



## Indian Automotive Industry towards Bharat Stage-VI

### Emission Norms: A Technical Review

Nayan Mirgal

Post Graduate Scholar

School of Mechanical Engineering,

Vellore institute of Technology,

Vellore, Tamil Nadu

India

#### ABSTRACT

The rapid growth of automotive industry in India is facing challenges of degradation in the quality of surrounding environment. To improve the current status of exhaust emissions from automobiles Government of India decided to implement Bharat Stage VI (BS-VI) norms from April 2020 in 15 major cities. Due to skipping of BS-V, Indian original equipment manufacturers (OEMs) are now facing a big challenge of confirming these norms. Sustainable mobility is the only solution for this which includes improvements in existing engine technology and fuels. This paper explains in brief about various means of sustainable mobility namely usage of alternate fuels, advanced combustion methods, engine downsizing, onboard diagnostics, use of after-treatment devices, electric and hybrid vehicles. Hydrogen which is the best fuel among all fuels, but not a better option because of safety issues. Hence to meet BS-VI emission limits advanced combustion methods, downsizing of engine and application of after-treatment devices could be the possible options that engine manufacturers have. This paper briefly explains key features of BS-VI and possible options to satisfy BS-VI limits. Finally, the current status of efforts taken by Indian OEMs to meet those norms is mentioned.

**Key Words:** Bharat Stage VI, Sustainable Mobility, Engine Downsizing, Onboard Diagnostics.

#### 1. INTRODUCTION

As per World health organization (WHO) India has greatest number of most polluted cities (30 in top 100) in terms of particulate matter (PM). Air pollution is fifth cause of death India. Currently in capital city Delhi vehicles are contributing around 59%, 50% and 18% of overall emissions of CO, HC and NOx respectively. To address this serious issue on 19th Feb 2016 Ministry of road transport and highway, India issued notification of Bharat stage VI (BS-VI) which will be implemented from 1st April 2020. In BS-VI modified mass emission standards and type approval requirement, compulsory usage of OBD in all kinds of vehicle, improved durability levels and requirements of fuel compatible with BS-VI are some noteworthy points. After taking lesson from Volkswagen scam in-service conformity (real world driving emissions) test using portable emission measuring system is also included in BS-VI. Following chart briefly covers modification involved in each vehicle sector compared to BS-IV [1-3].

Table 1: Features of BS-VI

Features of BS-VI		
<b>2&amp;3 wheelers</b>	<b>Passenger cars</b>	<b>Commercial vehicles</b>
<ul style="list-style-type: none"> <li>Worldwide harmonized motorcycle test for 2</li> </ul>	<ul style="list-style-type: none"> <li>Worldwide harmonized steady and transient cycles</li> </ul>	<ul style="list-style-type: none"> <li>Worldwide harmonized steady and transient cycles</li> </ul>

wheelers and Indian driving cycle for 3wheelers being used. <ul style="list-style-type: none"> <li>• Separate standards for NO<sub>x</sub> and HC</li> <li>• Evaporative emissions limits to 1.5 g/test</li> <li>• All mass emission limits are equivalent to EURO-V limits for L-category vehicles</li> <li>• Separate standards for 2 wheelers with engine less than 50cc</li> </ul>	are used <ul style="list-style-type: none"> <li>• Separate mass emission standards for SI and CI and limits are equivalent to EURO-VI limits of corresponding type of engine</li> <li>• Particulate number emission limit below 6 x 10<sup>11</sup>/km (PN limit also applicable to gasoline engines with direct injection)</li> <li>• In-service conformity test using portable emission measurement system (PEM)</li> </ul>	are used <ul style="list-style-type: none"> <li>• Mass emission standards equivalent to EURO-VI limits.</li> <li>• PN limit is 8 x 10<sup>11</sup>/Kwh for steady cycle and 6 x 10<sup>11</sup>/Kwh for transient cycle.</li> <li>• In-service conformity test using portable emission measurement system (PEM)</li> </ul>
<b>Usage of Onboard diagnostic (OBD) device</b>		

By looking at more stringent mass emission limits proposed in BS-VI, commercial vehicle sector who is mainly relying on diesel is facing major problem. To reduce NOx emissions by 67% than existing use of selective catalytic reduction is must. In addition to this introduction of particulate number limit forces OEMs to use diesel particulate filter (DPF) in their vehicles. Due to addition of these two after treatment devices cost of diesel vehicle raise by approx. 1 to 1.5 lacs. So now OEMs are shifting from diesel towards alternative fuels. CNG, LNG, HCNG, biodiesel, DME are possible fuels available for commercial vehicles.

## 2. POSSIBLE OPTIONS FOR SUSTAINABLE MOBILITY

### 2.1 Switchover to alternate fuels

Main reason for increased emission level is dirtiness of existing fuel. Gasoline and diesel are mixture of hydrocarbons so contain ample amounts of carbon which leads to hazardous tailpipe emissions on combustion. To achieve sustainable mobility switching to clean fuel like hydrogen, natural gas, biodiesel etc. is necessary. Currently in India due to lack of safety precautions onboard use of hydrogen is limited so natural gas and biodiesel are better options [4]. In Delhi all commercial transport vehicles are transformed to run on compressed natural gas. CNG fuelled two wheeler also launched in Delhi on 23rd June 2016. To promote CNG vehicles Government is opening CNG fuelling stations in major cities like Delhi, Mumbai, Pune and many more. Even though usage of neat hydrogen is very dangerous, hydrogen is combined with certain amount of CNG (5 to 15% by volume) to get benefits of both H<sub>2</sub> and CNG. CNG has lower flame speed so its combustion is improved by higher flame speed of hydrogen in HCNG engines [5]. In many countries commercial vehicles are driven on HCNG, Sweden is very much developed in this field.

**Table 2.1: Comparison of possible alternative fuels**

Property	Gasoline	Hydrogen	CNG	HCNG (5% H <sub>2</sub> )
Flammability limits (vol%)	1-7.6	4-75	5-15	5-35
Ignition energy (mJ)	0.24	0.02	0.29	0.21
Auto ignition temperature (K)	501-744	858	813	825
Flame velocity (cm/s)	37-43	325	45	110
Octane number	90-95	130	120	-
Flame temperature (K)	2470	2318	2148	2210

By looking towards superior properties of other fuels over gasoline one can understand that these fuels have great potential to achieve sustainable mobility. Following table gives brief idea about effects of usage of alternate fuels in internal combustion engines with respect to performance and emission characteristics.

Table 2.2: Brief idea about research in alternative fuels

Author	Year	Fuel	Results
Toshio shudo	2002	H <sub>2</sub> + DME	Higher thermal efficiency over wide range
K R Patil & S S Thipse	2010	H <sub>2</sub> + CNG	Power output increase by 3-4% Fuel consumption reduced by 4% CO emissions reduced by 40% NO <sub>x</sub> emissions reduced by 20%
Hongsheng Guo	2011	H <sub>2</sub> + Diesel	Combustion duration gets reduced Increased power output and combustion efficiency
D B Lata	2011	H <sub>2</sub> + LPG	Combustion duration gets reduced due to higher flame speed

## 2.2 Advanced combustion methods

Improving combustion efficiency is also one of the important mean to reduce tailpipe emissions, as major part of emissions is because of incomplete combustion. Nowadays to achieve complete combustion low temperature combustion (LTC) is popular. It includes homogeneous charge compression ignition (HCCI) and premixed charge compression ignition (PCCI). The primary goal of advanced combustion methods is to improve combustion and thereby avoid or at least reduce need of after treatment devices which makes whole system complicated and costly. LTC significantly lowers NO<sub>x</sub> and PM emissions [6].

HCCI is very old concept invented by Japanese scientist Onishi in 1979. As name indicate the goal of this strategy to achieve homogeneous mixture of air and fuel. For this fuel is either injected in intake port or directly into cylinder and sufficient time is given for mixture preparation before ignition. After that auto ignition of charge takes place due to compression in similar way like diesel engines.

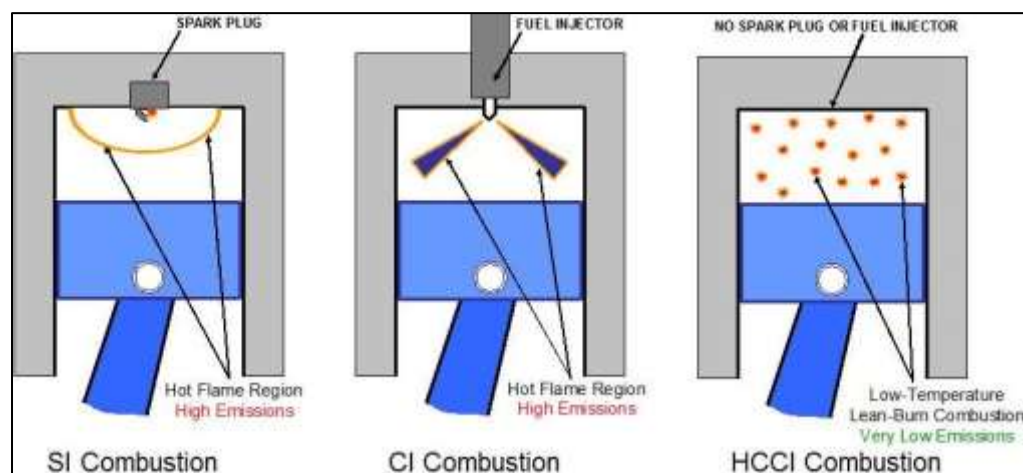


Fig 2.1: Comparison of different combustion modes

Extensive research in HCCI field conclude that LTC improves thermal efficiency by about 10% and also reduces NOx and PM significantly. In these engines heat release take place at same time across whole combustion chamber due to this keeping control over combustion phasing is little difficult. For successful operation of HCCI engine combustion operating range, cold start and excessive HC and CO emissions needs to be overcome. In spite of these challenges HCCI having great benefits over performance and emissions of engine, hence definitely we can consider it as future advanced mode of combustion [7].

**2.3 Engine down-sizing and down-speeding**

We know that at higher power density engines are more efficient and in downsizing air is supplied to engine at higher density by means of turbocharging or supercharging. Hence with down-sizing customer gets more fuel efficient engine without any compromise over performance. One of the leading engine manufacturer Perkins believe that for engines in class of rated power below 56 kW there is no need of selective catalytic reduction to meet necessary emission standards. This will also reduce cost of vehicle.

Down-speeding means producing engine with rated speed at which useful torque is obtained. Reduction in engine speed leads to lower frictional losses which finally increases efficiency of engine. It includes modification in drivetrain so that peak torque will be obtained at lower rpm and engine is allowed to operate in speed and load where it gives lower bsfc. Down-sizing and down-speeding together results in smaller engines which provides package of improved fuel economy, better efficiency and benefits over exhaust greenhouse gases. Fuel economy is driving factor in commercial vehicles, slight increase in fuel economy results in great financial benefit to them. Hence down-sizing and down-speeding have become more popular in this industry [8].

**2.4 Onboard diagnostics (OBD)**

OBD is modified diagnostic tool which is installed in power train control module. It meant to find area of malfunction by using fault codes stored in computer memory and alert the driver about it. Basically OBD monitors various engine components and components that forms emission system. When any malfunctioning is detected among above mentioned components OBD illuminates malfunction indicator lamp on dashboard to alert the driver. To reduce emission levels automakers implementing new technologies in their vehicles but it gives required results if all necessary components are in proper working condition. By doing continuous monitoring OBD not only maintains efficiency of that component but also prevent possible serious damage to other systems because of that faulty component. When OBD detects any malfunction, corresponding diagnostics trouble code gets stored in vehicle's computer memory then at the time of servicing technician retrieves that code by using scan tool and required component is gets repaired.

General motors introduced OBD-I in 1980 in their vehicles. Later California and United states environmental protection agency (EPA) introduced OBD-II in 1996. In India OBD-I gets implemented in April 2010 and OBD-II in April 2013. In following table list of items monitored by both OBD-I and OBD-II is given.

**Table 2.3: Different items monitored by OBD**

OBD-I	OBD-II
<ul style="list-style-type: none"> <li>• Fuel injection system</li> <li>• Coolant temperature</li> <li>• Exhaust gas recirculation</li> <li>• Emission control components circuit continuity for all emission related powertrain components</li> <li>• Distance travelled since MIL gets ON.</li> </ul>	In addition to OBD-I <ul style="list-style-type: none"> <li>• Catalyst</li> <li>• Particulate trap</li> <li>• Fuel system</li> <li>• Misfire</li> <li>• Lambda sensor</li> <li>• Fuel tank leakage and evaporative losses</li> </ul>

**2.5 Application of after treatment devices**

After comparing mass emission limits of gasoline and diesel vehicles one can easily predict that diesel vehicles have to suffer more. There is drastic reduction of 68% in NOx level limit for diesel vehicles which cannot be meet with existing EGR strategy. Manufacturers need to fit additional selective catalytic reduction (SCR) device in exhaust system. Lean NOx trap and De-NOx strategies are also possible solutions. In addition to that particular matter limit was reduce by 82-93% for light duty diesel vehicles depending upon vehicle class and 67% for heavy duty vehicles. Introduction of particulate number limit made it even worse for these vehicles. To meet PN limit of 6 x 10<sup>11</sup> /kWh manufacturers have to install particulate filters in exhaust system [9].

So it is now going to be a train of after treatment devices especially for diesel vehicles which not only increase vehicle cost by around 1-1.5 lacs but also exerts back pressure on engine which will reduce its efficiency.

## 2.6 Hybrid and fully electric vehicles

Hybrid and fully electric vehicles are meant to reduce dependency of automobiles on engines partially or fully respectively. In fully electric vehicles engine is replaced with battery pack, electric motor and controllers. Hybrid vehicles have both engine and electric motor. According to drive train arrangement hybrid vehicles can be of three types series, parallel and combined. Based on contribution of electric motor in traction hybrid vehicles are further classified as micro, mild, fully hybrid and plug-in hybrid [10].

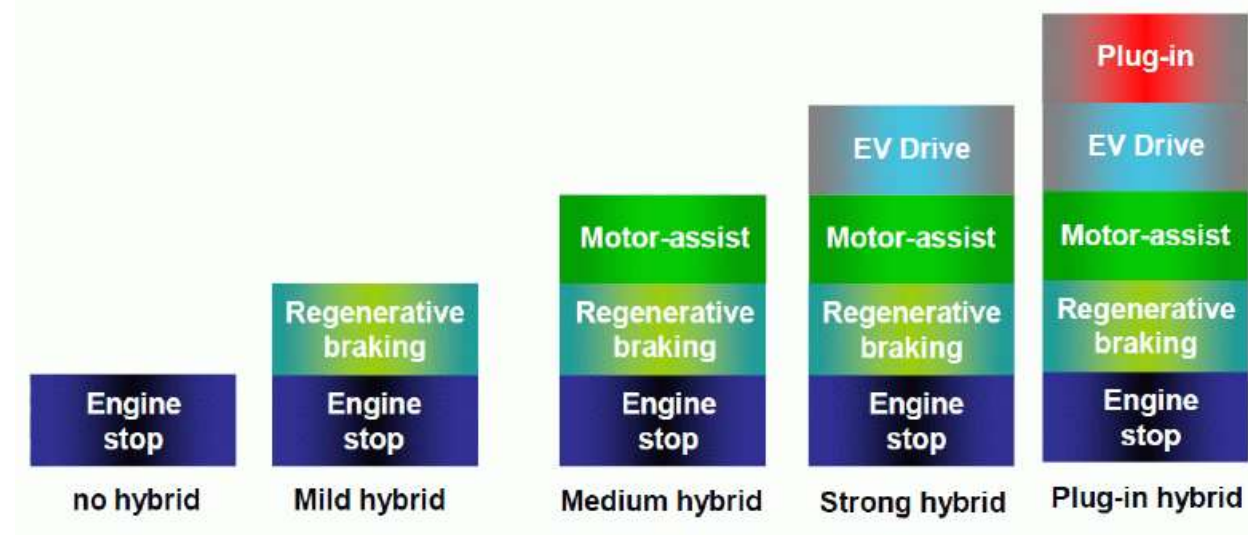


Fig 2.2: Overview of hybrid electric vehicles

Apart from emissions produced during electricity generation in power plants electric vehicles have almost zero emissions so it helps in improving quality of surrounding air. Pollution during electricity generation can be reduce by using renewable sources for electricity generation. Electric vehicles are cheaper in case of operating and maintenance cost due to very less mechanical parts. Due to absence of engine these vehicles runs very quietly, currently vehicle manufacturers are planning to add specific sound to make pedestrian aware about nearby electric vehicle. These vehicles are very effective in city driving where frequent stop-start and sudden acceleration is necessary. Even though electric vehicles are having these many benefits their usage is limited because of higher weight and cost of battery, lower range (120 Km/charging) and lack of standard procedures for disposal of batteries.

To promote usage of electric vehicles Government is providing subsidies to customer. Most of the automakers have invested their money in this field as it is one of the important mean of sustainable mobility.

## 3. EFFORTS OF INDIAN OEMS TO SATISFY BS-VI:

The effect of BS-VI has seen in Delhi auto expo 2016, where many Indian OEMs launched their extremely fuel efficient and clean vehicles to comply with these norms and be in the market.

TATA motors launched their diesel-electric hybrid "STARBUS" which has BS-IV compliant diesel powertrain to charge lithium ion phosphate batteries. Batteries can be also charge through regenerative braking. TATA claims around 25% increase in fuel economy and clean engine operation with this hybrid technology. To promote sustainable mobility they have also introduced 32 seater CNG-electric hybrid "STARBUS" which is even more fuel efficient and termed as zero emission bus. Earlier TATA has introduced "Revotron" 1.2 litre turbocharged MPFI engine. This downsized and down-speed engine produces highest power of 83.3 bhp at 1000 rpm earlier than other engines in this segment.

Ashok Leyland from Hinduja group has also introduced first non-plugin series diesel-electric hybrid bus "HYBUS" in Delhi auto expo 2016. It includes H-series 6 cylinder BS-IV compliant diesel engine for charging purpose. But there is no any mechanical connection between engine and drive axle which makes it more fuel efficient and lowers noise-vibration-harshness levels. As equipped with regenerative braking this bus is suitable for frequent start-stop driving conditions in urban areas. They have also launched BS-VI compliant truck-4940 equipped with 8000 cc Neptune engine producing 400 bhp power at 2200 rpm.

Mahindra and Mahindra launched fully electric passenger car "eVerito" having 72 V battery pack and offers driving range of 110 km on full charge. It uses lithium ion battery pack which takes 105 minutes to be fully charged through fast charging technology. Through regenerative braking, on-board telematics and intelligent energy management system running cost of vehicle comes down to INR 1.15 per km. Being fully electric it is zero emission passenger car.



#### 4. CONCLUSION

- BS-VI will definitely going to bring drastic change in automotive market in India.
- We will get more fuel efficient and very low emission producing vehicles in near future. Downsizing and down speeding will yield smaller and powerful engines. Diesel vehicles will get more expensive as they required more after treatment to stay clean. This will attract OEMs towards alternative fuels and hybrid technologies.
- Indian driving speeds are less than European driving speeds, hence it is difficult to achieve temperature which is necessary to operate particulate filter. Hence domestic tire-I and tire-II suppliers have great opportunity to innovate new engine technology and emission control technology suitable to Indian driving conditions.
- To achieve emission limits specified in BS-VI ample amount of engine electronics will required. This will enhance business of domestic and MNC automotive electronic suppliers. Vendors and engineering solution providing companies for Eco testing, fuel system testing and emission testing are also going to benefit a lot.
- Through all these efforts people can ensure significant reduction in air pollution from automobiles. This will bring remarkable improvement in air quality in highly populated cities as automobiles are main source of air pollution in cities.

#### REFERENCES

- [1]. Ashish Kumar, "Statistics Related to Climate Change – India 2015," April 2015, pp.529-551
- [2] Dr. Fatih Birol, *India energy outlook*, 3<sup>rd</sup> ed., vol. 2. Oxford: Clarendon2016, pp.68-73.
- [3] Lee, R., Pedley, J., "Technical Background on India BS VI Fuel Specifications," unpublished.
- [4] R. Nicole, "Vision 2030- Natural Gas Infrastructure in India," *Industry Group For Petroleum & Natural Gas Regulatory Board*.
- [5] Tobias kampf Andreas jahn, "Alternative Automotive Fuels - Supply, Technological and Environmental Scenarios To 2030." *IEEE Transl. J. Magn. Japan*, August 2016, vol. 2, pp.740-741.
- [6] Rolf Brück, Manuel Presti, "Advanced Combustion and Emission Control Tech Team Roadmap" *Journal of Combustion. Japan*, Sept 2015, vol. 2, pp.340-351.
- [7] Scott Curran, Reed Hanson, "Performance Of Advanced Combustion Modes With Alternative Fuels: Reactivity Controlled Compression Ignition Case Study" *Journal of Combustion. Japan*, March 2016, vol. 5, pp.45-60.
- [8] P Leduc, "Downsizing of Gasoline Engine: Efficient Way to Reduce CO<sub>2</sub> Emissions" *Journal of Oil and Gas Science and Technology*, March 2012, vol. 5, pp.35-43.
- [9] Mats Laurell, "The innovative exhaust gas after treatment system for the new Volvo 4 Cylinder Engines; a unit catalyst system for gasoline and diesel cars" *22nd Aachen Colloquium Automobile and Engine Technology*, May 2016, vol. 3, pp.25-40.
- [10] John Storey, "A guide to electric vehicles" *Journal of Renewable Energy*, March 2014, vol. 25, pp.10-24.