A Review on different processes employed to meet BS6 standards in Diesel Engines

Atharva Tilak, UG Student, MITCOE, Pune, atharva1998@gmail.com
Janhavi Mutalik, UG Student, MITCOE, Pune, janhavimutalik@gmail.com
Sayli Vadnere, UG Student, MITCOE, Pune, sayliavadnere@gmail.com
M. S. Jadhao, Assistant Professor, MITCOE, Pune, mangeshjadhao89@gmail.com

Abstract: Emission norms have been introduced and are being enforced by many countries including India in order to control the carbon footprints of the vehicles. India has proposed to adopt BS6 norms from April 2020 which are in line with the Euro 6 norms being followed in all the western countries. The purpose of this paper is to understand the challenges behind achieving the standards proposed by the government and the various methods being employed to meet these standards. This paper will look into the old technologies already employed to control emissions and how they can be modified to ensure compliance with the norms.

Keywords — Bharat Stage 6 emission norms, Catalysts, Cost, Diesel Engine Technologies, Efficiency, Pollutants

I. INTRODUCTION

With India's steady rise as an industrial powerhouse, there has been an exponential rise in the transportation industry in India. The majority of India's transport vehicles run on Diesel and this is a major contributor to India's carbon footprint. Hence, the Government of India decided to fast-track the process of implementing more stringent emission norms and skipped an entire set of norms (BS5) and set the target on BS6 norms which are in-line with norms followed by all developed countries. April 2020 has been selected as the implementation date for BS6 norms.

As the implementation deadline for BS6 norms draws closer, various methods namely SCR, DPF, LNT, EGR, etc. have been implemented in commercial diesel vehicles with varying degrees of successes with more methods in the final stages of testing.

II. AVAILABLE SYSTEMS FOR EMISSION CONTROL

A. Flow-Through Diesel Oxidation Catalysts

One of the oldest methods used to reduce CO, HC, and PM content from the exhaust gases. They are basically honeycomb like structures coated with the catalysts like Platinum and/or Palladium through which the exhaust gases can flow. Catalysts are of regenerative type and generally last for about 25-30 years

INPUT	CATALYST	OUTPUT
CO, SO_2		CO_2, H_2O,
HC, NOx		SO_2, SO_3

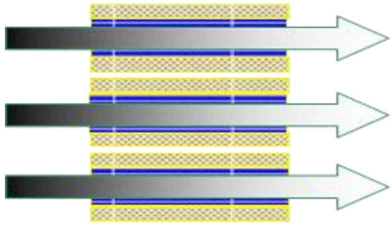

Figure 1: Schematic of Diesel Oxidation Catalyst

The efficiency of the system depends on the amount of Sulphur in the Diesel being used. Generally, the use of these systems ensures the reduction of PM (Particulate Matter) by about 40-50 percent.

B. Diesel Particulate Filters

As the name suggests, they are mainly used to remove the unburnt Carbon particles present in the exhaust gases. These are particularly harmful to humans as they are one of the major causes of cancer. As goes with any filter, they get blocked up over time and some mechanism must exist to remove the blockage. These are generally burning off the stuck particles when the temperatures are sufficiently high. By burning off trapped material, the filter is cleaned or "regenerated." The filters also need to be replaced from time to time for good performance. The lesser the Sulphur(less than 15 ppm is ideal) in the fuel, better is the performance. The system may employ a passive (catalyst used to reduce the ignition temperature of the soot particles) or an active (special heat supply given to burn off the soot particles) regeneration system for the filters.

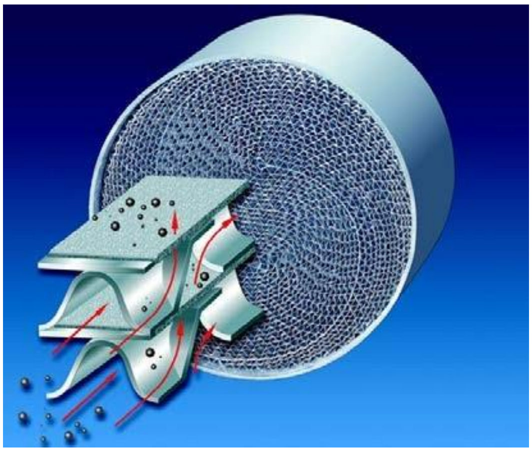

Figure 2: Metallic flow-through filter made up of corrugated metal foil and layers of porous metal fleece.

In some cases, the installation of a DPF causes a drop in fuel economy. This is mainly due to the back pressure developed in this system due to blockage of the exhaust flow due to particles stuck in the filter.

C. Exhaust Gas Recirculation

EGR involves recirculating a portion of the engine's exhaust back to the engine inlet (or intake manifold in the case of naturally ventilated engines). In some systems, an intercooler lowers the temperature of the recirculated gases. The cooled recirculated gases, which have a higher heat capacity and lower oxygen content than air, inhibiting NOx formation as high combustion temperatures lead to more NOx formation. A proper EGR System reduces NOx content in the exhaust by about 40 percent. Some optimization needs to be done in order to conserve fuel economy and reduce NOx content at the same time.

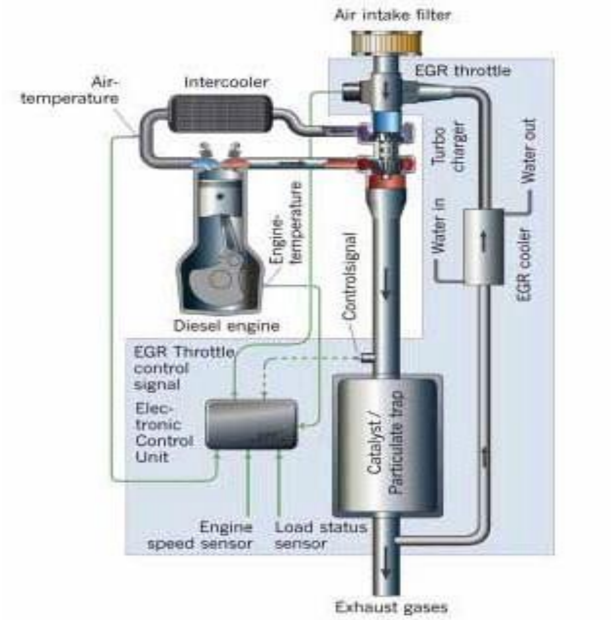

Figure 3: Low Pressure EGR with DPF

D. Lean NOx Catalysts

It is particularly difficult to reduce the Nitrogen compounds formed in the combustion chamber due to the high temperature of the chamber, presence of an Oxygen rich environment and high activation energy of the nitrogen compounds. Hence a reductant like HC, CO or H_2 is used further along the exhaust to decompose the nitrogen compounds. Currently, efficiencies of 10 to 30 percent have been achieved in NOx conversion. These systems often include a microporous structure made of zeolite and sometimes coated with a metal catalyst. This type of structure is used to facilitate proper decomposition of the NOx using the trapped catalyst particles in this microporous structure.

E. NOx Absorbing Catalysts

These systems are used when the NOx needs to be reduced in an oxygen rich environment. Lean NOx Trap (LNT) is a commonly used system. LNT system involves conversion of NO to NO_2, storing this as a nitrate, periodic removal of this nitrate from the alkaline earth oxide. The stored NOx is then periodically removed in a two-step regeneration step by temporarily inducing a rich exhaust condition followed by reduction to nitrogen by a conventional three-way catalyst reaction. These systems have an approximate efficiency of about 50 percent. NOx conversion is maximum near the 300 to 400 degrees point. Disadvantages are that when oxygen rich environment is needed for the regeneration of the catalyst, the fuel economy drops and this system requires ultra-low Sulphur fuels.

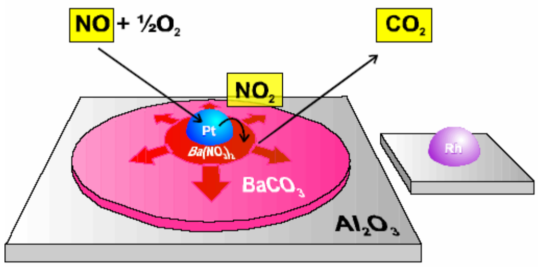

Figure 4: NOx trapping mechanisms under lean operating conditions.

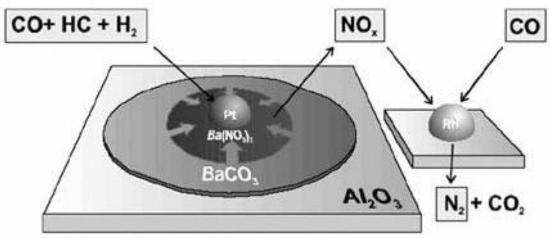

Figure 5: NOx trap regeneration occurs under brief periods of rich operation.

F. Selective Catalytic Reduction

Using SCR systems in diesel vehicles is very beneficial as it provides reduction of NOx, HC, and PM simultaneously. SCRs mainly provide high degree of NOx conversion. A SCR system is basically a substrate catalyst and a chemical reductant to convert NOx to atomic Nitrogen and Oxygen. The catalyst may either be ceramic based or metallic based. In a mobile system like a truck, an aqueous solution of Urea is the preferred reductant. The common reactions which occur are:

$$4\,NH_3 + 4\,NO + O_2 \longrightarrow 4\,N_2 + 6\,H_2O$$

$$2\,NH_3 + NO + NO_2 \longrightarrow 2\,N_2 + 3\,H_2O$$

$$8\,NH_3 + 6\,NO_2 \longrightarrow 7\,N_2 + 12\,H_2O$$

Modern SCR system designs combine highly controlled reductant injection hardware, flow mixing devices for effective distribution of the reductant across the available catalyst cross-section, durable SCR catalyst formulations, and ammonia slip clean-up catalysts that are capable of achieving and maintaining high NOx conversion efficiencies with extremely low levels of exhaust outlet ammonia concentrations over thousands of hours of operation. SCRs are quite versatile as they can be placed both upstream and downstream of the DPF (Diesel Particulate Filter). A general Urea tank lasts for about 15,000kms before refueling. In addition to NOx, SCR systems reduce HC emissions up to 80 percent and PM emissions 20 to 30 percent. They also reduce the characteristic odor produced by burnt diesel.

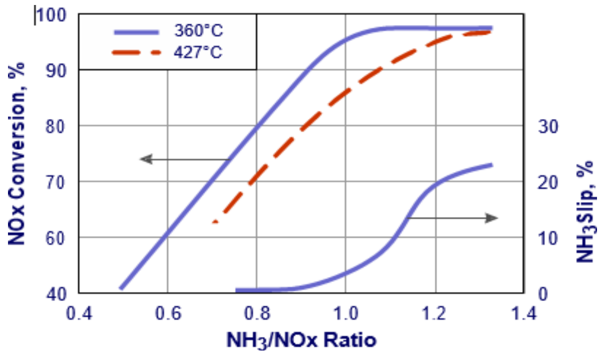

Figure 6: Graph of percent NO conversion Ammonia slip is minimized by developing specialized injectors and dispersers to ensure that the Urea is completely used. Low Sulphur fuel is preferred for better conversion rate.

III. COMBINATION OF SYSTEMS

As we have observed above, individually, neither of these systems is sufficient enough to provide the required reduction in emissions which will be specified in the BS6 norms. One major drawback of all these systems is that they require very low Sulphur content in the fuel being used. This is being overcome by using BS6 compliant fuel starting to be sold throughout India. Another drawback is that proper maintenance of these systems is required in a timely and periodic manner to maintain a good conversion rate for the various pollutants which isn't rigorously followed in India. Various attempts have been made to combine the various systems although only a few have been successful.

Heavy duty Diesel engines mainly used in large rigs require significant reductions (up to 60-70 percent) in their emissions to comply with the most recent norms. In most cases, modifications are being done to existing systems so as to reduce their drawbacks. A single catalyst is being employed for all the reduction processes. Computer chips and microprocessors (ECUs) are being used to read the conditions of the various points along the exhaust loop and accordingly change the working parameters of these emission control systems. Some novel solutions like combined NOx and SCR systems are being used where an on-board reductant like Urea isn't required.

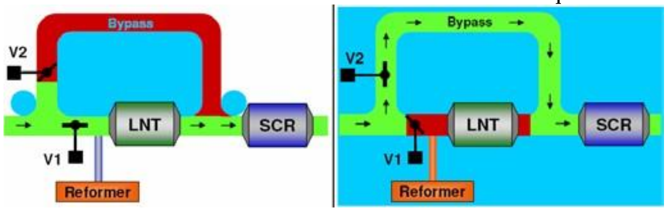

Figure 7: LNT, SCR combined catalyst system

The heat generated during HC and CO oxidation can be used for active DPF regeneration. In some smaller systems, the EGR system may be completely removed and only a high efficiency SCR system may be used. These systems have many advantages like: they reduce PM production due to more complete combustion, reduce heat rejection to the cooling system, and hence increase efficiency of the combined system by reduction in fuel consumption rates and more complete combustion. Fuel consumption is also mitigated by use of specialized fuel injectors which are controlled by ECUs to reduce NOx, HC and PM production in the cylinder itself.

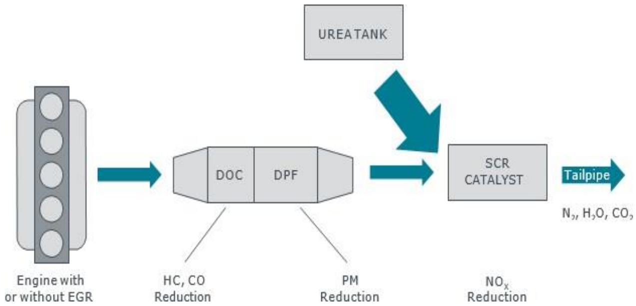

Figure 7: A modern system employed in Euro 6 compliant vehicles

In case of DPF usage, due to the backpressure developed, it results in a fuel economy loss of about 5 percent. To mitigate this, improvements are done by the manufacturers to the engine to compensate for the loss. On board diagnostics have also become a requirement in all modern vehicles as almost all the old systems now require an ECU (Electronic Control Unit). They form a closed loop system with a feedback loop in order to regulate the various parameters like Urea discharge, Oxygen rich air discharge, regeneration of particulate filter, etc.

IV. CONCLUSION

Pollution is one of the most important challenges a developing country like India must deal with to prosper. As heavy duty are the most major contributor to PM and CO emissions, it is very important for the government to establish laws to control these emissions. The manufacturers must strictly adhere to these laws and focus on quality rather than cost cutting. Even further research needs to be carried out in the various catalysts that can be used for the various reduction processes. Combined systems are the only way the emission standards can be maintained. Use of Electronic Control Systems must be increased to provide feedback loops to these various systems. On-board diagnostics must be provided on the vehicles. Better quality of fuel must be used in order to minimize the drawbacks of more Sulphur rich fuels on these emission control systems. The end consumers must be educated about the drawbacks of not maintaining their vehicles. Periodic maintenance and calibration of all these emission control systems must be carried out in order to ensure that they work at their rated efficiencies. Significant research needs to be carried out in order to develop cost effective technologies.

ACKNOWLEDGEMENTS

I would like to thank our HOD, Prof. Dr. Barve for his continued support. I would also like to thank Prof. Jadhao for his timely guidance.

REFERENCES

[1] MECA Diesel White Paper

[2] Ben Sharpe and Oscar Delgado, "India: Heavy-Duty Emissions." International Council on Clean Transportation and Diesel Net. (2014, July 21). "India: Heavy-duty: Emissions."

[3] Indian Emissions Regulation Booklet, ARAI

[4] Dr. Geng Zang, Catalyst technologies meeting BS5 and BS6 norms, ECMA

[5] K Senthur Pandian, The compliance of BS6 A sustainable approach, Mahindra and Mahindra

[6] India: Heavy Duty Emissions, TransportPolicy.net

[7] Emission Reduction Unit, Wikipedia

[8] Andersen, P. (2008). SCR Catalyst Technology for Low Emission Diesels. Diesel Engine Emissions and Energy Reductions (DEER) Conference. Detroit, MI.

[9] Johnson, T. V. (2002). Diesel emission control: 2001 in Review, SAE Technical Paper 2002-01-0285.

[10] Vialtis (2005). Euro 4 – Euro 5: SCR versus EGR. Aix-en-Provence, France.

[11] Stanton, D. W. (2013). "Systematic development of highly efficient and clean engines to meet future commercial vehicle greenhouse gas regulations." SAE International Journal of Engines **6**(3): 1395-1480.

[12] Johnson, T. V. (2002). Diesel emission control: 2001 in Review, SAE Technical Paper 2002-01-0285.