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On Board Diagnostics (OBD) Scan Tool to Diagnose Emission Control System

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Abstract- Climate change has become very important issue the world is facing today. To control impact of climate change and improve quality of life, one of the key factor targeted is vehicular emissions. To control emissions very stringent emission norms are introduced by various government agencies across the world. This called for increased use for electronics in the engines and vehicles. This complicates the matter at service and manufacturers. The engine computer (Electronic Control Unit) with international protocol like OBD is used to control electronic parameters in engines. This review paper describes emission compliance requirement with brief introduction of the OBD system along with scan tool to diagnose the system.

Keywords - *OBD (On Board Diagnostics), ECU (Electronic Control Unit), Scan tool, Diagnostic Trouble Codes (DTC)*

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I. Introduction

Climate change is key issue faced by the world today. One of the major reasons for the climate change is attributed to air pollution. Which is also causing serious public health problem in most cities of the world. There are many source of air pollution like automotive exhaust emissions, industrial exhaust, burning of wastage etc. where engine exhaust is main source of pollution. Studies show that air pollution causes many diseases lead to large medical cost and decrease in productivity. Common air pollutant includes:

1. Nitrogen oxides (NO_x) - These vehicular pollutants can cause lung irritation.
2. Particulate matter (PM) - These pollutants enter deep into lungs & lead to serious health hazards.
3. Carbon monoxide (CO) - CO reacts with blood & reduces oxygen transport to the brain and other organs.
4. Sulphur dioxide (SO_2) - It can react in the atmosphere to form fine particles and can cause a health risk to young children and asthmatics.

To prevent air pollution many organizations worldwide like EPA (Environmental Protection Agency), CARB (California Air Resources Board), IEA (International Energy Agency) are working. To prevent the negative effects of pollutants these agencies make several legal arrangements like emission standards. An emission standard sets a limit to amount of pollutant that present in exhaust of automobile. Europe has developed Euro namely Euro I to Euro VI, respectively. In India Bharat Stage (BS) emission standards developed by the government of India, it is shown in Table 1.

Table 1. BS Norms

Norms	CO (g/kwhr)	HC (g/kwhr)	NO_X (g/kwhr)	PM (g/kwhr)
Bharat Stage III	2.3	0.2	0.15	NA
Bharat Stage IV	1	0.1	0.08	NA
Bharat Stage VI	1	0.1	0.06	0.0045

As shown in table 1 the emission values are becoming more stringent day by day. To meet desired emission levels, aftertreatment emission control system is the effective solution used by engine manufacturers. Pollutants from the exhaust can be lowered/eliminated to some extend by using emission control systems before emitted in air.

II. Aftertreatment Emission Control System

Increased focus on reduction of PM and NOx emission forced vehicle manufacturers towards modifications in engine technologies as well as use of aftertreatment devices. Earlier emission norms are met by altering engine combustion with modification in combustion chamber design, improved fuel injection systems, charge air cooling and increased attention towards reduction of lubrication oil in combustion chamber. But with stringent emission norms use of aftertreatment devices becomes inevitable. Aftertreatment system includes diesel particulate filters, exhaust gas recirculation, diesel oxidation catalyst, lean NOx traps and Urea injection & SCR catalyst.

A. Exhaust gas recirculation (EGR)

In EGR system some of the exhaust gas is recirculated inside the combustion chamber. This EGR is either cooled or not cooled depends on the engine technologies. With this recirculated exhaust gas, fresh air content in the engine is reduced. This diluted mixture of the air reduces the combustion temperature as well as oxygen content and in turn NOx formation.

B. Lean NOx Trap technology (LNT)

LNT technology used to reduce NOx emission especially under lean conditions (where NOx content is high). LNT stores NOx on the catalyst washcoat during lean engine conditions. Then, when rich engine conditions meets it releases and reacts the NOx by the usual three way type reactions (oxidation and reduction reaction converting NOx to nitrogen & oxygen). It is also called NOx-storage-reduction (NSR) or NOx absorber catalyst (NAC).

C. Diesel oxidation catalyst (DOC)

Main purpose of oxidation catalyst is covert unburnt hydrocarbon & carbon monoxide to CO2. DOCs also decrease the concentration of particulate in exhaust by oxidizing some of the hydrocarbons.

D. Diesel particulate filter (DPF)

Particulate matter is one of the most undesired outputs of the diesel engines. PM is removed from the exhaust gas by physical filtration in DPF method. DPF traps particulate matters in the specially designed filter and passes exhaust gas for further treatment. The heat is also used to oxidize this trapped soot. The soot is converted into clean carbon dioxide gas and water vapour. Figure 1 shows a DPF construction.

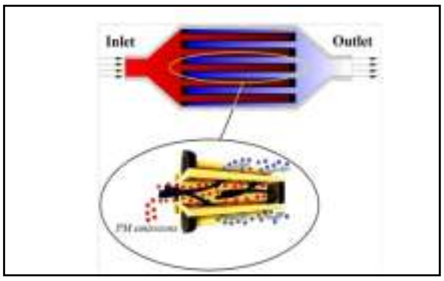

Figure 1. Diesel Particulate Filter

E. Selective catalytic reduction (SCR)

In this technology urea injects through a catalyst into the exhaust stream of engine. The chemical reaction takes place in which nitrogen oxides converted into nitrogen and water. Figure 2 shows a SCR block diagram.

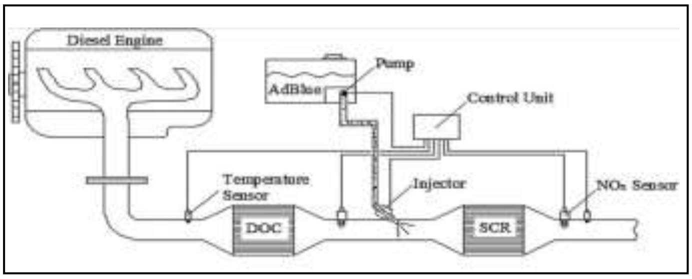

Figure 2. Selective Catalytic Reduction

To meet current and future regulations norms for emission, vehicle system are becoming increasingly complex because of interdependence between emission control components. Due to the increasing complexity of vehicle technology, the failure diagnosis becomes very difficult. A failure is an event that occurs when a system does not behave according its specification. Failures result in faults and errors. This led manufacturers to develop ways to effectively diagnose vehicle problems. To meet this purpose Society of Automobile Engineers (SAE) developed On-Board Diagnostics (OBD) system.

III. On-Board Diagnostics

During the 1980s, many vehicles equipping with control systems which can alert the driver about a malfunction and allow the technician to retrieve codes that identify malfunction in vehicle. These early diagnostic systems help to reduce emissions and help the technician to diagnosis fault. These systems are called as On-Board Diagnostics (OBD) which is embedded in Electronic Control Unit (ECU). Figure 3 shows an Electronic Control Unit. It is an embedded system which includes following blocks:

The Engine Control Unit (ECU) is the heart of a vehicles engine management system. It is the computer that controls electrical parts in vehicles embedded within an ECU. If there is a fault with any of the components, a malfunction indicator lamp (MIL) is illuminated, which is placed at the dashboard of the vehicle and a diagnostic trouble code (DTC) is generated. DTC is the standard error message format which contains the information about cause of the fault. From this DTC, mechanics identify the source of problems that arise in the vehicle.

Figure 3. ECU

ECU with OBD system monitors the emission system in the vehicles.

The OBD-I (On-Board Diagnostics I) system was implemented in 1980s. The first version of OBD was relatively simple and only monitored the oxygen sensor, fuel delivery system and the engine control module. Emission related faults could not detect by OBD I. Due to these limitations the California Air Resources Board (CARB) developed a new set of OBD standards. This new set was labelled OBD II.

OBD II systems are more 'user-friendly'. Regardless of the type of vehicle OBD II systems, now monitor the same components and use the same computer language for diagnosis vehicle system.

With the advancement in technology the ECU became capable of providing more diagnostic and sensor data to help mechanics identify the root cause of problems and to increase performance of vehicle. Later, OBD-II was introduced which is an improvement of the OBD I standard. OBD II expanded the list of components that were monitored to include emission-related components. OBD-II has been compulsory on all vehicles in the US market since January 1996. There are a few differences between OBD I and OBD-II.

The OBD system monitors the various control modules of the vehicle systems, as well as sensors and other components.

1. Structure of OBD

OBD structure varies according to the application and requirements. Following are parameters which governs OBD structure.

- Engine Application
- Model or Year

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- OBD phase or schedule
- Diagnostic capability
- Fuel type
- Engine application
- Vehicle or engine size
- Geographic region

OBD structure varies according to the engine application like marine, On highway, Off highway, heavy duty and light duty vehicles.

2. Function of OBD

OBD system continuously monitor a vehicle's emission control system for correct functioning. This monitoring is in terms of component monitoring and system monitoring. On detection of fault, MIL lamp which is mounted on dashboard is illuminated for fault indication. Fault storage is done by saving the information about fault in form of DTC and freeze frame in the ECU memory. By using this information technician take appropriate action to remove fault.

3. Fault monitoring requirements

There are 2 types in fault monitoring.

a) Component monitoring requirements

It include monitoring of all emission related input (sensors) and output (actuators) components. If the component get short or open it indicate two failure modes like out of range high and out of range low. Figure 4.4 explains this concepts. Green line shows the operation of sensor from 0.5V to 4.5V. Then below 0.5 V is out of range low and above 4.5 is out of range high.

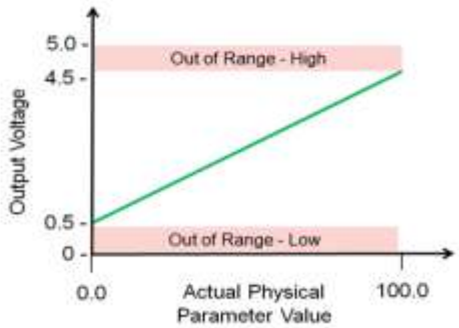

Figure 4.3 Circuit Continuity Diagnostics

b) System monitoring requirements

OBD Regulations require different degrees of System Monitoring:

•Functional Monitors

It detect complete/major functional failure of a specific component or sub-system (e.g. Missing/inert catalyst, Misfire Monitor, etc.)

•Emission Threshold Monitors

1.It detect failures of a component or sub-system that cause a specified increase in emissions (e.g. Degraded Catalyst, Insufficient EGR Flow, etc.)
2.Typically trigger at 1.5-2 times emission threshold (FEL)
3.Previous regulations required 3-8 system monitors
4.Future regulations require ~35 system monitors

4. Fault Indication

Confirmed faults are indicated to the driver using a Malfunction Indicator Lamp (MIL) present on the dashboard. This MIL is only for emission related problems and to indicate emergency start-ups or limp home modes.

5. Fault storage

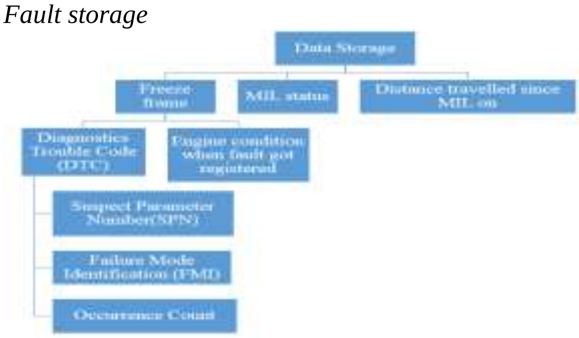

Figure 4.5 shows data storage requirements of OBD. The information is stroed in 3 types as MIL get on.

1. Freeze frame
2. MIL status
3. Distance travelled since MIL on

Freeze frame contains DTC and engine condition when fault get registered. DTC is made up of SPN FMI and occurrence count

Following are some important parameters in OBD system:

A. Diagnostic Trouble Codes (DTCs)

DTC is the standard error message format specified by the OBD-II. DTC is made to inform driver about the malfunction occurred in vehicle. There are four main types of DTC codes defined by the SAE standards. Figure 3 shows DTC:

1) First Character - System
2) Second Digit - Code Type
3) Third Digit - Sub-System
4) Fourth and Fifth Digits - Identifies Section

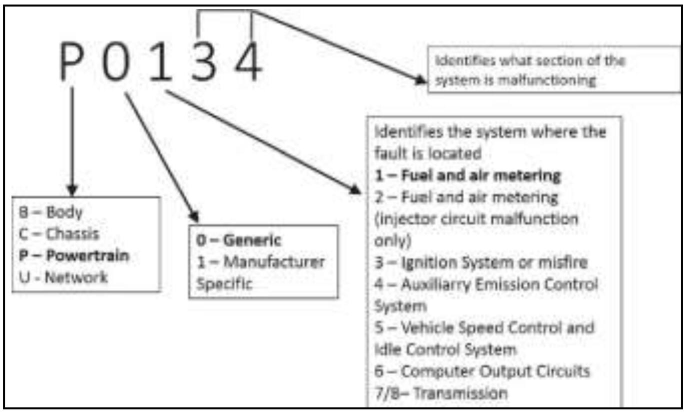

Figure 3. OBD II DTC

B. Malfunction Indicator Lamp (MIL) Illumination

If OBD detects a problem, the driver is informed by illuminating check engine lamp on dashboard. So that driver come to know that the vehicle should be taken to service centre. MIL will be illuminated in following conditions:

• A malfunction occurs which affects performance of emission system by exceeding the standards by 1.5 times.
• Manufacturer-defined specifications are exceeded.
• Catalyst deterioration.
• Misfire faults occur.
• A leak is detected in the evaporative system.

C. Freeze Frame

OBD II has additionality features that stores important information about the system condition at the instant a DTC is stored. This information is stored in form of freeze frame.
The values of all parameters are stored in freeze frame when any malfunction is detected and DTC is generated by OBD.

This parameter gives information about system working. This information is very useful to the technicians to repair the system and to improve performance of the system. To assess this useful information, technicians require an equipment named scan tool. Scan tool communicate effectively with the vehicle OBD system and get information about the system working.

IV. SCAN TOOL

In 1996 the EPA mandated that the computer interface for all vehicles should meet a common standard. Due to this repair shops didn't have to buy different scan tools, one for each brand of car they wanted to work on.Many commercial softwares are available to monitor the Traffic on CAN bus. They are as follows:

1. TOAD (TOTAL OBD & ECU Auto Diagnostics)

It is a complete professional all-in-one package that will allow to check performance of the car. It will show detail working of various systems, like engine and transmission.

2. CANalyzer

It is developed by the Vector Company. It provides advanced software tools for monitoring of CAN based systems. It also offers a graphic block diagram interface from which CAN based system is controlled or monitored.

3. PCAN Tools

PCAN is a package of software tools developed by the Peak company. It comes on dedicated CDs for free with the purchased HW modules. It covers the wide range of tools. From simple CAN monitoring ones, like PCAN-View, to more advanced tools like PCAN-Explorer. PCAN-Explorer provides all necessary functionality needed for advanced monitoring and analysis of CAN based systems.

4. Port

Port is another company offering software tools which monitors CAN bus. Apart from developing of their own CAN HW modules, they offer a simple CANopen device monitor tool programmed in Tcl/Tk.

5. Silver Scan Tool

Silver Scan Tool software provides test functionality for onboard diagnostics according to SAE J1979, SAE J1979 and ISO 27145 standards. All emission relevant electronic control modules that support these standards can be diagnosed.

Scan tool is an auto diagnostic tool. When this diagnostic device sends a Parameters ID (PID) to ECU, ECU will provide a response in a series of bits. These bits must be read and decoded to locate the fault in the system.

A. Parameters ID (PID)

PID is the command codes used by scan tool to communicate with the ECU. When it wants to get some information, a device will send a PID to ECU, and ECU will return the information requested.
The 9 available modes for PIDs are:

- *Mode 1: Display current real-time engine data.*

The ECMs will transmit current data value stored by the system and not the default or substitute values. Depending on the ECM and amount of parameters selected, data update rates may vary. The fewer data parameters were selected, the faster the update rate.

- Mode 2: Freeze Frame data.

ECU stores engine condition when an OBD detects faults. This data is called as a 'Freeze Frame'. This information is useful for diagnosis the fault.

- Mode 3:Emission related DTCs.

This service enables the scan tool to obtain stored emission-related DTCs from the power train ECMs.

- Mode 4: Clear all DTCs

This service clears all codes and turn off the MIL. It is suggested to print the DTCs before erasing them.

- Mode 5: Test results from oxygen sensor monitoring.

This service allows access to the on-board oxygen sensor monitoring test results. Different manufacturers use different methods to calculate test results for this service. The scan tool converts test values by using standard formula and displays it.

- Mode 6: Other sensors test result.

This service allows access to the test results for systems like continuously monitored (CAN only) and not continuously monitored.

- Mode 7: Pending DTCs.

This service enables scan tool to obtain "pending" or maturing diagnostic trouble codes. These are codes for emission-related components that were detected during the current or last completed driving cycle.

- Mode 8:Control operation of on-board system.

This service is used to control the operation of vehicle components, tests or systems. These tests are also known as 'On-Board Activation Tests'.

- Mode 9:Vehicle information.

Through this service the scan tool requests information specific to the vehicle such as:

• Vehicle Identification Number (VIN)
• Calibration IDs
• Calibration Verification Numbers (CVN, displayed as hexadecimal value)

In the developing stage of OBD, every vehicle require their own scan tool due to lack of standardization in communication protocols. The Society of Automotive Engineers (SAE) developed these standardized methods to provide the vehicle and scan tool compatibility.

As a result of this SAE initiative a new generation of hand-held scan tool was developed to interact with the OBD II. The hand-held scan tool became more powerful in terms of storage, processing, and display. Thus, the handheld scan tool became one of the primary links to proper diagnosis and repair of OBD equipped vehicles.

The following step describes the working of scan tool:

- The technician enters the PID in scan tool.
- The scan tool sends PID on the CAN (Controlled Area Network) bus.
- Devices available on the bus check PID and respond if that PID is corresponds to it.
- The scan tool reads the response, and displays it to the technician.

This response is decoded to get the information. Then by using different formulas the values of parameters are calculated.

V. CONCLUSION

A review on On-Board Diagnostics testing tool used for emission control system is done in this paper. The requirement of aftertreatment emission control system and its different types are discussed. A brief history of OBD has been presented. The main parameters such as Diagnostic Trouble Codes, Malfunction Indicator Lamp, Freeze Frame and Parameters ID are discussed. The paper explains in detail the process of self-diagnosis technique for emission control system by using scan tool.

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