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Alignment for BSVI Stipulation Moving Towards Carbon Neutral Earth

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***Abstract*— In the current global scenario, the automotive fraternity is trying to encompass the latest emission regulation to control the ever rising pollution and keep a check on the amount of harmful gases that are emitted to the atmosphere. An immediate and important step towards a cleaner and greener environment in India is the implementation of BS VI emission norms. This can be achieved through engine tuning, in-cylinder treatment and exhaust tuning.**

According to the Paris protocol 2015, India has agreed to reduce the carbon output and keep global warming below 2 degrees/year. By 2020 India aims at "17%" lower emissions compared to 2017. On an average, 2% reduction per year is expected to achieve the target. Gasoline engine has on an average "20%" higher fuel consumption than diesel which makes diesel application close to mandatory in automotive industry. The diesel emissions control thus becomes an important cog. As per the current study India, on paper, has the toughest CO_2 norms as it tries to be on par with the European nations that are already 4 stages ahead by adhering to Euro 6D norms. Based on the profound insight of the existing exhaust system technology portfolio, the exhaust after treatment challenges in the espousal of BS VI norms and solutions are discussed.

As India is aggressively moving from BS IV to BS VI, various parameters to support this transition have been discussed in this article. This particular study explores the technology criteria; functional readiness and manufacturing readiness towards implementing the advanced emission norms in India. The solutions to the challenges in development are approached with a structured, strategic glide path which considers both technological innovations as well as optimization of the development process.

***Keywords*— System integration, fuel economy, driving dynamics, emission testing, CO_2 reduction, Fuel Efficiency, Vehicle Optimization, After Treatment System, Emission Control**

I. INTRODUCTION

Achieving CAFÉ and PNGV targets has induced a huge fortune of investment on researches towards reduction of CO_2 from vehicles. The conventional ownership of vehicles might alter in future towards vehicle leasing Vs ownership strategy which reduces automotive population against personnel.

Although, for vehicles predominantly based on the conventional fuels, gasoline and diesel the solution for CO_2 reduction should be tailored on basis of usage: driving patterns and driver preferences for effective usage of the efficient vehicles. Indian automotive industry with stringent norms, skipping BSV and moving towards BSVI in 2020, is towards achieving significant improvements in CO_2 reduction. The article will concentrate on certain parameters that help define a system of checklists to develop a vehicle with improved fuel efficiency and thereby reduce CO_2.

Some of the important parameters;

- Rolling resistance
- Aerodynamics
- Energy management
- Power train optimization and electrification
- Energy sources
- Heat management
- Vehicle downsizing/Weight reduction
- Norms and protocols

To narrow down the scope, the article confines to considerations during development of an automotive exhaust system, which for now, remains the last engineered part of an automotive.

The consideration of simultaneous development of after treatment system during engine development is a value added practice the automotive fraternity is following recently. Optimization of exhaust system components to avoid adverse effects on vehicle fuel efficiency is discussed.

II. LIGHT WEIGHTING OF SYSTEM

Light weight designs of vehicle remains prerequisite for the realization of the potential for reduction of CO_2. Three main clauses which shall plough the way for effective weight reduction will be;

- Functional integration - Every part has to fulfill as many functions as possible in order to reduce number of parts.

- Material Substitution - Substitution of lightweight materials (carbon fiber compounds, magnesium etc)
- Downsizing of parts

A. Functional integration

Functional integration is an interesting idea of any system wherein every part associated with the system has to fulfill as many functions as possible. Multi functional parts are chosen or made to suit the requirements which in turn reduce the number of parts implemented in the system. Reducing number of parts is reducing weight which has a direct proportional relation with increased fuel efficiency.

B. Material Substitution

More often in automotive applications, commonization of material is carried out which increases the weight of the system drastically. There is also scope to substitute less weight materials in places where real time stress acting is low comparatively. Reducing the weight of the material in such areas will provide more room for weight reduction. Reduced weight is increased fuel efficiency (carbon fiber compounds, magnesium etc).

C. Downsizing of parts

Part downsizing is another important aspect to be considered for weight reduction. This should be done with the consideration of every child part used for the assembly. Part downsizing should start from the initial stages of the project, with strong ideas on the utility of the vehicle. Much analysis should be made to make sure that the substituted material could hold the acting stress.

III. Indian Planning Commission: Emissions

The foundation for automotive emission standards in India since the early 2000s is contained in two reports from the Indian Planning Commission. The National Auto Fuel Policy, announced on October 6, 2003, envisioned a phased program for introducing Euro 2-4 emission and fuel regulations by 2010. In order to establish limits beyond Bharat Stage IV, the Indian Planning Commission established an Expert Committee in 2013 to draft an updated Auto Fuel Vision and Policy 2025 which was published in May 2014. While legislators are not required to adhere strictly to the recommendations contained in these reports, they serve as a starting point for subsequent legislative action to establish the implementation schedule and other details of automotive emission standards. The implementation schedule of EU emission standards in India is summarized.

TABLE I
INDIAN EMISSION STANDARDS

(4-WHEEL VEHICLES)

Standard	Ref	Date	Region
India 2000	Euro 1	2000	Nationwide
Bharat Stage II	Euro 2	2001	NCR*, Mumbai, Kolkata, Chennai
		2003.04	NCR*, 11 cities†
		2005.04	Nationwide
Bharat Stage III	Euro 3	2005.04	NCR*, 11 cities†
		2010.04	Nationwide
Bharat Stage IV	Euro 4	2010.04	NCR*, 13 cities‡
		2015.07	Above plus 29 cities mainly in the states of Haryana, Uttar Pradesh, Rajasthan and Maharastra
		2015.10	North India plus bordering districts of Rajasthan (9 States)
		2016.04	Western India plus parts of South and East India (10 States and Territories)
		2017.04	Nationwide
BS V	Euro 5	n/a [a]	
BS VI	Euro 6	2020.04	Nationwide

* National Capital Region (Delhi)
† Mumbai, Kolkata, Chennai, Bangalore, Hyderabad, Secunderabad, Ahmedabad, Pune, Surat, Kanpur and Agra
‡ Above cities plus Solapur and Lucknow. The program was later expanded with the aim of including 50 additional cities by March 2015
[a] Initially proposed in 2015.11 but removed from a 2016.02 proposal

For 2-and 3-wheelers, Bharat Stage II applied from April 1, 2005 and Stage III standards came into force in April 1, 2010. Bharat Stage IV standards for gasoline fueled 2-wheelers came into force April 1, 2016. Bharat Stage VI standards for SI and CI 2- and 3-wheelers were proposed in February 2016.

The roll out of Bharat Stage IV limits nationwide was delayed by the challenge of convincing fuel producers to make the necessary investments required to supply 50 ppm sulfur fuel nationwide. Potential solutions that have been suggested include, deregulation of diesel prices, an environment compensation charge on diesel vehicles and an additional levy on diesel fuel.

Even in cities with Bharat Stage IV limits, there have been challenges ensuring the dominance of non-compliant vehicles.

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Some of these challenges include: exemptions granted to some specialty vehicle (e.g., taxis) manufacturers, registration of Bharat Stage III vehicles by vehicle owners outside of their place residence due to loopholes in residential proof, registration of commercial vehicles outside of the Bharat Stage IV zones and insufficient availability of some specialty vehicles (e.g., garbage trucks) in Bharat Stage IV configurations.

In its May 2014 report, *Auto Fuel Vision and Policy 2025*, the Expert Committee recommended that Bharat Stage IV fuel be required nationwide from April 2017 followed by a further step up to the BS V in April 2020 and BS VI in April 2024. Draft recommendations discussed prior to the report's release included a national Bharat Phase IV+ stage (40 ppm sulfur) starting in 2017 and a national Bharat Stage V fuel standard staring in 2021. The Oil Ministry supported proceeding directly from BS IV to BS VI but this was opposed by the automotive industry. In November 2015, a draft notice was published by the Ministry of Road Transport and Highways announcing that BS V would be implemented across the country starting 2019 and BS VI starting 2021. While the automotive industry was supportive of the dates for BS V, they claimed advancing the dates for BS VI by more than 1 year from those recommended by the Expert Committee would not leave sufficient time for testing and validation and were unrealistic.

Severe air pollution episodes at the end of 2015 in Delhi-NCR lead to a number of Supreme Court rulings that had significant impacts on the automotive industry. One ruling in late 2015 banned the sale of diesel cars in the NCR with engine displacements greater than 2.0 L from January 1 to April 1, 2016. Another ruling in early January 2016 asked the government to advance the implementation of BS VI emission standards from those contained in the November 2015 proposals. The government responded by withdrawing its November 2015 BS V/VI proposal and announced that they would move the implementation date for BS VI to April 1, 2020 for all models and skip over BS V standards. A new draft proposal was published in February 2016.

IV. FUEL ECONOMY

Attempts to set fuel economy standards started in 2007, but it were delayed due to inter-ministerial conflicts and pressure from the automobile industry. In January 2014, the Ministry of Power the Bureau of Energy Efficiency notified minimum fuel efficiency norms for passenger vehicles that are sold in India.

Two sets of standards were announced: one set for fiscal years 2016-17 to 2020-21 and another for fiscal year 2021-22 onwards. The Road Transport Ministry objected by claiming the new emission levels were being mandated a year ahead of an earlier agreed to deadline.

V. PASSENGER CARS

Emission standards for passenger cars are summarized. Since 2000, the limits are based on the respective stages of EU light-duty vehicle emission standards and the definition of a passenger car is consistent with the EU vehicle category M_1.

TABLE III
EMISSION STANDARDS FOR PASSENGER CAR

Stage	Year	CO	HC	HC+ NOx	NOx	PM	PN
		g/km					*#/km*
Gasoline Vehicles							
	1991	14.3	2.0	-	-	-	
	1996	8.68	-	3.00	-	-	
	1998 *	4.34	-	1.50	-	-	
India 2000	2000	2.72	-	0.97	-	-	
BS II	2005 †	2.2	-	0.5	-	-	
BS III	2010 †	2.3	0.20	-	0.15	-	
BS IV	2010 ‡	1.0	0.10	-	0.08	-	
BS V	n/a [b]	1.0	0.10[d]	-	0.06	0.0045[e]	
BS VI	2020 [a]	1.0	0.10[d]	-	0.06	0.0045[e]	$6.0\text{x}10^{11}$[e]

The pre-2000 limits shown in the table were applicable to passenger cars defined as vehicles of GVW ≤ 2,500 kg with up to 6 seats. Limits for BS V were proposed in November 2015 but later removed from an updated proposal ; transitioning the nation directly to BS VI from BS IV.

TABLE IIIII
DIESEL VEHICLES

Stage	Year	CO	HC	HC+ NOx	NOx	PM	PN
	1992	17.3	2.7	-	-	-	
	1996	5.0	-	2.0	-	-	
India 2000	2000	2.72	-	0.97	-	0.14	
BS II	2005 †	1.0	-	0.7	-	0.08	
BS III	2010 †	0.64	-	0.56	0.50	0.05	
BS IV	2010 ‡	0.50	-	0.30	0.25	0.025	
BS V	n/a [b]	0.50	-	0.23	0.180	0.0045	$6.0\text{x}10^{11}$
BS VI	2020 [a]	0.50	-	0.17	0.080	0.0045	$6.0\text{x}10^{11}$

* for catalytic converter fitted vehicles
† earlier introduction in selected regions, see India:
‡ only in selected regions, see India:
[a] Proposed schedule and limits
[b] Initially proposed in 2015.11 but removed from a 2016.02 proposal
[d] and NMHC = 0.068 g/km
[e] applicable only to vehicles using DI engines

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Gasoline vehicles must also meet an evaporative (SHED) limit of 2g/test (effective 2000).

VI. LIGHT COMMERCIAL VEHICLES

Since 2000, emission standards for light commercial vehicles (GVW ≤ 3,500 kg) are based on EU emission standards, with implementation dates identical to those for passenger car standards.

The applicable vehicle categories are N_1 Class I, N_1 Class II, N_1 Class III, and N_2. Category M1, N1, M2 and N_2 vehicles with reference mass ≤ 2840 kg can optionally be certified to light-duty chassis emission limits.

VII. AN INTRICATE LOOK AT THE RUDIMENTS FOR REDUCTION OF CO_2

Another important aspect affecting the vehicle performance is the driving characteristics and the driving atmosphere of the automotive. These two remain the most important aspects irrespective of any engineering being put up in the vehicle development for reduced CO_2 emission. Reducing global CO_2 emission and thus limiting global warming remains one big challenge of our time. With the target to limit global warming throughout the globe set by the G7 nations as 2°C/year, the need of the hour is to find the best ways and implement the ideas on reduction of road traffic emissions for it remains the main contribution for the production of CO_2. CO_2 reduction shall be achieved by looking at the large picture where the entire vehicle dynamics is to the tweaked in. It calls for a root clause analysis and every area that shall affect the fuel efficiency of the vehicle needs to be improvised to help achieve the reduction of CO_2.

It remains the task for the OEMs to develop technologies that will efficiently reduce the CO_2 production. Stringent norms helped development of new technologies and more research on CO_2 reduction globally.

VIII. EMISSION TESTING

India is following the New European Driving Cycle (NEDC) designed to assess the emission levels of car engines and fuel economy in passenger cars (excluding light trucks and commercial vehicles).

It was effective in year 2000 in European Union Type Approval of emissions and fuel consumption from light duty vehicles [EEC Directive 90/C81/01]. The cycle consists of four repeated ECE-15 urban driving cycles (UDC) and one Extra-Urban driving cycle (EUDC).

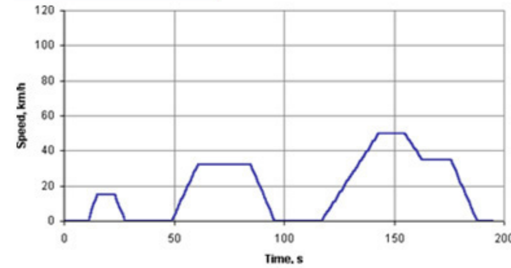

Figure 1: ECE 15 Cycle

Before 2000, emissions were measured over an Indian test cycle. The test is performed on a chassis dynamometer. The entire cycle includes four ECE segments repeated without interruption, followed by one EUDC segment.

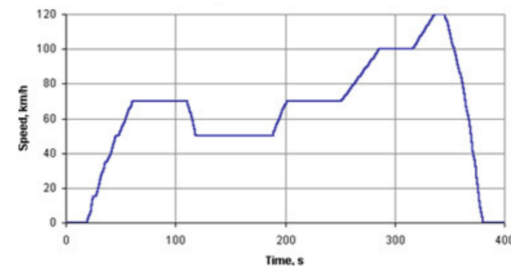

Figure 2: EUDC Cycle

Heavy Duty > 3500: European Stationary Cycle (ESC) test cycle was introduced together with the ETC (European Transient Cycle) and the ELR (European Load Response) tests by the Euro III emission regulation—Directive 1999/96/EC, effective year 2000—for emission measurement from heavy-duty diesel engines.

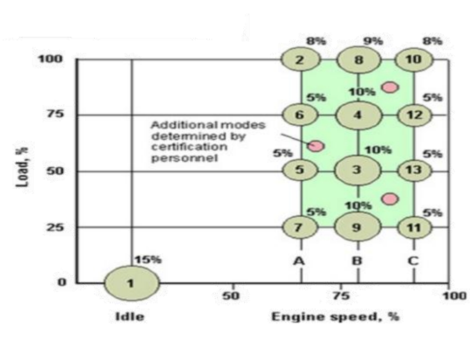

Figure 3: ESC Cycle

European Stationary Cycle: The ESC is a 13-mode, steady-state procedure that replaced the R-49 test. The engine is tested on an engine dynamometer over a sequence of steady-state modes.

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Emissions are measured during each mode and averaged over the cycle using a set of weighting factors. The final emission results are expressed in g/kWh.

Before the test, the vehicle is allowed to soak for at least 6 hours at a test temperature of 20-30°C.It is then started and allowed to idle for 40s.The ECE is an urban driving cycle, also known as UDC.

World Harmonized Stationary Cycle (WHSC): A steady-state engine dynamometer cycle for heavy-duty engines developed for engine emission certification/type approvals worldwide.

World Harmonized Transient Cycle (WHTC): A transient engine dynamometer cycle for heavy-duty engines developed for engine emission certification/type approvals worldwide.

World Harmonized Vehicle Cycle (WHVC): A non-regulatory chassis dynamometer test cycle for heavy-duty vehicles.

Non-road Transient Cycle (NRTC): NRTC is a transient engine dynamometer cycle for mobile non-road engines used for engine emission certification/type approval in the USA, European Union and other countries.

In November 2015, a draft proposal was published that required vehicles compatible with biodiesel blends up to B100 to certify with both diesel fuel and B100.

IX. Fuel Consumption By Improving The Vehicle Design And Technology

Fuel consumption is an aspect related to many features of the vehicle. Right from weight of the vehicle, the design, the dynamics, driving practices and many more affect directly the fuel efficiency of the vehicle. Vehicle design is one important aspect to increase the efficiency and the considerable points are:

A. Driving Dynamics and the driving practices

Irrespective of any engineering being fed into development of such efficient vehicles, the driving conditions and the driving characteristics plays a very important characteristics in sustaining the idea of improving fuel efficiency.

Driving condition is basically the roads and environment the vehicle is used in. Smooth roads with regulated flow of traffic keep the gear shifts and immediate acceleration to minimum. These conditions, in time pave way for reduced emissions.

Driving characteristics are based on each individual and their practices while maneuvering the vehicle. The idea behind economical driving should be inculcated in every driver who practices driving.

By and large, even after so much of engineering behind the wheels, driving characteristics remain the major player reflecting the fuel efficiency of the vehicle. Drive cycles as used in testing conditions should be developed and each individual should be trained under such drive cycles which will in time bring economic driving a habit. Every individual using a vehicle should first understand the importance of fuel efficiency and emission alarm.

B. Demand oriented drive

This part concentrates more on the driving characteristics. Anyone who drives must have a clear idea about the need of the hour, and act accordingly. People must be made aware of the impact they could bring by adapting to a regulated driving practices. With knowledge on the impact they could bring by adapting to demand oriented driving, drivable characteristics shall change quickly and effectively. An awareness education should be implemented across the country.

C. Norms and Protocols around the Globe

Koyoto Protocol-is an agreement made in Kyoto Japan that postulates that CO_2 emissions are very high and need to be curbed.

- The agreement introduces rules to encourage countries take whatever measures are needed to cut down on their CO_2 emissions
- Some countries do not want to ratify it because of the negative consequences on their economies.

X. Best Known Practices For Reduced CO_2

- Short journeys: bicycle, public transport, walk
- Drive-off after cranking a.s.a.p.
- Try to avoid harsh acceleration and heavy braking
- Use higher gears as soon as traffic allows it
- Switch off engine whenever it is safe to do so
- Remove roof racks when not in use
- Regular maintenance, right tire pressure
- Use air-conditioning sparingly
- Do not carry unnecessary weight

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AUTHOR'S PROFILE

Dr. S Rajadurai, born in Mylaudy, Kanyakumari Dt, Tamil Nadu, India, received his Ph.D.in Chemistry from IIT Chennai in 1979. He has devoted nearly 35 years to scientific innovation, pioneering theory and application through the 20th century, and expanding strides of advancement into the 21st century. By authoring hundreds of published papers and reports and creating several patents, his research on solid oxide solutions, free radicals, catalyst structure sensitivity, and catalytic converter and exhaust system design has revolutionized the field of chemistry and automobile industry.

As a corporate executive in the United States and India for over three decades, Dr. Rajadurai managed strategy on power train development and emission control for low, ultra low, super ultra low and partial zero-emission systems. From 1990-1996, he was the Director of Research at Cummins Engine Company. He was the Director of Advanced Development at Tenneco Automotive between 1996 and 2002 and subsequently Emission Strategist and Director of Emissions at ArvinMeritor until 2004. From 2004-2009, he was Vice-President of ACS Industries and since 2009 as Head of R&D Sharda Motor Industries Ltd.

Dr. Rajadurai has held leadership positions on the Board of Directors for the U.S. Fuel Cell Council, Manufacturers of Emission Control Association (MECA), Chairman of MECA Committee on Advanced Technologies and Alternate Fuels and Walker Exhaust India. He is an active participant in Clean and Green Earth Day demonstrations since 1997 and US Clean Diesel School Bus Summit (2003). He was a panelist of the Scientists and Technologists of Indian Origin, New Delhi 2004. He is a Fellow of the Society of Automotive Engineers. He was the UNESCO representative of India on low-cost analytical studies (1983-85). He is a Life Member of the North American Catalysis Society, North American Photo Chemical Society, Catalysis Society of India, Instrumental Society of India, Bangladesh Chemical Society and Indian Chemical Society.

Naveen.S, born in Coimbatore District, Tamil Nadu, India, completed his Mechanical Engineering in Amrita University in 2010. He is a seasoned engineer working strategies to improve emission control, engine after treatment, carbon balancing & fuel efficiency. He has experience in end to end management of automotive after treatment system development, homologation rudimentary implementations and validation. His expertise extends to good command over creating quality competitive, cost effective and value added cutting edge solutions that meet project requirements and product specifications. He is managing the program management team & BS VI applications of Sharda Motor Industries limited, R&D, Chennai. He has rich understanding and diversified exposure in the field of product lifecycle management. Having completed his Masters in Automotive Engineering from Staffordshire University, UK (2013), he has strong knowledge in DMAIC methodology to handle projects from concept definition, to manufacturing. He has an eye for intricate details to optimize vehicle emissions, CO_2 control and fuel efficient vehicle design.