combustion process is premixing meanwhile certain amount of diesel has time period to combine with air during the ignition delay period. Next to the premixed stage the combustion will takes place with diesel being burnt during controlled combustion stage. As stated earlier the intention of a combustion system in an engine is to burn the fuel and thus turn it into heat. A fuel injector is a device which is used to impinge the fuel into the engine for preparing the correct fuel-air mixture which in turn offers effective combustion to the engine. The capillary and nozzle of diesel fuel injectors are made in such a manner that they can form the diesel packets while spraying the fuel inside the combustion chamber.

The study was made on a DI diesel engine to evaluate its outcome on performance and emission at 200 bar, 220 bar and 240 bar injection pressure. The dissimilar nozzle hole size injectors such as 3 holes 0.28 mm dia and 5 holes 0.20 mm dia were taken. The result shows that the 5 hole nozzle of Ø = 0.2 mm at the fuel injection pressure of 220 bar gives improved performance and emission characteristics [1]. The study was done to evaluate the effect of different nozzle hole sizes on performance, combustion and emissions by using various diameters for a 3hole nozzle. The diameters chosen are 0.28 mm as base and 0.20 mm as modified. It was observed that 0.20 mm modified nozzle progresses the vaporisation, atomisation and air-fuel mixing in a lesser time period [2]. This investigation was done to explore the performance of Jatropha not fit for human consumption vegetable oils and its blend. The trials were executed on 5,7,9 and 11 hole nozzle injector for an injection pressure of 210 bar. It is seen that the 9 hole nozzle provides decent performance and lesser emission rates [3]. This investigation deals with the outcome of diverse constraints which includes hole number, diameter and length of holes, nozzle sac diameter and the needle seat angle of injectors were studied based on injection rate and sac pressure. Outcomes demonstrate that decrease in sac pressure by 46%, therefore doubling the hole number had massive variation in injection rate. Even though, the sac pressure will increase up to 60%, when the hole diameter is decreased by 40% in spite of the quasi-constant injection rate [4].

This study deals with the evaluation of diesel engine's performance using neem oil methyl ester (NOME). The engine runs at a constant speed of 1500 rpm and CR of 17.5. The various injectors used are 3, 4, 5 holes of 0.3 mm diameter and the injection timing are 19°, 23°, 27° and 31° BTDC. The pressure of 205, 220, 230, 240 and 260 bars were selected for evaluation. It is found that the injection timing of 27°, injection pressure of 240 bar and 5 hole injector gives greater performance with NOME [5]. Studied the performance of single cylinder 4 stroke variable compression ratio engine with cottonseed oil methyl ester (COME) as fuel. The various injection timing used are 19°, 23° and 27° BTDC and the injection pressure of 210, 220, 230 and 240 bars and 3, 4 and 5 hole injectors of 0.3 mm diameter of each were selected. The results shows that 4 hole injector and IT of 19° and pressure of 230 bar gives better engine performance and emission [6].

The experiment was done to evaluate the performance of CRDI engine using acid oil methyl ester (AOME) biodiesel blended with diesel and ethanol. First the injection timing is varied between 25° BTDC to 5° ATDC and next the injection pressure is varied between 600 to 1000 bar. The compression ratio and the engine speed were kept constant at 17.5 and 1500 rpm respectively for both cases. It is evaluated that injection timing of 10° and the injection pressure of 900 bar gives higher performance and lesser emissions [7].

The diesel engine's performance depends mainly on their injection scheme strategy. Hence the advances were done in the injection system design to achieve better engine performance. The injectors will inject the fuel at very high pressure and thus the material selected must able to withstand the high stresses. Superior accuracy and tolerance were given in the injection system design.

2. Experimental Setup

Table 1. Engine specifications.

Engine type	Four stroke, single cylinder, air cooled direct injection diesel engine
Piston type	Bowl- in- piston
Capacity	661 cm^3
Maximum power/ HP	4.4 kW/ 7.2 HP at 1500 rpm
Maximum torque	28 Nm
Bore x stroke	87.5 mm x 110 mm
Compression ratio	17.5:1
Speed	1500 rpm
Dynamometer	Electrical dynamometer with loading unit
Injection timing	23.4°Btdc
Injection Pressure	Injection pressure 240 bar
Type of fuel injection	Pump-in-line injection system
No. of nozzle holes	3, 4, 5

The engine specifications were shown in table 1, the rated power of the engine is 4.4 kW. The engine is a 4 stroke, single cylinder and air-cooled diesel engine coupled with electrical dynamometer. The injectors used are 3, 4 and 5 holes with diameter of 0.25 mm each fueled with diesel, biodiesel and B20 blend. The engine rums at a constant speed of 1500 rpm and the CR of 17.5. The injection pressure of 240 bar and the injection timing of 23.4° were selected for the complete experiment.

Thermocouple is employed to measure the ambient air temperature. An exhaust gas analyzer is employed to calculate the amount CO, CO_2, HC, NO_x and O_2.

3. Results and Discussions

The experiment was performed to investigate the effect of different nozzle hole number in CI engine. The combustion, performance and emission characteristics of various nozzles are tested under different load conditions using diesel, biodiesel and B20 blend. Some of the engine parameters and emissions are calculated and represented in the form of graphical representation.

3.1 Brake thermal efficiency

Brake Thermal Efficiency is known as brake power of a heat engine. It helps to determine how an engine converts heat energy to mechanical energy. Brake thermal efficiency (BTE) measures the effectiveness of chemical energy conversion into beneficial work in an engine. Effect of nozzle hole number on BTE for 3, 4 and 5 hole nozzles for various fuels used are shown in Figure 1 to Figure 3 respectively. Hence it was evaluated that nozzle holes number has substantial impact on spray penetration and droplet size. From the above graphs it was observed that for 4 hole nozzle the BTE amplified slightly as a outcome of improved vaporization and atomization for diesel and RSME. 5 hole nozzle shows increased BTE for B20 blend alone. It is clear that for diesel and biodiesel the 4 hole nozzle is preferred than the other two nozzles for better BTE.

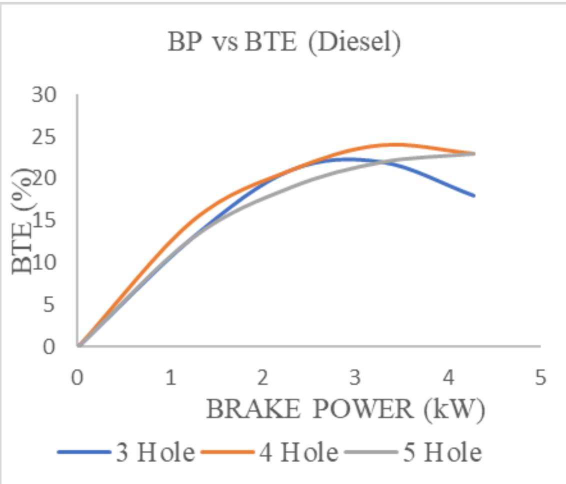

Figure 1. Effect on BTE for Diesel.

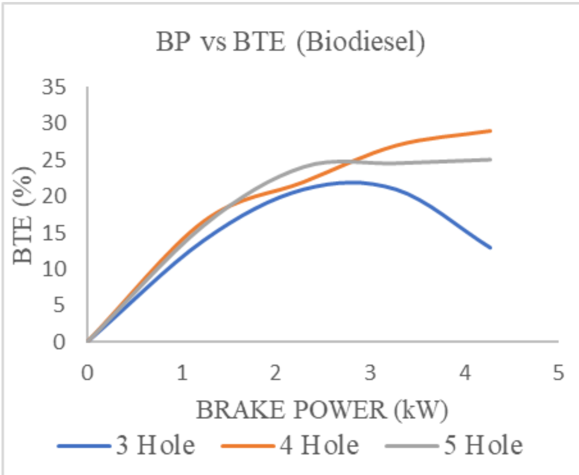

Figure 2. Effect on BTE for Biodiesel.

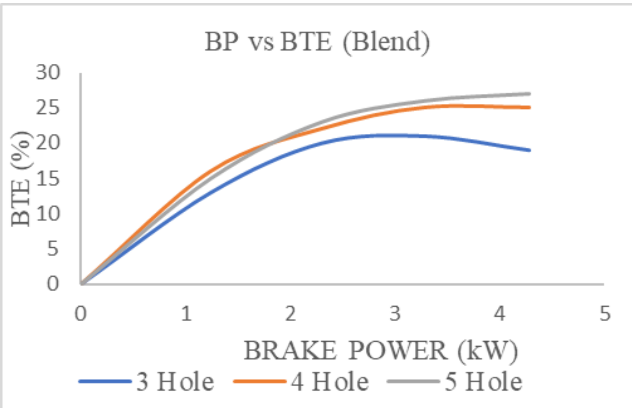

Figure 3. Effect on BTE for Blend.

IOP Conf. Series: Materials Science and Engineering **912** (2020) 042007 doi:10.1088/1757-899X/912/4/042007

3.2. Brake specific fuel consumption

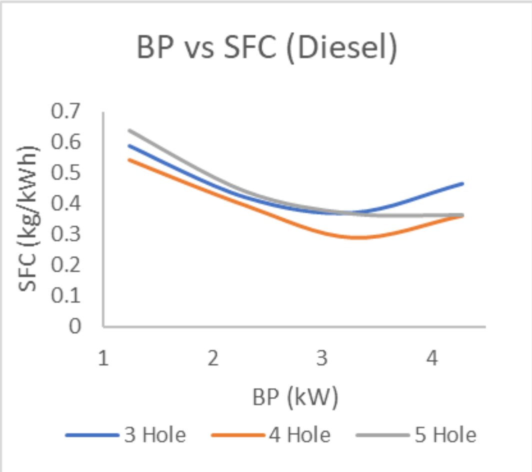

Figure 4. Effect on SFC for Diesel.

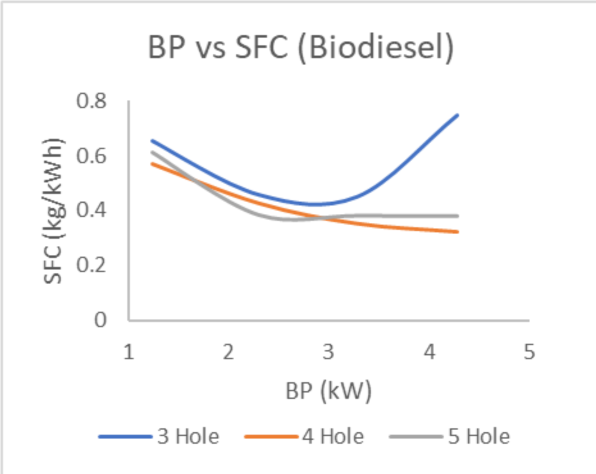

Figure 5. Effect on SFC for Biodiesel.

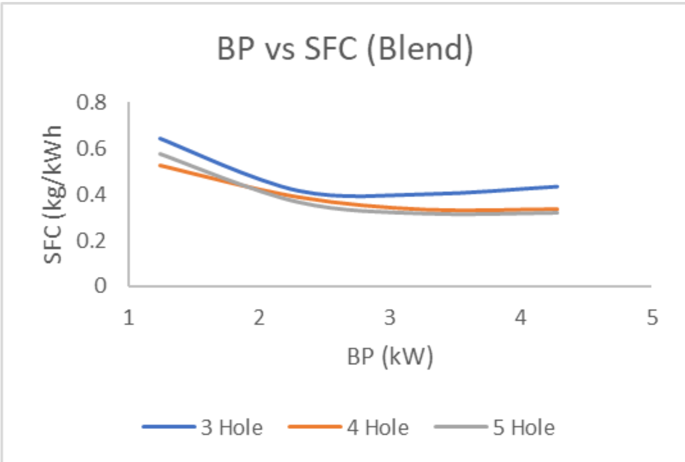

Figure 6. Effect on SFC for Blend.

Brake-specific fuel consumption (**BSFC**) is the fuel efficiency of prime mover in which fuel burns to yield shaft or rotational. Thus BSFC relates the efficiency of an internal combustion engine with its shaft output. It is also the amount of fuel consumed to the power generated. Consequence of nozzle hole number on BSFC for 3,4,5 hole nozzles are shown in Figure 4 to Figure 6 respectively. The BSFC depends principally on fuel aspects such as viscosity, density and its chemical structure. For the 4 hole nozzle, the BSFC was encouragingly falling due to increased mixing rates of fuel and air. From the outcomes it is found that 4 hole nozzle have low BSFC when compared with other nozzles for diesel, bio diesel and B20 Blend fuel.

3.3. Heat release rate
HRR is a vital parameter of combustion found by the application of the first law of thermodynamics on the cylinder gas pressure variable. Based on HRR the various combustion stages were classified. The combustion stages are classified into premixed combustion stage, mixed combustion stage, and late combustion stage.

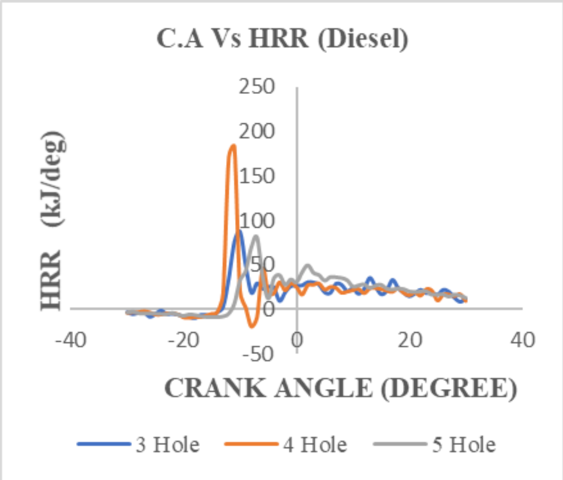

Figure 7. Effect on HRR for Diesel.

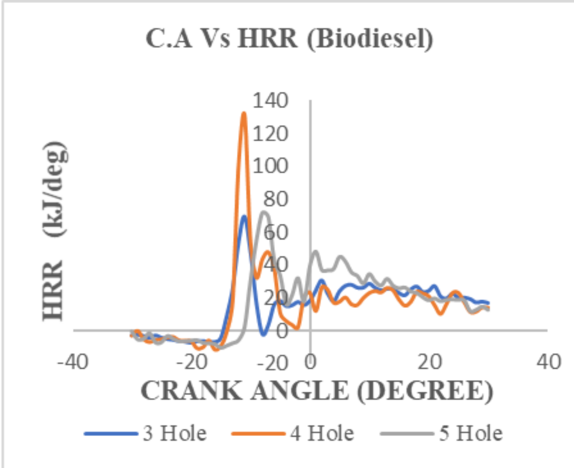

Figure 8. Effect on HRR for Biodiesel.

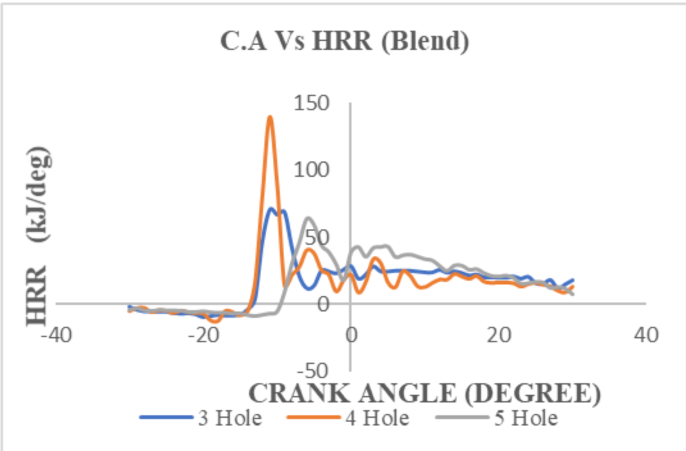

Figure 9. Effect on HRR for Blend.

Effect on heat release rate for 3, 4 and 5 hole nozzles are shown in Figure 7 to Figure 9 respectively. The peak rise in Heat Release Rate for the 4 hole nozzle is because of the delay during the early stage of combustion.

3.4 Cylinder Pressure

The pressure inside the engine cylinder is a vital parameter to be observed during the combustion process to evaluate the performance characteristics of the diesel engine. It is dependent on the amount of fuel taking part in uncontrolled combustion. Variation of cylinder pressure for 3, 4 and 5 hole nozzles are shown in Figure 10 to Figure 12 respectively. From the graphs it is evaluated that the 4 hole nozzle has high in-cylinder pressure compared with the other nozzles. It is due to the complete vaporization of the fuel in 4 hole nozzle and results in appropriate mixing of air and fuel.

3.5 Carbon monoxide

Carbon monoxide is mainly due to the partial combustion in which the complete oxidation process does not occurs. CO mainly depends on the air fuel mixture, if the rich mixture is used the level of CO will be higher. In rich mixtures due to shortage in air the CO_2 cannot be formed from the carbon and thus CO is formed. The large amount of CO is formed during the starting of the engine and rapid acceleration. Effect on carbon monoxide emissions for 3, 4 and 5 hole nozzles are shown in

Figure 13 to Figure 14 respectively. By relating the graphs, it is found that for 4 hole nozzle due to thoroughness in the fuel and air mixing the CO emission is prominently lowered with diesel, RSME and B20 blend.

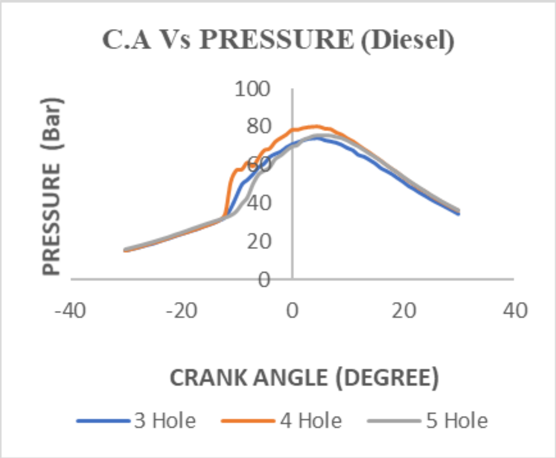

Figure 10. Variation of pressure for Diesel.

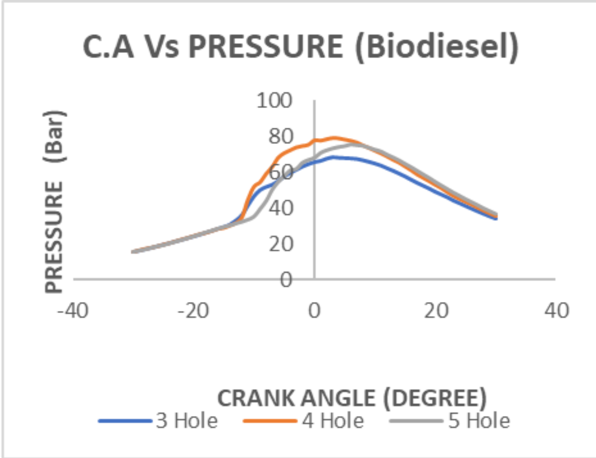

Figure 11. Variation of pressure for Biodiesel.

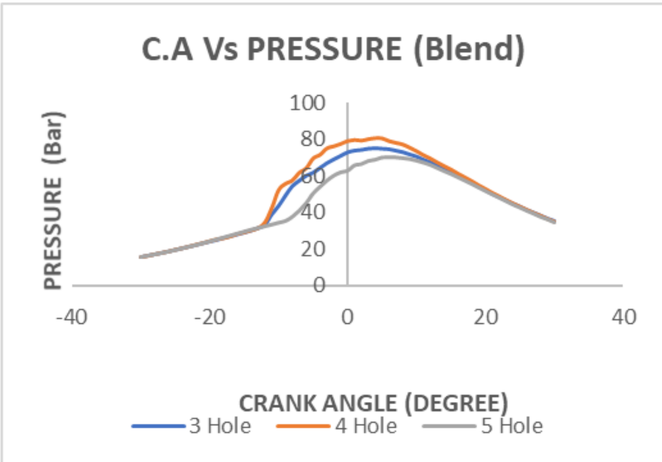

Figure 12. Variation of pressure for Blend.

3.6 Hydrocarbon emission

Hydrocarbon emissions are the source of unburned fuels that impinge on to the cylinder wall. The HC emissions are due to lean mixtures, in lean mixtures the flame speeds might be too little for combustion and causes wall quenching. When the unburnt fuel burns in the successive cycle it will produce HC emissions. Effect on HC emissions for 3, 4 and 5 hole nozzles are shown in Figure 16 to Figure 18 respectively. From the graphs it is evident that HC formation is considerably decreased with 4 hole nozzle with diesel, RSME and B20 blend because it will produce high flame speeds for better turbulence.

3.7 Oxides of nitrogen (NOx)

The volume of NO_x formed is due to the peak temperature reached in the cylinder, oxygen concentrations, and residence time. The large amount of NO_x is formed during the early stage of the combustion, when the piston is motionless close to the top of its stroke. At this stage the temperature of the flame is at its peak. Effect on NOx emissions for 3, 4 and 5 hole nozzles are shown in Figure 19 to Figure 21 respectively. From the graphs it is observed that NOx emission increases with 4 hole nozzle this is owing to the complete combustion of air and fuel.

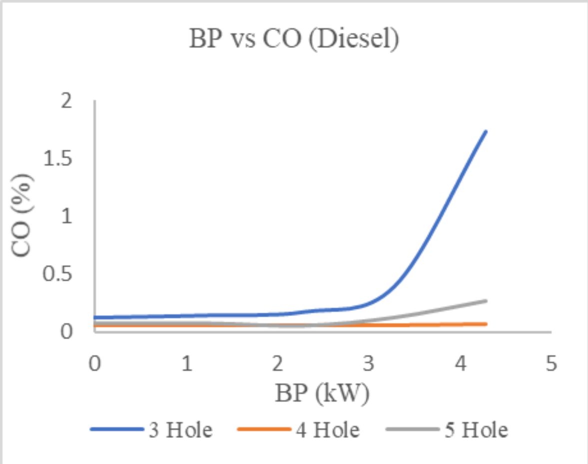

Figure 13. Effect on CO for Diesel.

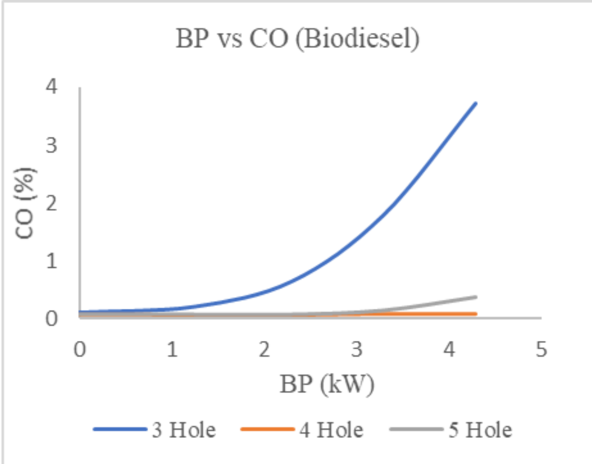

Figure 14. Effect on CO for Biodiesel.

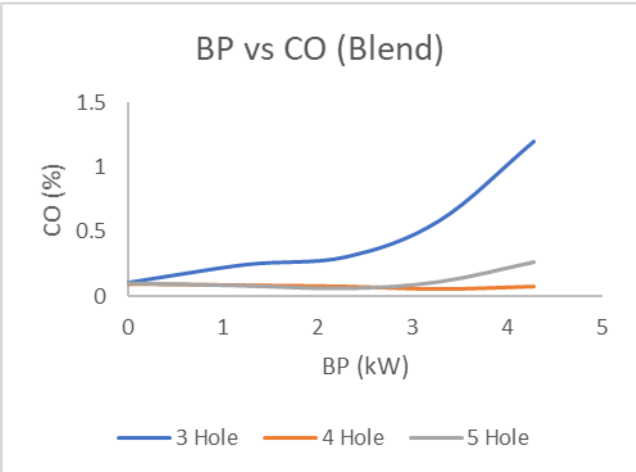

Figure 15. Effect on CO for Blend.

3.8 CO_2 Emissions

During combustion the hydrocarbon fuel burns with air to liberate heat energy, in this process the carbon in the fuel reacts with oxygen in the air to produce carbon-dioxide as a by-product. The carbon-dioxide emissions are the source of the complete combustion. Effect on CO_2 emissions for 3, 4 and 5 hole nozzles are shown in Figure 22 to Figure 24 respectively. From the graphs it is seen that the 4 hole nozzle produces high CO_2 emissions, hence the 4 hole nozzle generates complete combustion in the CI engine as compared with the 3 and 5 hole nozzle for all the fuels tested.

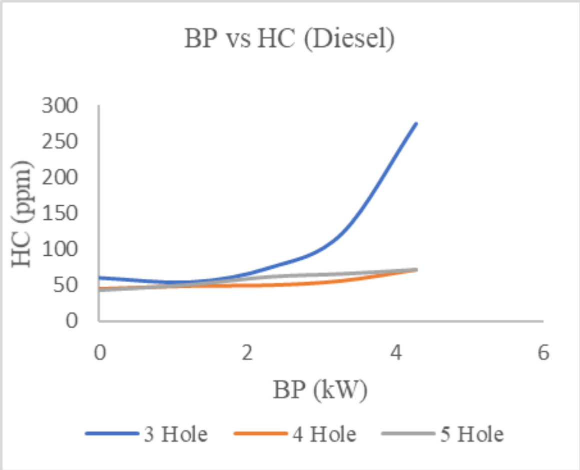

Figure 16. Effect on HC for Diesel.

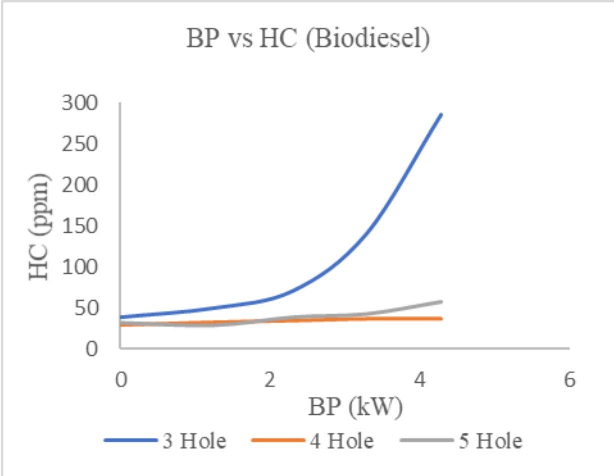

Figure 17. Effect on HC for Biodiesel.

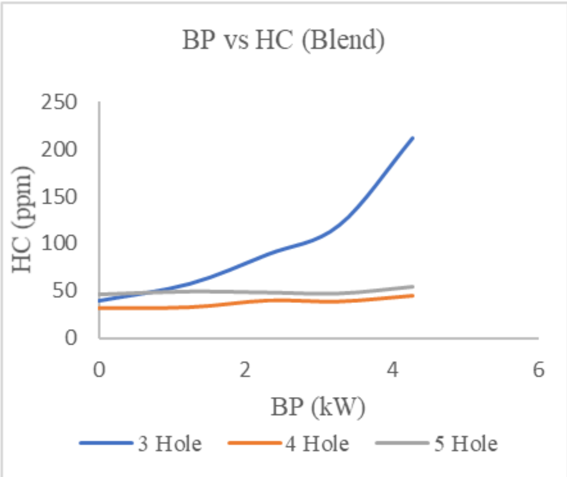

Figure 18. Effect on HC for Blend.

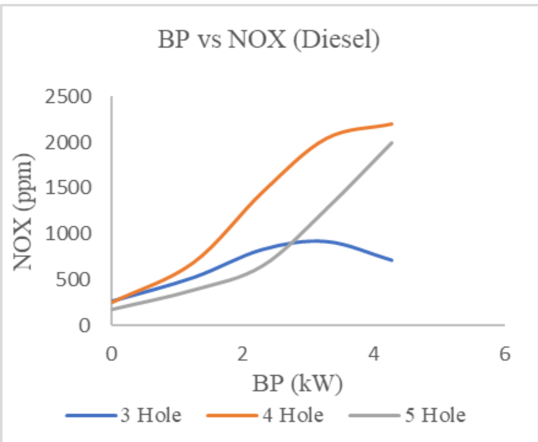

Figure 19. Effect on NOx for Diesel.

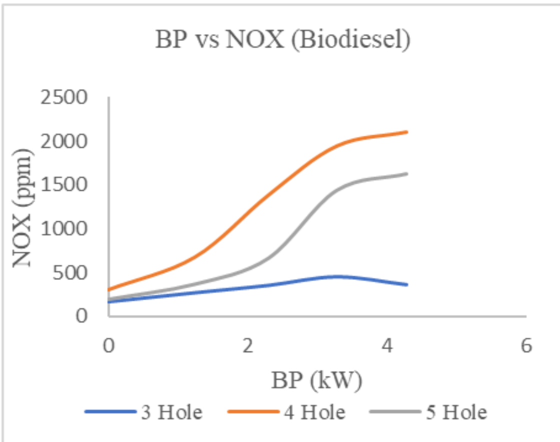

Figure 20. Effect on NOx for Biodiesel.

IOP Conf. Series: Materials Science and Engineering **912** (2020) 042007 doi:10.1088/1757-899X/912/4/042007

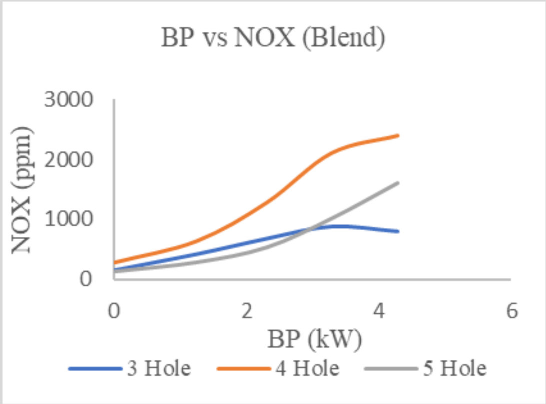

Figure 21. Effect on NOx for Blend.

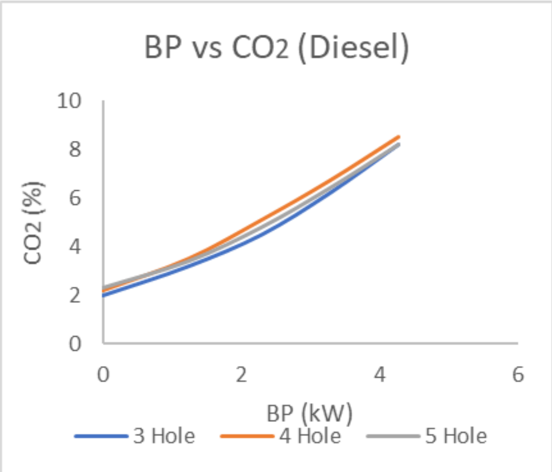

Figure 22. Effect on CO_2 for Diesel.

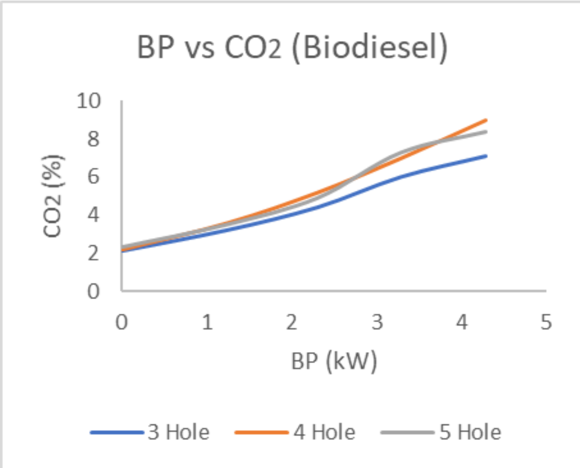

Figure 23. Effect on CO_2 for Biodiesel.

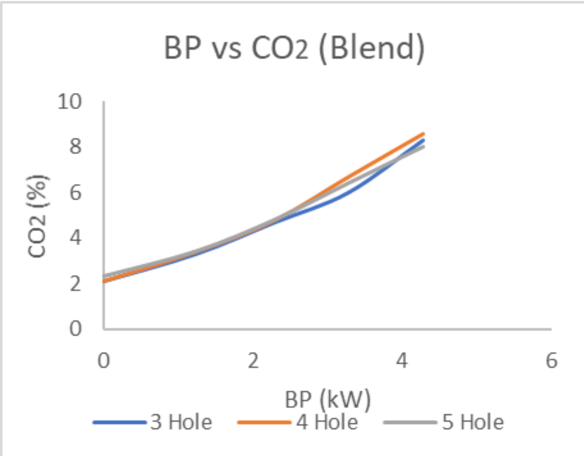

Figure 24. Effect on CO_2 for Blend.

4. Conclusion

The combustion, performance and emission characteristics of a single cylinder diesel engine is studied by varying the number of injector nozzle hole The 0.25 mm diameter hole injector is selected and the number of holes is varied to 3,4 and 5. Tests are done with diesel, RSME and B20 blend, from the results observed it is determined that 4 hole nozzle generates encouraging results concerning engine performance, combustion and emission compared with the other two nozzles for all the fuels used. The major drawback is that increase in NOx and CO_2 emissions were observed for all the tested fuels. The 3 hole and 5 hole nozzle gives higher CO and HC emissions whereas NO_X is reduced due to lesser heat release rate and improper mixing of air and fuel.

Acknowledgement

The authors thank the management of Sri Venkateswara College of Engineering for give us with the essential experimental setup to execute this work.

5. References

[1] Sharma R, Singh R R and Vishwakarma S K 2013 Experimental study of the effect of fuel injector nozzle holes on direct injection diesel engine *IOSR Journal of Mechanical and Civil Engineering* **7.**

[2] Vijay Kumar M, Veeresh Babu A, Ravi Kumar P and Manoj Kumar Dundi T 2018. Influence of different nozzle hole orifice diameter on performance, combustion and emissions in a diesel engine *Australian Journal of Mechanical Engineering* **1** 1-6.

[3] Senthil Kumar R., 2014 Experimental Investigation of Injectors Nozzle Hole on CI engine Using Jatropha Oil as Bio-fuel, *International Journal of Scientific Research Engineering & Technology* 3 1-7.

[4] Pirooz A R Y A 2014. Effects of injector nozzle geometry on spray characteristics, an analysis *Indian J. Sci. Res.* **5** 354-361.

[5] Halewadimath, S.S., Banapurmath, N.R. and Khandal, S.V., 2017. Performance, Emission and Combustion Characteristics of Modified Diesel Engine Fuelled with Neem Oil Methyl Ester (NOME) *SciFed Journal of Biofuel and Bioenergetics*, **1**.

[6] Suresh G, Kamath H C and Banapurmath N R 2014. Effects of injection timing, injector opening pressure and nozzle geometry on the performance of cottonseed oil methyl ester-fuelled diesel engine *International Journal of Sustainable Engineering* **7** 82-92.

[7] Rajesh S, Kulkarni B M, Banapurmath N R and Kumarappa S 2018. Effect of injection parameters on performance and emission characteristics of a CRDi diesel engine fuelled with acid oil biodiesel–ethanol blended fuels *Biofuels* **9** 353-367.