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Combustion Characteristics of DI Diesel Engine Using Diesel and Bio-Diesel Blends

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ABSTRACT: There is a demand to diagnose environment friendly fuels and performance for the Diesel engine due to increasing intake of fossil fuel which is conducive in exploding the pollution levels of atmosphere. The intent of the study is to optimize the factors which are accountable for the performance and emission analysis DI diesel engine. The best combination of input parameters is recorded at E20, 3 hole nozzle, in 100% load which results in maximum Brake thermal efficiency and minimum Unburned hydro carbon, CO and NOx emissions of the engine. The method of finding biodiesel from various sources and blending them with diesel is adopted in many economically developed and developing countries around the world.The active study have exposed the use of inedible oil for engines as an substitute for diesel fuel. Nevertheless, around is a constraint in using inedible oil in diesel engines due to their high viscosity and low volatility. In the present work, E10, E20 and diesel are used to perform experiment with three different fuel injectors (3 hole, 4 hole, 5 hole) on performance, emission and combustion characteristics of diesel , E10, E20 blends in single cylinder air cooled diesel engine.

Keywords: Diesel Engine, Fossil Fuel, Fuel Blend, Combustion Chamber, Emission Characteristics, Air Cooled, Fuel Injectors

I. INTRODUCTION

Alternative energy sources need to be highly-developed in order to meet the increasing demand for fossil fuels. Moreover, from environmental occurrence, these new resources of energy must be environment friendly. Although the waste and non-edible oils can be blended with diesel fuel and used as fuels for diesel engines, and particularly non edible oils, fulfil these imperatives and is seen as a potential substitute for mineral diesel. Diesel engines due to the better fuel economy have been widely used in automotive field. However, the limited reserve of fossil fuel and deteriorating environment have made scientists seek to alternative fuels for diesel while keeping the high efficiency of diesel engine. Biodiesel is produced from fatty acids triglycerides and can be used in diesel engines without serious problems. Some other types of vegetable oils, such as sunflower oil, corn oil and olive oil, that are abundant in many areas, along with some wastes, such as used frying oils and animal fats, appear to be attractive for biodiesel production. The properties of biodiesel are something like same as the diesel fuel and it can be in a straight line used as alternative fuel for diesel engine destitute of any important engine modification. But have a few disadvantage like higher, viscosity, cloud point, density, and lower heating value and volatility compare to diesel and thus a non-edible ethanol is used.

The properties of biodiesel are something like same as the diesel fuel and it can be in a straight line used as alternative fuel for diesel engine destitute of any important engine modification. But have a few disadvantages like higher, viscosity, cloud point, density, and lower heating value and volatility compare to diesel [1]. [2]Improving the viscosity of vegetable oil by blending, pyrolysis and emulsification does not solve the problem completely. Research has shown that one way to improve the fuel properties of oils and fats is their transesterification. [3] studied the combustion, performance and emission characteristics of ethanol (biodiesel) and its blends in dieselengine, from their experiments, they found that **E20** gives more brake thermal efficiency at full load condition, compared with the other blends.[4] Studied the basic fuel properties like calorific value, density of Ethanol and its blends and compared these properties with those of pure diesel fuel. [5] Studied the performance and emission characteristics of single cylinder diesel engine fueled with ethanol with the manipulate of fuel injection pressure. Biodiesel formed from ethanol by transesterification process is used as fuel in diesel engine. The tests were conducted at full load at dissimilar injection pressures (180-230 bars). The fuels E10, E20,dieselwere used for the test. The engine performance and emission test results were balance with pure diesel. From the test results it was found that 3 hole fuel injector with E20 as a fuel causes superior performance and enhanced emissions characteristics for all fuels.

In general-purpose, there are some modifications in injection design and intake conditions to reduce emissions in diesel engine. The factors like number of holes, holediameter, fuel blend are investigated on a Direct Injection diesel engine. In our experimental work we varied different no of nozzle hole in the fuel injector for ethanol blends and diesel in diesel engine; thus, the different combination causes significant changes in performance and exhaust emissions.

1.1 Renewable Energy Technology

When Automobiles were first invented in the 1880's there were a variety of fuel sources. Some were steam powered, some fuel powered, etc. But they soon became powered mostly by petroleum based fuels. And these days, some sort of fossil fuel powers nearly 100% of our vehicles. This in addition to the use of petroleum products in industry and manufacturing has resulted in an incredible thirst for Petroleum based products. However, these fuels are limited and depleting day by day as the consumption is increasing very rapidly. Moreover, their use is alarming the environmental problems to society. Hence, the scientists are looking for alternative fuels. Earlier it's simply been cheaper to use petroleum-based fuels to power automobiles. But as the time has changed, fuel prices continue to rise over the years. In 2008 we've seen fuel price well over 130$ per barrel and we'll see prices over 150$ per barrel soon after 2015. Among all Petroleum based fuel, diesel oil is used in a diesel engine that dominates the field of commercial transportation and agricultural machinery due to its ease of operation and higher efficiency. The consumption of diesel oil is several times higher than that of petrol. Due to the shortage of petroleum-based fuel and its increasing cost, effort are on to develop alternative fuels especially, to the diesel oil fully or partially replacement. [3] The important approaches that are at various stages of their development, adaptation and implementation towards diesel substitution in automobile sector are related to the use of Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG), CNG in Combination with Hydrogen (CNG+H2), Dimethyl Ether (DME), Diethyl Ether (DEE), and Anhydrous Alcohol as well as industrial alcohol in combination with chemical additives Recently, the biodiesel based on non-edible oil stocks has been emerging as a technically feasible, economically competitive, environmentally sustainable and socially beneficial substitute automotive fuel for diesel.

1.2 Reasons to Look for Alternative Fuel

Alternative fuels for automobiles are currently a topic of growing interest and importance. On the basis of October 2013 data, there are approximately 34 million flexible fuel vehicles and the sale of hybrid electric vehicles numbered more than 9 million (September 2014 data). Other figures in terms of number of vehicles produced include 17.8 million natural gas vehicles (December 2012) and 17.5 million LPG powered vehicles (December 2010).

An alternative fuel vehicle may be defined as a vehicle that is powered by any fuel other than the conventional petroleum fuels (diesel or petrol). It also indicates any technology of engine powering that does not entail solely petroleum (such as solar powered, electric car or hybrid electric vehicles). Such a vehicle is therefore "cleaner" and safer for the environment.

A green vehicle (also known as an environmentally friendly vehicle) is a motor vehicle for the road that produces less environmental impacts than comparable traditional internal combustion engine vehicles that are powered by diesel or gasoline, or one that utilizes specific alternative fuels.

One day, our sources for traditional fuels including petroleum would be depleted. Owing to the fact that these fuels are typically not renewable, a lot of people are worried that a day would come when the demand for these fuels would be more than the supply, triggering a considerable world crisis. Non-environmentalists also concur with the opinion that the majority of oil fields (situated in the Middle East) in the world are associated with problems – both political and economic. Determining a new method or solution with respect to finding different countries to create new fuels would reduce the unrest and conflict resulting from the world's dependence on fuel supply from the Middle East. The use of alternative fuels considerably decreases harmful exhaust emissions (such as carbon dioxide, carbon monoxide, particulate matter and sulfur dioxide) as well as ozone-producing emissions. According to a commonly accepted scientific theory, burning fossil fuels was causing temperatures to rise in the earth's atmosphere (global warming). Though global warming continues to be just a theory, a lot of people across the globe are of the belief that discovering sources of cleaner burning fuel is an essential step towards enhancing the quality of our environment. Alternative fuels can be less expensive to use not just in terms of the fuel itself but also in terms of a longer service life. This in turn means savings for the long term. Biofuels, bio products, and bio power provide modern and fresh relevance to the old belief that trash for one person is a treasure for another. That's good news considering that Americans produce in excess of 236 million tons of waste each year.

Biodiesel and ethanol cooperatives are a result of the great outmoded farmer cooperatives that assist with returning power to the hands of the people. Often, alternative fuels can be developed domestically, utilizing a country's resources and thereby strengthening the economy. Vehicles driven on hydrogen fuel cells and diesel are more economical with respect to fuel compared to an equivalent gasoline vehicle.

Wireless charging is one of the factors that make alternative fuels more convenient. Automaker Nissan already displayed the technology in concert along with a parking assist system which mechanically guides the vehicle to its "docking station" or parking spot. The driver just presses a button or utters a command, releases control over the wheel, and the vehicle takes care of the rest. Once the vehicle is parked, the driver just turns the car off, closes the door, and carries on with his business. No need to go the gas station and no plugs. All that's required is low-cost electricity and adequate gas in the tank whenever you have to travel in your car.

More and more onboard sensors now provide cars with the ability to tackle the most challenging driving tasks such as modifying cruise speeds to suit traffic situations in real time, emergency stops, and parking. In combination with Advanced Driver Assistance Systems and Advanced GPS navigation, we can soon expect a day to come when driving would be absolutely "hands free."

The development of the 'connected car,' characterized by seamless communication of the automobile with sensor onboard systems of its own, in addition to road and signal infrastructure, so as to decrease time expended in traffic, prevent accidents, and connect occupants to the web by way of mobile and on-board devices – is triggering increased electrification for vehicle architectures.

Ethanol and biodiesel are the two major biofuels created from bioenergy. Ethanol can be developed from sugar cane in Brazil or other tropical countries and from crops such as soya bean and corn in the United States and other places where the climate is temperate. Biodiesel is mostly developed from vegetable oils and may be utilized in any diesel automobile devoid of modification.Gasoline comprising 10 percent of ethanol can be utilized in the majority of modern autos bereft of modification. Higher mixes of ethanol (20 percent and 85 percent) may be utilized in modern FFV (Flexi Fuel Vehicles) available from the majority of automobile companies. Compressed biogas can be utilized for Internal Combustion Engines after the raw gas has been purified. The taking away of H2S, H20 and particles may be considered as standard creating a gas with the same features as Compressed Natural Gas. The utilization of biogas is specifically interesting for climates where a biogas powered power plant's waste heat could be utilized in the course of the summer.

1.3 Ethanol as a Potential Biodiesel

Ethanol is used extensively as a solvent in the manufacture of varnishes and perfumes; as a preservative for biological specimens; in the preparation of essences and flavorings; in many medicines and drugs; as a disinfectant and in tinctures (e.g., tincture of iodine); and as a **fuel** and gasoline additive. Ethanol as a fuel reduces harmful tailpipe emission of carbon monoxide, particulate matter, oxides of nitrogen, and other ozone-forming pollutants.

The largest single use of ethanol is as an engine fuel and fuel additive. Brazil in particular relies heavily upon the use of ethanol as an engine fuel, due in part to its role as one of the globe's leading producers of ethanol. gasoline sold in Brazil contains at least 25% anhydrous eth**a**nol. Hydrous ethanol (about 95% ethanol and 5% water) can be used as fuel in more than 90% of new gasoline fueled cars sold in the country.

II. PROCEDURE OF BIODIESEL

2.1. Properties of Biodiesel

A series of tests were conducted to characterize the properties and compositions of the biodiesel. The properties of biodiesel and its blends with diesel fuel are shown in Table 1. The density of the biodiesel is approximately 8% higher than that of diesel fuel. Therefore, it is necessary to increase the fuel amount to be injected into the combustion chamber to produce the same amount of power.

Biodiesel has promising lubricating properties and cetane ratings compared to low sulfur diesel fuels. Fuels with higher lubricity may increase the usable life of high-pressure fuel injection equipment that relies on the fuel for its lubrication. Depending on the engine, this might include high pressure injection pumps, pump injectors (also called unit injectors) and fuel injectors. Additionally, the selection of the processing parameters, especially solvent and catalyst types, is mainly influenced by the types of raw materials because different raw materials consist of different types of components such as free fatty acids (FFAs), contaminants, etc. This can be observed from a study reported by Halim and Kamaruddin [19], who compared the biodiesel production using palm oil and waste cooking oil. They stated that the production yield from waste cooking oil was lower than palm oil due to the high amount of water content which resulted in substrate hydrolysis and hence reduced the yield. Thus, apart from the cost and availability of raw material, many other factors related to the raw material selection need to be considered to ensure a high yield and quality of biodiesel.

Table 1.Properties of biodiesel comparison with diesel

Properties	**Ethanol**	**Pure diesel**
Density at150c (gm/cc)	0.8944	0.82
Calorific value (KJ/kg)	29000	42500

2.1.1. Fuel efficiency

The American Society for Testing and Materials has set standards in order to judge the quality of a given fuel sample. Engines operating on E20 have similar fuel consumption, horsepower, and torque to engines running on diesel. E20 with 20% biodiesel content will have 1% to 2% less energy per gallon than diesel, but many E20 users report no noticeable difference in performance or fuel economy. Biodiesel also has some emissions benefits, especially for engines manufactured before 2010. For engines equipped with selective catalytic reduction (SCR) systems, the air quality benefits are the same whether running on biodiesel or petroleum diesel. However, biodiesel still offers greater greenhouse gas benefits than conventional diesel fuel. The emissions benefit is roughly commensurate with the blend level; that is, E20 would have 20% of the emissions reduction benefit of E100.

When using high-level blends, several factors should be considered. Pure biodiesel contains less energy on a volumetric basis than petroleum diesel. Therefore, the higher the percentage of biodiesel (above 20%), the lower the energy content per gallon. High-level biodiesel blends can also impact engine warranties, gel in cold temperatures, and may present unique storage issues.

III. EXPERIMENTAL SETUP

3.1.1 Procedure

The Experiment has been carried out in a 4.4 KW, Single cylinder Diesel engine using Diesel, E10,E20 along with three different fuel injectors varying the no of holes and their corresponding blends under varying loads. The fuel spot is thoroughly cleaned before every single fuel change and the engine is allowed to run for at least 30 minutes to procure steady-state condition. The AVL combustion analyzer is employed to enumerate the rate of heat release from the considered values of pressure and crank angle. A five gas analyzer is employed to analyze NOx, CO2, CO and the unburned hydrocarbons (UBHC). Fuel consumption of the system is determined using a Burette and a chrommelalumel thermocouple is employed in association with a digital temperature pointer to evaluate the exhaust gas temperature. Figure1 shows the schematic view of the experimental setup.Figure2 is the actual view of our diesel engine in which our experiment takes place.

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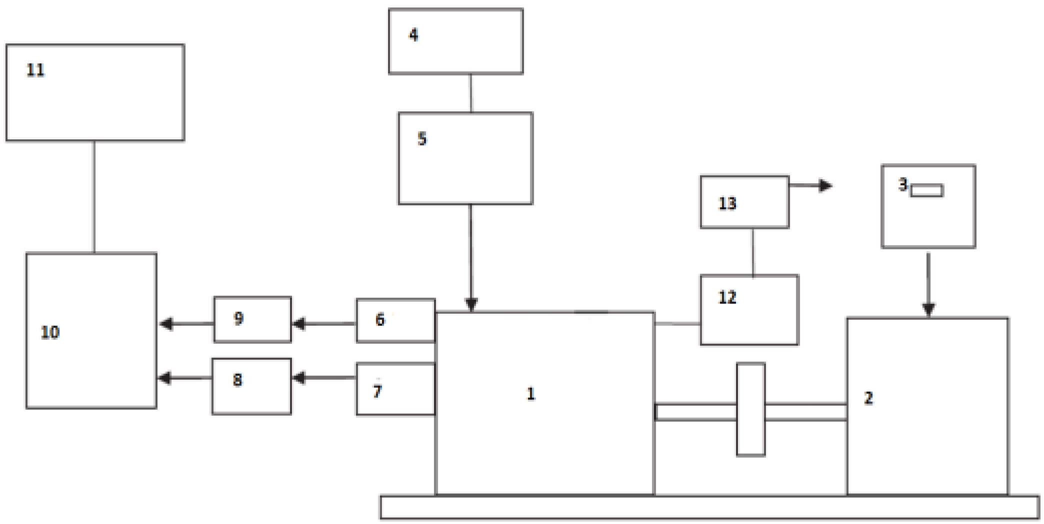

(1)Diesel engine, (2) Electrical dynamometer, (3) Dynamometer control panel, (4) Fuel tank, (5) Fuel measurement, (6) Pressure transducer, (7) TDC Position sensor, (8) Charge amplifier, (9) TDC amplifier circuit, (10) Analog to digital card, (11) Personal computer, (12) Exhaust gas analyzer, (13) AVL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

Fig 1.Experimental setup – Schematic view.

3.1.2 Test methodology

First the maximum torque of the engine is calculated and the engine is started under no load condition by hand cranking using de-compression lever. The engine is run under no load condition for a few minutes so that the speed stabilizes at rated value. The engine is run under constant speed and fuel consumption time indicator is arranged with 10cc of fuel quantity. Using eddy current dynamometer the experiment conducted for variable loads. The engine test were performed using bio diesel and the results were recorded. The above procedure is repeated at the same operating conditions for all the blends. Here Diesel, E10 and E20 blends are usedin this experiment. The different parameters required for evaluation of fuel was noted.

Table 2.Parameters for Fuel Evaluation with Ethanol Blend

NUMBER/FACTORS	1	2	3
FUEL BLEND	Diesel	E10	E20
NO OF HOLES	3	4	5
LOAD (%)	50 %	75 %	100 %

IV. RESULT AND DISCUSSION

In this Experimental work the performance, emission and combustion characteristics of diesel engine using three different fuel injectors (3,4,5holes) for diesel and ethanol blends (E10 and E20) were studied.

4.1 Brake Thermal Efficiency

Brake Thermal Efficiency is defined as break power of a heat engine as a function of the thermal input from the fuel. It is used to evaluate how well an engine converts the heat from a fuel to mechanical energy. The variation of brake thermal efficiency with different fuel injectors for diesel and biodiesel fuels are taken into consideration to obtain values using the formula given below.

$$ŋbt= \frac{B.P}{TFC\ X\ C.V}$$

The Relationship between Brake Thermal Efficiency and Brake power using different fuel injectors for diesel, Biodiesel and their

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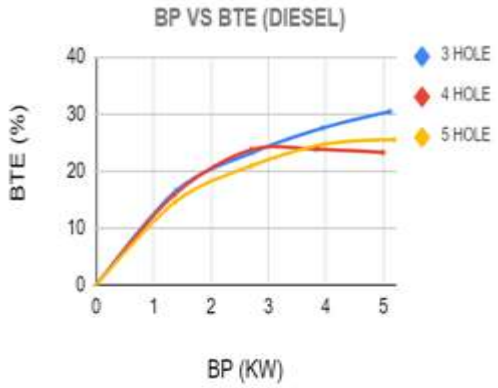
corresponding blends are shown in Fig (5), (6) and (7). The Brake Thermal Efficiency improves with an increasein the engine load Brake thermal efficiency (BTE) measures the effectiveness of chemical energy conversion into beneficial work in an engine.Hence it was evaluated that nozzle holes number has substantial impact on spray penetration and droplet size.From the graphs it was observed that for 3hole nozzle the BTE amplified slightly as a outcome of improved vaporization and atomization for diesel and Ethanol.



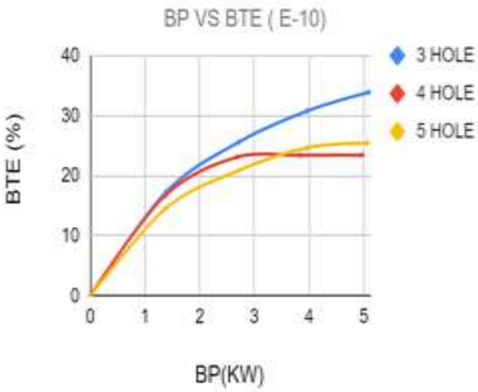


Fig 2. Brake power vs Brake thermal efficiency for Diesel

Fig 3. Brake power vs Brake thermal efficiency for E10

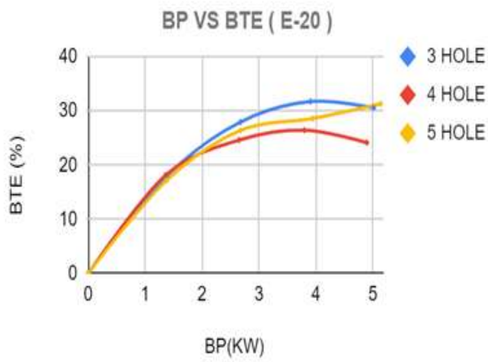


Fig 4. Brake power vs Brake thermal efficiency for E20

4.2 Specific Fuel Consumption

The variation of Brake specific fuel consumption with brake power for different injection timings for diesel and biodiesel fuels are taken into consideration to obtain values using the formula given below.

$$BSFC=\frac{TFC}{Brake\ Power}$$

The variation of SFC with brake power for diesel and biodiesel blends was shown in Fig. (8), (9) and (10). It is observed that the SFC increases with the increase in proportion of biodiesel in the diesel. This may be endorsed to the lower heating standards of biodiesel and higher viscosity which cause offensive mixing of air and fuel. By advancing injectionthere is a stepwise rise in maximum pressure and better specific fuel consumption, thus increasing the premixed heat release, which results in significant portion of heat being released during the compression stroke.

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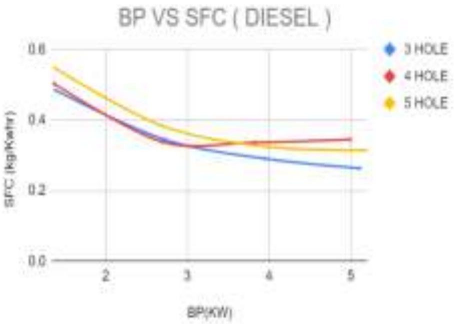


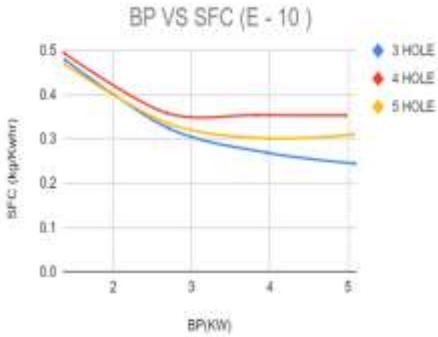


Fig 5. Brake power vs Specific fuel consumption for DieselFig 6.Brake power vs Specific fuel consumption for E10

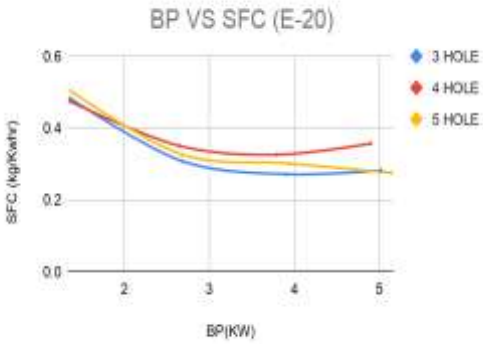
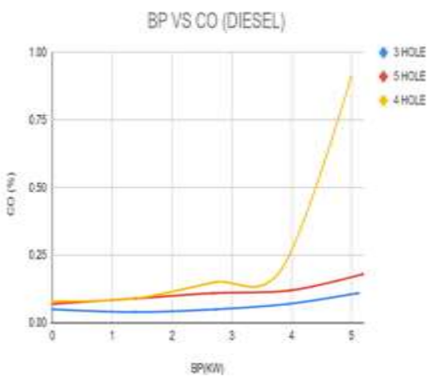


Fig 7. Brake power vs Specific fuel consumption for RB100

4.3 Carbon Monoxide Emission

Carbon monoxide (CO) is a colorless, odourless, and tasteless flammable gas that is slightly less dense than air. Carbon monoxide consists of one carbon atom and one oxygen atom, connected by a triple bond that consists of a net two pi bonds and one sigma bond. Carbon monoxide results from the incomplete combustion where the oxidation process does not occur completely. This concentration is largely dependent on air/fuel mixture and it is highest where the excess-air factor (λ) is less than 1.0 that is classified as rich mixture.

The Relationship between Carbon Monoxide and Brake power under different fuel Injectors for diesel, Biodiesel and their corresponding blends are shown in Fig (11), (12) and (13). Variation of carbon monoxide with brake power using different injectors for diesel and ethanol blends areshown below.



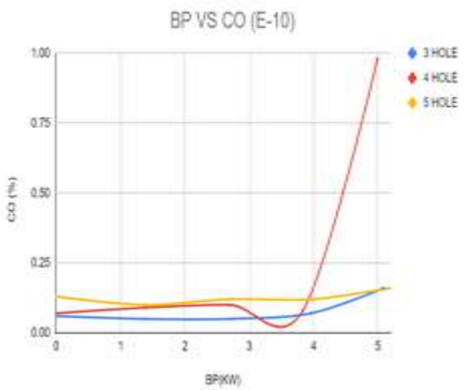


Fig 8. Brake power vs Carbon monoxide for DieselFig 9. Brake power vs Carbon monoxide for E10

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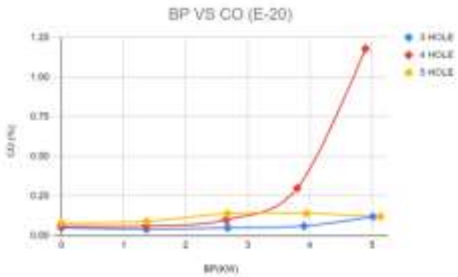


Fig 10. Brake power vs Carbon monoxide for E20

4.4 Hydrocarbon Emission

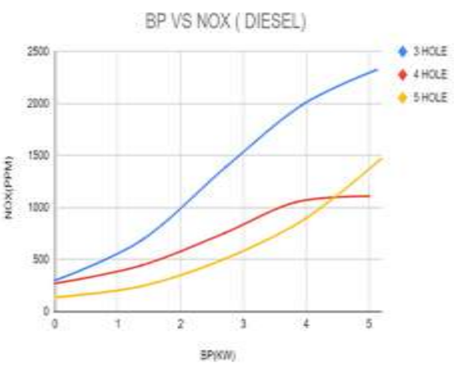
The effects of injection on diesel engine HC emissions operated with diesel and biodiesel blends are noted. HC emission in diesel engines origins due to lean mixture through delay period and under mixing of fuel after that out from injector nozzle at lesser velocity.Hydrocarbon emissions are composed of unburned fuels as a result of insufficient temperature which occurs near the cylinder wall. At this point, the air–fuel mixture temperature is significantly less than the center of the cylinder.

It Shows that there isa effect of injection nozzle diameter on diesel engine HC emissions operated with diesel and biodiesel blends. HC emission in diesel engines origins due to lean mixture through delay period and under mixing of fuel after that out from injector nozzle at lesser velocity.

4.5NOx Emission

NOx emission increases with elevated engine temperature. Diesel engines use highly compressed hot air to ignite the fuel. Air, mainly composed of oxygen and nitrogen, is initially drawn into the combustion chamber. Then, it is compressed, and the fuel is injected directly into this compressed air at about the top of the compression stroke in the combustion chamber. The fuel is burned, and the heat is released. Normally in this process, the nitrogen in the air does not react with oxygen in the combustion chamber and it is emitted identically out of the engine.

Variation of NOx emission with brake power for Diesel and biodiesel blends is shown in Fig. (17), (18) and (19). NOx emission increases with elevated engine temperature. As the brake power increases the emission of oxides of nitrogen also increases.There is a variety of NOX in the BP with 3 holes in each one of the different nozzle orifice NHD with diesel fuel. The development of NOX mainly depends on various factors, such as fuel quality, the oxygen level in fuel, high cetane number, increasing the fuel injection pressure and atomisation of fuel.The NOX emissions increased by the use of 0.20 mm NHD this results due to the exhaust gas temperature increases. By reducing the smaller orifice NHD, it enhances the high temperature combustion chamber and results in good spray. By increasing the NHD, nitrogen oxide is reduced due to a lower temperature in a combustion chamber; fuel atomisation is poor and there is no complete evaporation.



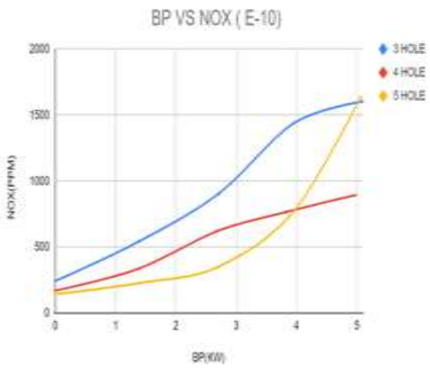


Fig 11. Brake power vs Nitrogen oxide for DieselFig 12. Brake power vs Nitrogen oxide for E10

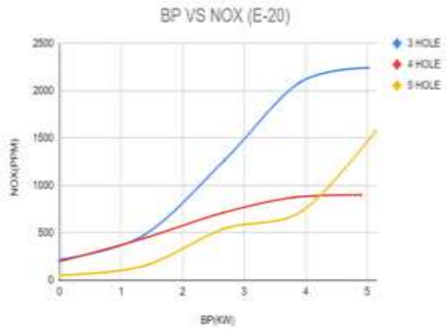


Fig 13. Brake power vs Nitrogen oxide for E20

V. CONCLUSION

In the present work, performance, emission and combustion characteristics of diesel and ethanol blends in DI diesel engine have been studied. The lower CO emissions of E20 may be due to their increased oxidation and combustion as compared to diesel.By retarding injection specific fuel consumption, HC and CO emission values decreased and NOx emission, and Brake thermal efficiency values increased for E20 compared with E10 and diesel fuel.

The experiments conducted with diesel and the same is compared with that of E20 and E10. From the table the combination which has the maximum MRSN ratio will be taken as the best combination among the nine in achieving the objective. It can be seen that the MRSN313 has the highest value among the nine for diesel, E20 and E10 respectively.

Finally, a theoretical study regarding combustion characteristics of Biodiesel in a diesel engine is explained.

REFERENCES

[1]. Agarwal.D and Agarwal.A.K. Performance and emission characteristics of a Jatropha oil (preheated and blends) in a direct injection compression ignition engine. International Journal Applied Thermal Engineering, 27 2314-2323 (2007).

[2]. Agarwala, Atul Dhara, Jai Gopal Guptaa, Woong Il Kimb, KibongChoib, Chang SikLeeb, Sungwook Park 2014, Effect of Fuel Injection Pressure and Injection Timing of Karanja Biodiesel Blends on Fuel Spray, Engine Performance, Emissions and Combustion Characteristics, Fuel,111, 374–383 (2004).

[3]. Arya pirooz, Effect of injector nozzle geometry on spray characteristics which is an analysis procedure, University of Birmingham, Amirkabir University of technology, Indian J.Sci.Res. 5 (1): 354-361, 2014.

[4]. Avinash Kumar Agarwal, The Brake specific fuel consumption for biodiesel and its blends was higher than mineral diesel but brake thermal efficiency of all the biodiesel blends was lower than mineral diesel,(2014).

[5]. Parthiban.R ,The main purpose of this research was to discuss about the optimization of spray characteristics of biodiesel fuel in a spray chamber,et al J. Chem. Pharm. Res., 2016.

[6]. Prasanna Raj Yadav, Saravanan.C.G, Kannan.M,Influence of injection timing on DI diesel engine characteristics Alexandria Engineering Journal,54, 881–888 (2015).

[7]. Raghu.P, Sundarrajan.S ,Rajaraman.R,Ramaswamy.M and Sathyanaryanan.S, Heat transfer investigation on a single cylinder diesel Engine using diesel and biodiesel, International journal of Mechanical and Production Engineering research and development ,8,72-76 (2018).

[8]. Shubham Gupta and Sumitkumar, Experimental Investigation of Bio-Diesel with Corn Oil, International Journal of Mechanical and Production Engineering, vol.3(2) (2015).