PG Student Sunil Kumar Sen, ,2020, 8:6
ISSN (Online): 2348-4098
ISSN (Print): 2395-4752

Comparative Performance and Emission Analysis of BS-IV and BS-VI Diesel Fuel using BS-III C.I. Engine

PG Student Sunil Kumar Sen, Asst. Prof. Anoop Kumar Pathariya , Asst.Prof. Hitesh Khare
Department of Mechanical Engineering
TIT Bhopal, M.P. India

Abstract- Generally, Internal combustion engines (ICEs) are primarily responsible for the production of carbon dioxide (CO2), carbon monoxide (CO), hydrocarbons (HC) and oxides of nitrogen (NOx). Particulate matter (PM) or carbon soot, is another by-product of diesel as well as direct-injection petrol engines. To reduce vehicular pollution, Government of India introduced BS-VI vehicular emission standard in place of BS- IV. So India is all set to move to a BS-VI future. The Bharat stage -VI emission norms is the advanced emission standard for the automobiles and is equivalent to Euro-VI norms currently in place across countries in Europe. Due to this leading auto makers had to hike their investments to upgrade existing models and make them BS-VI technology. Therefore, in this study an attempt has been made to compare the performance characteristics following parameters were studied: Brake power, mechanical efficiency, Brake mean effective pressure, specific fuel consumption, Brake thermal efficiency and volumetric efficiency. Further emission analysis of BS-IV and BS-VI Diesel fuel in C.I. Engine was also analyzed. Results indicate that BS-VI diesel fuel has higher performance characteristics and lower emission level than BS-IV diesel fuel.

Keywords- Bharat Stage-IV, Bharat Stage -VI, Euro- VI Emission standards, I.C Engines, C.I engine

I. INTRODUCTION

Bharat stage emission standards (BSES) are emission standards governed by the Government of India to monitor the emission quality from IC engines and SI engines. The standards and implementation guidelines were set by the Central Pollution Control Board working under the Ministry of Environment, Forest and Climate Change.

[1] In 2000 these standards were introduced based on European regulations. Progressively stringent norms have been rolled out since then. All new vehicles manufactured after the implementation of the norms have to be compliant with the regulations.[2] Since October 2010, Bharat Stage (BS) III norms have been enforced across the country. In 13 major cities, Bharat Stage IV emission norms have been in place since April 2010[3] and it has been enforced for entire country since April 2017. In 2016, the Indian government announced that the country would skip the BS V norms altogether and adopt BS VI norms by 2020.[4] In its recent judgment, the Supreme Court has banned the sale and registration of motor vehicles conforming to the emission standard Bharat Stage IV in the entire country from 1 April 2020.[5] On 15 November 2017, the Petroleum Ministry of India, in consultation with public oil marketing companies, decided to bring forward the date of BS VI [6] grade auto fuels in NCT of Delhi with effect from 1 April 2018 instead of 1 April 2020.

In fact, Petroleum Ministry OMCs were asked to examine the possibility of introduction of BS VI auto fuels in the whole of NCR area from 1 April 2019. This huge step was taken due the heavy problem of air pollution faced by Delhi which became worse around 2019. The decision was met with disarray by the automobile companies as they had planned the development according to roadmap for 2020. The phasing out of 2-stroke engine for two wheelers, the cessation of production of the Maruti 800, and the introduction of electronic controls have been due to the regulations related to vehicular emissions.[7] While the norms help in bringing down pollution levels, it invariably results in increased vehicle cost due to the improved technology and higher fuel prices. However, this increase in private cost is offset by savings in health costs for the public, as there is a lesser amount of disease-causing particulate matter and pollution in the air. Exposure to air 2 pollution can lead to respiratory and cardiovascular diseases, which is estimated to be the cause for 620,000 early deaths in 2010, and the health cost of air pollution in India has been assessed at 3% of its GDP.

The first emission norms were introduced in India in 1991 for petrol and 1992 for diesel vehicles. These were followed by making the Catalytic converter mandatory for petrol vehicles and the introduction of unleaded petrol in the market.[8] On 29 April 1999 the Supreme Court of India ruled that all vehicles in India have to meet Euro I or India 2000 norms by 1 June 1999 and Euro II will be mandatory in the NCR by April 2000. Car makers were not prepared for this transition and in a subsequent judgement the implementation date for Euro II was not enforced.

[9] [10] In 2002, the Indian government accepted the report submitted by the Mashelkar committee. The committee proposed a road map for the roll-out of Euro based emission norms for India. It also recommended a phased implementation of future norms with the regulations being implemented in major cities first and extended to the rest of the country after a few years.[11] Based on the recommendations of the committee, the National Auto Fuel policy was announced officially in 2003.

The roadmap for implementation of the Bharat stage norms were laid out until 2010. The policy also created guidelines for auto fuels, reduction of pollution from older vehicles and R&D for air quality data creation and health administration.[12]

Villafuerte et. al. [13] conducted a comprehensive study on the real-time on-road emissions of NOx, NH3, N2O and PN from a Euro VI HDV equipped with a Diesel Oxidation Catalyst (DOC), a Diesel Particle Filter (DPF), a Selective Catalytic Reduction (SCR) system and an Ammonia Oxidation Catalyst (AMOX) is presented. Our analyses revealed that up to 85% of the NOx emissions measured during the tests performed are not taken into consideration if the boundary conditions for data exclusion set in the current legislation are applied. In another study conducted by Bertoa et. al. [14] studied the impact that cold ambient temperatures have on Euro 6 diesel and spark ignition (including: gasoline, ethanol flex-fuel and hybrid vehicles) vehicle emissions using the World harmonized Light-duty Test Cycle (WLTC) at -7°C and 23 °C. Results indicate that when facing the WLTC at 23°C the tested vehicles present emissions below the values set for type approval of Euro 6 vehicles (still using NEDC),

with the exception of NOx emissions from diesel vehicles that were 2.3-6 times higher than Euro 6 standards. Carslawa and Tyler et al. [15] report the first direct measurements of nitrogen dioxide (NO2) in the UK using a vehicle emission remote sensing technique. Measurements of NO, NO2 and ammonia (NH3) from almost 70,000 vehicles were made spanning vehicle model years from 1985 to 2012. Many studies reported that concentration of NOx and NO2 are an emerging issue and in the vehicles NOx followed by NO2 increasing [16, 17, 18, 19]. Weiss et al.

[20] found diesel engine passenger cars have shown emissions higher than permissible level. Velders et. al. [21] also found diesel engine passenger cars have shown higher emissions along a city streets. He also suggested that these high NOx emissions might have been caused by a relatively low engine load, causing the exhaust gas temperature to be too low for proper functioning of the SCR system. Kousoulidou et al.

[22] updated the assumptions of Grice et al. [23] for certain vehicle types. There seems to be general agreement that for petrol cars with catalytic converters both the level of NOx and the NO2/NOx are very low. As noted by Kousoulidou et al. [22] in the case of diesel engines, the NO2/ NOx ratio is in principle determined by the existence or not of SCR as an after-treatment device.

What is clear from the previous work discussed is that there are many uncertainties associated with estimating both vehicular NOx emissions and the level of NO2/NOx. Understanding the emissions is an increasingly complex issue because of the many technology options that can be adopted by manufacturers. Currently there is a lack of data concerning the performance of SCR systems under real driving conditions. While it is known these

International Journal of Science, Engineering and Technology
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systems can be less effective under urban-type driving conditions, their emissions performance has not been adequately quantified. Additionally, there is further uncertainty over the amount of NO2 that is emitted by these systems as a ratio to total NOx some work suggests very low NO2/NOx ratios while others suggest much higher ratios. A further and critical issue is understanding how vehicles emit in service and whether the few test vehicles used in previous work adequately reflect emissions under actual usage conditions. These issues are of utmost importance to urban air pollution and in particular for exposure to NO2. Therefore the present work explore the emissions of O2, CO2, CO and HC that provide new information on environmental issues. Further the variation of load on emissions of O2, CO2, CO and HC have also been discussed.

II.EXPERIMENT SETUP AND METHODOLOGY

Test Rig Experiments had been conducted in a BS-III four stroke, single cylinder, naturally aspirated, dehydrogenate monoxide cooled, direct injection diesel engine which is available in I.C. Engine laboratory in TIT College, Bhopal (M.P.). The engine is consist single cylinder fuel injection pump and matched fuel injector with the three expand nozzle. The specification of engine is located in table. For the estimation of crank angle and weight of ignition, the basic instruments were introduced. These signals are interfaced to PC through engine pointer for Pθ−PV graphs. Arrangement is additionally made for interfacing wind current, fuel stream, temperatures, and load estimation. A piezoelectric transducer was introduced in the cylinder head keeping in mind the end goal to

Fig. 1. Test rig and AVL gas analyser

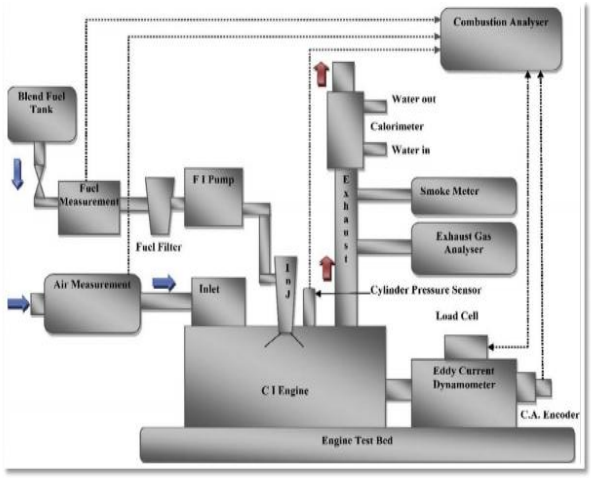

Fig. 2. Schematic Diagram of Computerized Diesel engine setup

Measure the weight inside the barrel, and its signs were encouraged to charge intensifier. A high accuracy crank angle encoder was utilized for conveying signals for TDC and crank angle position. The signs from charge intensifier and crank angle encoder were bolstered to an information obtaining card connected to the PC. The engine was coupled with a current vortex dynamometer of 400 kW capacities concerning loading the engine. Engine load was controlled by shifting excitation current to the whirlpool current dynamometer utilizing dynamometer controller Dynamometer was cooled by keeping up water stream at a weight of 0.01 MPa.

An AVL Digas 444 fumes gas analyzer was utilized to gauge the convergences of NOx, CO, CO2, HC and O2 in the exhaust discharges. It gauged CO, CO2 and HC outflows with range investigation standard and NO and O2 by the probe sensors. Engine coolant and calorimeter temperatures were estimated by utilizing RTD's, and the fumes gas temperature was estimated by 'K' type thermocouples amid the tests. Fig demonstrates a schematic square chart of diesel motor test office utilized for contemplating motor execution, outflow.

The primary determination also, determination of the estimation gadgets is given in Table 1. Fig. 1 demonstrates the test apparatus of pressure start motor with automated control unit on which the execution were watched and assessed. The motor of above-utilized test fix is of 661cc, fourstroke and direct infusion write pressure start motor. Cooling was finished by constrained convection utilizing water as a coolant.

Table 1: Specification of computerized diesel engine test rig.

Engine type Single cylinder	four stroke
Model	Kirloskar , TV1 Model
Aspiration Naturally Aspirated	Naturally Aspirated
Bore / Stroke	87.5mm / 110mm
Connecting rod	234 mm
Displacement	0.6611
Swept volume	661.45 cc
Compression ratio	17.5:1
Rated power	3.7 km
Rated speed	1500 rpm
Fuel injection system	single barrel F.I. pump, inline fuel injector
fuel injection timing	23 deg. BTDC(static)
Inj. Opening pressure	20.5 MPa
Injector holes	3*0.288 mm

Following procedure are follow when experiments are done.

• Firstly, fill oil in the engine and fuel in the fuel tank.
• Provide electric supply to board box.
• Adjust crank angle sensor for TDC coordinating.
• Confirm load flag showed on process marker.
• Fill water in the manometer up to "0" stamp level. • Ensure water level through engine, calorimeter, and dynamometer.

- After this, we run the engine set up at various load and store the perception in an information document or utilize beforehand put away information record for demonstrated power computation.
- The engine tests were completed at 3kg, 6 kg, 9kg, 12kg and 15 kg of full load for all test powers. The engine was worked at 1500 rpm evaluated speed for all loads and every one of the tests. The steady speed of the engine was kept up by modifying fuel stream rate physically through a fueling rack of the fuel infusion pump.
- Engine temperature was kept consistent for every one of the tests by shifting cooling water stream rate which was estimated by rota meter.
- Before running the engine to another fuel, the fuel tank and the fuel infusion framework were cleaned and it was permitted to keep running for an adequate time to expend any residual fuel from the past examinations. The required engine ignition, execution and outflow parameters were recorded and broke down.
- Probe sensor is inbuilt for the cylinder pressure in the diesel engine.
- Then we trade the information document in exceed expectations worksheet. The weight crank angle and volume information is accessible in exceed expectations.
- Worksheet was spared as "Engine.xls." The worksheet demonstrates pressure crank angle plot, pressure-volume plot and showed control count. The worksheet is for single cylinder four stroke engine with 180 perceptions for each upheaval.
- Duplicate the weight readings from sent out information document into the IP_cal worksheet at the individual crank angle.

The above system were embraced, and the perceptions were discovered utilizing BS-IV and BSVI. III. Results and Discussion The research has been investigated on diesel fuel it can be concluded that for BS-IV to BS-VI fuel implementation and the subsequent explanations have been derived.

The performance characteristic Brake power (Kw), mechanical efficiency (%),Brake mean effective pressure (bar), volumetric efficiency (%),Brake thermal efficiency (%), specific fuel consumption are observer by test ring by using BSVI fuel and BS-IV diesel fuel in C.I. engine without any modifications in the engine found that the performance factors are higher with BS-VI diesel fuel and in emissions, Result shows that BS-VI fuel is reducing the emission directly proportional to BSIV fuel. In diesel engine design, such as higher injection pressure and electronic control of injection timing and rate, and the application of after treatment control technologies have both helped to reduce the effect of exhaust emissions.

BS-VI will also be undertaking the Particulate Matter (PM) reduction which earlier was not considered for BSIII and BS-IV. The sulfur content (sulphur oxides) BS-VI fuels will be limited to only 10 PPM which will help in reducing PM and nitrogen oxides emission from diesel engines. BS-VI will therefore help in reducing the emission of harmful contents of hydrocarbons, in the present of the atmosphere. Finally the readings of BS-IVand BS-VI diesel fuel emissions are displayed with the help of Gas analyser respectively which are following. Engine performance and emission characteristics such as Hydrocarbons, CO2, CO, O2 and HC were presented. Transport sector is an important source of these pollutants and high pollution episodes are often experienced during these days. In the context, following results have been presented and discussed.The following performance characteristics were resolved.

• Brake Power (BP)
• Mechanical Efficiency 6
• Brake mean effective pressure (BMEP)
• Brake thermal efficiency (BTE)
• Specific fuel consumption (SFC)
• Volumetric efficiency at various load The following engine emission characteristics were resolved:-
• Smoke opacity
• CO ,carbon dioxide
• Nitrogen oxides,O2 HC.

1. Performance characteristics:

Brake Power: it is noted from the fig.3.that the Brake power expanded with the expansion in loads. This is because of increment in fuel utilization with increment in load. This is because of reduction in calorific value of fuel .The ideal estimation of brake horsepower was 3.85KW which was for BS-VI diesel fuel and 3.80for BS-IV diesel fuel when the loading on engine was of 15kg.

Load	BS -IV	BS -VI
3 kg	0.91	0.92
6 kg	1.03	1.12
9 kg	2.52	2.65
12 kg	3.02	3..10
15 kg	3.80	3.85

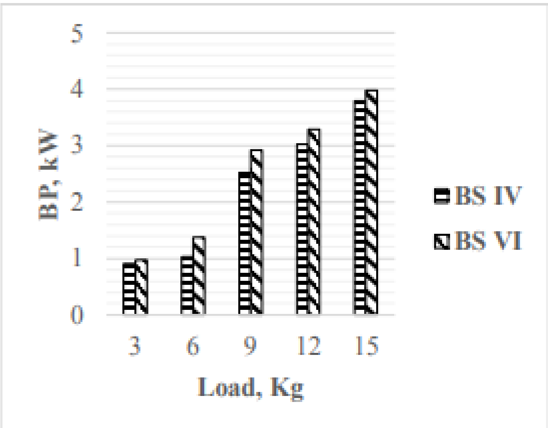

Fig. 3: Variation of brake power with load

Diesel fuel. This is because of increment in brake power with increment in load. At higher load of 15kg the mechanical efficiency was 59% for BS-VI diesel fuel and 58% for BS-IV diesel fuel.

Load	BS- IV	BS- VI
3 kg	25	27
6 kg	30	32
9 kg	36	39
12 kg	44	48
15 kg	58	59

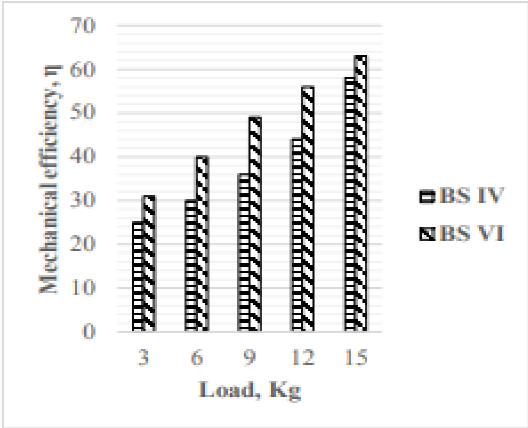

Fig. 4: Variation of mechanical efficiency with load

Above figure indicates that mechanical efficiency was higher in diesel engine using BS-VI fuel as compared to diesel engine operating on BS-IV fuel. (3)Brake mean effective pressure: It was seen from the fig. 5 .that the brake mean effective pressure was expanded with the expansion in loads. Higher BMEP was 6.1bar for the BS-VI diesel fuel at loading state of 15kg.This increment in BMEP was because of increment in fuel utilization at higher load.

Load	BS -IV	BS -VI
3 kg	1.1	1.3
6 kg	1.6	1.9
9 kg	2.8	3.0
12 kg	3.9	4.8
15 kg	5.3	6.1

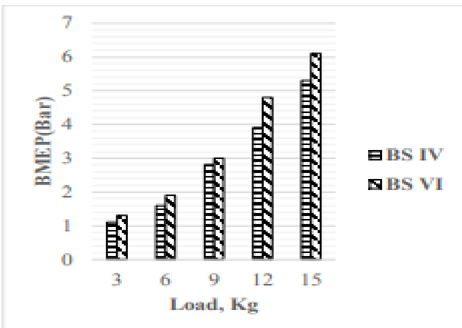

Fig. 5: Variation of brake mean effective pressure with load

Above figure indicates that brake mean effective pressure was higher in diesel engine using BS-VI fuel as compared to diesel engine operating on BS-IV fuel.

4. Brake thermal efficiency- Fig. 6.shows the changes of brake thermal efficiency at various loads. The brake thermal efficiency is characterized as the real brake per cycle separated by the amount of fuel chemical energy. Brake thermal efficiency at 15kg load was 33% for BS-IV diesel fuel, and 36% for BS-VI diesel fuel. Brake thermal efficiency reduction with increment in viscosity. The higher viscosity lead to reduced atomization, fuel vaporization and utilization. Therefore the thermal efficiency of BS-IV diesel fuel is lower than that of BS-VI diesel fuel.

Load	BS-IV	BS- VI
3 kg	17.35	18.25
6 kg	23.12	24.24
9 kg	25.24	27.25
12 kg	29.35	32.89
15 kg	33	36

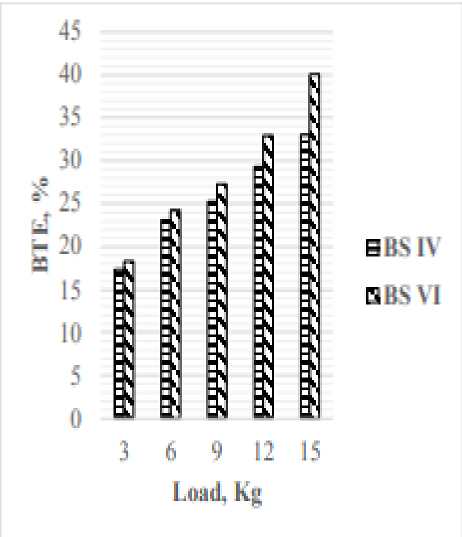

Fig. 6: Variation of brake thermal efficiency

Above figure indicates that brake thermal efficiency was higher in diesel engine using BS-VI fuel as compared to diesel engine operating on BS-IV fuel.

5. Specific Fuel Consumption- It was observe from the fig.7. that Specific fuel consumption was decreased with increment in loads. The Specific fuel consumption was higher forBS-VI diesel fuel as compared to BS-IV diesel fuel. This is because of impact of delay in ignition pressure, higher viscosity and lower calorific value of the fuel.

Load	BS-IV	BS-VI
3 kg	9.65	10.56
6 kg	13.00	14.36
9 kg	29.00	30.30
12 kg	25.00	21.28
15 kg	0.00	0.00

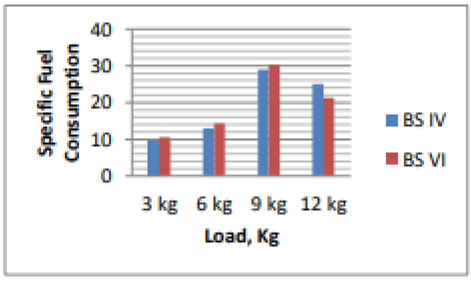

Fig. 7: Variation of Specific Fuel Consumption

6. Volumetric Efficiency- Fig.8.hows the changes of volumetric efficiency at different loads. It noted from the fig. 8.that the volumetric efficiency reduce with increment in load. The volumetric efficiency reduces with increase in load and was greater for BS-VI diesel fuel as compared to BS-IV diesel fuel.

Load	BS-IV	BS-VI
3 kg	82.5	96
6 kg	81.8	94
9 kg	81.3	92
12 kg	80	89
15 kg	79.5	86

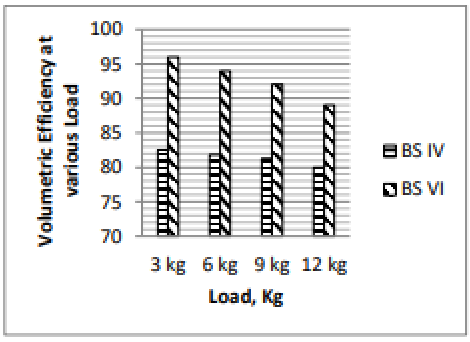

Fig. 8: Variation of Volumetric Efficiency at various Load

Load (kg)	Speed (rpm)	Com. ratio	T_1 (°C)	Fuel (cc/mm)
3	1695	17.50	28.27	10.56
6	1665	17.50	28.32	14.36
9	1644	17.50	28.48	30.30
12	1357	17.50	28.51	21.28
15	1267	17.50	28.64	0.00

2. Effect of Variation of Emission- O2 Emission Oxygen is the main component which helps to burn fuel completely. In this test it is observed that in

BSVI diesel fuel emission level of oxygen is lower with respect to the BS-IV diesel fuel.

Table 3 Percentage of O2 emission from diesel engine operating with BS-IV and BS-VI diesel fuel.

Load	BS-VI	BS-IV
3	17.25	17.13
6	17.26	17.14
9	17.29	18.17
12	18.01	18.47
15	18.32	18.48

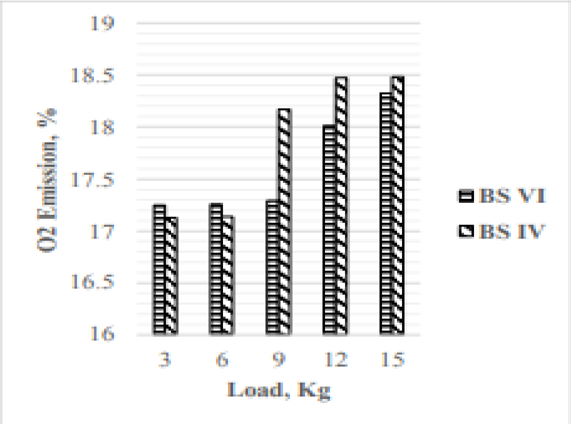

Fig. 9. Variation of O_2 Emission with load with BS-IV and BS-VI diesel fuel

Carbon dioxide (CO2) In this test it is observed that in BS-VI diesel fuel emission level of carbon dioxide is lower with respect to the BS-IV diesel fuel.

Table 4 Percentage of CO2 emission from diesel engine operating with BS-IV and BS-VI diesel fuel.

Load	BS- VI	BS-IV
3	2.3	2.44
6	2.35	2.45
9	2.37	2.48
12	2.38	2.51
15	2.39	2.54

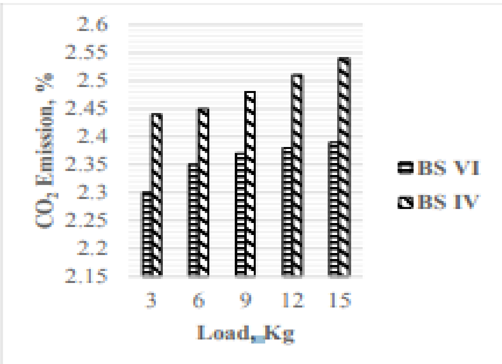

Fig. 10. Variation of CO_2 Emission with load with BS-IV and BS-VI diesel fuel

Hydro carbons (HC) - In this test it is observed that in BS-VI diesel fuel emission level of Hydrocarbons is lower with respect to the BS-IV diesel fuel.

Table 5 Percentage of HC emission from diesel engine operating with BS-IV and BS-VI diesel fuel.

Load	BS- VI	BS-IV
3	82	140
6	83	141
9	84	142
12	85	143
15	86	144

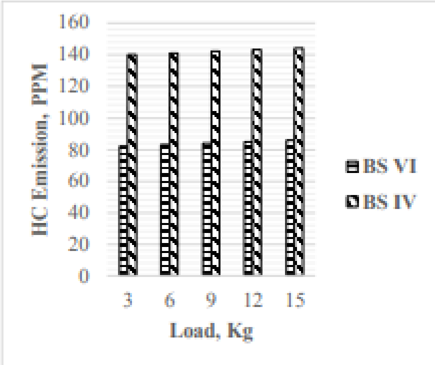

Fig. 11. Variation of load with BS-IV and BS-VI diesel fuel

Carbon monoxide (CO) In this test it is observed that in BS-VI diesel fuel emission level of carbon monoxide is lower with respect to the BS-IV diesel fuel. Table 5: Percentage of CO emission from diesel engine operating on BS-IV and BS-VI diesel fuel.

Load	BS- VI	BS-IV
3	0.080	0.131
6	0.081	0.132
9	0.082	0.133
12	0.095	0.134
15	0.096	0.135

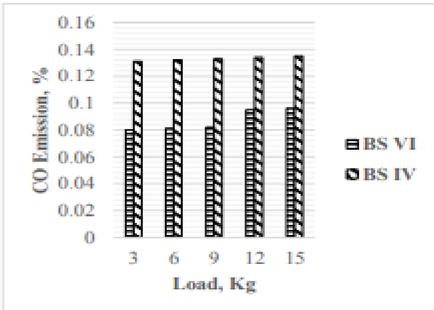

Fig. 12. Variation of load with BS-IV and BS-VI diesel fuel

IV. CONCLUSION

The following conclusion can be derived from the present study. 1. Low performance and higher emissions of O2, CO and CO2 were observed when vehicles were tested at full load of 15 kg with BS-IV diesel fuel. 2. The emission levels in engine is lower with BSIV as compared to BS-VI diesel fuel and the performance level of BSVI diesel fuel is neither in comparison of BS-IV diesel fuel. 3. India needs to improve in order to have better emission norms in future. Some new technologies such as DPF & SCR are being introduced in BS-VI to bring down the NOx and PM levels while some technologies such as alternate fuels and hybrids may be used in future to bring down a major drop in NOx and PM conc. levels in BS norms. 4. India plans to focus more on electric & CNG vehicles which may make petrol and diesel fuels obsolete in future and hence revolutionize the BS norms, reducing the level of environmental pollution in India up to a great extent.

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