Effect Injection operating pressure on Hydrogen enriched Karanja Oil Methyl Ester (KOME) blend B20 in a dual fuel DI diesel engine

Kursam Krishna[1], Bellam Sudheer Prem Kumar [2], K.Vijaya Kumar Reddy [3], Ravi Kumar Kotturi [4]

[1&4] Research Scholar in Department of Mechanical Engineering, JNT University, Hyderabad, India
[2& 3] Professor in Department of Mechanical Engineering, JNT University, Hyderabad, India

***Abstract*— *Anxiety of greenhouse gases and exigency of conventional fuels is an attractive exploration reneged to the researchers view, turn towards alternative fuels. The present work is to demonstrate on performance, combustion and emission characteristics of 20% Karanja Methyl Ester (KOME) blend (B20) and hydrogen with 5, 10, and 15 lpm (liters per Minute) of low flow rate on a dual fuel mode direct injection diesel engine operated at 1500 rpm with rated power output of 3.5 kW. The experimental test were conducted at three various injection operating pressure of 200, 220, and 240bar. The obtained data of above test were compared with base line pressure of diesel at 200 bars. Higher brake thermal efficiency, less brake specific fuel consumption, lower HC, and CO emissions with raised concentration of NOx were obtained at IOP of 240 bars for B20- hydrogen dual fuel mode. The current analysis discovered that the IOP of 240 bars for 15 lpm hydrogen flow rate with B20 dual fuel approach was optimum.*

Keywords*— *Dual Fuel Engine; Karanja Bio diesel; Hydrogen; Emissions.

I. INTRODUCTION

Petroleum based fuels are the major sources of energy on this planet. Combustion of Petroleum based fuels has creates serious trouble to the environment and the geopolitical atmosphere of the world. The focal draw backs on environment by petroleum based fuel combustion are exhaust pollutants of CO, CO2, Unburned Hydrocarbons, and Oxides of Nitrogen. With all these effects collectively generated an interest to fetch for the clean alternative renewable energy source.

Biodiesel is a significant alternative fuel for mineral diesel, which can be used directly in existing diesel engines with little or without any modification. Among the all non-edible oils Karanja oil is a vital biodiesel feedstock in context of renewable, because these trees can grow even in dry areas with poor, marginal, sandy and rocky soils.V.K. Shahir, C.P.Jawahar, and P.R.Suresh [1] evaluated comparative study of diesel and biodiesel with particularly on emissions. Biodiesel can be used in existing Internal Combustion Engines with or without any change and compared to conventional diesel fuel a great reduction in Matter of particulate, Hydrocarbons (HC) and carbon monoxide (CO) emissions. These effects caused by a small amount of power lose, rise in fuel consumption and augment in nitrogen oxide (NOx) emission. Avinash Kumar Agarwal and K Rajamanohan [2] conducted an experiment on Karanja oil moreover its blends and accomplished that Karanja oil blends with diesel up to 50% (v/v) with preheating and without preheating would replace diesel for running the CI engine for less emissions and increased performance. R. Sierens, and S. Verhelst [3] are done experiment on hydrogen fuel engine and find that an external mixture formation system for natural gas, hydrogen, and hythane were increases the power output of the engine without any danger of back fire. Carl Wilhelmsson, Per Tunestal and Bengt Johansson [4] of Operation strategy of a Dual Fuel port injected heavy duty HCCI Engine with the analysis of variable geometry turbo charger and observed decreased NOx emissions. Jacob Wall [5] carried out an experiment on Enriched Hydrocarbon Combustion and evaluated that the addition of hydrogen has been shown to decrease the formation of NOx, CO and unburned hydrocarbons and also thermal efficiency increased and specific fuel consumption decreased with addition of hydrogen at low as of 5-10 % percent. Radu Chiriac and Nicolae Apostolescu [6] investigations were conducted on Rapeseed biodiesel blend B20, B20 with hydrogen addition at 1400 rpm and 2400 rpm of dual fuel engine at 60% load. In this study without hydrogen B20 has significantly more NOx emissions at all speeds and less smoke and CO emissions, while combustion of both fuels nearly equal and with hydrogen enriched to B20 at 60% load find that higher NOx emission and to lower smoke and CO emissions. Ahmed Syed, Syed Azam Pasha Quadri, G Amba Prasad Rao, and Mohd Wajid [7] were investigated on Mahau oil methyl ester and resulted with increased brake thermal efficiency, reduced fuel consumption, and lesser HC, CO and smoke emissions with increased concentration of NOx were obtained at 250 bar injection pressure for B20-hydrogen dual fuel mode. The different test fuel properties are shown in Table I.

The present investigation was carried out on KOME B20 as pilot fuel and hydrogen as supplementary fuel induced at inlet manifold on dual fuel diesel engine and the performance, combustion, and emission parameter were evaluated at various injections operating pressure. Hydrogen induction theory behind the concept was that can extend the operation of lean limit, improve ability to burn capacity, and minimizes duration of burning time.

Table. I: Properties of Test Fuel

Properties	**Diesel**	**Hydrogen**	**B20**	**Karanja**
Density(Kg/m³)	850	0.08	831	885
Calorific Value(kj/Kg)	44500	119930	42770	40750
Viscosity(gm/cc)	2.76	…	3.88	5.12
Flash Point(°C)	76	…	81	161
Pour Point(°C)	3.1	…	3.1	5.1
Cetane value	47	…	53	56.65
Acid Value (mg KOH/g)	…	…	…	1.13
Sp.gravity	0.835	0.091	0.844	0.937

II. EXPERIMENTAL SETUP AND METHODOLOGY

The experimental analysis carried out on fully computer based, single cylinder, 4 stroke, water cooled, Dual fuel DI diesel engine coupled with Eddy current dynamometer shown in Fig.1, specifications in Table.:II, and instrumentation data Table 3 all the tests were conducted at 100 % load with at a speed of 1500 ramp. The piezoelectric sensor was used to know the cylinder inside pressure of the engine. The position of the crank shaft was measure with the help of a digital shaft encoder. The experimental data developed by using National Instrument Lab VIEW acquisition system. The combustion analysis carried out on the averaged value of 100 cycles after the engine reached steady state operation. In the view of safety measures a special in-house intake manifold designed to connect flame arrestor, which prevents the back fire, pre-ignition, pressure rise, and knock. The cylinder of hydrogen keeps certain distance from the engine to avoid heat transfer from the engine and periodic monitoring on hydrogen supply line if any leakages. Finally the parameters of performance, combustion and emission characteristics are noted for analysis. The five gas analyzer MARS MN-5 was used to record exhaust emissions of engine. The methodology adopted in the experimental work as follow:

- **Initial stage**: The test was conducted with diesel fuel in a single fuel mode of operating at constant speed with 100% load to obtained base line result.
- **Second stage**: The test was performed with B20 fuel with same mode, load, and speed of above and compared base line result.
- **Third stage:** The test was accomplished at dual fuel method with B20 and low concentrations of hydrogen (5, 10, and 15 lpm) supplement to intake air, the results were evaluated all at 100% load conditions for three injection operating pressures of 200, 220, and 240 bar.

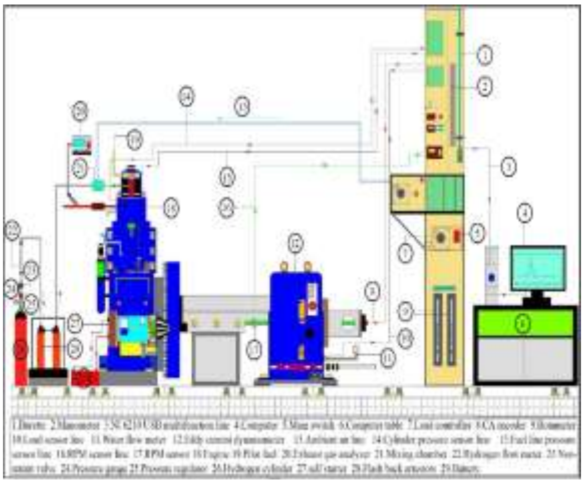

Fig.1:Test Engine Line Diagram

Table.I: Engine Specifications

Make	**Kirloskar AV-1**
Rated power	3.7 kW, 1500 rpm
Bore and stroke	80 mm x 110 mm
Compression ratio	17:1
Cylinder capacity	553 cc
Dynamometer	Eddy current dynamometer
Orifice diameter	20 mm
Fuel	Diesel and hydrogen

Calorimeter	Exhaust gas calorimeter
Cooling	Water cooled engine
Starting	Hand cranking and auto start

III. RESULTS AND DISCUSSION

In this experiment effects of various(200 , 220, and 240 bar) injection operating pressure (IOP) analyzed with B20, and B20 with various low percentages of hydrogen (5, 10, and 15 lpm) at constant speed of dual fuel mode engine on engine performance, combustion, and emissions are evaluated at full load.

A. Energy Share

The energy share of Dual fuel injection strategy employed in this experiment for breakthrough the better premixed lean combustion. The energy share of a fuel generally obtains on fuel consumption, heating value of fuel, and rate of combustion. From the fig.2 shows the variation of B20 energy share with hydrogen flow rate (5, 10, and 15 lpm) at different injection operating pressure. In this analysis acknowledged that the energy release rate of B20 was high from 200 to 240 bar of IOP quantified at full load in all operating conditions. Simultaneously from figure 3 shows hydrogen flow rates decreases with increasing pressure. The high pressure fuel injection causes better mixing of pilot fuel and supplement fuel which makes complete combustion of B20 mixture. The energy share percentage of B20 as defined the ratio of energy of pilot fuel to sum of pilot and supplement fuel in equation (1), and the equation (2) used to calculate the percentage of hydrogen share.

Energy of B20=Mass of B20 x Lower heating value of B20

Energy of Hydrogen=Mass of hydrogen x Lower heating value of hydrogen

$$\%\ \text{B20 Energy share} = \frac{Energy\ of\ B20\ X 100}{(\text{Energy of B20} + \text{Energy of Hydrogen})} \quad (1)$$

$$\%\ \text{Hydrogen Energy share} = \frac{Energy\ of\ Hydrogen\ X\ 100}{(\text{Energy of B20} + \text{Energy of Hydrogen})} \quad (2)$$

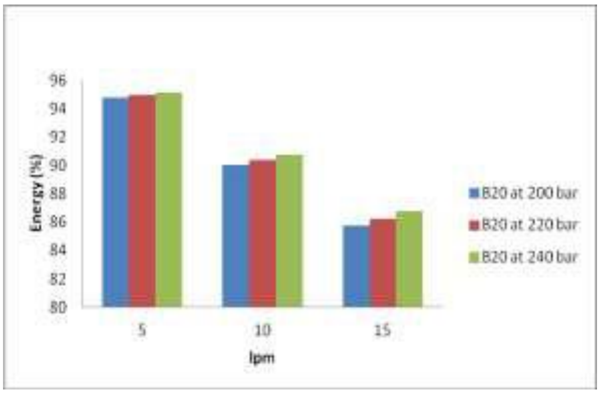

Fig.2: B20 energy share (%) with Hydrogen flow rate (lpm) at different injection operating pressure

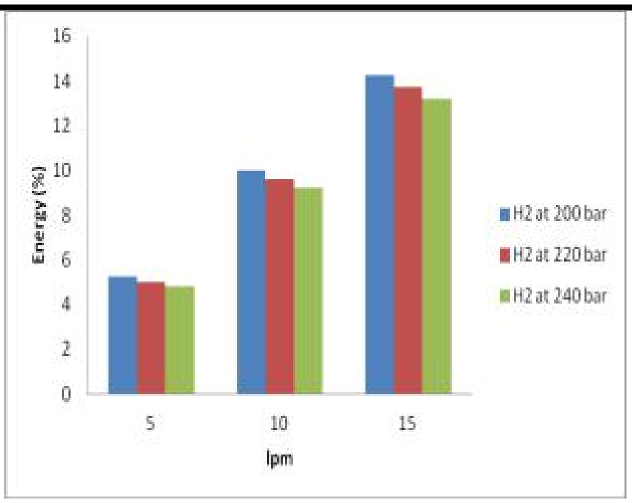

Fig.3: Hydrogen energy share (%) with Hydrogen flow rate (lpm) at different injection operating pressure

B. PERFROMANCE CHARACTERISTICS

Thermal efficiency of Karanja biodiesel blends was more than pure diesel at all engine operating conditions. Increasing IOP was more efficient in increasing BTE of pure diesel in comparison to Karanja biodiesel blends, which hints that higher injection pressure was more successful in improving the spray characteristics of fuels with lower viscosity, which is pure diesel in this case [8, 9] Fig. 4 indicates the variation of brake thermal efficiency of the engine with injection operating pressures with respective of pure diesel, B20 and B20 with 5, 10, and 15 lpm of hydrogen.

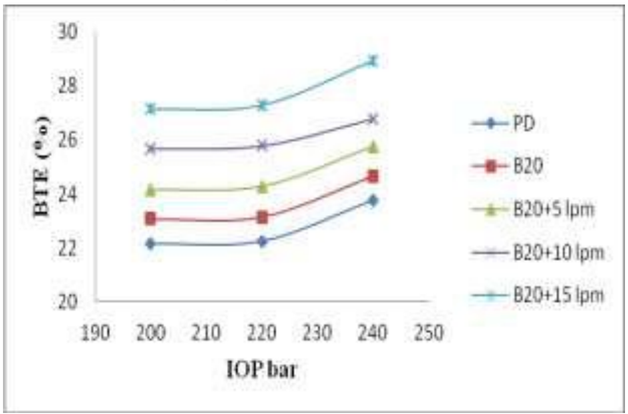

Fig.4: Variation Brake Thermal Efficiency with IOP with 100% load

Brake thermal efficiency at IOP of 200, 220, and 240 bar for pure diesel, B20, B20+5 lpm, B20+10 lpm, and B20+15 lpm were 22.15-22.25-23.75 % , 23.06-23.19-24.64 %, 24.16-27.29-25.76 %, 25.69-25.79-26.78 %, and 27.14-27.34-28.94 % obtained at 100 % load. Brake thermal efficiency of test engine increases with increasing IOP from 200 to 240 bar, the theory behind this increase was like that quick vaporization of atomization causes significant improvement in air fuel-mixture which resulted near complete combustion.

Brake specific fuel consumption was directly proportional to the engine size as engine volume goes down so does BSFC, which determined as the ratio of fuel flow to brake power. Fig. 5 illustrated the variation of brake specific fuel consumption with IOP from IOP for the test fuel of pure diesel, B20 and B20 with 5, 10, and 15 lpm of hydrogen. BSFC at 200, 220, and 240bar IOP for pure diesel, B20, B20+5 lpm, B20+10 lpm, and B20+15 lpm were 0.40-0.39-0.37 %, 0.38-0.37-0.35%, 0.36-0.35-0.33%, 0.35-0.33-0.31 %, 0.32-0.31-0.28% at 100% load. The availability of oxygen content in the Karanja methyl ester [10] BSFC reduces was lower as compared to that of diesel fuel due to finer atomization of pilot fuel droplets and improved mixing of air-fuel [11] compared to the bigger size droplets formed at low injection pressure that unhurriedly vaporize.

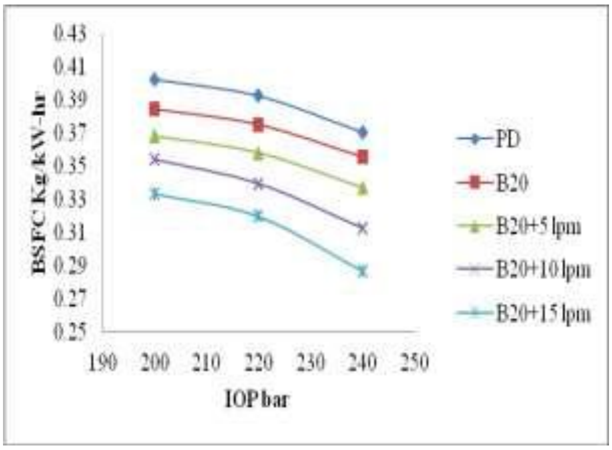

Fig.5: Variation of Brake Specific Fuel Consumption With different Injection Operating Pressure at 100% load

C. COMBUSTION CHARACTERISTICS

Figure 6, 7, and 8 shows the variation of cylinder pressure with crank angle at different injection operating pressure with the fuel of Pure diesel, B20, and B20 with various hydrogen (5, 10, and 15 lpm) flow rates.

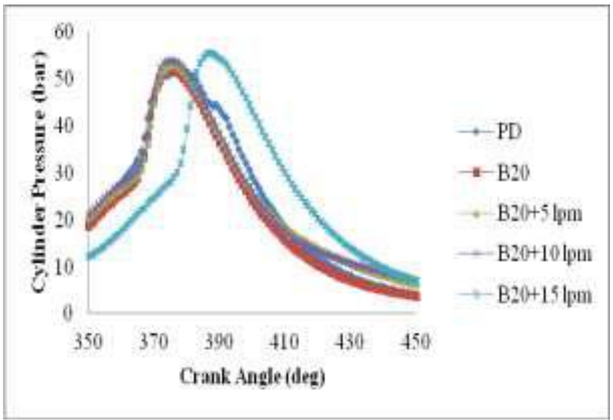

Fig.6: Variation of cylinder pressure with crank angle at 200 bar IOP

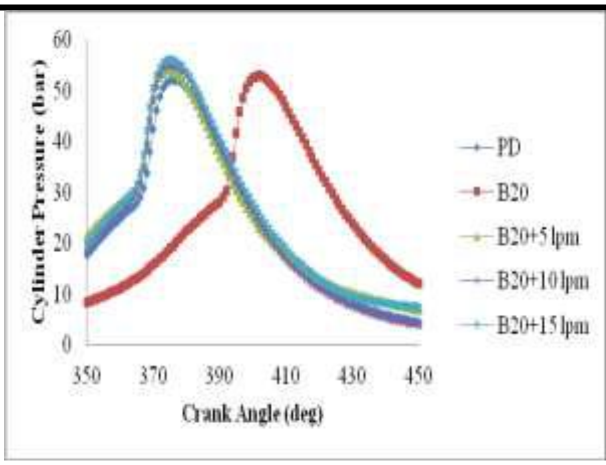

Fig.7: Variation of cylinder pressure with crank angle at 220 bar IOP

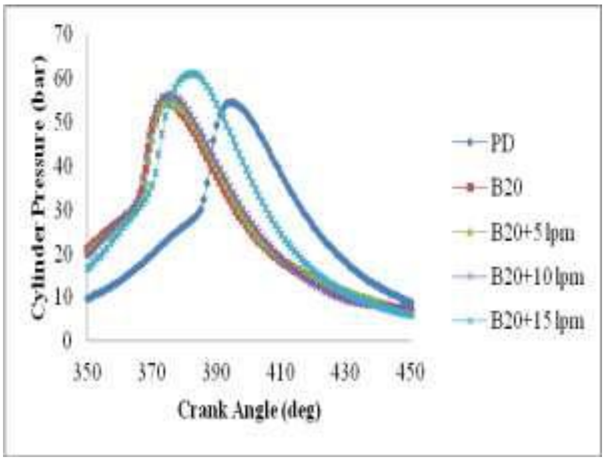

Fig.8: Variation of cylinder pressure with crank angle at 240 bar IOP

The experiment was validated at 200 bar, the peak pressure results for pure diesel, B20, B20+5 lpm, B20+10 lpm, and B20+15lpm were 51.77, 51.92, 53.06, 53.88, and 55.46 % at 100% load. The raise in Peak pressure with rising of injection operating pressure perhaps endorsement of small delay period which causes increase in cylinder temperature turns by fine atomization and premixed combustion.The rate of peak pressure released strategy from emancipated during premixed combustion in the period of delay. The experimental analysis at 100% load and 240 bar of IOP was generous increase of peak pressures find with pure diesel , B20, B20+5 lpm, B20+10 lpm, and B20+15 lpm were 54.44, 54.47, 54.77, 56.22, and 60.99 % bar. The exploration behind the increment of peak pressure from 200 to 240 bar IOP may be fewer ignition delay period which helps raise of cylinder temperature due to proper pre-mixed combustion and fine atomization [12, 13]

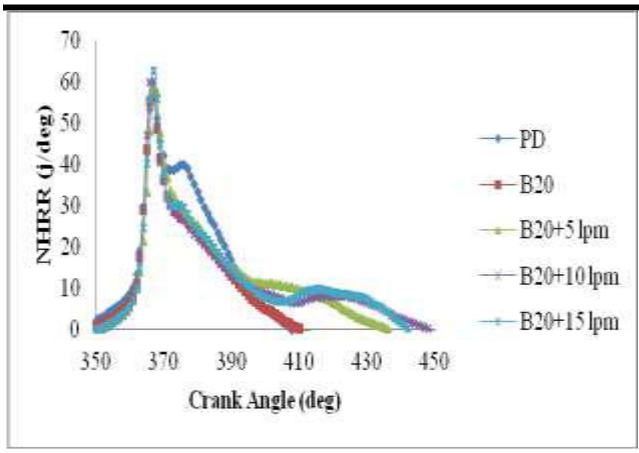

Fig.9: Variation of Net heat release rate with crank angle at 200 bar IOP

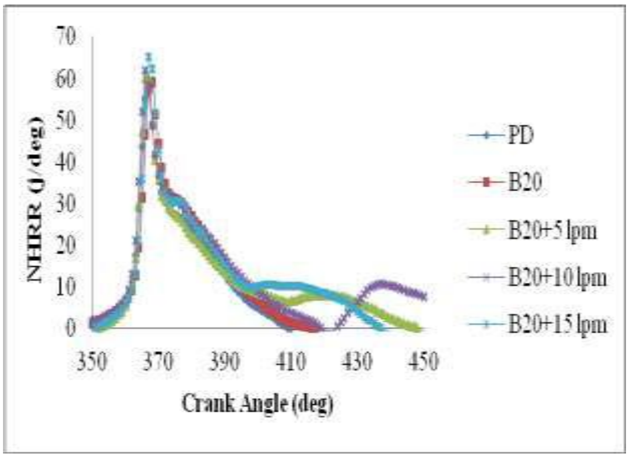

Fig.10: Variation of Net heat release rate with crank angle at 220 bar IOP

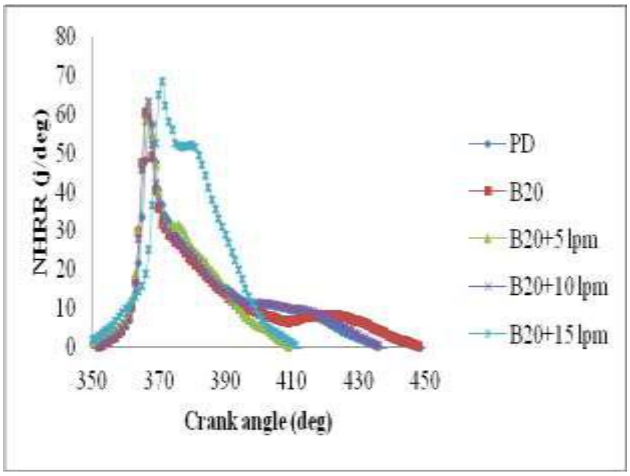

Fig.11: Variation of Net heat release rate with crank angle at 240 bar IOP

From Figure 9, 10, and 11 shows the net heat release rate curves with respect to crank angle at various IOP with the test fuels of pure diesel, B20 and B20 with hydrogen 5, 10, and 15 lpm flow rate of hydrogen. The base line pressure of 200 bar, the rate of net heat release for pure diesel, B20, B20+5 lpm, B20+10 lpm, and B20+15 lpm of test fuels was 56.58 J/deg CA, 56.66 J/deg CA, 58.31 J/deg CA, 60.17 J/deg CA, and 62.73 J/deg CA quantified at 100% load. The boost of injection operating pressure with boosting the NHRR values from 200 to 240 bar and the maximum pressure values for pure diesel, B20, B20+5lpm, B20+10 lpm, and B20+15 lpm of hydrogen was 58.31 J/deg CA, 60.17 J/deg CA, 61.72 J/deg CA, 63.39 J/deg CA, and 68.37 J/deg CA at 100% load. The dual fuel mode of NHRR was principally depends on the mixture quality, rate of mass flow and calorific value of both the liquid and gaseous fuels. The increase of IOP from 200 to 240 bar pressure with increasing NHRR in dual fuel mode due to involvement of two fuels with different characteristics and properties causes concurrently burned in the cylinder.

D. EMISSION CHARACTERISTICS

The CO emissions release rate curves with respect to IOP with the test fuels of pure diesel, B20 and B20 with hydrogen 5, 10, and 15 lpm flow rate of hydrogen as shown in fig.12. The base line pressure of 200 bar, the rate of CO emissions release for pure diesel, B20, B20+5 lpm, B20+10 lpm, and B20+15 lpm of test fuels was 0.364 %, 0.294 %, 0.26%, 0.224, and 0.118% at 100% load.

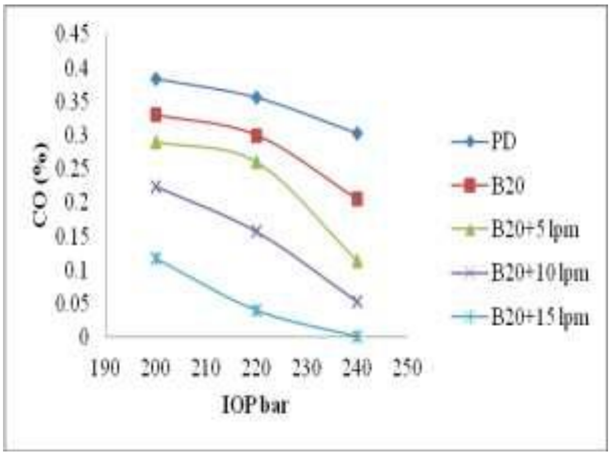

Fig.12: Variation of various CO emissions with different IOP at 100% load

The CO emission decreases with increasing pressure from 200 to 240bar pressure and the maximum pressure of CO values for pure diesel, B20, B20+5lpm, B20+10 lpm, and B20+15 lpm of hydrogen was 0.302%, 0.205 %, 0.113 %, 0.053 %, and 0.002 % at full load. CO emissions reduce from IOP of 200 to 240 bar, because of complete combustion of the smaller droplets

The CO2 emissions release rate curves with respect to IOP with the test fuels of pure diesel, B20 and B20 with hydrogen 5, 10, and 15 lpm flow rate of hydrogen as shown in fig.13. The base line pressure of 200 bar, the rate of CO2 emissions release for pure diesel, B20, B20+5 lpm, B20+10 lpm, and B20+15 lpm of test fuels was 9.91, 9.21, 8.59, 8.07, and 7.69 % at 100% load.

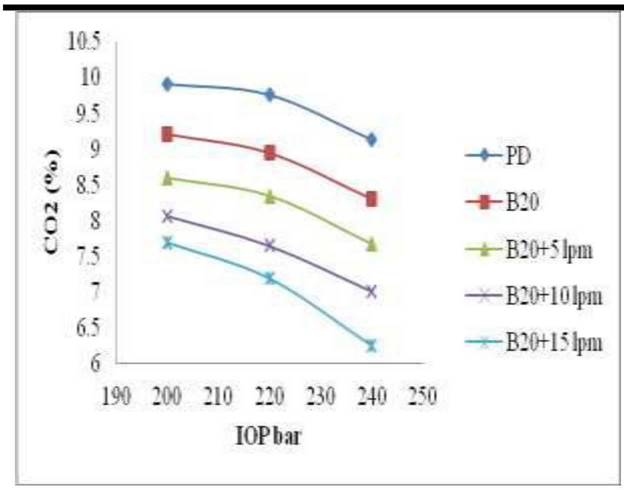

Fig.13: Variation of various CO2 emissions with different IOP at 100%load

The CO2 emission decreases with increasing pressure from 200 to 240bar pressure and the maximum pressure of CO values for pure diesel, B20, B20+5lpm, B20+10 lpm, and B20+15 lpm of hydrogen was 9.14,8.31, 7.67, 7.01,and 6.25 % at full load. CO2 emissions reduce from IOP of 200 to 240 bars, because of availability of oxygen in B20 causes complete combustion of the smaller droplets.

The NOx emissions release rate curves with respect to IOP with the test fuels of pure diesel, B20 and B20 with hydrogen 5, 10, and 15 lpm flow rate of hydrogen as shown in fig.14. The base line pressure of 200 bar, the rate of NOx emissions release for pure diesel, B20, B20+5 lpm, B20+10 lpm, and B20+15 lpm of test fuels was 350, 820, 971, 1024, and 1150 ppm at 100% load. The NOx emission increase with increasing pressure from 200 to 240bar pressure and the maximum pressure of NOx values for pure diesel, B20, B20+5lpm, B20+10 lpm, and B20+15 lpm of hydrogen was 495, 925 , 1019 , 1117, and 1275 ppm at full load. The NOx emission increases from IOP of 200 to 240 bars due to rapid rate of combustion, gas temperature of cylinder high, peak pressure reached with raised pilot injection pressure.

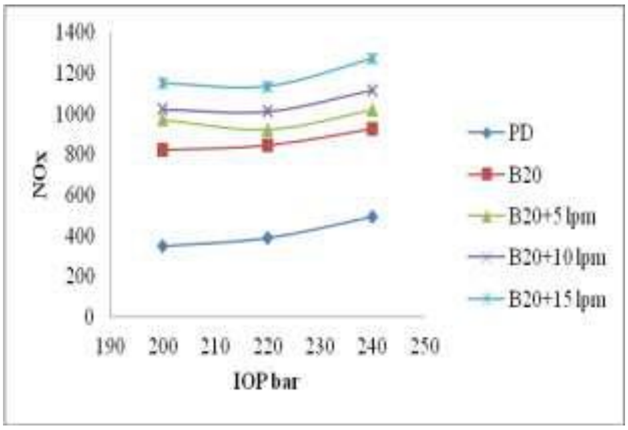

Fig.14: Variation of various NOx emissions with different IOP at 100% load

Fig. 15 depicts the changes in HC emissions by varying injection IOP pressures of 200, 220, and 240 bar with pure diesel, B20 and B20 with 5, 10, and 15lpm hydrogen respectively. The base line data pressure of 200 bar, the rate of HC emissions release for pure diesel, B20, B20+5 lpm, B20+10 lpm, and B20+15 lpm of test fuels was 170, 149, 102 ppm, 120,101 and 70 ppm at 100% load. At less IOP causes improper atomization HC increases. The HC emission decrease with increasing pressure from 200 to 240bar pressure and the maximum pressure of HC values for pure diesel, B20, B20+5lpm, B20+10 lpm, and B20+15 lpm of hydrogen was 122, 103 , 75 , 52, and 35 ppm at 100% load. HC diminished from IOP of 200 to 240 bar, because of proper mixing of fuel, near complete combustion and wall temperature of cylinder reduces in quench layer.

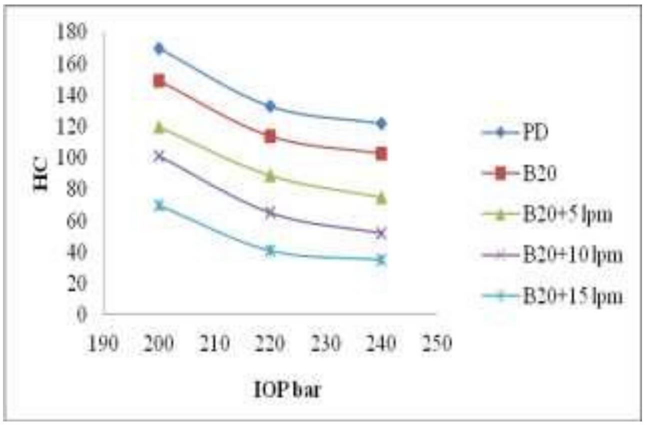

Fig.15: Variation of HC emissions with different IOP at 100 % load

IV. CONCLUSION

- The analysis of above experiment was validated successfully on pilot fuel of B20 and hydrogen enriched with different concentrations at altered injection operating pressure. The effects of results were praised at 200, 220, and 240 bar IOP marked that 240 bar IOP was better pressure for optimum performance, combustion and low emission. The conclusions of experimental results were ensure based on the B20 and B20 with hydrogen for IOP of 240 bar and compared base line pure diesel performed at 200 bar IOP at 100% load. Brake thermal efficiency of the engine increases up to 28.94% with 100% load condition at 240 bar IOP test fuels for B20 with 15 lpm of hydrogen when compared with baseline IOP.
- Brake Specific Fuel Consumption decreases with increasing IOP from 200 to 240 bar with test fuel of B20 with supplement of hydrogen at 15 lpm of flow rate. At 240 bar IOP full load BSFC find minimum of 0.28 Kg/kW-hr mean while maximum at base line IOP.
- Inside cylinder pressure and net heat release rate were

obtained maximum at 240 bar IOP with 15 lpm of hydrogen and B20 at 100% load.

- CO emissions were reduced with increasing IOP from 200 to 240 bar. The near zero of HC 0.002% resulted at the maximum IOP and B20 with 15 lpm of hydrogen.
- CO2 emissions obtained maximum at 200 bar IOP and minimum at 240 bar IOP for all the test fuel performance.
- NOx emissions increases with increasing IOP because of chemical kinetics and higher temperature release in cylinder. The raised rate of NOx discovered maximum at 240 bar IOP and minimum at 200 bar IOP for all test conditions.
- In dual fuel mode minimum HC 35 ppm emissions were obtained at 240 bar IOP for the fuel of B20 with hydrogen 15 lpm flow rate.

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