EFFECT OF VARIATION OF TEMPERATURES AND OF PRESSURES OF BIODIESEL DIESEL BLENDS ON PERFORMANCE AND EMISSION CHARACTERISTICS OF HCCI MODE DIESEL ENGINE

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Abstract

The density and viscosity of jetropha oil were reduced by heating it using induction coil heater. The lower injection pressure at elevated temperature helps in better spray characteristics which in turn improves combustion of fuel inside the combustion chamber. Experiments were conducted to evaluate combined effect of injection pressures and temperatures on performance and emission characteristics of diesel engine. Due to preheating the ignition delay was shorter and the higher rate of pressure rise was higher which led to slight increase in break power than diesel and crude jetropha oil the reduction in carbon dioxide, hydrocarbon, nitrous oxide emissions were observed for preheated fuel. Thus, injecting the fuel at suitable temperatures and pressures lead to reduction in exhaust emissions with slight or no effect on engine break power.

Keywords: Preheating, flashing, HCCI, CI engine, flash boiling, jetropha biodiesel

Chapter-1

Introduction

1.3 Achieving HCCI through spray injection

The conventional methods for Homogenous Combustion in Compression Ignition engines are

i. Variable Valve Timing
ii. External Gas Recirculation
iii. Early Injection

The variable valve timing can give homogenous mixture by changing the timing of inlet and exhaust valves. The duration of power stroke is increased and the duration of other strokes is reduced. This allows more time for the power stroke and thus allows more time to initiate atomization and fuel mixture preparation. Hence making the combustion process homogenous. Though VVT method can also lead to autoignition if it is not achieved properly.

As HCCI's autoignition event is highly sensitive to temperature, The simplest temperature control method can also be used to vary the inlet temperature by resistance heaters. The increased inlet temperature advances ignition in the combustion chamber and thus allows more time to mixture preparation. Hence makes the mixture homogenous. but this approach is too slow to change on a cycle-to-cycle frequency.

External Gas recirculation can be used to achieve HCCI as EGR recirculates a portion of an engine's exhaust gas back to the cylinders. This dilutes the O_2 in the incoming air stream and provides gases which are inert to combustion and act as absorbents of combustion heat to reduce peak in-cylinder temperatures. Because NOx forms when a mixture of nitrogen and oxygen is subjected to only high temperature, the lower combustion chamber temperatures are caused by EGR as it replaces some of excess oxygen and reduces the amount of NOx the combustion generates (though at some loss of engine efficiency). Gases re-introduced from EGR systems will also contain near equilibrium concentrations of NOx and CO.

The exhaust has dual effects on HCCI combustion. It dilutes the fresh charge, delaying ignition and reducing the chemical energy and engine output. Hot combustion products conversely increase gas temperature in the cylinder and advance ignition. Thus, depending upon temperature of recirculated gas the ignition can be advanced and HCCI can be achieved.

The main reason to achieve HCCI is to make homogenous mixture by allowing more time to prepare mixture or by external mixture formation. These techniques have some limitations as they can’t control Auto ignition, low load operating range etc. As it produces low power range if achieved by VVT method. The early injection may also lead to higher pressure and higher temperature if not injected properly. The EGR system can also lead to reduced engine output as it delays.

But Injecting fuel directly in gaseous phase may reduce physical delay and allow more time to make chemical delay and gives more time to mixture preparation. So, to make a homogeneous mixture within a time limit it is required to inject fuel directly into cylinder in gas phase.

The fuel can be injected in the combustion chamber in the gas form by:

a) Supercritical injection
b) Flash-boiling

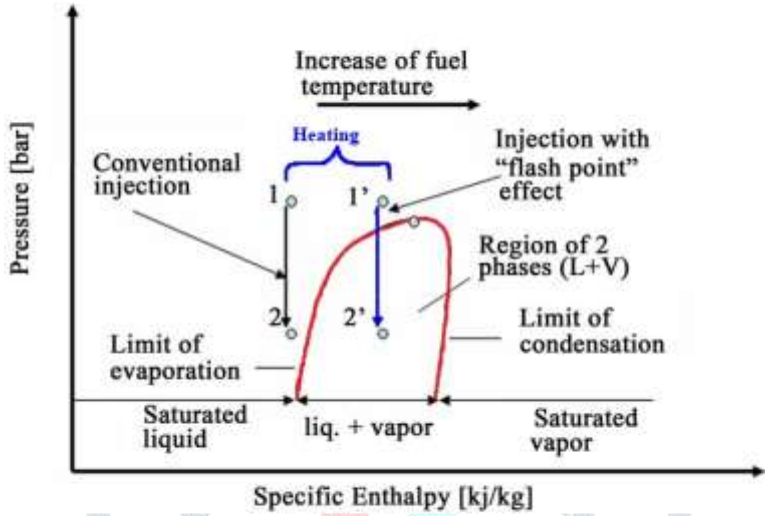


Figure 1. Flashing in P-H diagram.

From the above figure it can be seen that to achieve flashing of fuel into the combustion chamber of a compression ignition engine., it is needed to preheat the fuel up to the subcooled temperature of the fuel. After preheating the fuel, the fuel is then passes into injector nozzle where the further processes are followed.

To achieve desired pre- conditions of fuel the fuel is heated up to its subcooled temperature region and then the fuel is passes into the injector nozzle. As the subcooled liquid is expanded in the injector at large pressure drop, the metastable conditions can be achieved. A sudden drop in the pressure make the fuel to go in metastable state. And at this much low pressure the cavitation starts which is initiated by nucleation process. This nucleation process is then followed by bubble formation process. As the nuclii gets bigger it converted into the bubbles as the surrounding liquid takes up the latent heat from nuclei and starts converting its phase into gas form.

The gaseous injectant hen mixes better with the gaseous air and makes the homogenous mixture. here the reduced physical delay gives more and more time to mixture preparation. Thus, by allowing the combustion process to last longer the homogenous mixture inside the combustion chamber, combustion temperature decrease, decrease in soot particles and emissions can be achieved. Also, the homogenous mixture combustion gives lesser tendency to knock.

Here it is to be noted that the perfect flashing of liquid fuel into the gaseous form directly into the combustion chamber of compression ignition engines can be achieved by modifying nozzle dimensions and changing the length of injector.

1.6 Preheating

For Spray injection in compression Ignition engines, the temperature of the fuel needed to be raises up to certain point. The temperature of fuel is increased above its critical temperature in the supercritical injection and the temperature of fuel is needed to be raised up to its subcooled range.

So, in spray injection techniques the temperature of fuel before injecting the fuel into combustion chamber is raised. This increase in temperature is achieved by preheating the fuel up to required point of different spray injection methods.

A typical image of preheating setup of Peter Joppig and his team is shown here to explain positions for heating apparatus on the intake manifold of an engine.

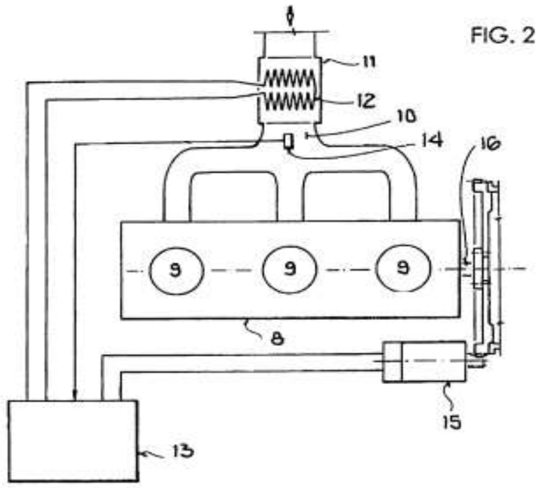


Figure 2. Preheating Set up [2]

During the preglow phase 1, 2, 3 between switching on the ignition and activation of the starter, the current supplied to the heating elements in the heating flange is variably controlled. During a first-time period 1, the heating element is initially supplied with full current until the heating flange reaches a reference temperature. After the reference temperature has been reached, a post-heating phase 2 and a start readiness phase 3 begin in which the heating power is controlled in such a way that the heating flange is kept at a constant temperature.

The cold start/preheat method according to the invention can be used on an internal combustion engine of this type. An internal combustion engine, in particular a diesel engine 8 having, for example, three combustion cylinders 9, takes in its air by means of an intake pipe 10. A heating flange 11 having heating elements 12 which project into the intake pipe 10 is arranged in the intake pipe 10. The power control and the supply of current to the heating elements is undertaken by a control unit, in particular an engine control unit, 13. In order to regulate the temperature level of the intake charge air, the control unit 13 receives input from a temperature sensor 14 which measures the air temperature in the intake pipe downstream of the heating elements but before entry into the combustion cylinders. The starting process is initiated by the control unit 13 by activating a starter 15. The pinion of the starter 15 engages here in a gear Wheel in a non-positive manner and in a manner known per se. The gear Wheel is in turn connected in a non-positive manner to the crankshaft 16 of the internal combustion engine and turns the crankshaft When the starter is activated. The cold start method according to the invention can advantageously be used on an internal combustion engine of this type.

Chapter 2

2. Literature review

2.1 Literature review on Preheating

Preheating of biodiesel blends leads to smoother operation and lesser emissions.[1]-[13] have worked on different types of biodiesel and presented the effects on performance and emission characteristics of the Bio fuel on CI engine. Particularly P. Pradhan et. Al worked on effect of preheating of jetropha oil on performance and emission characteristics.

So A Preheated fuel is injected at lower injection pressure than normal injection pressure, it leads to fine spray of injectant fuel and ultimately it vaporises the fuel easily. Which leads to homogenous combustion.
and thus leads to much lower emissions at slightly changed break power and efficiency at all loads.

2.3 Research Gap

The research in flash-boiling area is focused on petrol and its comp like octane, pentane only and in GDI mode. Further there is even less research on flashing on compression ignition engine. The flash-boiling of biodiesel-diesel blends can eliminate the problem of atomization of vegetable oils. Also, the existing HCCI system employed by different methods have different problems like autoignition, low power range, reduced engine output etc. So, the present work is focused on finding newer method for achieving HCCI in conventional CI engines.

Chapter 3

3. Experimental setup and methodology

3.1.1 Engine Block diagram

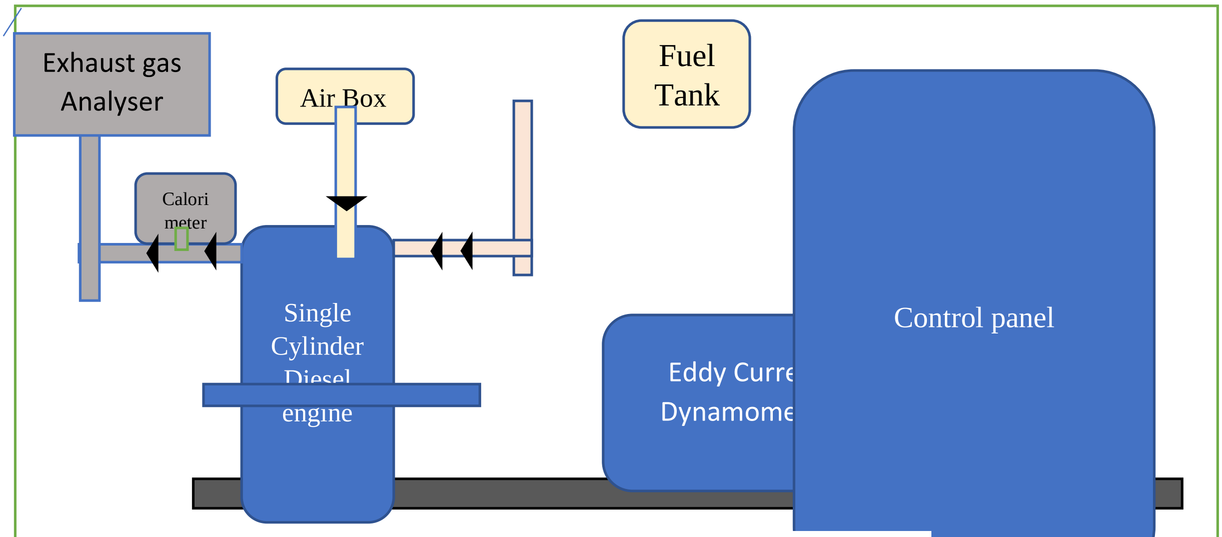


Figure 3 Block diagram of engine setup

3.

Figure 4: Engine setup

1. Single cylinder four stroke diesel engine
2. Eddy current dynamometer
3. Rotameter
4. Air box
5. Fuel tank
6. Burette
7. Fuel control valve
8. Load cell
9. Pressure sensor
10. Performance testing m/c
11. AVL exhaust gas analyzer
12. Exhaust probe

3.1.3 Technical Specifications of the Test Engine:

Engine	
Make	Kirloskar
Model	AV1
Cooling	Water Cooled
Power	5HP @ 1500 RPM
Stroke	110mm
Bore	80mm
Volume	553 cc
Compression Ratio	9.51: 1

Table 3-1 Engine Specifications

3.1.4 Eddy Current Dynamometer:

These machines make use of the principle of electro-magnetic induction to develop torque and dissipate power. A toothed rotor of high permeability steel rotates with a fine clearance between water cooled steel loss plates. Two annular coils generate a magnetic field parallel to the machine axis and motion of the rotor give rise to changes in the distribution of magnetic flux in the loss plates. This in turn gives rise to circulating eddy currents and the dissipation of power in the form of electrical resistive losses. Energy is transferred in the form of heat to cooling water circulating through passages in the loss plates, while some cooling is achieved by the radial flow of air in the gaps between rotor and plates. Varying the current supplied to the annular exciting coils controls power, and very rapid load changes are possible.

Figure 5: Eddy Current

3.1.11 Engine emission measurement

Figure 6: AVL Exhaust gas analyzer

In order to measure exhaust constituents from the engine AVL exhaust gas analyzer is used. Apart from measuring exhaust emissions this analyzer also measures engine RPM as well as lubricating oil temperature and equivalence ratio.

Table 3.2 AVL Exhaust gas analyzer specifications

Measuring gas	Measuring method	Measuring range
CO	NDIR	0-15 %
HC	NDIR	0-15000 ppm
NOX	Electrochemical	0-5000 ppm
CO2	NDIR	0-20%
O2	Electrochemical	0-25%

3.1.10 Other measuring devices

a) **Load cell**: The load cell is connected to the eddy current dynamometer. It measures the load acting on the dynamometer due to torque generated. It is basically a stress-strain gauge.

b) **'K' type thermocouples**: 'K' type thermocouples suitable for high temperature measurements are used to measure the temperatures at different points. The temperatures measured by thermocouples are indicated in software. The sequence of temperatures on indicator is as follows:

T1- Exhaust gas inlet temperature

T2- Exhaust gas outlet temperature

T3- Calorimeter water inlet temperature
T4- Calorimeter outlet temperature
T5- Engine coolant inlet temperature
T6- Engine coolant outlet temperature
T7- Ambient temperature

c) **RTD (PT-100)**: The ambient temperature is measured by resistance type RTD (PT-100) sensor. The sensor output is transmitted by transmitter to the computer.

d) **Pressure sensor**: The piezoelectric transducer type sensor measures pressure inside combustion cylinder. The sensor signal is conditioned by the pressure transmitter and transmitted to computer.

e) **Encoder**: The encoder measures crank angle and gives signal when piston is at TDC (Top Dead Center).

Chapter 4

1. Results and conclusion

4.1 result

Break power at various injection pressures and temperatures

Load (%)	BP for Diesel at 25 ˚C and 150 bar(%v/v)	BP for B20 at 25 ˚C and 150 bar(%v/v)	BP for B20 at 160 ˚C and 150 bar (Kw)	BP for B20 at 180 ˚C and 150 bar (Kw)	CO for Diesel at 25 ˚C and 150 bar(%v/v)
0	0.19	0.198	0.218	0.183	0.204
20	0.709	0.645	0.69	0.659	0.643
40	1.425	1.421	1.304	1.349	1.379
60	2.466	2.099	2.119	2.127	2.122

Bsfc at various injection pressures and temperatures

Load (%)	Bsfc for Diesel at 25 ˚C & 150 bar (gm/Kw.sec)	Bsfc for B20 at 25 ˚C & 150 bar (gm/Kw.sec)	Bsfc for B20 at 160 ˚C & 150 bar (gm/Kw.sec)	Bsfc for B20 at 180 ˚C & 150 bar (gm/Kw.sec)	Bsfc for B20 at 200 ˚C & 150 bar (gm/Kw.sec)
0	0.581717452	0.647923175	0.653086612	0.882411067	1.23078609
20	0.209693324	0.26808368	0.293347302	0.394120123	0.880272465
40	0.157192982	0.240974224	0.257668712	0.259451446	0.733820282
60	0.144950044	0.181046188	0.188768287	0.213471582	0.670086531

Bsfc at various injection pressures and temperatures

Load (%)	Mech Eff for Diesel at 25 ˚C and 150 bar (%)	Mech Eff for B20 at 25 ˚C and 150 bar (%)	Mech Eff for B20 at 25 ˚C and 150 bar (%)	Mech Eff for B20 at 180 ˚C and 150 bar (%)	Mech Eff for B20 at 200 ˚C and 150 bar (%)
0	49.47916667	49.38574939	49.54545455	50	49.3765586
20	49.44211994	49.453125	51.37751303	49.54887218	49.46543122
40	60.0252738	60.03513395	60.06448641	60.06233304	60.03379806
60	81.68267638	89.24731183	73.93579902	73.95688456	91.52396269

HC emissions at various injection pressures and temperatures

Load (%)	HC for Diesel at 25 ˚C and 150 bar(ppm)	HC for B20 at 25 ˚C and 150 bar(ppm)	HC for B20 at 160 ˚C and 150 bar(ppm)	HC for B20 at 180 ˚C and 150 bar(ppm)	HC for B20 at 200 ˚C and 150 bar(ppm)
0	60	54	48	56	91
20	77	60	56	68	96
40	83	65	62	78	101

60	89	86	81	84	104

NOx emissions at various injection pressures and temperatures

Load (%)	NOx for Diesel at 25 °C and 150 bar(ppm)	Nox for B20 at 25 °C and 150 bar(ppm)	NOx for B20 at 160 °C and 150 bar(ppm)	NOx for B20 at 180 °C and 150 bar(ppm)	NOx for B20 at 200 °C and 150 bar(ppm)
0	54	71	48	78	183
20	122	145	133	163	197
40	284	390	388	425	435
60	423	439	454	443	468

CO emissions at various injection pressures and temperatures

Load (%)	CO for Diesel at 25 °C and 150 bar(%v/v)	CO for B20 at 25 °C and 150 bar(%v/v)	CO for B20 at 160 °C and 150 bar(%v/v)	CO for B20 at 180 °C and 150 bar(%v/v)	CO for B20 at 200 °C and 150 bar(%v/v)
0	0.12	0.09	0.08	0.11	0.09
20	0.13	0.09	0.07	0.12	0.11
40	0.09	0.08	0.05	0.1	0.1
60	0.05	0.06	0.03	0.09	0.09

CO2 at various injection pressures and temperatures

Load (%)	CO_2 for Diesel at 25 °C and 150 bar(%v/v)	CO_2 for B20 at 25 °C and 150 bar(%v/v)	CO_2 for B20 at 160 °C and 150 bar(%v/v)	CO_2 for B20 at 180 °C and 150 bar(%v/v)	CO_2 for B20 at 200 °C and 150 bar(%v/v)
0	2.61	2.56	2.51	2.82	2.53
20	3.51	3.57	3.43	3.8	3.39
40	5.22	5.34	5.4	5.36	5.12
60	6.95	7.52	5.75	5.1	5.78

4.2 performance characteristic

The following performance parameter has been evaluated and compared:

1) Brake power
2) Brake specific fuel Consumption
3) Mechanical efficiency

4.3.1 Variation in brake power with load

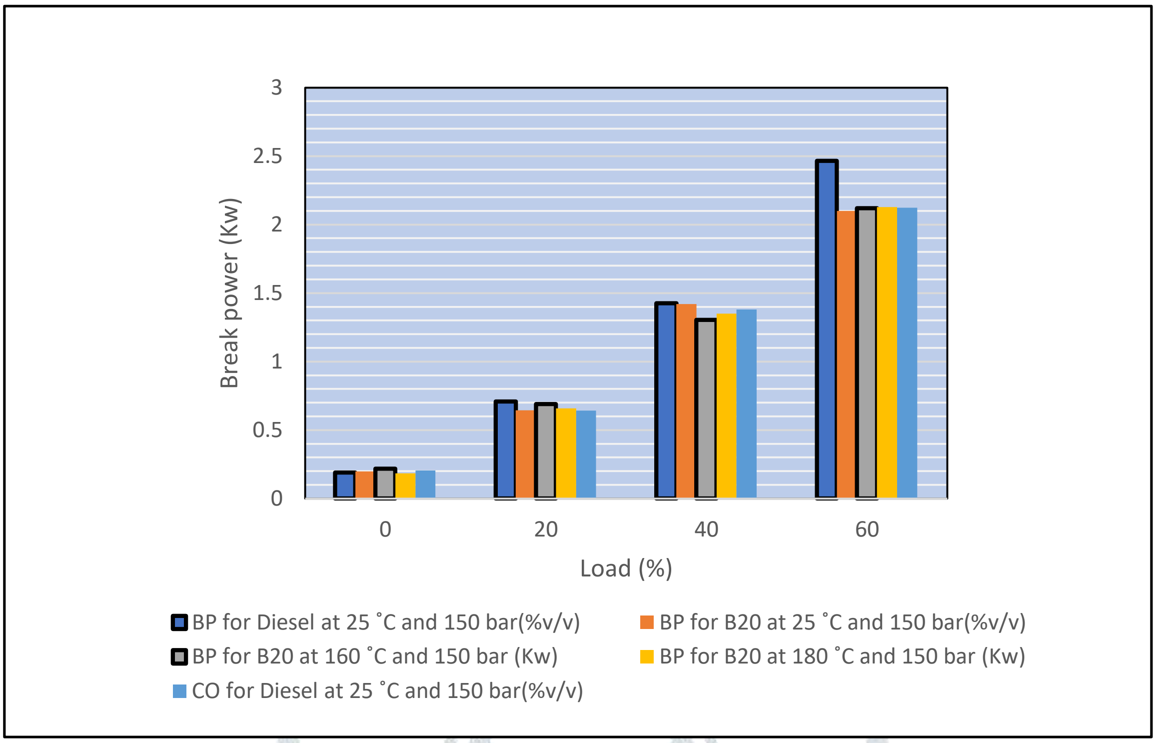


Figure 4.1 Variation in BP with Load

As shown in fig 4.1 brake power increases with increase in load for both diesel and B20. Brake power is slightly decreases for B20 fuel compared to diesel fuel for same load.

Due to preheating the break power further increases as the rate of pressure rise for B20 is much before than expected This reduces ignition delay and leads to start combustion much earlier.

4.3.2 Variation in brake specific fuel consumption with load

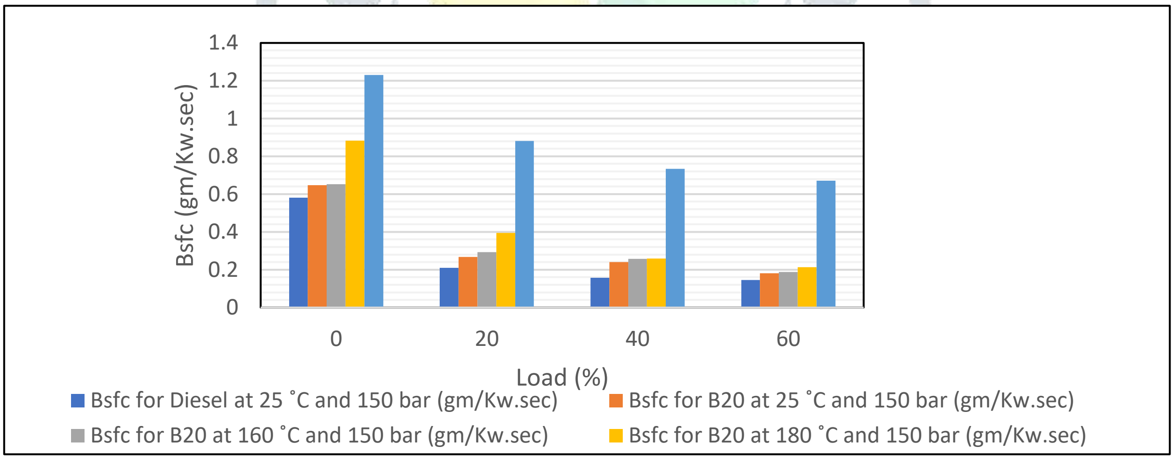
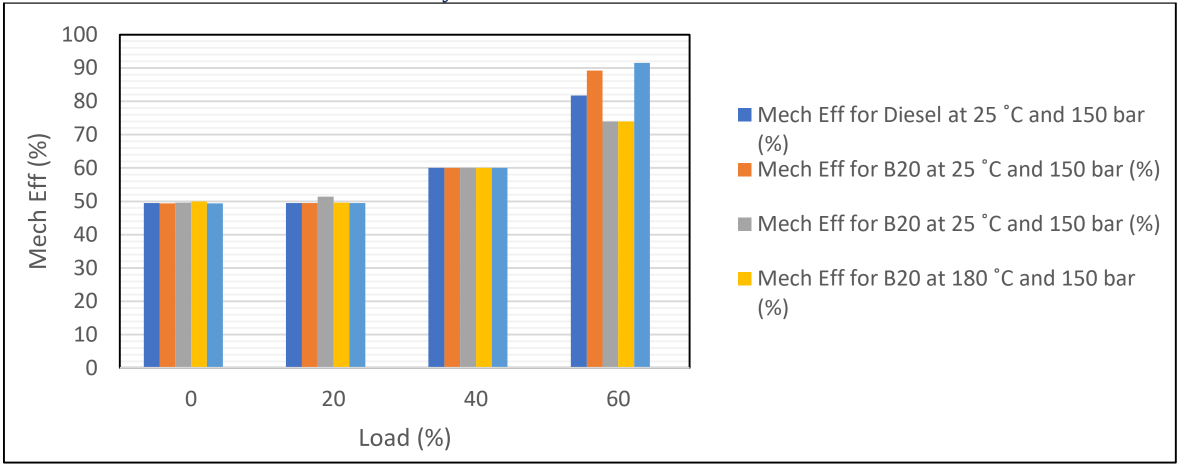


Figure45.2 Variation in BSFC with Load

As shown in fig 4.6\2 BSFC decreases with increase in load for both diesel and B20 fuel. BSFC is higher for B20 fuel compared to diesel fuel for same load.

The bsfc for B20 was increased due to more amount of fuel needed to burn to get same heat and break power as that of diesel fuel

4.3.2 Variation in Mechanical efficiency with load



4.3 Emission characteristic

The following emission characteristic has been evaluated and compared:

1) PM emission
2) NOx emission
3) CO emission

4.3.1 Variation in HC with Load

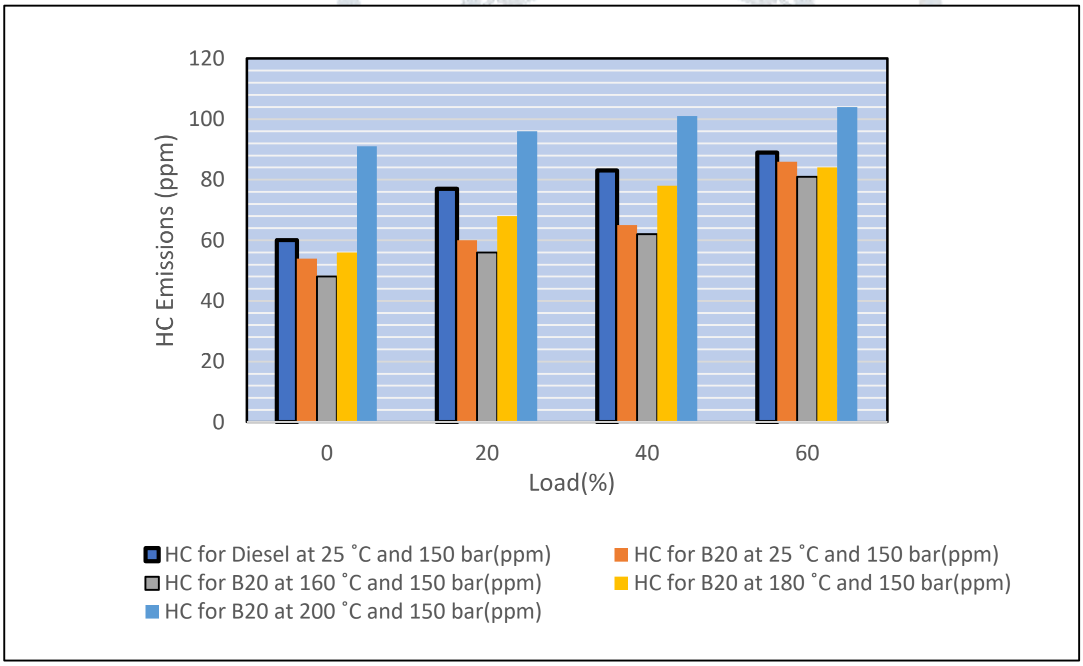


Figure 4.3 Variation in HC with Load

As shown in fig. 4.9 HC emission is increases with load in both diesel and B20 fuel. HC emission is lower for B20 compared to diesel for all load percentage.

With preheating the bsfc further increases due to reduced density and increased fuel consumption in each spray.

4.3.2 Variation in NOx with Load

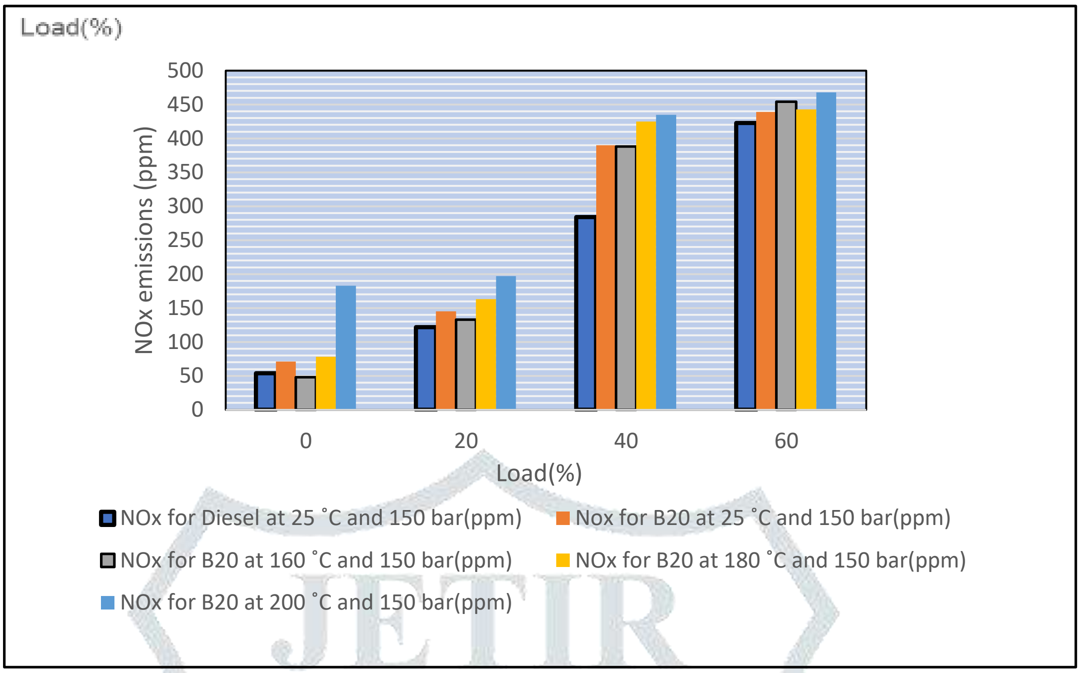


Figure 4.4 Variation in NOx with Load

As shown in fig 4.10 NOx emission is increases with load in both diesel and B20 fuel. NOx emission is higher for B20 compared to diesel for all load percentage.

The preheating of B2o lead to higher combustion temperature and the formation of NO took place due to higher temperature and availability of oxygen.

4.3.3 Variation in CO with Load

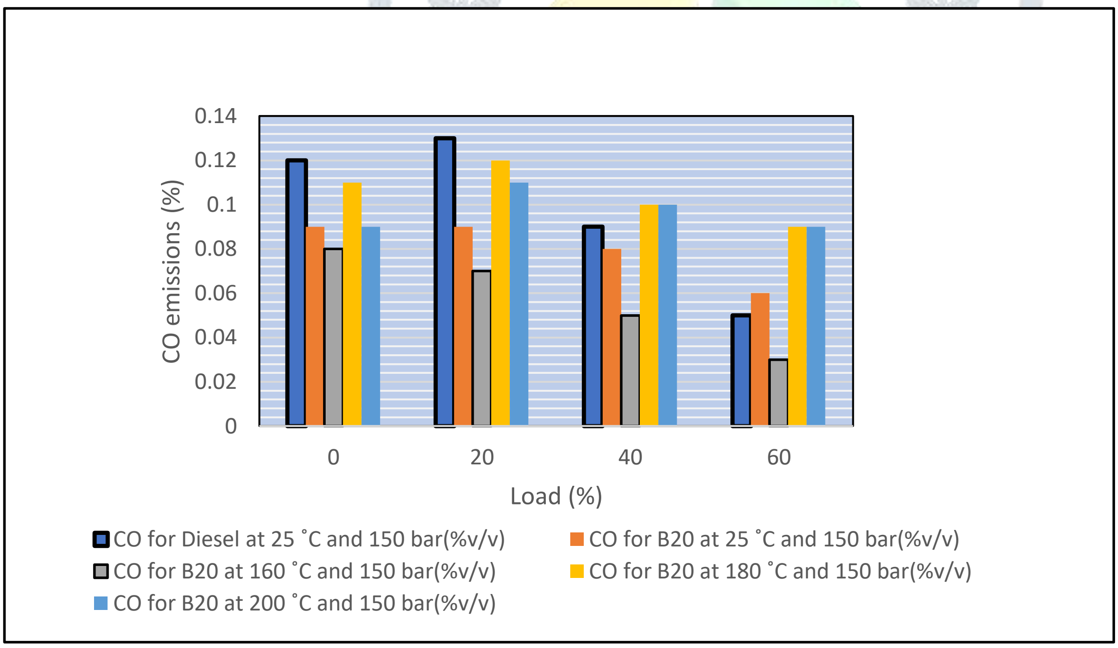
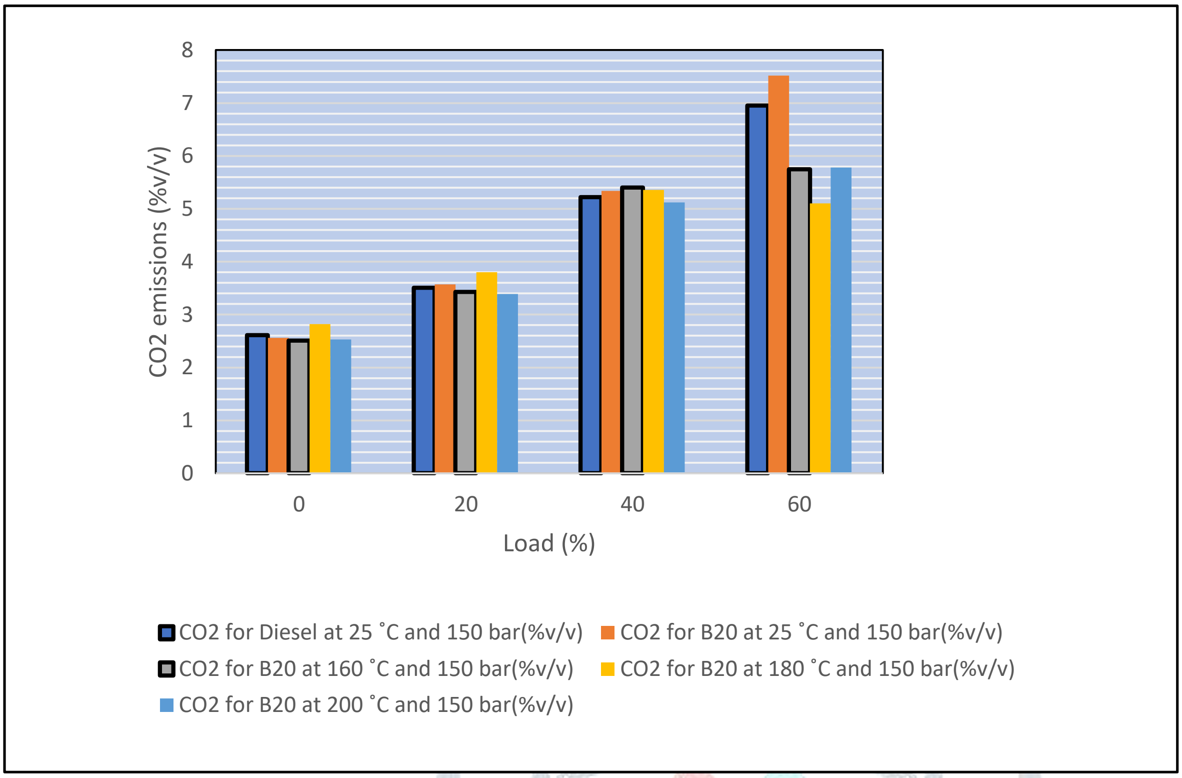


Figure 4.5 Variation in CO with Load

As shown in fig. 4.11 CO emission is decreases with load in both diesel and B20 fuel. CO emission is lower for B20 compared to diesel for all load percentage.



Conclusion

- Due to preheating the peak rate of pressure rise ROPR occurred max before TDC at full load and no load due to lower ignition delay and earlier start of combustion than Diesel and B20 at normal conditions
- With increased temperatures the fuel consumption per unit break power increases for all temperatures for B20.as heating of B20 leads to reduced density ,so again more amount of fuel is injected into combustion chamber . overall effect of heating of B20 fuel lead to rapid increase in fuel consumption
- An increase in exhaust gas was observed due to burning of increased higher amount of fuel injected to meet extra power requirement this led to increase in NOx emissions at increased temperatures.

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Add data about injector dimensions, parameters working conditions etc.

Add data of engine specifications