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Retrofit adaptation of exhaust sensors for Euro 6 Emission standard

Latha N¹, Sathish Kumar²

P.G. Student, Department of Electronics Engineering, Sir MVIT College, Bangalore, Karnataka, India¹

Associate Professor, Department of Electronics Engineering, Sir MVIT College, Bangalore, Karnataka, India²

ABSTRACT: The government has made a firm emission legislation, in order to reduce the air pollution occurring due to exhaust emission. The regulation has become very strict that by year 2020 majority of automobiles in India should be Bharath stage VI compatible, to achieve this government has decided for direct transformation in norms from BS IV to BS VI by skipping BS V. There will be lakhs of automobiles which obey BS IV norms and it will be practically expensive to design and use the BS VI vehicles by putting an end to existing BS IV vehicles used in the society. A faster and low cost effective solution to this problem is retrofitting a sensor with a control unit, with a little modification in the control algorithm for controlling the Exhaust Gas Recirculation (EGR) Actuator and Air fuel mixture. The retrofitting sensor as mentioned above in existing BS IV vehicles gives a smart solution for the upcoming BS VI regulations which gives still lesser PM content.

KEYWORDS: Retrofit, Emission standards, Bharath stage norms, Euro 6, Particulate matter sensor, Exhaust Gas Recirculation (EGR) Actuator, Air Fuel Mixture.

I. INTRODUCTION

The number of vehicles are increasing every year and they have direct impact on environmental pollution because of their incompletely burnt hydrocarbons. The composition of exhaust gas mainly depends on proper proportion of air and fuel during combustion. If burning of hydrocarbon occurs with enough oxygen then gives carbon dioxide and water which are less harmful. But if the combustion process is incomplete due to the less proportion of oxygen availability for fuel reaction then it produces polluted smoke and poisonous particulate matter and gases which will affect the human health. In order to prevent such harmful environment, government has framed emission legislation to limit the amount of hazardous gases which comes out as an exhaust gas. Though at present vehicles obeys the existing emission standard BS IV which is an alternative to Euro 4, the pollution is still increasing. With an objective to protect environment for improving the air quality it has become necessary to further reduce the threshold value which is set as allowed emission limit. For that reason government has set a regulation so that all vehicles should fulfil the new emission norm Euro 6 by 2020. As a care taker of air quality the government has decided to skip Euro 5. The idea of skipping Euro 5 norms has high impact on fuel producers as well as car manufacturers.

The reason for migration from Euro 4 to Euro 6 is that the Particulate matter content of diesel vehicle is reduced from 25mg/km to 5mg/km and also nitrogen oxide emission from 180mg/km to 80mg/km. For detecting the particulate matter in exhaust a particulate matter sensor along with sensor control unit is placed in the exhaust path and similarly for detecting the mono nitrogen oxides NO and NO₂ a NO_x sensor with its controlling unit can be retrofitted in the existing vehicle. These components individually measure the amount of respective content by using a chemical mechanism and send this information to the main Engine Control Unit (ECU). As ECU has control on air fuel mixture and Exhaust Gas Recirculation (EGR) actuator, it can send signal to modify the proportionality of air and fuel mixture so that the particulate matter can be reduced. The stoichiometric mixture defines ratio of air and fuel. For a diesel system this ratio is 14.7:1 which means for burning one gram of fuel 14.7 grams of oxygen is required in order to achieve complete or best possible combustion. EGR uses a mechanism to reduce the amount of NO_x by recirculating portion of exhaust gas back to the combustion cylinders which reduces the amount of O₂ entering the combustion chamber and allow gases as a combustion heat absorbents. Primarily this NO_x formation is due to the combination of

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nitrogen and oxygen at high temperature. In diesel engine the heat exchanger is used to cool the exhaust gas, as diesels mainly operate in presence of excess air EGR plays an important role in the reduction of NO_x. The present work mainly focus on particulate matter sensor and faster low cost effective solution for Euro 6 adaptation of vehicles.

II. RELATED WORK

The advancement in the automotive technology has integrated new components along with enhanced features in the automobiles exhaust path with an intension to reduce the hazardous gases. In diesel vehicles, Diesel Particulate Filter (DPF) is integrated in the tailpipe to reduce the PM content in the exhaust which eliminate the soot to a range approximately 85% or sometimes 100% based on certain conditions. As mechanism of reduction it use a catalyst or a fuel burner which will heat the filter to combustion temperature. If a DPF is damaged, then it cannot filter the soot, more PM content will be escaping from it. So, a sensor called Particulate Matter Sensor along with its control unit is used in the exhaust path to monitor the amount of particulate matter or soot coming out of DPF in exhaust path. Many approaches has been implemented as a soot sensing mechanism. By incorporating a sensor in the exhaust tail pipe, the amount of PM and NO_x in the forthcoming norms can be reduced when compared with existing norms. The percentage reduction can be seen in the below figure 1(a) and (b).

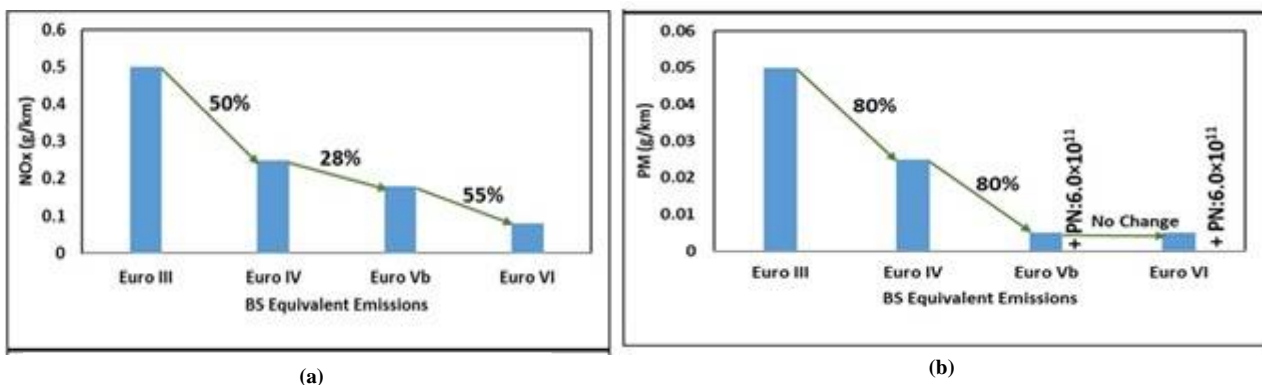


Fig.1 (a) NO_x reduction based on Emission norms; (b) PM Reduction based on Emission norms

The maximum allowable limit for the respective gaseous content in each norms is given in figure 2 (c).The present work mainly deals with methodology based on accumulating type soot sensors which works on the principle of collecting the particulates on the surface of a pair of electrodes. The deposition of soot results change in electrical properties of the system, by means of which detection of excessive soot emitted causing DPF failure can be determined.

Tier	Date	CO	NO _x	HC+NO _x	PM
Diesel					
Euro 1†	July 1992	2.72 (3.16)	-	0.97 (1.13)	0.14 (0.18)
Euro 2	January 1996	1.0	-	0.7	0.08
Euro 3	January 2000	0.64	0.50	0.56	0.05
Euro 4	January 2005	0.50	0.25	0.30	0.025
Euro 5	September 2009	0.500	0.180	0.230	0.005
Euro 6 (future)	September 2014	0.500	0.080	0.170	0.0025

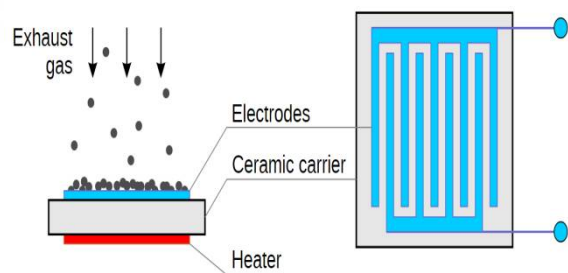


Fig 2. (c) European emission norms for passenger cars with allowed NO_x and PM content (d) Schematic of resistive electrode for soot sensing

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The mechanism used for soot calculation is given in the figure 2 (d). If the detection electrodes are covered with soot, then regeneration is performed by integrated electric heater where the accumulated soot oxidation occurs, preceding the next accumulating cycle. Because of this operating principle, real-time PM concentration readings is not possible with accumulating sensors. Typically it gives time-averaged results that can be correlated to the DPF pass/fail criterion as specified by the appropriate OBD requirements.

III. CONTROL ALGORITHM

The ECU supports a reprogram-ability feature which is the main supporting parameter for this retrofitting activity. There is a closed loop control between ECU, EGR actuator and air fuel meter as shown in figure 3 (f) . The proper control of EGR actuator control depends on the information received by the virtual sensors achieved by monitoring certain parameters using software functionality or a real sensor to measure parameters like temperature, pressure, air flow. If there is excess amount of NOx in the exhaust, NOx sensor detects and control unit of its sensor informs to the ECU. Thus ECU controls the EGR flow in order to reduce the NOx. Similarly the presence of PM content in the exhaust coming out of DPF is monitored by PM sensor. If the amount exceeds the threshold value, then the respective Sensor Control Unit (SCU) informs to the main engine. Since the particulate matter is a result of in appropriate proportion of oxygen during combustion of fuel, based on information received by SCU, the ECU now can check the signal received by Air Flow sensor as shown in figure 3 (e) and modifies it if proportion is not as per stoichiometric mixture. There by the PM emission can be reduced in the exhaust. Retrofitting these components needs a small update of functionality in control algorithm. As ECU supports reprogramming, software can be flashed to the controller of ECU. The figure 3 (g) below gives an overview of NOx and PM sensor placing in the exhaust path.

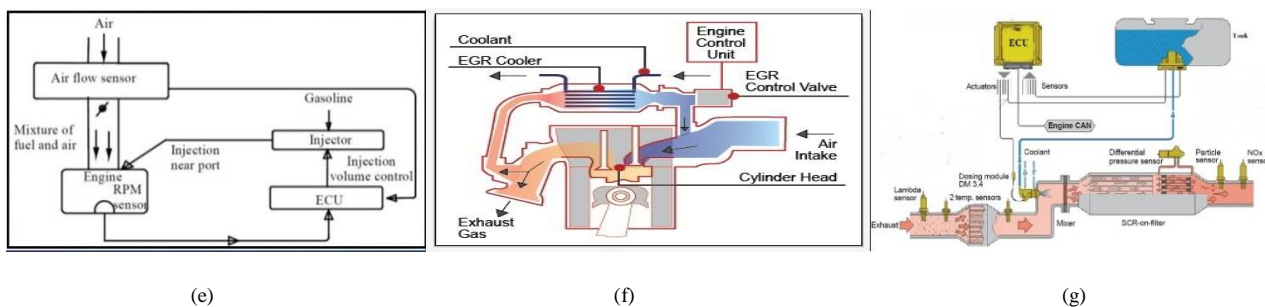


Fig.3: (e) Air Fuel control through ECU; (f) EGR actuator control through ECU; (g) sensor placing in the exhaust path

IV. EXPERIMENTAL RESULTS

The figure 4 shows the experimental results conducted on PM sensor for particulate measurement. It mainly sensor with its control unit (SCU) interfaced with ECU and follows four phases for detection of soot. The power-on phase, diagnosis phase, regeneration phase and measurement phase. The measurement for soot is performed only after a SCU gets a demand for soot measurement. If there is a soot deposition in electrodes, then a closed connection exists and electrodes draws a current. The amount of current drawn resembles the soot and if the current value exceeds the specified limit it is an indication of DPF malfunction and the respective information is sent to the main ECU. Similarly, NOx sensor is used to monitor the NOx content in the exhaust. If measured value exceeds the limitation, the respective control unit of sensor will inform to the ECU. As there is a closed loop control between ECU, sensors, EGR and air fuel meter, any change in exhaust in turn monitor the change in the stoichiometric ratio. Thus the integration of the NOx and PM in exhaust with little modification in control algorithm gives a best solution for Euro 6 adaptation.

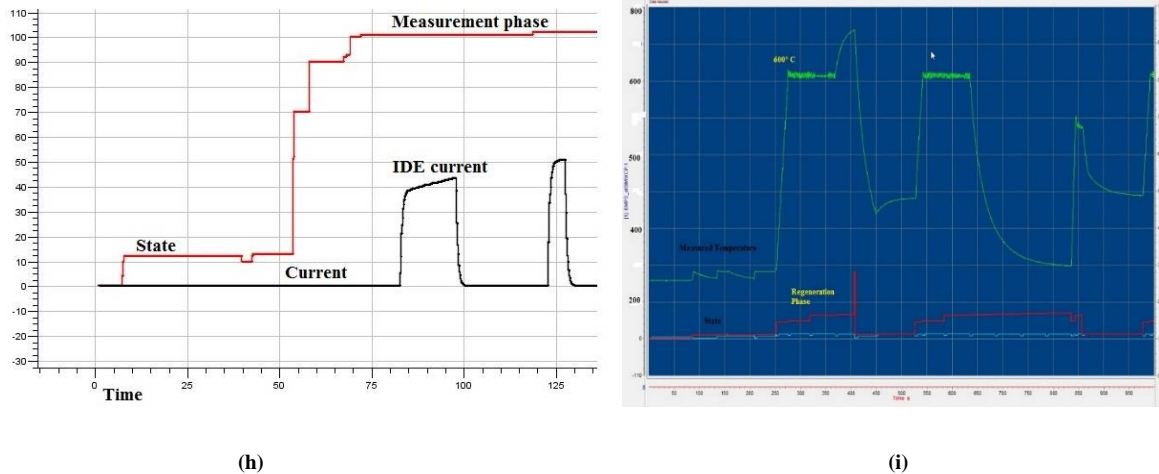


Fig.4 (h) IDE current in the presence of soot; (i) Soot burning in Regeneration Phase

V. CONCLUSION

The presented work gives an easy, low cost, efficient and an effective methodology for upgrading the existing vehicles to Euro 6 norms and also gives an overview on working principle of soot sensor and soot measurement. With the addition of few software functionalities to control the MAF and EGR actuator in the ECU control algorithm based on the input information from Soot sensor and NOx sensor the respective hazardous gases can be controlled in exhaust emission. The purpose of reducing the particulate matter as well as NOx can be achieved by integrating those sensors in the exhaust gas emission path. The objective of soot sensing is achieved and is designed efficiently with a capability to perform diagnosis of heater element of sensor and self-diagnosis in order to achieve On Board Diagnosis (OBD) of system.

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