Performance Analysis of Emission Behaviour on Turbocharger And EGR in BS4 Vehicles Based on Fuel Efficiency

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Abstract- *This paper mainly deals with the performance behaviour of turbocharger and EGR in BS3, BS4 and BS6 vehicle. In day today life, automobile industries plays a major role in reduction of pollution from the various vehicles. Indian Government formed the sixth stage of emission norms to keep the pollution under control. Turbocharger and Exhaust Gas Recirculation (EGR) plays an important component of emission performance. So, from the customer point of view for better understanding how these two components performed in BS3, BS4 and BS6 vehicle. Based on the fuel efficiency, this paper analysis the few emission characteristics of turbocharger and EGR. Based on the results the stake holders can easily understand the new technology fitted in BS6 and how the results varied from these three stages of vehicles and it can be helpful to shift from Bharat stage III, Bharat Stage IV to Bharat Stage VI and we the citizen of India helps to maintain the nature as a futuristic resource of our Clean India.*

Keywords- Turbocharger, Exhaust Gas Recirculation (EGR), Emission, Pollution control, Bharat Stage III, Bharat Stage IV and Bharat Stage VI

I. INTRODUCTION

1.1 Bharat Stage 3 (BSIII):

BSIII regulation was first rolled out in 2005 and their sale was made mandatory across the nation by 2010. The introduction of the more stringent norms led to a remarkable reduction in emissions from petrol-powered passenger vehicles, with a maximum permissible Carbon Monoxide emission of 2.3 g/km, Hydro carbons + Nitrogen Oxides discharge of 0.35 g/km, and Respirable suspended particulate matter discharge of 0.05.

The diesel models emitted a peak carbon monoxide of 0.64 g/km, a nitrous oxide of 0.50 g/km, and Hydro carbons + Nitrogen Oxides discharge of 0.56 g/km. Furthermore, the Sulphur content in the Bharat Stage III-compliant fuels was restricted to 100 PPM.

Carmakers achieved compliance with the BSIII emissions by installing a catalytic converter that curbed the discharge of Carbon Monoxide and Hydrocarbons.

1.2 Bharat Stage 4 (BSIV):

Before we understand about BS6 emission or BS6 compliant engine, let's understand the current BS4 (BSIV) emission norms, engine, performance, and its significance.

ghThe BSES, which is the governing organization for emissions from all types of vehicles in the country, introduced the first emission norms with the name 'India 2000' in the year 2000. BS2 and BS3 were introduced in 2005 and 2010, while BS4 norms came into effect in 2017 with stricter emission standards or norms.

Among the regulations set by the governing body, emission-related changes included tailpipe emissions, Electronic Control Unit (ECU), ignition control, etc. The most visible change was the AHO (Automatic Headlamp On), this is one of the norms under the BS4 which catered to the safety aspect of the new emission standards.

1.3 Bharat Stage 6 (BSVI):

The governing body, Bharat Stage Emission Standards (BSES), regulates the output of pollutants from vehicles plying in the country. The Central Pollution Control Board which falls under the Ministry of Environment, Forest and Climate Change sets the standards to regulate emissions from vehicles in India.

The first emission standard or norm, introduced in the year 2000, was known as 'India 2000' and later, BS2 and BS3 were introduced in 2005 and 2010, respectively. While the

first three emission norms were introduced at regular intervals, BS4 was introduced in 2017, after a gap of seven years.
The BS6 emission standard is the sixth iteration of the emission norm and comparatively, it's a substantial leap in terms of reducing pollution compared to the outgoing BS4. This is also because the BS5 (BSV) has been skipped in an effort to move to better emission norms.

1.4 Difference between BS4 and BS6

Both BSIV and BSVI are emission norms that set the maximum permissible levels for pollutants emitting from a car or a two-wheeler exhaust. Compared to the BS4, BS6 emission standards are stricter. While manufacturers use this change to update their vehicles with new features and safety standards, the biggest or the significant change comes in the form of stricter permissible emission norms.

The below table offers an insight into the change in the permissible emission levels of BS6 vehicles compared to BS4 vehicles:

Fuel Type	Pollutant Gases	BS6 (BSVI)	BS4 (BSIV)
Petrol Passenger Vehicle	Nitrogen Oxide (NOx) Limit	<60mg>	<80mg>
Petrol Passenger Vehicle	Particulate Matter (PM) Limit	<4.5mg/km	-
Diesel Passenger Vehicle	Nitrogen Oxide (NOx) Limit	<80mg>	<250mg>
Diesel Passenger Vehicle	Particulate Matter (PM) Limit	<4.5mg/km>	<25mg>

Difference between BS4 and BS6

1.5 Emission Generated by Vehicles

The pollution emitted from vehicles in India is measured by government agencies. They use the Air Quality Index (AQI) to gauge the level of pollution in a city. The AQI uses the below criteria to measure emission:

- Sulfur Dioxide (SO2)
- Nitrogen Oxide (NO2)
- Carbon Monoxide (CO)
- Particulate Matter (PM)
- Ozone (OZ)

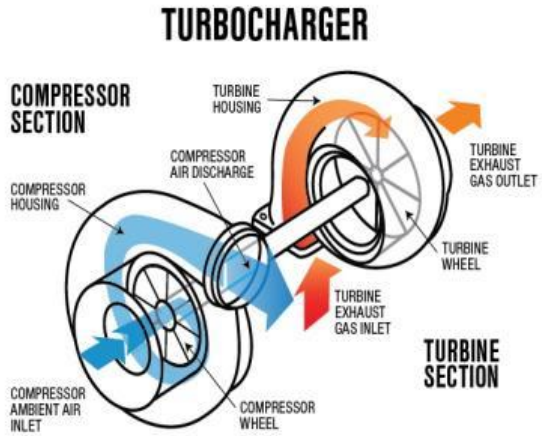
II. COMPONENTS DESCRIPTION

2.1 Turbocharger

A turbocharger is a device fitted to a vehicle's engine that is designed to improve the overall efficiency and increase performance. This is the reason why many auto manufacturers are choosing to turbocharge their vehicles. The new Chevrolet Trax and Equinox are both offered with turbocharged engines and as time goes on, more and more vehicles will be fitted with them.

2.2 Working of Turbocharger

A turbo is made up of two halves joined together by a shaft. On one side, hot exhaust gasses spin the turbine that is connected to another turbine which sucks air in and compresses it into the engine. This compression is what gives the engine the extra power and efficiency because as more air can go in the combustion chamber, more fuel can be added for more power.



Pictorial diagram of Turbocharger

2.3 Advantages and Disadvantages of Turbocharger

Turbochargers are sometimes referred to as devices that offer "free power" because unlike a supercharger, it does not require the engine's power to drive it. Turbocharged engines are also not affected in the same way as naturally aspirated engines are when they go at higher altitudes. Turbochargers also improve the fuel efficiency of a vehicle however there is a misconception when it comes to turbocharged vehicles and fuel efficiency.

Firstly is heat. Because a turbo is powered by hot exhaust gasses, it gets very hot. Sometimes under certain

engine conditions, the turbocharger itself could start glowing red but of course this doesn't happen in everyday driving conditions. The other big disadvantage of a turbocharger is something called turbo lag. Under certain conditions, whenever you put your foot down on the throttle, there is a delay between the time you demand power from the engine and the moment you actually start to feel it.

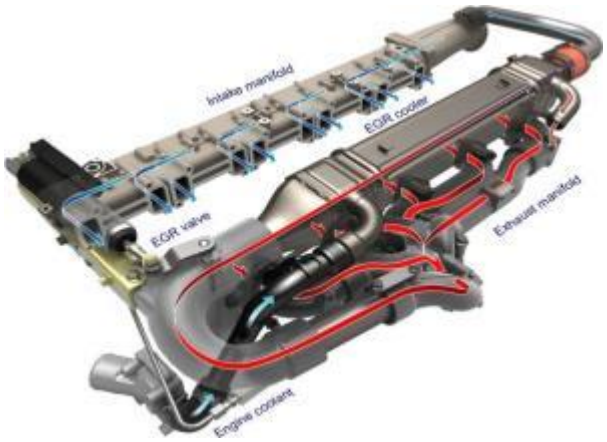
2.4 Exhaust Gas Recirculation (EGR)

Exhaust Gas Recirculation refers to the redirection of the exhaust gases after the combustion process and use it to achieve various goals in the engine of the vehicle. This could range from controlling the temperature inside the combustion chamber to improving the fuel economy of a car and everything in between. As we know, the quality of air inside the combustion chamber, the ignition process, pressure and temperature inside the engine decide all the performance, fuel and emission parameters and output of a car, tweaking these could bring in a ton of benefits in all these regards. That is the reason why so much research has gone into these aspects and new technologies keep coming up as the emission and performance requirements keep on increasing. Governments are always bringing in tougher emission regulations to keep the environmental pollution in check and the customers are looking for more powerful or more fuel-efficient cars at the same time.

These are the reasons why coming up with new technologies to tackle all these issues is an absolute must. Because these technologies are becoming extremely expensive and the mission regulations are becoming stricter day by day, the industry is rapidly heading towards electrification. This includes hybrid and fully electric powertrains primarily to combat the issue of pollution and fuel economy. Granted, electrification is an expensive affair at the moment, but with time, the technology with becoming widely adopted and the volumes will increase reducing the cost substantially. We might eventually the same cost of the car powered by either electricity or an internal combustion engine. While that might be a bit far away, we will have to do with techniques like the EGR for now.

2.5 Working of Exhaust Gas Recirculation

The working of this process is fairly simple but the implications are impressive. There is an EGR-valve fixed after the exhaust manifold and before the catalytic converter. This valve opens and redirects some of the exhaust gases back to the intake manifold, where these are mixed with fresh air. Once mixed, the concentration of the oxygen in the fresh air is reduced and the temperature of the fresh air is increased slightly. Now, the exhaust gases are inert gases because they have already been burnt and free oxygen is not present in the exhaust gases. Therefore, the Nitrogen in the air is not able to react with the excess oxygen and the formation of NOx (Nitrogen Oxides) is decreased. This is one of the most harmful gases in the exhaust of a car and is required to be controlled according to the emission laws. By being inert in nature, these gases prevent the combustion to reach high temperatures where all the harmful toxic gases are formed. Sometimes, an EGR cooler is also attached to the components before mixing it with the fresh air to reduce the temperature of the combustion



Components of EGR

At high RPMs, the combustion process is very fast and the piston moves up and down quickly. This results in almost complete combustion which is efficient in every way. However, during day-to-day operation, an engine is not always at full load (accelerator pedal pressed completely) and hence, there are always free Oxygen molecules in the combustion chamber from the fresh air which have not been burnt.

2.6 Advantages and Disadvantages of EGR

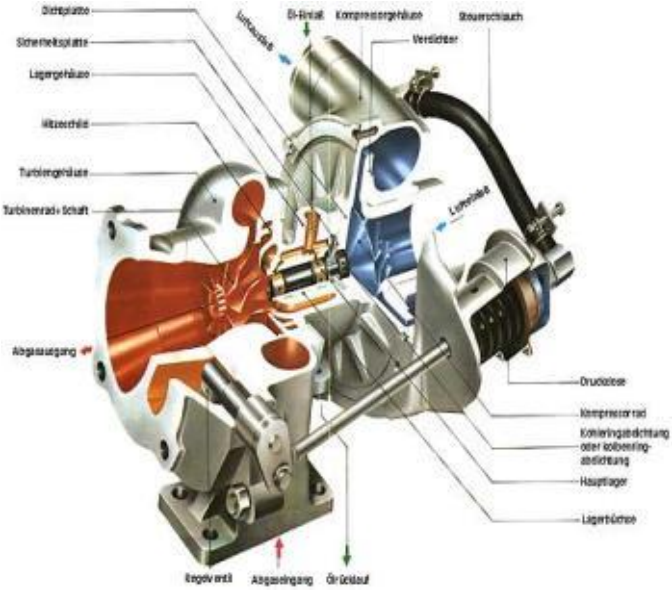
There are plenty of advantages to EGR including reduced fuel consumption, controlling of temperature and pressure inside the combustion chamber, reduction of harmful and toxic pollutants and a ton more. In the case of diesel engines, the ignition lag is contained under low load conditions.

Disadvantages to this technique but the one point of contention in the case of petrol engines could be engine knock. Because the temperature is slightly increased due to the addition of exhaust gases.

III. CONDITIONS OF TURBOCHARGER AND EGR

3.1 Normal Conditions of Turbocharger

Before Turbocharger diagnostic, initially turbocharger dismantle from the engine and the manual testing is carried out whether the blade of the turbocharger is good or bad and either it will cloaked by dirt or fuel adulteration particles.



Cut section of Turbocharger

Bad condition of Turbocharger component

The condition of turbocharger is badly affect, then the performance of the turbocharger gives improper results, it will leads to the result in emission. This type of problems happened because of varying of sudden throttle and breaking, it leads to affect the shoe towel or washer or bolt injection. If any one of these affected leads to improper functioning of turbocharger and the result varying the emission of the vehicles.

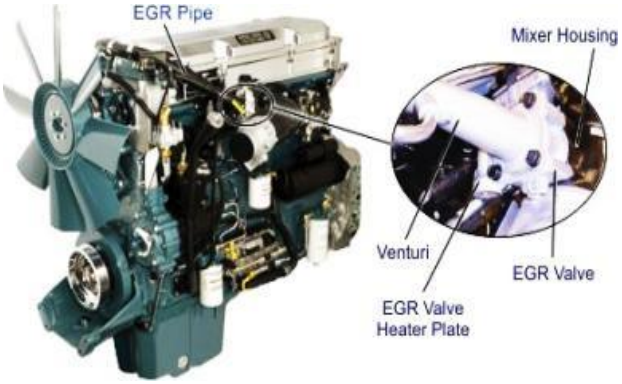
3.2 Turbocharger – if fails

A turbocharger is an air pump, which supplies air for the engine combustion process at higher pressure and density than ambient air. The turbocharger air contains a higher concentration of oxygen allowing greatly improved combustion, for more power, cleaner emissions, improved engine torque output and reduces the pumping losses within the engine offering all-round better performance.

As an integral part of the engine's oil, fuel, air and cooling systems, any faults in these systems, can cause an incorrect turbo operation and potentially damage.

3.3 Normal Conditions of EGR

EGR plays a vital role in range from controlling the temperature inside the combustion chamber to improving the fuel economy of a car and everything in between. As we know, the quality of air inside the combustion chamber, the ignition process, pressure and temperature inside the engine decide all the performance, fuel and emission parameters and output of a car, tweaking these could bring in a ton of benefits in all these regards.



Components of EGR

3.4 EGR – if fails

EGR is blocked due to fuel imbalance and air mixer. So, the continuous H2 + CO from the D-EGR cylinder, it will continuously allow the same from the line. So, that automatically the EGR corrupt and blocked.

Bad condition of EGR

IV. EXPERIMENTAL PROCEDURE

This research paper is carrying with BSIII & BSIV vehicle for analysis the turbocharger and EGR in Mahindra & Mahindra Logan BSIII & BSIV engine.

These two engine are connected with system having Diagnostic software DCM 1.2. software. Initially the engine is running in idle position, once egr and turbocharger having get signal and voltage from the ECM and battery, the diagnostic tool analysis the performance of turbocharger and egr and show the results in the respective pop up in the software window.

Based on the result from the fuel circuit, emission controlled and turbocharger air inlet, we can study the performance of these two components.

BSIV Vehicle VIN plate

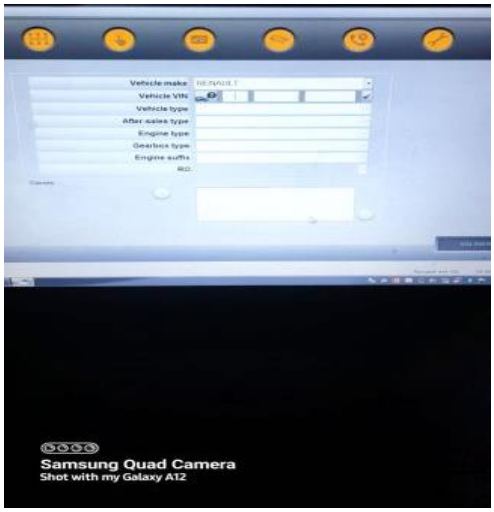
BS III Vehicle VIN plate

The pollution results are taken from the pollution certificate of the same BSIII & BSIV engine and the results are analyzed and compared with the other Bharat Stage vehicles.

While taking the analysis of emission performance from the turbocharger and egr, every time the before analysis fuel is to change because of adulteration of fuel is also cause one of the factors in the pollution. So, change the fuel from separate bunk, fueling the tank with different bunk with 5 liters of fuel.

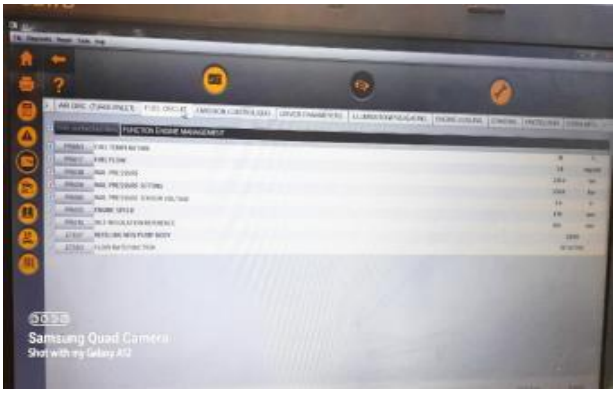
Before fuel fueling, tank is to be cleaned and dried at room temperature. Once the fuel is fueled from the bunk, the engine is started and running in idle time for few minutes, then only the previous diesel in the diesel line, diesel injector are totally burned out. After a stipulated time engine running, then experiment is to be carried out with turbocharger and egr.
This procedure is repeated from fueling in Indian Oil, Bharat, Reliance and the performance results in taken with help of diagnostic software and the results are compared and analyzed.

Software view of BS III

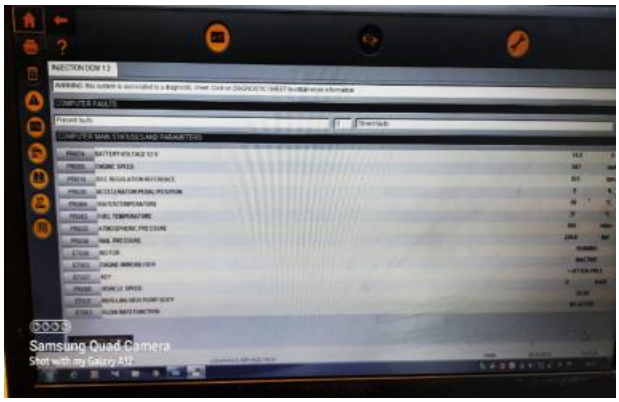


Software view of BS IV

V. EXPERIMENT RESULTS

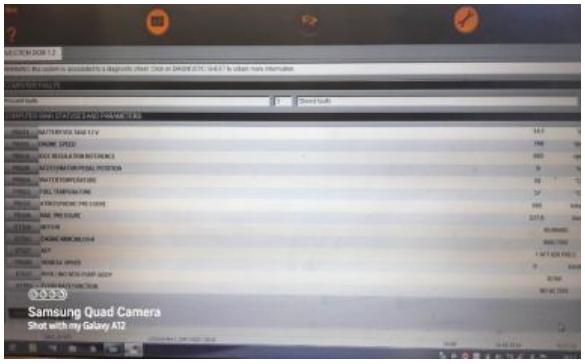


Fuel circuit view in software tool for BS III vehicle

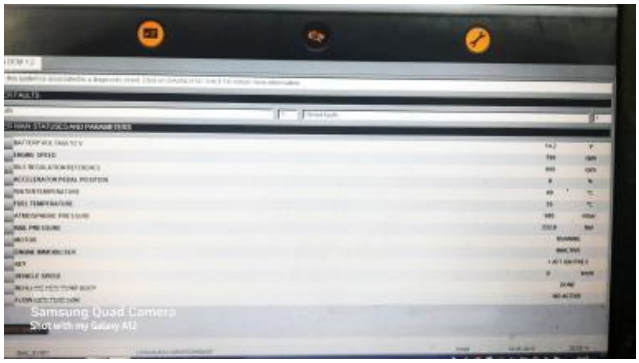


Overall circuit view in software tool for BS III ve**h**icle

Fuel circuit view in software tool for BS IV vehicle



Overall circuit view in software tool for BS IV vehicle



General Parameters from diagnostic sheet of software tool

For our project discussion and review, these are the data's we are taken from the diagnostic tool software.

This project mainly deals with the emission performance so, we concentrate and choose the fuel circuit, emission control circuit, air circulation circuit for analyze the emission performance.

Form 59

[See rules 115 (2)]

Pollution Under Control Certificate

Authorised By :
State Transport Department

Date	:	01/06/2022
Time	:	17:41:55 PM
Validity upto	:	30/11/2022

Certificate SL. No.	:	TN08800070015735
Registration No.	:	TN02AB4671
Date of Registration	:	25/May/2007
Month & Year of Manufacturing	:	May-2007
Valid Mobile Number	:	******5969
Emission Norms	:	BHARAT STAGE II
Fuel	:	DIESEL
PUC Code	:	TN0880007
GSTIN	:	
Fees	:	Rs.60.00(GST as applicable)
ML observation	:	No

Vehicle Photo with Registration plate
60 mm x 30 mm

Sr. No.	Pollutant (as applicable)	Units (as applicable)	Emission limits	Measured Value (upto 2 decimal places)
1	2	3	4	5
Idling Emissions	Carbon Monoxide (CO)	percentage (%)		
	Hydrocarbon, (THC/HC)	ppm		
High idling emissions	CO	percentage (%)		
	RPM	RPM	2500 ± 200	
	Lambda	-	1 ± 0.03	
Smoke Density	Light absorption coefficient	1/metre	2.45	1.0

This PUC certificate is system generated through the national register of motor vehicles and does not require any signature.

Note : 1. Vehicle owners to link their mobile numbers to registered vehicle by logging to https://vahan.parivahan.gov.in

Authorised Signature with stamp of PUC operator
60mm x 20 mm

Pollution certificate of BS IV

Form 59

[See rules 115 (2)]

Pollution Under Control Certificate

Authorised By :
State Transport Department

Date	:	01/06/2022
Time	:	17:40:16 PM
Validity upto	:	30/11/2022

Certificate SL. No.	:	TN08800070015734
Registration No.	:	TN66F5018
Date of Registration	:	04/Jul/2012
Month & Year of Manufacturing	:	June-2012
Valid Mobile Number	:	******3969
Emission Norms	:	BHARAT STAGE III
Fuel	:	DIESEL
PUC Code	:	TN0880007
GSTIN	:	
Fees	:	Rs.60.00(GST as applicable)
ML observation	:	No

Vehicle Photo with Registration plate
60 mm x 30 mm

Sr. No.	Pollutant (as applicable)	Units (as applicable)	Emission limits	Measured Value (upto 2 decimal places)
1	2	3	4	5
Idling Emissions	Carbon Monoxide (CO)	percentage (%)		
	Hydrocarbon, (THC/HC)	ppm		
High idling emissions	CO	percentage (%)		
	RPM	RPM	2500 ± 200	
	Lambda	-	1 ± 0.03	
Smoke Density	Light absorption coefficient	1/metre	2.45	1.13

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Note : 1. Vehicle owners to link their mobile numbers to registered vehicle by logging to https://vahan.parivahan.gov.in

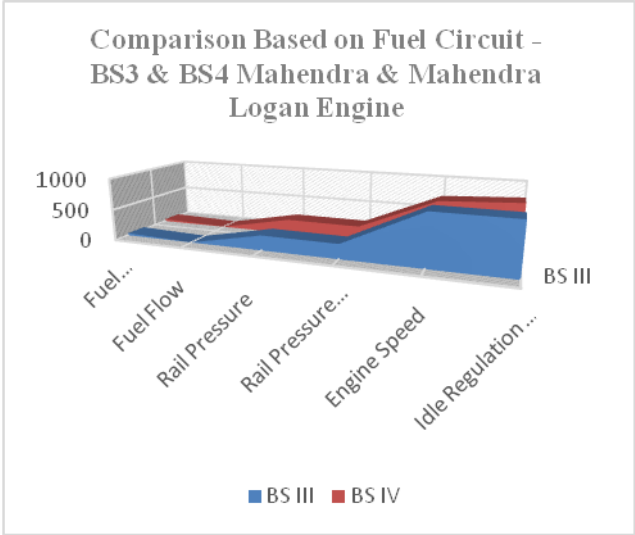
Authorised Signature with stamp of PUC operator
60mm x 20 mm

Pollution certificate of BS III

VI. EXPERIMENTS DATA AND ANALYSIS

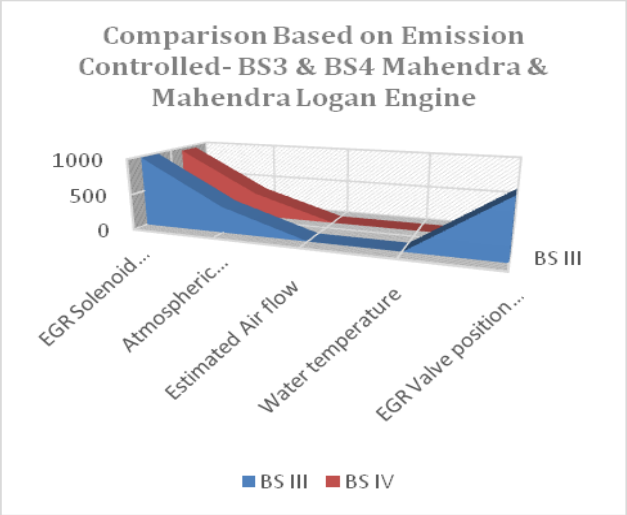
Comparison Based on Fuel Circuit - BS3 & BS4 Mahendra & Mahendra Logan Engine

Sl. No	Parameters	BS III Value	BS IV Value
1	Fuel Temperature (°C)	36	34
2	Fuel Flow (mg/stroke)	1.8	3.8
3	Rail Pressure (bar)	236.4	234.4
4	Rail Pressure Settings (bar)	230	230
5	Engine Speed (rpm)	810	739
6	Idle Regulation Reference (rpm)	805	800



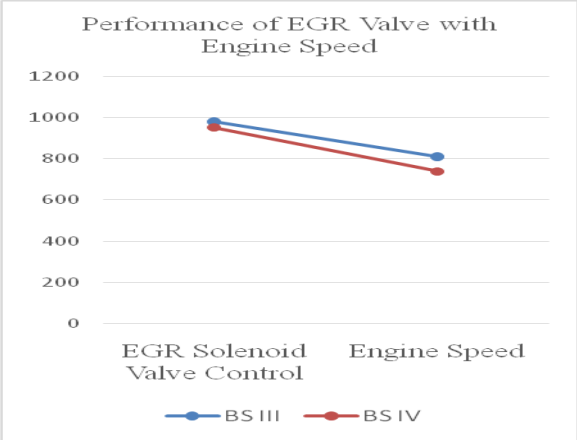
Comparison Based on Emission Controlled - BS3 & BS4 Mahendra & Mahendra Logan Engine

Sl. No	Parameters	BS III Value	BS IV Value
1	EGR Solenoid Valve Control (mbar)	980	950
2	Atmospheric pressure (mg/stroke)	365.5	350.4
3	Estimated Air flow (mg/stroke)	1.6	1.8
4	EGR Valve opening reference (%)	0	0
5	EGR Valve position sensor (%)	0	0
6	Water temperature (°C)	54	50



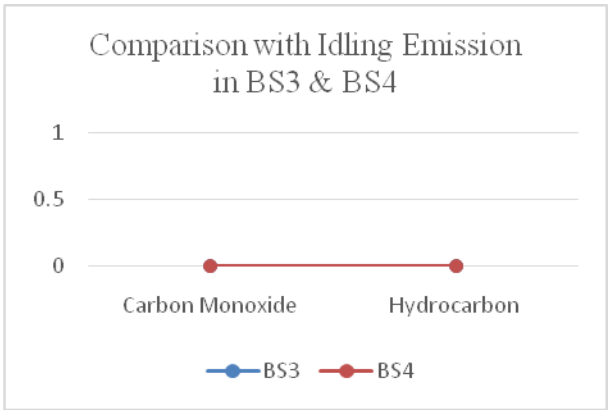
Comparison between BS3 & BS4 based on EGR Solenoid Valve control along with Engine speed

Sl. No	Parameters	BS III Value	BS IV Value
1	EGR Solenoid Valve Control (mbar)	980	950
2	Engine Speed (rpm)	810	739



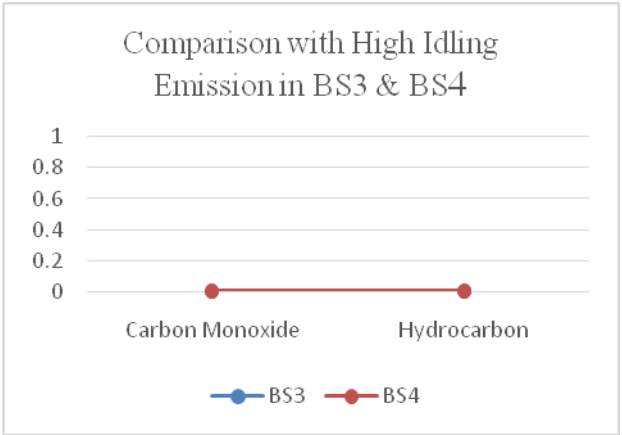
Comparison between BS3 & BS4 based on Smoke Density

Sl. No	Parameters	Pollutants (as applicable)	Emission Limits	BS3	BS4
1	Idling Emission	Carbon Monoxide	% Percentage	-	-
2		Hydrocarbon	PPM	-	-
3	High Idling Emission	Carbon Monoxide	% Percentage	-	-
4		RPM	2500±200	-	-
5	Smoke Density	Light absorption coefficient	2.45	1.0	1.13



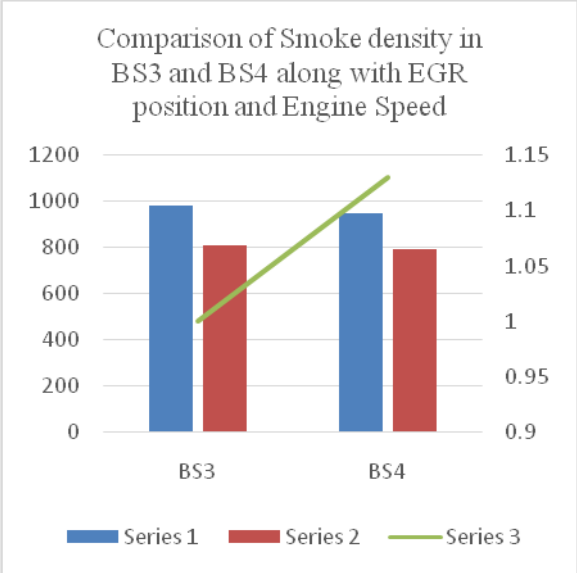
Graph analysis between BS3 & BS4 based on Idling Emission

Sl. No	Parameters	BS III Value	BS IV Value
1	EGR Solenoid Valve Control	980	950
2	Engine Speed	810	739
3	Smoke Density	1.0	1.13



Graph analysis between BS3 & BS4 based on High Idling Emission

Comparison between BS3 & BS4 based on smoke density



VII. DISCUSSION AND REVIEW

In this paper, we had analyzed few parameters from the experiments results. Before started the experiments, we fueled the tank with diesel 5 liters and running the engine more than half an hour to measure the reading from the software.

Once we connected the system software with Mahendra and Mahendra Logan BS III and BS IV vehicle, the initial reading was noted in tabular form as in Comparison between BS3 & BS4 Mahendra & Mahendra Logan Engine Based on Fuel Circuit.

we analysed the fuel flow and engine speed values varied, for controlling the engine speed in ideal the fuel flow is more in BS IV when compared with the BS III. It is shown in the Figure No. 7.1 Graph analysis between BS3 & BS4 Mahendra & Mahendra Logan Engine Based on Fuel Circuit
Comparison made between BS3 & BS4 Mahendra & Mahendra Logan Engine Based on Emission Controlled. For controlling EGR Solenoid valve, the BS IV vehicle consume less air flow. So, in BS IV technology less air consume more controlling of EGR Solenoid valve, therefore BS IV EGR efficiency good enough when compared to BS III vehicle.
we can easily analysed that, BS IV vehicle more good enough in technology wise so that it gives less engine speed while in idling time and also EGR solenoid valve also gives better efficiency compared to BS III vehicle technology.

From the overall slow idling and high idling emission control is good in both the cases of BS III and BS IV vehicle.

Finally, we compare the smoke density value of BS III and BS IV vehicle from the pollution certificate and got the little deviation of 0.13 high in BS IV vehicle. Even though the engine speed and EGR solenoid valve is better performance but little deviation from the smoke density of BS III Vehicle.
It has mainly happened because of turbocharger component having little clearance in that component.

Incase, according to our project perspective, if every component have to go periodic maintenance and cleaning. Episodic troubleshooting is must for our vehicle. It is mandatory for all the vehicles, then only customer came to know that the performance of the individual component of the vehicle.

VIII. CONCLUSION

In case of fuel specifications in terms of BSVI the main understanding is that the consequence of the fuel effects on the emission of controlled air pollutants has reduced because of the recent advancements in the engine after treatment technologies. For controlling the emission, even some unburnt gases like Nox, CO and other emission pollutant everything will completely burned with the help of emission controlling fluid which was added in the engine. The BS IV and BS III engine also having less pollutant of emission if the customer have to periodic assessment done in turbocharger and EGR valve to make better emission control and make our future India clean.

Every citizen of India have to make a responsibility for futuristic clean and green India.

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