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Effect of Nozzle Hole Geometry On Diesel Engine Using Diesel And Biodiesel Fuel

R.Rajaraman[1*], R.Sundarrajan[1], B.Sathyanaryanan[1], P.Raghu[1]
[1]*Department. of Mechanical Engineering, Sri Venkateswara college of Engineering, Pennalur, Sriperumbudur, Tamilnadu, pincode -602117.India,**
Corresponding Author: R.Rajaraman

***Abstract**: In this study the experimental attempt was carried out to investigate the performance, combustion and emissions by changing the various nozzle holes size of the injector such as (3 hole x Ø0.28 mm), (3 hole x Ø 0.30 mm), (4 hole x Ø 0.28 mm), (4 hole x Ø 0.30 mm), (5 hole x Ø 0.28 mm), (5 hole x Ø 03.0 mm).The experiments are performed on Kirloskar 4-stroke single cylinder direct injection diesel engine fueled with diesel and rubber seed oil methyl ester (RSOME) at 1500 rpm, and coupled with electrical dynamometer with the standard injection timing of 23.4° bTDC (before top dead centre) with an injection pressure of 240 bar kept up invariant throughout the experimental diesel and RSOME work. It is found that Ø 0.28 mm nozzle hole diameter 4 hole gives higher brake thermal efficiency, lower specific fuel consumption, Carbon monooxide, HC, for Diesel and RSOME compared with other nozzle geometry conditions.*

***Keywords:** Biodiesel, Nozzle hole diameter, Diesel engine*

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I. Introduction

In a diesel engine the fuel is injected into a highly compressed gas volume. The temperature and pressure of the gas causes the fuel to auto ignite. Some residence time is required for ignition as the thermo chemical reactions concerned do not take place instantly. Therefore, the initial phase of the combustion event is premixed since some fuel has had time to mix with air during the ignition delay. After the premixed phase the combustion continues with fuel being burnt in mixing controlled diffusion flames. As mentioned before the purpose of a combustion system in an engine is to burn the fuel and thus turn it into heat. The characteristics of the combustion process in a diesel engine are partly determined by the gas state in the combustion chamber determined by factors such as boost pressure, compression ratio, charge temperature and EGR-rate. The fuel injection process also has a major influence on the combustion and emission formation processes. Factors that strongly influence the atomization and combustion of the fuel are injection pressure, fuel injection timing, hole parameters, the interaction between the fuel sprays and the geometry and gas flow in the combustion chamber, the use of multiple injections and rate shape. Some complex mechanisms are involved in the mechanical interaction between the initial liquid fuel jet and the gas charge as the fuel is atomized prior to combustion.

[1] analyzed the performance of diesel engine high-powered with neem oil methyl ester (NOME). The engine operating conditions such as injection timing, Injection pressure and number nozzle holes were varied and better operational conditions were reported. The engine was forever operated at 1500 rpm with Compression ratio of 17.5. For diesel engine operation with NOME, it could be disclosed that injection timing of 27-degree bTDC, and injection pressure of 240 bar proceeds better performance in terms of higher brake thermal efficiency with reduced emissions. Injector of 5-hole issue better results as compared to other injectors.[2] studied and evaluated the effect of using n-butanol in vegetable oil–diesel fuel blends on engine performance and exhaust emissions of a direct injection diesel engine operating at full load (100% throttle conditions) with different engine speeds without any engine modification. Neat canola-hazelnut-cottonseed oil (CHC) and neat sunflower–corn–soybean oil (SCS) blends were prepared as equal vol.% by splash blending method.

[3] investigated the search for maintainable and clean-burning renewable fuels. Were the cottonseed oil methyl ester (COME) was used in a four-stroke, single-cylinder variable compression ratio diesel engine. Tests were carried out to study the effects of fuel injection timing, fuel injector opening pressure (IOP) and injector nozzle geometry on the performance and combustion of COME biodiesel fuel used in a compression ignition engine with a single fuel mode. The results proposed that with retarded injection timing of 19° BTDC, increased IOP of 230 bar and a four-hole nozzle injector of 0.3 mm size caused in overall better engine performance with an increased brake thermal efficiency and reduced HC, CO and smoke emission levels.

The effect of injection timing on performance and emission characteristics of a CI engine fueled with diesel and methyl soyate and make a comparison between the two. The simulations have been carried out for three different injection timings of 17º, 20º and 23º BTDC. The predicted results indicate a decrease in the brake thermal efficiency and an increase in the brake specific fuel consumption with the advancement in injection timing for both the fuels, the performance of diesel being better than the biodiesel. Exhaust gas temperature increases along with the NO_x and CO_2 emissions, while the particulate matter and smoke emissions decrease with the advancement in injection timing. NOx, CO_2 emissions and exhaust temperature are found to be more, while PM and smoke emissions are less for methyl soyate when compared to diesel[4].

The recent developments on the production and characterization of biodiesel as well as the experimental work carried out by many researchers in this field. Biodiesel is a renewable substitute fuel for petroleum diesel fuel made from vegetable or animal fats by a monoalcholic transesterification process. Biodiesel is produced by the transesterification reaction of triglycerides of vegetable oils with methanol with the help of basic, acidic and enzymatic catalysts. Methanol is the commonly used alcohol in this process, due in part to its low cost. Methyl esters of vegetable oils have several outstanding advantages among other new-renewable and clean engine fuel alternatives[5]. Biodiesel production using inedible vegetable oil, waste oil, and grease has become more attractive recently. The economic performance of a biodiesel plant can be determined once certain factors are identified, such as plant capacity, process technology, raw material cost, and chemical costs. The cost of biodiesel fuels varies depending on the base stock, geographic area, variability in crop production from season to season, the price of crude petroleum, and other factors[6].

The major, an important part of the diesel engine is fuel injector nozzle. For a long era, the mechanism of the injector nozzle is atomization of the fuel spray this is commonly thought to be aerodynamic atomization theory. The nozzle fuel flow in diesel engine powerfully affects the development of fuel atomization and improves the combustion, performance and emissions. The nozzle hole numbers, increasing the injection pressure and orifice sizes severely influence the combustion and performance due to the spray parameters like penetration length and droplet size.

II. Experimental Setup

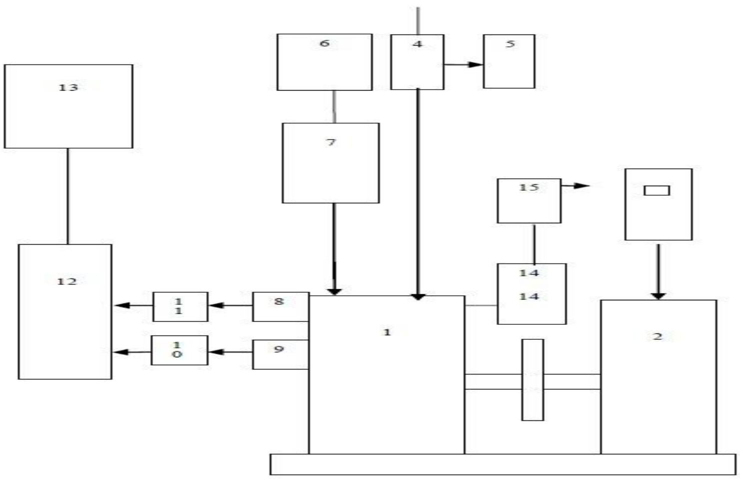

Fig.1. Experimental setup

1)Diesel engine,(2) Electrical dynamometer, (3) Dynamometer control panel,(4) Air box,(5) U-tube manometer, (6) Fuel tank, (7) Fuel measurement,(8) Pressure transducer,(9) TDC position sensor,(10) Charge amplifier, (11) TDC amplifier circuit, (12) Analog to digital card, (13) Personal computer, (14) Exhaust gas analyzer, (15) AVL smoke mete

The experiments were conducted on a single cylinder, 4 stroke, constant speed, air cooled diesel engine was coupled to Electrical dynamometer, direct injection. The engine equipped with thermocouples to measure the temperature of air and gas, Rotameter to measure the water flow rate and manometer to measure air flow and fuel flow. An exhaust gas analyzer is used to measure CO, CO_2, HC, NO_x and O_2. The experimental investigation will be done on three different nozzle hole orifice diameters with diesel fuel. In the engine, providing a stable value engine speed of 1500 rpm and compression ratio of 17.5:1, the injection pressure 240 bar and the injection timing 23.4° bTDC. In order to achieve the performance, combustion and emissions, the engine will perform at various loads such as, 0, 20, 40 60, 80 and 100%. In each of the load 3 sets of reading it will be noted that the air flow, fuel flow exhaust gas temperature, in-cylinder average temperature, engine cylinder pressure, the CO emissions, NOx emissions, HC emissions and the average value will be considered. The experimental setup was shown in fig.1.

III. Result and Discussion

In this experimental work the performance, emission and combustion characteristics in DI diesel engine at standard injection timings 23.4^o bTDC for various nozzle holes size of the injector such as (3 hole x Ø0.28 mm), (3 hole x Ø 0.30 mm), (4 hole x Ø 0.28 mm), (4 hole x Ø 0.30 mm), (5 hole x Ø 0.28 mm), (5 hole x Ø 03.0 mm) for Rubber seed oil methyl ester (RSME) and diesel fuel was studied.

3.1 Brake thermal efficiency

The variation of nozzle hole geometry for 0.28 mm NHD and 0.30 mm Nozzle Hole Diameter (NHD) for RSME and diesel fuel was shown in Fig. 2. From the above fig.2. it is observed that for smaller orifice of 0.28 mm 4hole NHD the BTE increased slightly as a result of enhanced vaporization and atomization for diesel and RSME. In the case of larger NHD, the BTE has decreased because of the improper mixing of air fuel which is due to the poor atomization and vaporization of fuel i.e. increasing of fuel droplet size. Also, high injection pressure may responsible to increase the velocity of fuel droplets which will pass away without mixing air properly and lowers the BTE because of improper combustion.

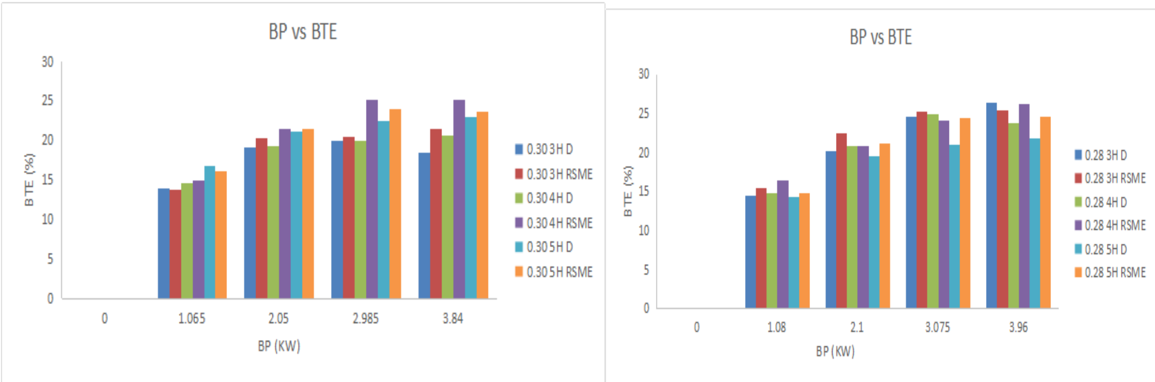

Fig.2 Variation of brake thermal efficiency with brake power for nozzle hole diameter of 0.28 mm and 0.30 mm for RSME and diesel fuel

3.2 Brake specific fuel consumption

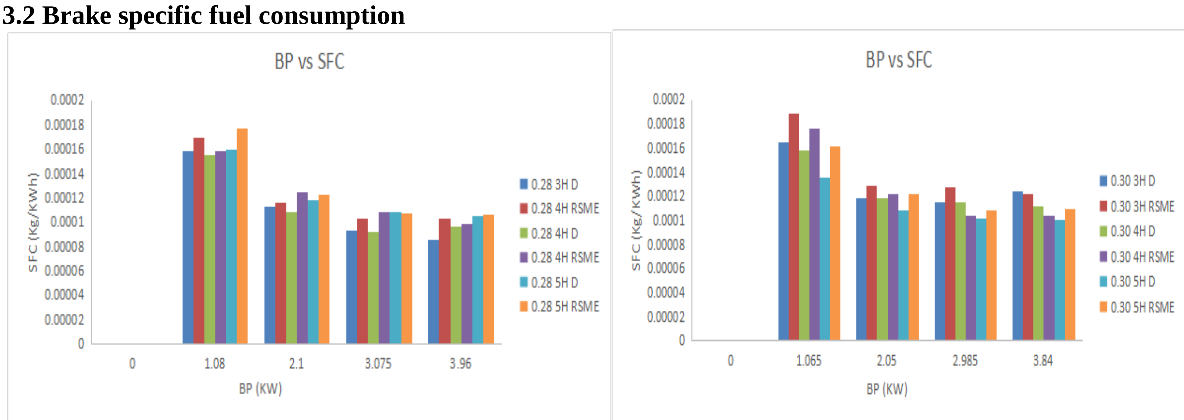

Fig.3 Variation of brake specific fuel consumption with brake power for nozzle hole diameter of 0.28 mm and 0.30 mm for RSME and diesel fuel

The effect of nozzle hole geometry for 0.28 mm NHD and 0.30 mm NHD for RSME and diesel fuel are shown in fig.3. The BSFC drift mainly depends on fuel such as density, viscosity and chemical composition. In this case of a 0.28 mm NHD, the BSFC are significantly reducing because of higher rates of mixing of air-fuel. This is indicating the fact that smaller nozzle requires higher injection pressure to ensure complete combustion and to bring down fuel consumption. For higher NHD the BSFC is increasing due to the deprived atomization. The decrease in BSFC was due to the fact that, as the BMEP increases, the rate of increasing brake power was much more than that of the increased fuel consumption owing to a rise in the combustion temperature (indicated by cylinder pressure) with load.

3.3 Heat release rate

There are different heat release rate with respect to crank angle (full load) with 3 hole, 4 hole and 5 hole different orifice nozzle hole diameters of 0.28 mm and 0.30 mm fueled with Diesel and Bio-Diesel (RSME) is shown in the fig.4. The peak rise in Heat Release Rate is decreased by the 4 holes, 0.28 mm nozzle hole diameter because of the delay results due to the early start of combustion. The smaller nozzle hole diameter causes the slow burning in premixed phase which results lower heat release rate was shown in fig.4.

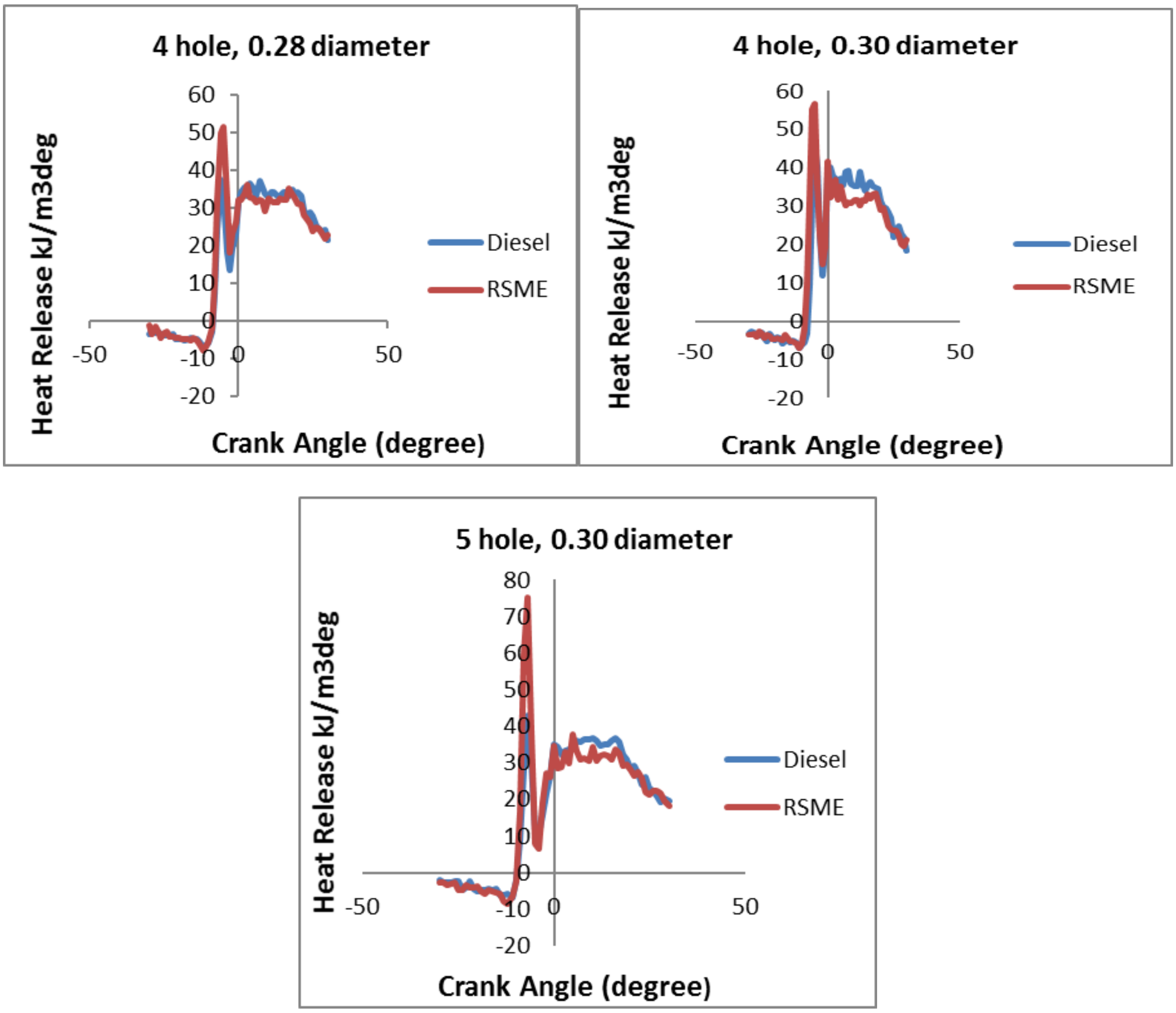

Fig.4 Variation of heat release rate for nozzle hole diameter of 0.28 mm and 0.30 mm for RSME and diesel fuel

3.4 . Carbon mono oxide

The variation of nozzle hole geometry on carbon mono oxide (CO) emissions for RSME and diesel fuel are shown in fig 5. The CO pollution are often found in the engine exhaust gases. CO emissions is nothing but the behavior of incomplete combustion due to rich air-fuel mixture. Thus, due to increase in load from 0% to 100% the CO emissions was found to be increased. By comparing the above figure 5 for both NHD the CO emission is considerably reduced by the smaller orifice of 0.28 mm 4hole NHD with both diesel and RSME. It enhances the distribution of vaporization of fuel and better atomization of fuel for the smaller orifice NHD. For larger NHD use CO emissions has increased due to poor vaporization and atomization. By reducing the NHD, it has aided to achieve to finer atomization and reduced fuel droplet particle size which finally yields better efficiency and reduces the CO emission.

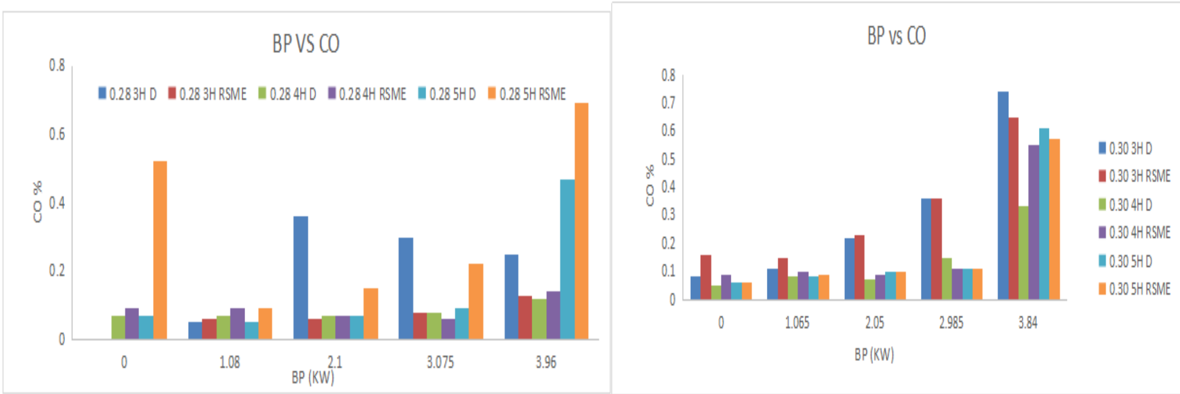

Fig.5. Variation of carbon monoxide emission with brake power for nozzle hole diameter of 0.28 mm and 0.30 mm for RSME and diesel fuel

3.5 Hydrocarbon emission

The variation of nozzle hole geometry on HC emission for RSME and diesel fuel are shown in fig.6. respectively. We know that, HC emission is caused due to low velocity of fuel which is not sufficient to penetrate air spray and induced improper air- fuel mixing or low equivalence ratio (Ø). Low equivalence ratio is the ratio of the actual air–fuel ratio to the stoichiometric air–fuel ratio. The formation of unburned hydro carbon is due to the improper combustion of fuel in the combustion chamber. By the above graphs it is evident that HC formation is substantially is decreased with 0.28mm 4hole NHD with both diesel and RSME. Reducing the orifice diameter enhances the high temperature as a result of this rise in temperature complete burning of fuel occurs in the combustion chamber. For 0.30 mm NHD HC has increased because of the hardened response due to lower temperature in combustion chamber which are caused by poor atomization and evaporation.

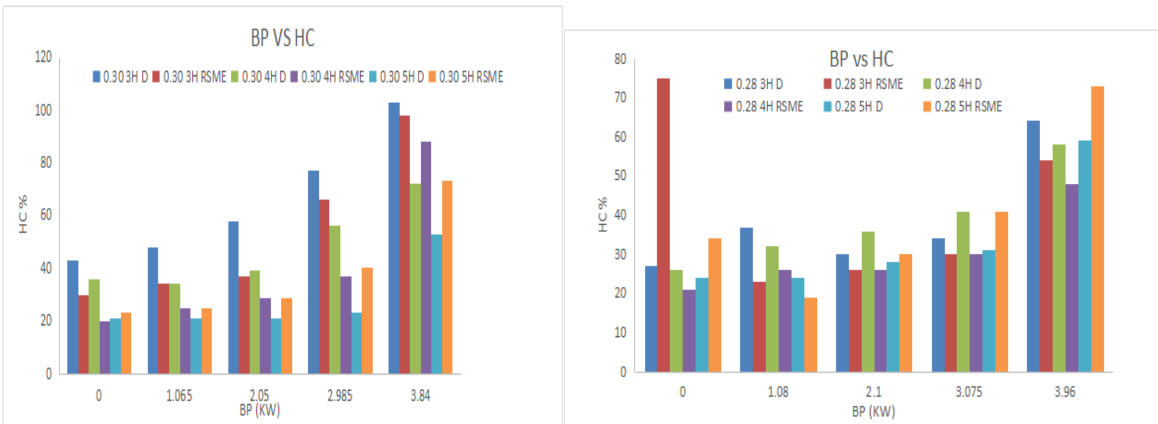

Fig.6. Variation of Hydrocarbon emission with brake power for nozzle hole diameter of 0.28 mm and 0.30 mm for RSME and diesel fuel

3.6 Oxides of nitrogen(NOx)

Result of nozzle hole geometry on oxides of nitrogen emission for RSME and diesel fuel are shown in fig.7. The development of NOx mainly depends on various factors such as quality oxygen level in the fuel, high cetane number increasing the fuel injection pressure and atomization of fuel. From the fig 7. it is determined that NOx emission increases with 0.28 NHD this is due to the exhaust gas temperature increases. By reducing the smaller orifice NHD, it raises the high temperature combustion chamber and results in better spray characteristics . By increasing the NHD nitrogen oxide is decreased due to lower temperature in combustion chamber 0.30 mm 3hole NHD has lower oxides of nitrogen emission when compared with 0.28 mm NHD. But the fuel atomization for larger NHD are poor and there is no complete evaporation.

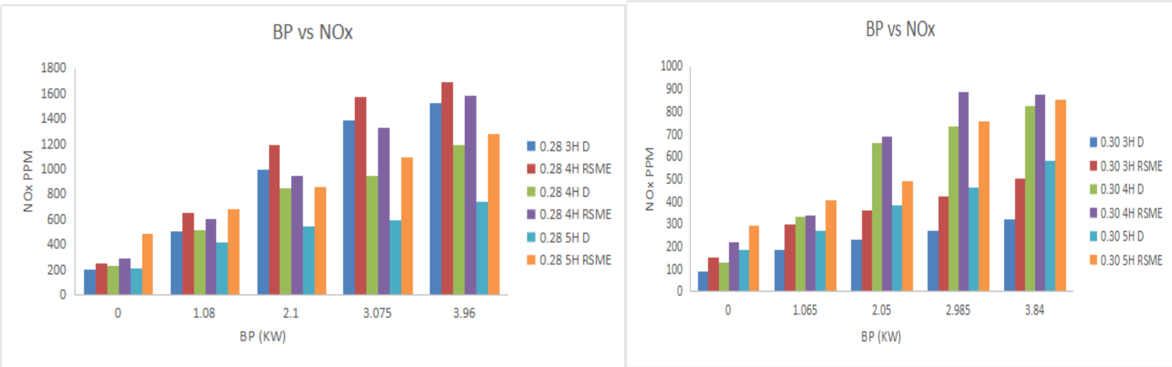

Fig. 7. Variation of Hydrocarbon emission with brake power for nozzle hole diameter of 0.28 mm and 0.30 mm for RSME and diesel fuel

IV. Conclusion

The performance, emission and combustion characteristics in DI diesel engine at standard injection timings 23.4^{o} bTDC for various nozzle holes size of the injector such as (3 hole x Ø0.28 mm), (3 hole x Ø 0.30 mm), (4 hole x Ø 0.28 mm), (4 hole x Ø 0.30 mm), (5 hole x Ø 0.28 mm), (5 hole x Ø 03.0 mm) for Rubber seed oil methyl ester (RSME) and diesel fuel was studied. The smaller orifice also improves the mixing, which is shown by shorter combustion duration. This results in reduction of heat and time losses, resulting in a higher BTE, i.e. lower specific fuel consumption. The nozzle hole geometry of (Ø 0.28mm) has improved combustion for all test cases, resulting in an increase in fuel conversion efficiency compared to the (Ø 0.30mm) NHD for diesel than bio-diesel(RSME) fuel.

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