Effect of Bharat Stage-VI Fuel on Bharat Stage-III and Bharat Stage-IV Engines

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Abstract: - On 1st April 2018 Indian Ministry of Petroleum & Natural Gas has introduced the Bharat Stage-VI fuel in the market which has the less emission as compared to the BS- IV fuel. Due to the change of the Bharat stage Norms from III to IV the norms allotted fuels also changes. There is much more availability of BS-III and BS-IV vehicles with the Indian Auto Manufacturers, so to state the effect of BS- VI fuels on old engines we have performed an experiment using BS-VI fuel on BS-IV Norms based engine. Till 2010 BS-III norms were discontinued and BS-IV fuel was introduced in India. Due to this there was mismatch of norms, due to which pollution rate has increased up to 13% in past 5 years. So, we are going to test the BS-VI fuels on this BS- IV engine, and obtain the test results, and compare the performance of same engine with different fuels. The experiment was conducted on Engine Soft Software, which is an Engine Performance Monitoring System along with study of open Electronic Control Module. According to the results obtained appropriate maintenance tips would be suggested.

Key Words: - BS-VI Norms, BS-VI Fuel Composition, Engine Soft Software, New Technologies, Maintenance Tips, etc.

1. Introduction:

Today in India emission has become the most dreaded issue. A lot of respiratory disorders is faced by peoples because of this. The huge contribution for the air pollution is the exhaust from the automobiles. The main issue in India is the traffic jam, because of which the vehicle remains in idling for longer time, resulting in more fuel consumption and emission from the vehicles [1][2]. Considering the increasing rate of air pollution in India, on 1st April 2018 Indian Ministry of Petroleum & Natural Gas has introduced the Bharat Stage- VI fuel in the market which has less pollution as compared to Bharat Stage- IV fuel [4]. Due to the change in the emission norms the Norms based fuel also changes. Still there are BS-III and BS- IV Vehicles available with the Indian Auto Manufacturers, because of which the air pollution rate has increased up-to 13% in past five years [6]. This research paper is based on the testing of these BS- VI fuel on BS- IV engines. The government claims the fuel to be the "Ultra Clean" but its effect may be different on the Norms based engine.

2. Bharat Stage VI Norms and Bharat Stage VI Fuel:

2.1 Bharat Stage VI Norms:

This are the emission standard instituted by the government of India to regulate the output that is caused by the I.C. engines of the motor vehicles. This Bharat Stage Norms are totally based on the European Norms which are introduced in India in year 1991 for Petrol Vehicles and 1992 for Diesel Vehicles. Till 2010 Bharat Stage III Norms were discontinued fully but the auto manufacturers were still selling the BS- III vehicles till 2014. On 1st April 2017 Honourable Supreme Court of India has put the Ban on selling of BS- III vehicle. BS-IV norms were introduced in year 2010 and were made mandatory nationwide. Now Government of India has decided in 2016 to skip Bharat Stage- V norms and directly apply Bharat Stage- IV norms. The table below shows the Bharat Stage Norms Comparison. [4]

Table 1: Petrol Engine Emission Norms in g/km

Emission Norms	CO	HC	NOx	PM
BS- III	2.3	0.2	0.15	Na
BS- IV	1	0.1	0.08	Na
BS- V	Skipped			
BS- IV	1	0.1	0.06	$6*10^{x}$

Number of Particulate Per Km

Table 2: Diesel Engine Emission Norms in g/km

Emission Norms	CO	HC	NOx	HC + NOx	PM
BS- III	0.64	Na	0.5	0.56	0.05
BS- IV	0.5	Na	0.25	0.3	0.025
BS- V	Skipped				
BS- IV	0.5	Na	0.06	0.17	$6*10^{x}$

Number of Particulate Per Km

2.2 Bharat Stage VI Fuel:

The fuel composition of different stage fuel is compared in the image mentioned below [5]

Table 3: Comparison of Fuel Composition of Petrol

Sr No.	Characteristics	Units	Bharat Stage III	Bharat Stage IV	Bharat Stage V	Bharat Stage VI
1.	Density 15° C	Kg/m^3	720-775	720-775		
2.	Distillation					
3.	a) Recovery up to 70 ° C (E70)	% Volume	10-45	10-45		
	b) Recovery up to 100 ° C (E100)		40-70	40-70		
	c) Recovery up to 180 ° C (E180)		-	-		
	d) Recovery up to 150 ° C (E150)	° C	75 min	75 min		
	e) Final Boiling Point (FBP)		210	210		
	f) Residue Max		2	2		
4.	Research Octane Number (RON)		91	91		
5.	Anti-Knock Index (AKI)/ MON, Min		81 (MON)	81 (MON)		
6.	**Sulphur, Max**	**% Mass**	**150**	**50**	**10**	**10**
7.	Lead Content (as pb), Max	g/l	0.005	0.005		
8.	Reid Vapour Pressure (RVP), Max	Kpa	60	60		
9.	Benzene, Content, Max a) For Metros b) For the Rest	% Volume	1	1		
10.	Olefin Content, Max	% Volume	21	21		
11.	Aromatic Content, Max	% Volume	42	35<		

Table 4: Comparison of Fuel Composition of Diesel

Sr No.	Characteristics	Bharat Stage III	Bharat Stage IV	Bharat Stage V	Bharat Stage VI
1.	Density 15° C Kg/m^3	820-845	820-845		
2.	**Sulphur Content mg/kg, max**	**350**	**50**	**10**	**10**
3.	a) Cetane Number Minimum and / or	51	51		
		And	And		
	b) Cetane Index	46	46		
4.	Polycyclic Aromatic Hydrocarbon	11	11		
5.	Distillation				
	a) Reco Min at 350 ° C	-	-		
	b) Reco Min at 370 ° C	-	-		
	c) 95% Vol Reco Min at 0 ° C	360	360		

As it can be seen that for both Petrol and Diesel fuel the sulphur content is reduced by 40 mg/kg, this result in the ultraclean of the fuel. This composition of the fuel can be achieved by proper hydro-processing of the fuel from the refinery. Sulphur in fuel when burnt it gets mixed with the oxygen and form SOx (Oxides of Sulphur). If these "SOx (Oxides of Sulphur)" when emitted from the exhaust of the automobiles tail pipe it gets mixed with air and pollute the air. If this pollution creating content in the fuel is reduced then the "SOx (Oxides of Sulphur)" production from the exhaust will be reduced.

The upcoming petrol and diesel engines are having new technology of the fuel injection system according to which they Injects fuel directly in the combustion chamber. This leads the injector tip to be subjected to extremely high temperature of the combustion chamber as well as the particulate matter generated inside the engine. The sulphur content in the BS- IV fuel is 50 mg/Kg, this sulphur then lubricates the internal moving parts of the fuel injector.

Now, in BS- VI fuel the sulphur content is 10 mg/Kg. Here, sulphur provides lubrication for the fuel injectors. Now, when this new fuel has low sulphur content then there are chances that friction in the injectors and may the injector gets worn from the internal portion. If these worn particles enter the fuel holes made in the injector tip, there are chance that it may block the nozzle and fuel supply to the engine may not be sufficient. Hence, this result in decrease in overall performance of the engine.

In order to reduce the friction in the injectors, fuel additives need to be mixed with the fuel in order to give sufficient lubrication to the fuel injectors. The fuel additives do not affect the fuel properties, but it gets utilised in the injector as a lubricating film between the moving parts.

The Bharat Stage-VI fuel is only available in Delhi NCR [5], so the fuel is arranged by the transport facility from Delhi to Mumbai under the supervision of the Authors 1 and 2 of this paper.

3. Experimentation:

The testing was conducted at Apex Innovation PVT. LTD, Sangli, Maharashtra, India. The testing authority has the Test Bed Setup along with the various instrument connected to the computer and readings are calculated on the Engine Soft Software. [3]

This paper is based on the using BS- VI fuel on BS- IV engines and the experiment is conducted on the Single Cylinder, 4-stroke, VCR (Variable Compression Ratio) type Petrol Engine connected to the Eddy Current Dynamometer. It is provided with the various instrument for combustion pressure, crank angle, airflow, fuel flow, temperature and load Measurements.[3]

In petrol mode, engine works with programmable Open ECU, throttle Position Sensor, Fuel Pump, Ignition Coil, Trigger Sensor etc. Engine Performance like Brake Power, Indicated Power, Frictional Power, Brake Mean Effective Pressure, Indicated Mean Effective Pressure, Brake Thermal Efficiency, Indicated Thermal Efficiency, Mechanical Efficiency, Volumetric Efficiency, Specific Fuel Consumption, Air fuel Ratio, Heat Balance and Combustion analysis etc. can be evaluated with the help of one Software named “Engine Soft”. This “Engine Soft” is used for finding out the engine performance and based on that it plots the graph. The test setup has an open ECU study system, because

of which the fuel injection timing can be advanced as per the requirement. So, the test is conducted on the basis of constant fuel supply at all the loading and the rpm range. [3]

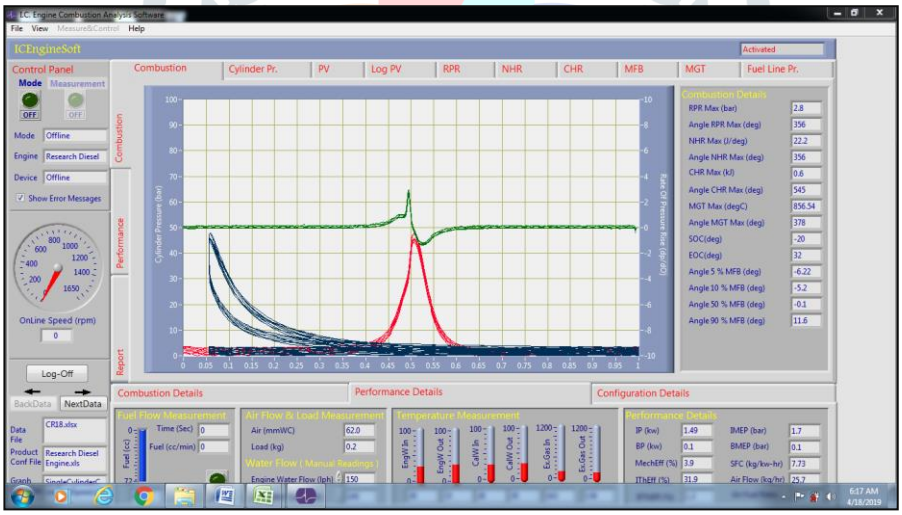


Figure 1: Preview of the Engine Soft Software.

Engine Soft is the Lab view based Engine Performance analysis Software package for online Evaluation of performance of the engine. It is used for monitoring, reporting, data entry, data logging. The software evaluates power, Efficiencies, fuel consumption and heat release. It is configurable as per engine setup. Various graphs are obtained at different operating conditions. While on line testing of engine is in RUN mode necessary signals are scanned, stored and presented in the form of graphs. Stored data file is accessed to view the data graphical and tabular formats. The results and graphs can be printed. The data in excel format can be used for the further analysis.

Exhaust Analyser is connected with the tailpipe of setup. The exhaust analyser shows the reading of *HC*, *CO*, CO_2, O_2, & NO_x. It has sensors i.e. NDIR (Non- Dispersive Infrared Sensor) which detects CO and CO_2 emission, Chemiluminescence Detector (CLD) which detects NO emission, Flame Ionization Detector (FID) which detects HC emission and Lambda Sensor which senses the O_2.

3.1 Specification of the Test Bed Setup:

The specification of the engine testbed is mentioned below on which the testing is to be performed and the results are evaluated in the form of graph and excel sheet, which can be referred whenever needed for the analysis purpose. [3]

Product	1 Cyl., 4-Stroke, VCR, Multi- Fuel with Open ECU for Petrol Mode
Product code	240PE
Engine	Petrol Mode: 3.5 kW, @1500 rpm CR range 6-10, Stroke 110mm, bore 87.5mm, 661cc, Water Cooled
Dynamometer	Eddy Current type, Water Cooled with Loading Unit
Propeller Shaft	With Universal Joint
Air Box	With Orifice Meter and Manometer
Fuel Tank	15 litres with glass fuel metering column
ECU	Model PE3, potted enclosure with pe monitor and pe viewer software
Piezo Sensor	Range 350 bar with low noise cable
Crank Angle Sensor	Rev. 1 Degree, speed 5500 rpm, with TDC Pulse
Data Acquisition device	NI USB-6210, 16- bit, 250 kS/s
Temperature sensor	Type RTD, PT100 and Thermocouple type K
Temperature Transmitter	Type 2 Wire I/p Output 4-20 mA
Load Sensor	Strain Gauge, Range 0-50 Kg
Fuel Flow Transmitter	DP transmitter, Range 0-500 mm WC
Air Flow Transmitter	Pressure Transmitter, Range (-) 250mmWC
Software	“Engine Soft” Engine Performance analysis software
Rotameter	Engine cooling 40-400Lph; Calorimeter 25-250Lph
Pump	Monoblock Type
Overall Dimension	W 2000 * D 2500 * H 1500 mm

Figure 2: VCR Engine Setup with Description

3.2 Experimental Procedure:

The experiment was performed on two basic independent parameters like Constant Fuel Supply and the compression ratio for the BS- IV and BS- VI fuel, on SI Engine.

Experimental Procedure for the reading is given below.

1. Check the lubrication, cooling water and the fuel system of engine for their adequacy
2. Switch ON the electric supply and ensure that all digital and electric instrument are ON.
3. Start the engine and run under idling condition (no load) for 10 minutes to ensure warm and steady state operating condition.
4. Set the compression ratio at the selected value using the tilting arrangement of the engine.
5. Set the injection Pressure at the standard value using nut provide on the cylinder head near fuel injector line. The observation noted were at constant injection pressure of 200 bars.
6. Records all thermal performance parameters for no load condition through a data acquisition system interfaced with the computer. Commercial Software, Engine Soft LV is used to interface record and analyse the data.
7. Since it is the open ECU based system so, adjust the fuel supply at the constant rate and then very the engine rpm by applying the load to bring the fuel supply at the required rate.
8. Repeat the steps for 1600, 1500, 1400, 1300 rpm for the constant fuel supply under loading for the compression ratio of 10. Then change the compression ratio to 9 and again repeat the same procedure for the same rpm range.
9. After the experimentation is conducted on BS- IV fuel, then drain the BS- IV fuel and fill the tank with the BS- VI fuel with the compression ratio 10 follow the same procedure as done for the BS- IV fuel compression ratio 10 and then change the compression ratio to 9. Then the experimentation part is completed.
10. Then compare both the observation of both the fuel with compression ratio 9 and 10. For the results take the average of all the four readings and compare between them and give the appropriate remark.

NOTE: - After the testing and result evaluation, only compression ratio 10 readings of both the fuel is considered. Since test is conducted considering the highest compression ratio.

4. Observation for Bharat Stage- IV fuel with Compression Ratio 10:

Engine Details:

IC Engine setup under test is research Petrol having power 4.50kW @ 1800 rpm which is 1 cylinder, four stroke, Variable Speed, Water cooled, Petrol Engine, with cylinder bore 87.50mm, Stroke Length 110.00mm, Connecting Rod Length 234.00mm, Compression Ratio 10.00, Swept Volume 661.45 cc.

Combustion Parameters:

Specific Gas Constant: 1 kJ/Kg K, Air Density: 1.17 Kg/m^3, Adiabatic Index: 1.41, Polytropic Index: 1.69, Number of Cycles: 10, Cylinder Pressure Reference: 0, TDC Reference: 0

Performance Parameters:

Orifice Diameter: 20.00mm, Orifice Coefficient of discharge: 0.60, Dynamometer Arm Length: 185mm, Fuel Pipe Diameter: 14.50mm, Ambient Temperature: 27°C, Pulses Per Revolution: 360, Fuel Type: Petrol, Fuel Density: 740 Kg/m^3, Calorific Value: 44000 kJ/Kg.

Table Shows the values of various speed (rpm), Load (Kg), Indicated Power, Brake Power, Friction Power (kW)

Speed (rpm)	Load (Kg)	IP (kW)	BP (kW)	FP (kW)
1600	14.05	4.98	4.27	0.71
1500	14.03	5.02	4.29	0.74
1400	14.61	4.77	4.17	0.60
1300	15.59	4.22	3.86	0.36

Graph 1: Load (Kg) vs Indicated Power, Brake Power, Friction Power (kW)

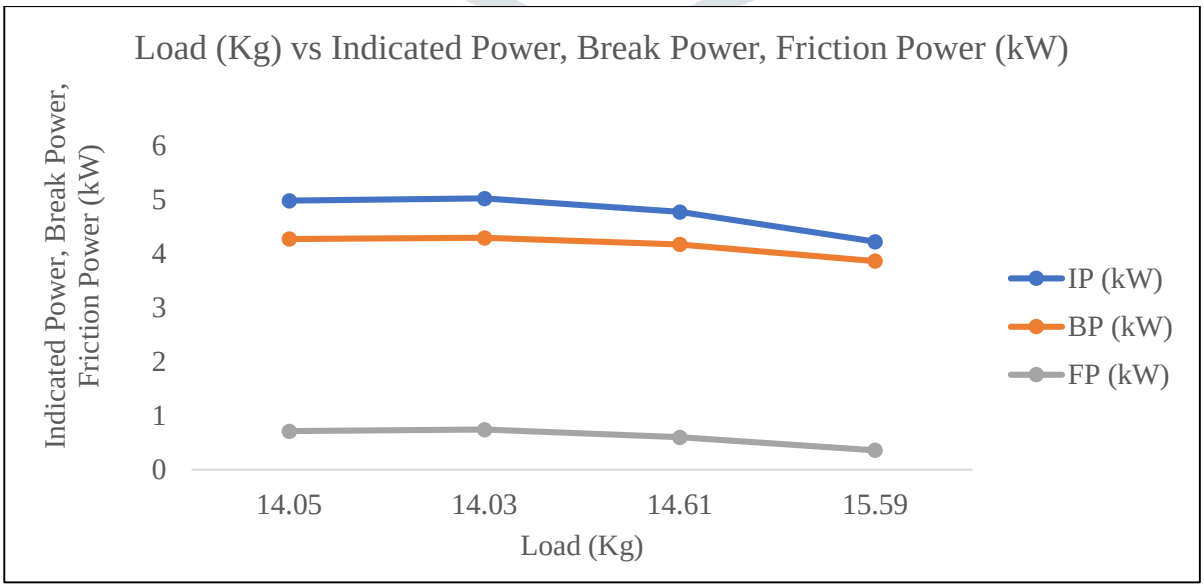


Table Shows the values of various speed (rpm), Load (Kg), Indicated Mean Effective Pressure, Brake Mean Effective Pressure, Friction Mean Effective Pressure (bar)

Speed (rpm)	Load (Kg)	IMEP (bar)	BMEP (bar)	FMEP (bar)
1600	14.05	5.64	4.84	0.80
1500	14.03	5.67	4.84	0.83
1400	14.61	5.76	5.04	0.72
1300	15.59	5.88	5.38	0.50

Graph 2: Load (Kg) vs Indicated Mean Effective Pressure, Brake Mean Effective Pressure, Friction Mean Effective Pressure (bar)

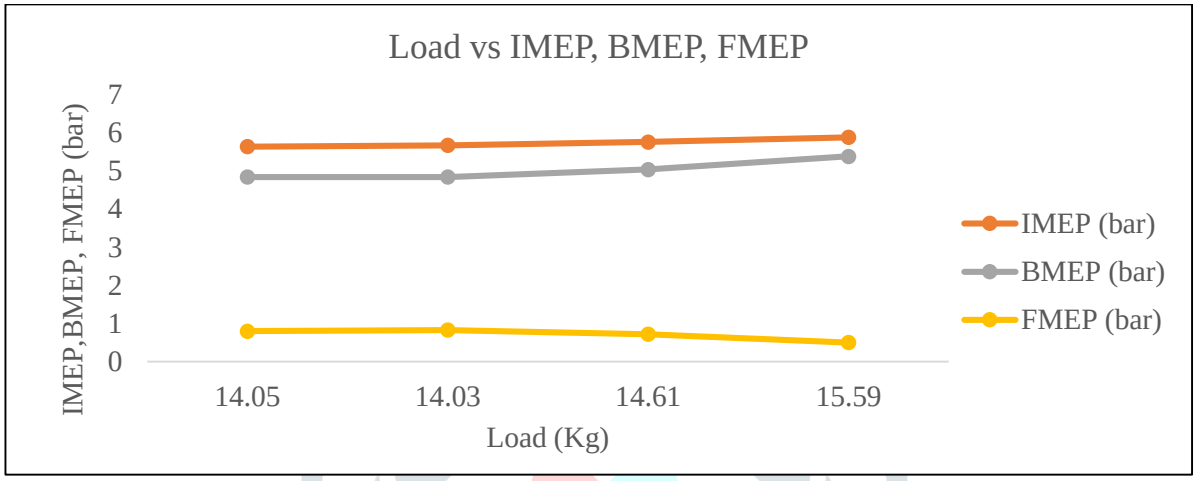


Table Shows the values of various speed (rpm), Load (Kg) ITH Eff, BTH Eff, Mech Eff, Vol Eff (%)

Speed (rpm)	Load (Kg)	ITH Eff (%)	BTH Eff (%)	MECH Eff (%)	Vol Eff (%)
1600	14.05	26.22	22.50	85.82	59.13
1500	14.03	26.08	22.55	85.33	59.05
1400	14.61	25.85	22.62	87.49	61.54
1300	15.59	25.09	22.93	91.42	68.13

Graph 3: Load (Kg) vs Indicated Thermal Efficiency, Brake Thermal Efficiency, Mechanical Efficiency, Volumetric Efficiency (%)

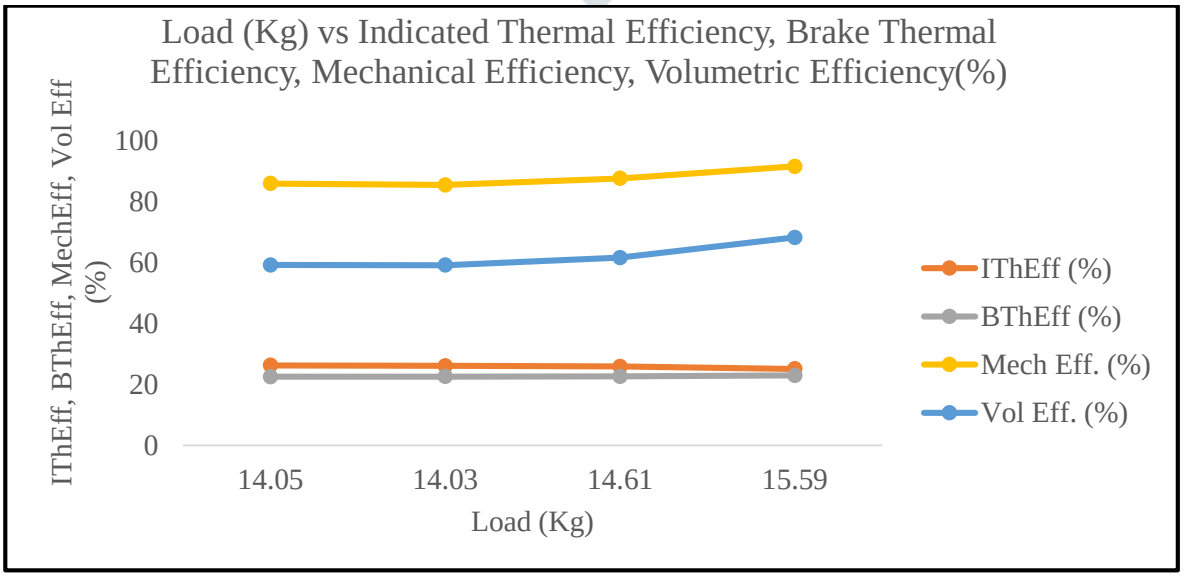


Table Shows the values of various speed (rpm), Load (Kg) and Torque (Nm)

Speed (rpm)	Load (Kg)	Torque (Nm)
1600	14.05	25.49
1500	14.03	25.46
1400	14.61	26.51
1300	15.59	28.30

Graph 4: Speed (rpm) vs Load (Kg) and Torque (Nm)

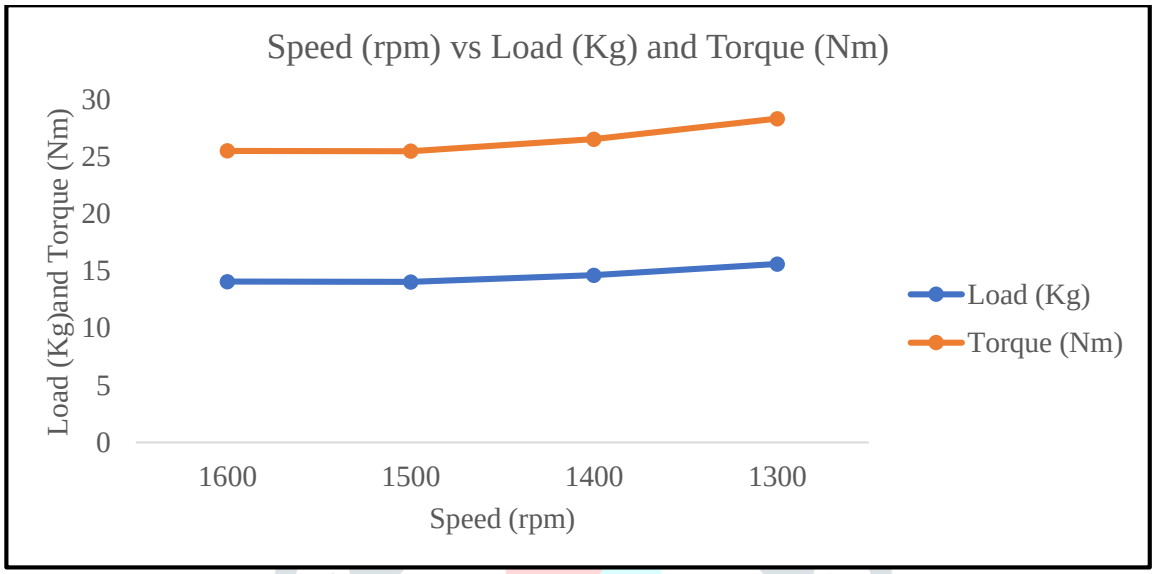
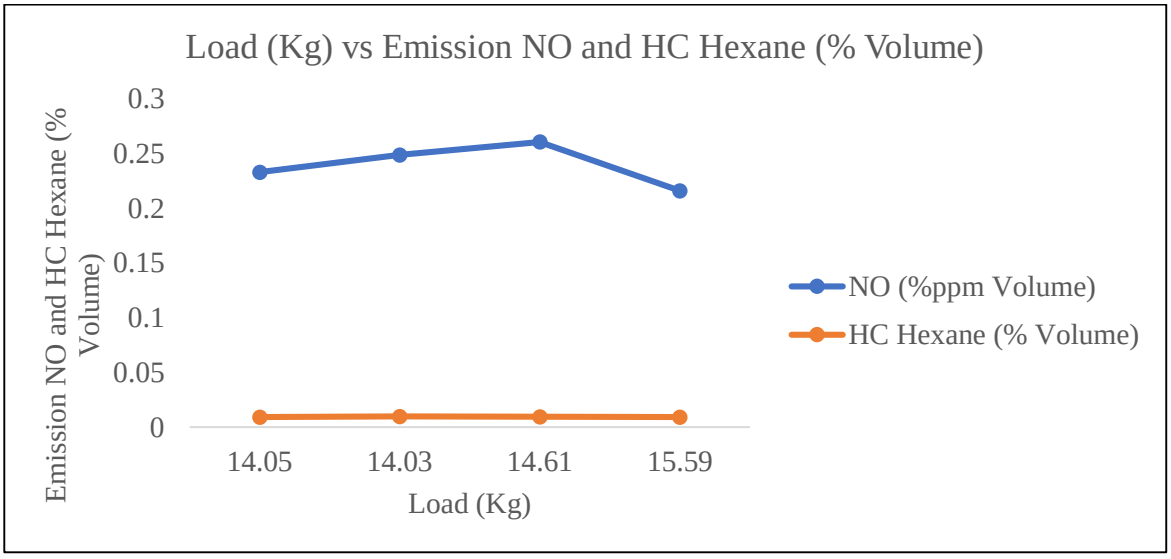


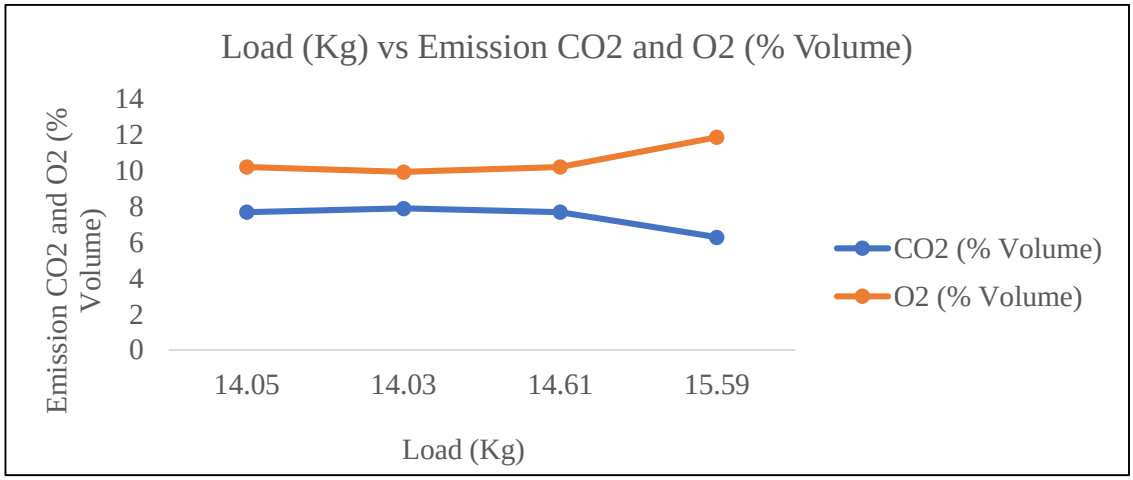
Table Shows the values of various speed (rpm), Load (Kg), Emission NO, HC Hexane, CO2 and O2 (%Volume)

Speed (rpm)	Load (Kg)	NO (% Volume)	HC Hexane (% Volume)	CO2 (% Volume)	O2 (% Volume)
1600	14.05	0.2329	0.0092	7.70	10.22
1500	14.03	0.2486	0.0098	7.90	9.94
1400	14.61	0.2605	0.0094	7.70	10.22
1300	15.59	0.2159	0.0092	6.30	11.88

Graph 5: Load (Kg) vs Emission NO and HC Hexane (%Volume)



Graph 6: Load (Kg) vs Emissions CO2 and O2 (%Volume)



4.1 Nomenclature used in Experimentation:

Sr no.	Terms	Full form	Sr no.	Terms	Full form
1.	IP	Indicated Power	8.	BTH Eff	Brake Thermal Efficiency
2.	BP	Brake Power	9.	MECH Eff	Mechanical Efficiency
3.	FP	Friction Power	10.	Vol Eff	Volumetric Efficiency
4.	IMEP	Indicated Mean Effective Pressure	11.	NO	Oxides of Nitrogen
5.	BMEP	Brake Mean Effective Pressure	12.	CO_2	Carbon dioxide
6.	FMEP	Friction Mean Effective Pressure	13.	O_2	Oxygen
7.	ITH Eff	Indicated Thermal Efficiency	14.	HC	Hydrocarbon

5. Observation for BS- VI fuel with Compression Ratio 10:

Engine Details:

IC Engine Setup under test is Research Petrol having 4.50 kW @ 1800 rpm which is 1 cylinder, Four Stroke, Variable Speed, Water cooled, Petrol Engine, with Cylinder Bore 87.50mm, Stroke Length 110.00 mm, Connecting Rod Length 234.00 mm, Compression Ratio 10, Swept Volume 661.45 cc.

Combustion Parameters:

Specific Gas Constant: 1.00 kJ/Kg k, Air Density: 1.17 Kg/m^3, Adiabatic Index: 1.41, Polytrophic Index: 1.74, Number of Cycles: 10, Cylinder Pressure Reference: 0, TDC Reference: 0.

Performance Parameters:

Orifice Diameter: 20.00mm, Orifice Coefficient of Discharge: 0.60, Dynamometer Arm Length: 185mm, Fuel Pipe Diameter: 14.50mm, Ambient Temperature: 27°C, Pulses Per Revolution: 360, Fuel Type: Petrol, Fuel Density: 740 Kg/m^3, Calorific Value of fuel: 42500 kJ/Kg.

Table Shows the values of various speed (rpm), Load (Kg), Indicated Power, Brake Power, Friction Power (kW)

Speed (rpm)	Load (Kg)	IP (kW)	BP (kW)	FP (kW)
1600	12.11	4.45	3.69	0.76
1500	12.31	4.35	3.53	0.81
1400	12.85	4.07	3.44	0.63
1300	13.22	3.81	3.30	0.51

Graph 7: Load (Kg) vs Indicated Power, Brake Power, Friction Power (kW)

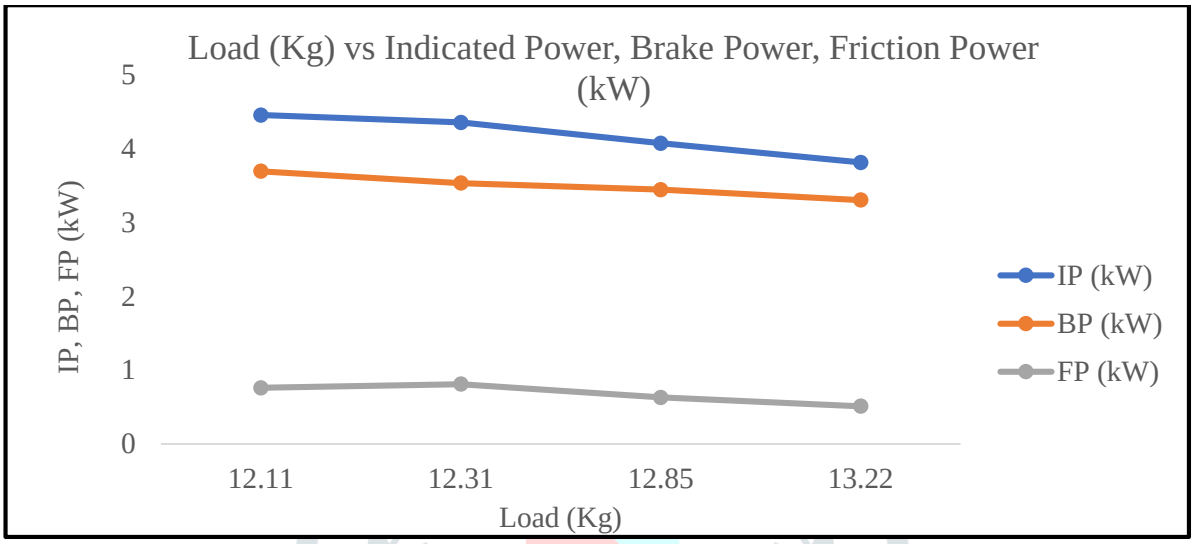


Table Shows the values of various speed (rpm), Load (Kg), Indicated Mean Effective Pressure, Brake Mean Effective Pressure, Friction Mean Effective Pressure (bar)

Speed (rpm)	Load (Kg)	IMPE (bar)	BMEP (bar)	FMEP (bar)
1600	12.11	5.03	4.17	0.86
1500	12.31	5.22	4.25	0.98
1400	12.85	5.24	4.43	0.81
1300	13.22	5.26	4.56	0.70

Graph 8: Load (Kg) vs Indicated Mean Effective Pressure, Brake Mean Effective Pressure, Friction Mean Effective Pressure (bar)

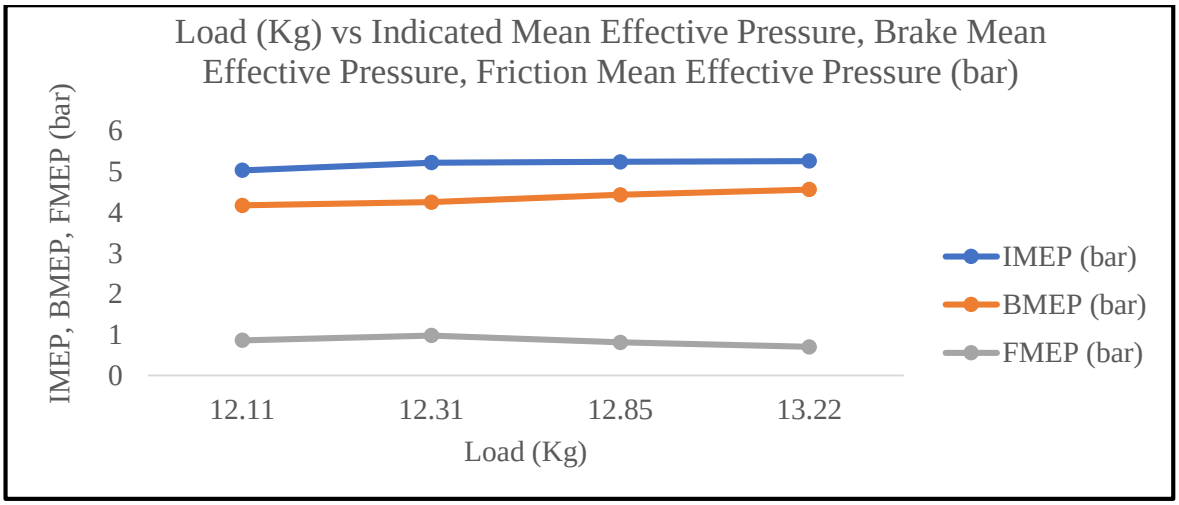


Table Shows the values of various speed (rpm), Load (Kg) ITH Eff, BTH Eff, Mech Eff, Vol Eff (%)

Speed (rpm)	Load (Kg)	ITH Eff (%)	BTH Eff (%)	MECH Eff (%)	Vol Eff (%)
1600	12.11	22.79	18.89	82.90	56.91
1500	12.31	25.02	20.33	81.26	59.75
1400	12.85	23.43	19.81	84.56	62.16
1300	13.22	22.62	19.59	86.61	64.51

Graph 9: Load (Kg) vs Indicated Thermal Efficiency, Brake Thermal Efficiency, Mechanical Efficiency, Volumetric Efficiency (%)

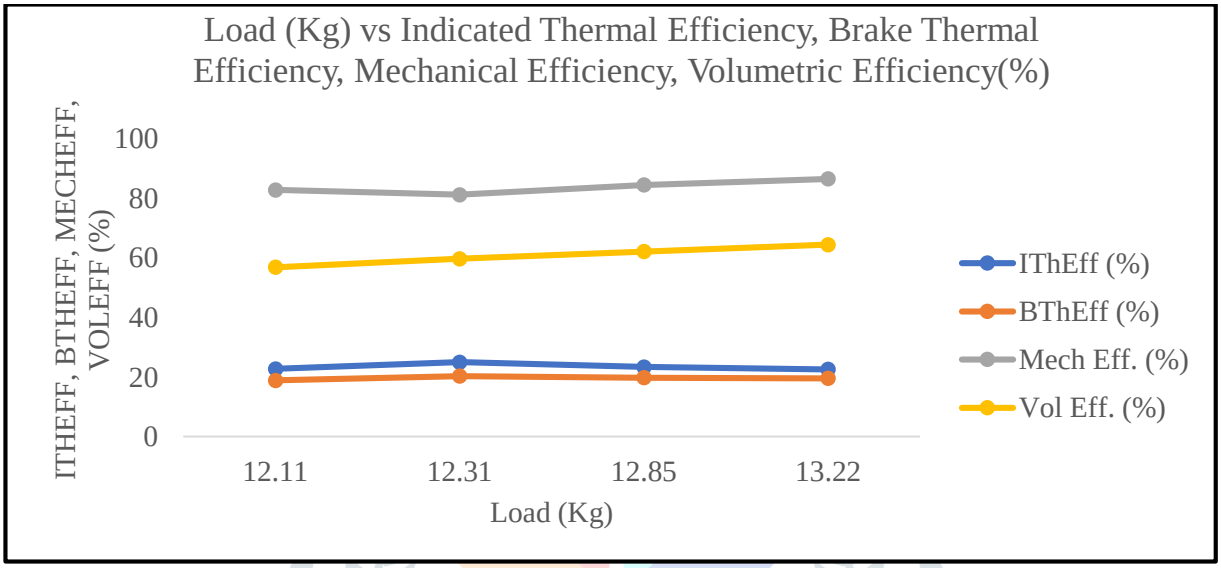


Table Shows the values of various speed (rpm), Load (Kg) and Torque (Nm)

Speed (rpm)	Load (Kg)	Torque (Nm)
1600	12.11	21.97
1500	12.31	22.34
1400	12.85	23.31
1300	13.22	23.99

Graph 10: Speed (rpm) vs Load (Kg) and Torque (Nm)

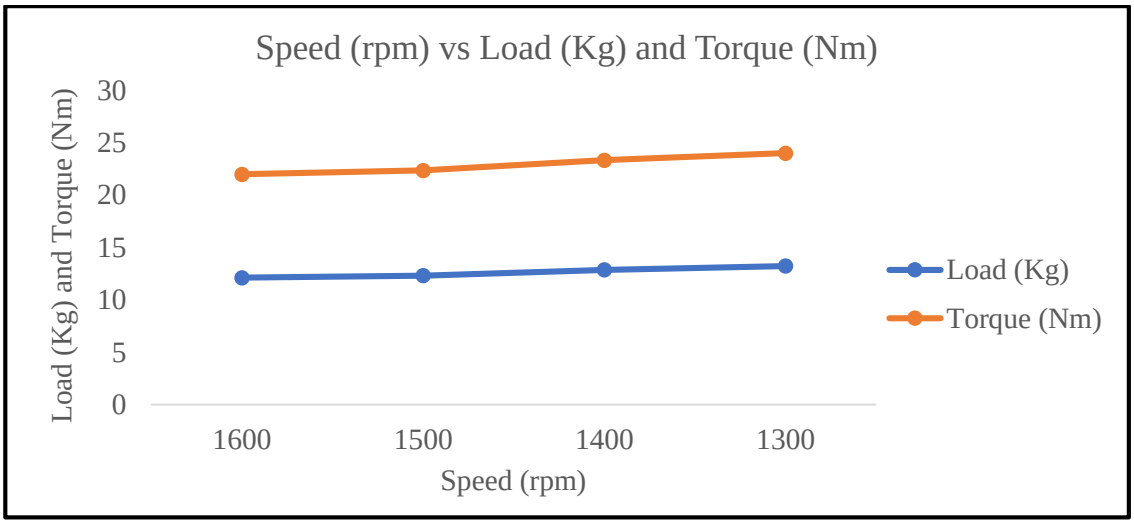
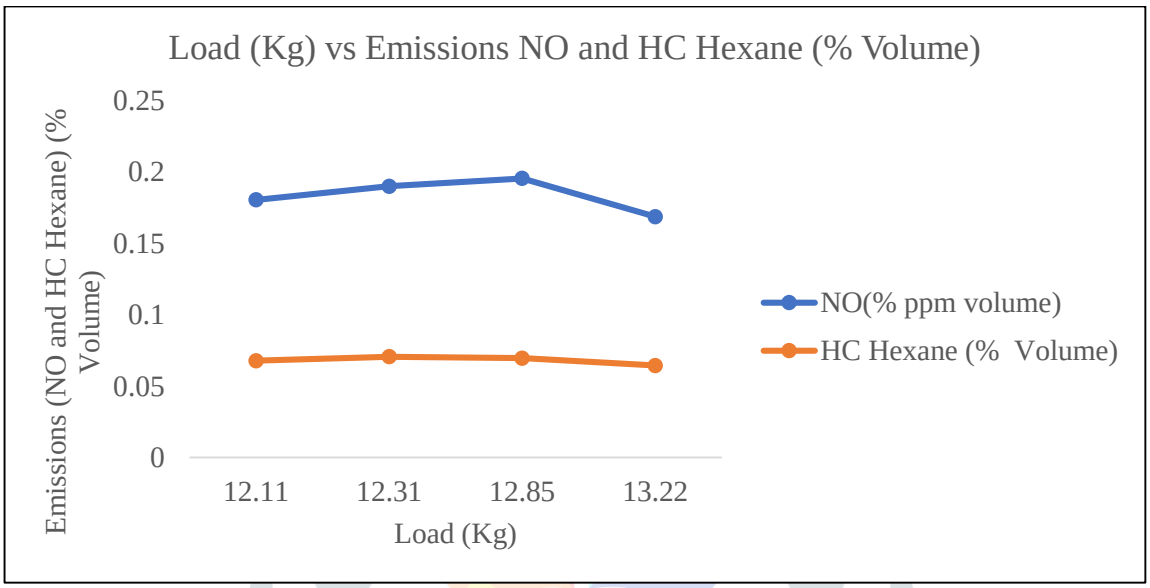


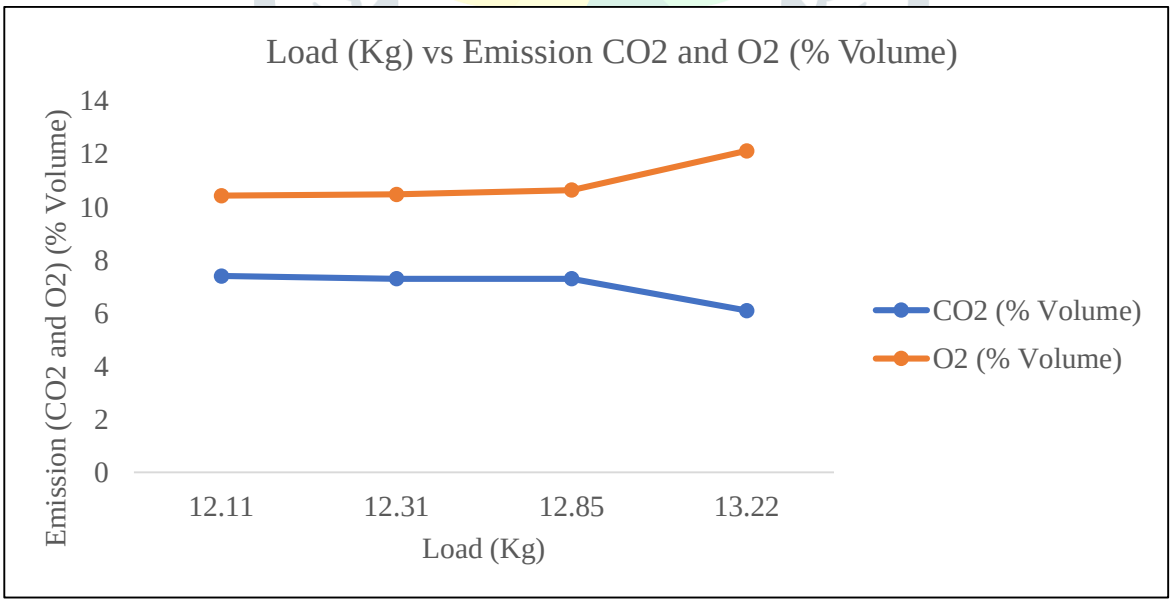
Table Shows the values of various speed (rpm), Load (Kg), Emission NO, HC Hexane, CO2 and O2 (%Volume)

Speed (rpm)	Load (Kg)	NO (% Volume)	HC Hexane (% Volume)	CO2 (% Volume)	O2 (% Volume)
1600	12.11	0.1804	0.0678	7.40	10.43
1500	12.31	0.1899	0.0706	7.30	10.48
1400	12.85	0.1954	0.0696	7.30	10.64
1300	13.22	0.1687	0.0645	6.10	12.12

Graph 11: Load (Kg) vs Emissions NO and HC Hexane (% Volume)



Graph 12: Load (Kg) vs Emissions CO2 and O2 (% Volume)



NOTE: - The testing is conducted by keeping the fuel supply constant and varying the load and the engine speed. Because of which there are difference in load parameter of the readings.

5.1 Nomenclature used in Experimentation:

Sr no.	Terms	Full form	Sr no.	Terms	Full form
1.	IP	Indicated Power	8.	BTH Eff	Brake Thermal Efficiency
2.	BP	Brake Power	9.	MECH Eff	Mechanical Efficiency
3.	FP	Friction Power	10.	Vol Eff	Volumetric Efficiency
4.	IMEP	Indicated Mean Effective Pressure	11.	NO	Oxides of Nitrogen
5.	BMEP	Brake Mean Effective Pressure	12.	CO_2	Carbon dioxide
6.	FMEP	Friction Mean Effective Pressure	13.	O_2	Oxygen
7.	ITH Eff	Indicated Thermal Efficiency	14.	HC	Hydrocarbon

6. Results:

Sr. No	Parameters	BS- IV CR- 10	BS- VI CR- 10	Remark
1.	NO (% Volume)	0.2394	0.1836	Decreases in BS- VI fuel as compared to BS- IV fuel
2.	CO_2 (% Volume)	7.40	7.02	Decreases in BS- VI fuel as compared to BS- IV fuel
3.	O_2 (% Volume)	10.565	10.917	Increases in BS- VI fuel as compared to BS- IV fuel
4.	HC (% Volume)	0.0094	0.0681	Increases in BS- VI fuel as compared to BS- IV fuel
5.	Indicated Power (kW)	4.747	4.178	Decreases in BS- VI fuel as compared to BS- IV fuel
6.	Brake Power (kW)	4.147	3.490	Decreases in BS- VI fuel as compared to BS- IV fuel
7.	Friction Power (kW)	0.6025	0.6767	Increases in BS- VI fuel as compared to BS- IV fuel
8.	Mechanical Efficiency (%)	87.515	83.832	Decreases in BS- VI fuel as compared to BS- IV fuel
9.	Torque (Nm)	26.44	22.90	Decreases in BS- VI fuel as compared to BS- IV fuel

All the above-mentioned results are calculated from the average of all the four readings of BS- IV CR10 and BS-VI CR10. And the Remark are based on the difference of the two readings.

From the above table we analyse that,

- After using the BS-VI fuel on BS-IV engine, there are variations in various parameters of the engine. Where NO and CO_2 is decreased in BS- VI fuel, but O_2 and HC are increased by small amount in BS-VI fuel as compared to BS- IV fuel.
- Indicated Power is the power developed inside the engine is decreased in BS- VI fuel as compared to BS- IV fuel.
- Brake power is the power available at the road wheels, it decreases in BS- VI fuel as compared to BS-IV fuel.
- Friction Power is the power loss due to friction in cylinder is Increased in BS- VI fuel as compared to BS- IV fuel.
- Mechanical Efficiency is the effectiveness of the machine in transforming input quantity to the mechanical output generated is decreased in BS- VI fuel as compared to BS- IV fuel.
- Torque is the force that tend to cause the rotation of the crankshaft is decreased in BS- VI fuel as compared to BS- IV fuel.

7. Conclusion:

- It is clear that the main difference in BS- IV and BS- VI petrol fuel is the reduction in the sulphur content of the fuel. As shown in Table 3 and Table 4.

  For Petrol Fuel:

  Sulphur content in BS- IV fuel: - 50 mg/Kg

  Sulphur content in BS- VI fuel: - 10 mg/Kg

  For Diesel Fuel:

  Sulphur content in BS- IV fuel: - 50 mg/Kg

  Sulphur content in BS- VI fuel: - 10 mg/Kg
- If we use BS- VI fuel in BS- IV engines, then there are variations observed in the engine parameters as well as in Emission from the Exhaust. The major Problem of BS- IV fuel is the NOx formation is greater. Which is reduced in BS- VI fuel, because of the low sulphur content in the fuel the burning of the sulphur is less. Hence, the temperature of the combustion reduces. So, NOx formation also reduces. Along with the use of Electronically controlled EGR (Exhaust Gas Recirculation) system the NOx formation will be controlled to the greater extent.
- Sulphur in fuel when burnt it combines with the oxygen and forms SOx (Oxides of Sulphur) which when released in the air pollute the air. Causing respiratory disorders to the humans. In BS- VI fuel the sulphur content is reduced so, this ultimately reduces the SOx (Oxides of Sulphur) formation.
- Sulphur act as a lubrication to the small gap in the fuel injectors. If the sulphur content from the fuel is reduced then it will cause friction in the injector operation and wearing of the injectors result in poor performance of the fuel injection operation resulting in decrease in overall performance of the engine. [6][10]
- Increase in O_2 and HC Hexane is the result of incomplete combustion. This can be reduced by proper turbulence of the air fuel charge in the combustion chamber leading to complete air-fuel mixture inside

combustion chamber. This proper turbulence can be achieved by redesigning the combustion chamber, incorporation of Turbo Charging with Intercooler, resulting in complete and clean combustion and reduction in exhaust emission.

- From the above Statement the HC and O_2 are the exhaust emission because of incomplete combustion. So, this incomplete combustion of the charge inside the engine reduces the Indicated Power developed inside the engine. Sulphur contributes to the calorific value of fuel. If the sulphur content of the fuel is reduced then calorific value of the fuel reduces. So, the Power produced inside the engine reduces. [11]
- Friction Power increases since, sulphur content in BS- VI fuel is less as compared to BS- IV fuel. The indicated power produced in the engine is reduced. So, power require to overcome friction will increase since engine is not able to develop the sufficient Indicated power. So frictional losses in more if BS- VI fuel is used in BS- IV engines. Also, the sulphur act as a lubricator in the very compact spaced components like fuel injectors. Hence, it also contributes in the wearing of the fuel injectors parts.
- The reduced Brake power of the engine can be recovered by the concept of Engine Downsizing, where the size of the engine is reduced along with modern fuel injection technology like GDI (Gasoline Direct Injection) system with the incorporation of Turbocharging and Intercooling resulting in higher the compression ration of the engine. Leading to complete combustion of the fuel with less emission in the exhaust. [1]

8. Future Scope:

- The government of India has made mandatory that as per the BS- VI norms, New generation Two-Wheelers will come with fuel Injector system and complex CDI system and advance catalytic converter to meet the emission norms. [1][9]
- The available stock of two- Wheeler with the Indian auto manufacturers can be converted to BS- VI vehicles by replacing the carburettor with the fuel injection system and new CDI system and catalytic converters. Similarly, for petrol and diesel cars also this will add up-to 20,000 to 30,000 INR to the vehicle ex- showroom Price. And for two wheelers it will add up to 10,000 to 15,000 INR to the vehicle ex- showroom price. [1][9]
- The new generation Four- Wheelers comes with GPF's (Gasoline Particulate Filter) and DPF's (Diesel Particulate Filter) along with SCR (Selective Catalytic Reduction) which tends to reduce HC, NO_X, and CO_2 by mixing AdBlue (AUS 32) an aqueous Urea Solution in the exhaust stream to break down the harmful emission to the less harmful exhaust. [1][6][7]
- The government of India has made a compulsion for the Delhi Peoples, to not to sell their vehicles in the other state, since RTO is not giving the NOC to the vehicle owners to sell the vehicles. In that case the vehicle owners in the Delhi NCR should maintain their vehicle timely to ensure the prime condition of the engine and less emission from the engine exhaust. [10]
- The GDI (Gasoline Direct Injection) system has a major dis-advantage that it produces more Particulate Matter on every combustion stroke in the engine. This will result in carbon deposits on the inlet valve chocking of the fuel injector jets leading to poor injection spraying. If this thing is not maintained timely

it will again create and increase the same problem for which it is designed to reduce the emission. [1][9][7]

9. Maintenance Tips:

1. Proper maintenance of the vehicle driveline is essential for the free motion of each and every rotating parts of the engine. It removes dirt, and sludges form the parts and it should be lubricated to ensure friction free moving of the vehicle.
2. Ensure timely replacement of the Purge Canister, since it absorbs the vapour of the fuel coming out of the fuel tank and prevent fuel vaporisation in air which causes 10 times more pollution then fuel burnt in combustion chamber.
3. Fuel Filter is the primary element in the supply of the clean fuel to the engine. If the fuel is free from dirt, dust and other kind of impurities then combustion will also be clean. Timely changing of the fuel filter is must to ensure healthy running of the engine.
4. Timely cleaning of the EGR valve is also necessary for complete utilization of fuel and NOx reduction. If the EGR valve is clogged then the performance of the engine will be reduced, the engine will produce more NOx.
5. Timely Cleaning or replacement of the DPF and GPF is essential to ensure free moving of the exhaust filtrate from the tailpipe. If the DPF, GPF is clogged then it creates backpressure on the engine.
6. In new BS-VI vehicles there are AdBlue (AUS 32) an aqueous Urea Solution tanks. Since it is a liquid so need to be refilled. So, whenever there is an engine oil change, these AdBlue (AUS 32) an aqueous Urea Solution tanks need to be refilled to ensure adequate quantity of AdBlue with the vehicle.

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