DEVELOPMENT PERSPECTIVES OF ON BOARD DIAGNOSTIC SYSTEM IN LIGHT OF NEW APPROVALS OF VEHICLES

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Abstract

The first rules of on board diagnostic were published in 1981. The standard had been improved in the next years, until the condition of today and also in the future, which result is presently used OBD II system, and in the close future - OBD III.

On-board diagnostic system – OBD II is present in most passenger and utility vehicles in USA; the idea originated on the turn of 70-ties and 80-ties. It was dictated by the willingness to control engine functions and to diagnose related subassemblies.

One of the methods to reduce emission of toxic components is continuous control over engine elements that are directly or indirectly responsible for level of emission of these components. Introduction of these requirements caused creation of the self-diagnostic definition and utilising innovation definition self-diagnostic: All the diagnostic devices have been designed according to main goal of the OBD standard, i.e.: one connector – one cable – one device – all diagnostic data now and in the future.

In my paper I would like to present our results of investigations the level implementation diagnostic procedures (monitors) in vehicles (equip in SI and CI engines) with new approvals in Poland and basic terms in OBD system and OBD standards.

1. Introduction

Self-diagnostic is to minimize the volume of substances generated by the combustion engines polluting the natural environment. Self-diagnostic is the basis for creating the best conditions for the most effective operation of the engine.

The first rules of on board diagnostic were published in 1981. The standard had been improved in the next years, until the condition of today and also in the future, which result is presently used OBD II system, and in the close future - OBD III.

Introduction of requirements caused creation of the self-diagnostic definition:

Self-diagnostic system comparing value of signals from circuit of electronic control device with control values. If the real signal value does not comply with control value, the memory of the control devices records the error code.

It was forecasted 20 years ago that there would be no reduction in number of diesel engines used in passenger and delivery vehicles. In the course of the last 10 years we could observe quite opposite phenomenon. The advantages of diesel engine and development of engine computer control causes dynamic growth of quantity of vehicles with diesel engines. Thanks to advantages as: lower fuel consumption, high durability, reliability, 100% of trucks and buses use such kind of engine. In case of delivery vehicles, sales in 1995 of vehicles with diesel engine constituted 90% in France and 95% in Great Britain in comparison to whole sales volume of vehicles in this segment (fig. 1) [1].

The increase of number of vehicles in the world has caused growth of toxic emission. Because of growing environment pollution, the agencies of environmental protection and automotive concerns are searching for the possibilities of emission reduction and substances being results of hydrocarbon fuels combustion. More and more complicated modernisation of
presently produced vehicles is performed for global problem reduction.

In the late nineteen hundreds more stringent exhaust emission regulations were introduced in Europe and they are now in force. Specifically new requirements regarding emissions and fuel quality improvements specified as Euro III (Stage 2000) and Euro IV (Stage 2005) were approved in the European Union on 30 June 1998 (published in the Directive 98/69/EC and amended by directives 1999/102/EC and 2001/1/EC [1]), and by United Nation Economic Commission for Europe (ECE) on 29 March 2001 – Regulations ECE R.83.05 (fig. 2 and fig. 3) [2, 3, 4]. In these new regulations the emission limits of carbon monoxide (CO), hydrocarbons (HC) and nitrogen oxides (NO\textsubscript{x}) as well as the particulate matters (PM) of passengers cars (PC) and light commercial vehicles (LCV) diesel engines are being tightened and future improvements in emission performance are required.

The regulations included in the Polish law, “Law of Traffic”, lay the obligation on the automotive vehicle manufacturer or importer to obtain the Type Approval Certificate issued by the Minister of Transportation. Following the provisions of the above law the Minister of Transportation has issued a Regulation on the technical conditions and examination of vehicles, according to which the Type Approval Certificate shall be issued on the basis of positive results of examination for type approval, i.e. examination whether a given type of vehicle fulfils, among others, the conditions described in the Regulations accepted by Poland for use, regarding the enclosures to the Agreement Concerning the Adoption of Uniform Conditions of Approval and Reciprocal of Approval for Motor Vehicle Equipment and Parts done at Geneva on March 20, 1958.

To comply with the exhaust emission limits, and in particular the limits after 80 000 km mileage, it is necessary to ensure a proper technical state of the engine (elements that affect the level of polluting substances emission) and its continuous control.

An on going monitoring of these systems will allow for early detection of malfunction in the first stage when the effect of exhaust gases on the environment is still minimal [5, 6, 7]. The above discussed requirements are fulfilled by the on-board diagnostic system OBD in compliance with the Directive No. 98/69/EC and 1999/102/EC throughout 2500 kg, N1 class I) as of 1 January 2000 (for new type approvals vehicles) and as of 1 January 2002 for all first registered vehicles of this type. As of 29 March 2001 the ECE UNO 83.05. Regulations the OBD system have been implementation all European countries including Poland.
Main targets of OBD system applications (fig 4 and fig. 5):

- diagnostic effectiveness – ability of detection and location of malfunctions,
- universality – ability of system development with new functions and subsystems and easy application in new types.

2. Important terms in on board diagnostic system

OBD II has more ability than the ever before to know what is going on inside an engine. The main reason is the increased emission output when something goes astray, but more important to protect catalytic converter from being damaged by excessive hydrocarbon or carbon monoxide. Due to this, new area are monitored, including catalytic converter conversion efficiency and crankshaft speed to determine engine misfire.

To understand OBD II logic, we will first start with a few basic terms:

- diagnostic – a test that is run on a system or component to determine it is operating according to specifications. Main areas of concern include misfire, oxygen sensors, oxygen sensors heater, EGR (Exhaust Gas Recirculation) and catalytic converter efficiency,
• passive test – is a diagnostic test that monitors a system or component,
• active test – an active test actually executes an action when performing a diagnostic function,
• freeze frame – stores vehicles information at the moment an emissions system test that will have an affect on emission (fig. 6). If EOBD (European On Board Diagnostic) detects a failure, the following data must be saved in a freeze frame [12]:
- calculated load,
- engine speed,
- fuel/air regulation Fuel Trim (if available),
- fuel pressure (if available),
- intake manifold pressure (if available),
- vehicle speed,
- engine coolant temperature,
- fuel control system status - open-loop, close-loop (if available),
- the failure code,
• response time – by studying the car below, you will see that the amount of time needed to make the transition from rich to lean cannot surpass 100 ms on the pre-catalytic converter O₂ sensor (fig. 7),

![Fig. 6. Definition of “freeze frame” and present Fig. 7. Heated oxygen sensors (HO₂S) – response time parameters [12]](image1)

![Fig. 8. Fuel trim system monitoring](image2)

![Fig. 9. Exhaust gas recirculation EGR change in manifold absolute pressure [12]](image3)

• fuel trim system monitoring – the theory for fuel trim monitoring is to look at the
average short or long term correction needed to bring the air/fuel ratio into line. If these fuel trim values reach and stay at their limits for a period of time, a malfunction is indicated (fig. 8),

- EGR system monitoring – this uses a change in MAP to determine how effective the EGR system is. The EGR valve will be forced open during closed throttle deceleration and a change in MAP corresponding to the chart below will be required (fig.9),

EOBD system should be controlled:
- defective catalyst,
- defective lambda sensor,
- engine misfire,
- defective fuel/air regulation,
- failure in a component, that will cause increased emissions, above the limits.

3. Result of tested vehilces

![Fig. 10. Functions of generic scan tool](image)

Stored fault functions may be read out by the monitoring devices Scan – Tool type, which is connected by diagnostic connector. We taken advantage of polish diagnostic scanner made in Poland by one of polish company.

Devices automatically identify with one of four classes of data communication bus in automotive vehicles and automatically enter into transmission.

Those devices was tested during diagnosis American vehicles made between 1996 and 1999 and new cars produced in Europe and Asia. We tested 200 vehicles with spark ignition engines and diesel engines, which we can buy on polish market. Diagnostic link connector was located in different places in cockpit of vehicles. Tested vehicles characterize be different level of functionality OBD II/EOBD system.

4. Resume

The basic requirements of each OBD regulation is that these systems in any type of car of any manufacturer production have to comply strictly with the law imposed modes of operation and diagnostic limits and should generate the same standardized diagnostic information stream.
The freedom of choice between two following techniques of such testing was left. The first technique makes use of manufacturer prepared warn-out faulty real parts. The second is based on electronics simulation of component deterioration and malfunctions. The first method, although looking pretty straightforward is timing consuming, requires special service information and tools and depends heavily on a manufacturer’s good will of collaboration.

Fig. 11. Percentage share of monitors in tested vehicles with SI and CI engine

Fig. 12. Percentage share of sensors in tested vehicles with SI and CI engine

The second method seems to be by far more time/cost efficient as it potential allows to test
quickly OBD systems in a broad range of malfunctions conditions. As it does not require component of this potential efficiency new test technology and instrumentation should be developed.

How to introduce intently misfire events of controlled intensity and statistical characteristic into an engine combustion process. This is a crucial problem in testing misfire monitor, which is undoubtedly the most complicated and trouble some OBD II supported procedure. Two approaches to the misfire insertion were considered. The first one is based on controlled switching off shutdowns to chosen cylinders by disabling relevant injectors. The results of technical feasibility study of two approaches were presented and advantages of the second approach pointed out.

How to simulate electronically deterioration and malfunctions of lambda sensors and catalytic converters by transformation of the pre and father catalytic converter new lambda sensors output signals into signals which are characteristic to deteriorated of faulty sensors and converters. New unique method of such transformation was proposed. It is based on digital filter algorithms implemented on modern Digital Signal Processors (DSP)> 

References

[2] ECE Reg No.83.05 (E/ECE/324-E/ECE/TRANS/ 5051 Rev.1/Add.82/Rev.1, provisions concerning the approval of vehicles with regard to the emission of pollutants according to engine fuel requirements.
[3] ECE Reg No.84.00 (E/ECE/324-E/ECE/TRANS/ 505 Rev.1/Add.83): Uniform provisions concerning the approval of power-driven vehicles equipped with internal combustion engines with regard to the measurement of fuel consumption.

Jargon and acronyms

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<tr>
<th>Abbreviation</th>
<th>Description</th>
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<tr>
<td>CI</td>
<td>Compression ignition</td>
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<tr>
<td>CO</td>
<td>Carbon monoxide</td>
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<td>DI</td>
<td>Direct injection</td>
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<td>DTC</td>
<td>Diagnostic Trouble Code</td>
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<td>EGR</td>
<td>Exhaust Gas Recirculation</td>
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<td>EOBD</td>
<td>European On Board Diagnostic</td>
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<tr>
<td>EVAp</td>
<td>Evaporation Prevention</td>
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<td>HC</td>
<td>Hydrocarbons</td>
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<td>IDI</td>
<td>Indirect injection</td>
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<td>LCV</td>
<td>Light Commercial Vehicle</td>
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<td>MAP</td>
<td>Manifold Absolute Pressure</td>
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<tr>
<td>MIL</td>
<td>Malfunction Indicator Light</td>
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<td>NO\textsubscript{x}</td>
<td>Nitrogen oxides</td>
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<td>OBD II</td>
<td>On Board Diagnostic II</td>
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<td>OBD III</td>
<td>On Board Diagnostic III</td>
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<tr>
<td>OBM</td>
<td>On Board Measurement</td>
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<td>PC</td>
<td>Passengers cars</td>
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<td>PCV</td>
<td>Positive Crankcase Ventilation</td>
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<td>PM</td>
<td>Particulate Matter</td>
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<td>SAE</td>
<td>Society of Automotive Engineers</td>
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<td>SI</td>
<td>Spark ignition</td>
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