

A New Method for Emission Control System Malfunction Detection During the Periodic Technical Inspection

REŠETAR M.^{1*}, PEJIĆ G.¹, ILINČIĆ P.² and LULIĆ Z.²

¹ Centre for Vehicles of Croatia, Capraška 6, Zagreb, HR-10000, Croatia

² University of Zagreb, Faculty of Mechanical Engineering and Naval Architecture, Ivana Lučića 5, Zagreb, HR-10002, Croatia

*corresponding author: Marko Rešetar

e-mail: marko.resetar@cvh.hr

Abstract

The paper shows a new method for detecting emission control system malfunction during periodic technical inspection (PTI). The on-board diagnostic (OBD) test results were collected and processed during the PTI of vehicles in Croatia in 2020. The study included petrol and diesel passenger cars that passed the tailpipe test and for which an OBD test had also been performed. In 11.5% of the tested cars, at least one stored diagnostic trouble code (DTC) was found. Due to the significant number of vehicles with identified DTCs, a new and more efficient method for the detection of potentially defective vehicles has been suggested. The introduction of the OBD test mandatory for all vehicles equipped with a European on-board diagnostic (EOBD) system is proposed. In addition to the existing OBD data, it is recommended to introduce the number of DTCs as mandatory, and such data should be relevant for passing the roadworthiness test.

Keywords: On-board diagnostic (OBD); Diagnostic trouble code (DTC); Periodic technical inspection (PTI); Emission control; Emission standard

1. Introduction

Due to the relatively expensive repair and replacement costs of exhaust after-treatment system components, vehicle owners, especially in countries with lower income, often decide to disable their functionality or completely remove them from the vehicle. Although such manipulations are often presented as "not illegal", they conflict with the European regulations' requirements that prohibit the use of defeat devices (Official Journal of the European Union, 2007). Before placing a vehicle on the market, prescribed emission limit values must be met during the type approval emission test. In most cases, in later phases of exploitation, they are no longer monitored.

The periodic technical inspection (PTI) of vehicles in Croatia is performed by the Centre for Vehicles of Croatia (CVH) (Rešetar et al., 2018). During the PTI, a

tailpipe emission test is compulsory. For diesel vehicles, only the opacity of exhaust gas is measured, and the K-value is calculated. For petrol vehicles, the volume concentration of carbon monoxide is measured, and the lambda value is calculated. Because of limited technical capabilities, existing emission testers in PTI stations cannot be used for the detection of emission control system malfunction. The International Motor Vehicle Inspection Committee (CITA), based on their research, proposed the introduction of emission testing for diesel vehicles involving NO_x measurements (CITA, 2019). However, testers that can additionally measure NO_x emissions are quite expensive. Equipping all PTI stations, all over the country, with such testers would require significant financial resources and only diesel vehicles would be covered with this new test.

According to the European legislation, all petrol PCs sold within Europe since 2001, and diesel PCs manufactured from 2004, must be fitted with an on-board diagnostic (OBD) system for emission control (Official Journal of the European Communities, 1998). According to the *Directive 2014/45/EU*, for roadworthiness tests, the OBD test can be used as an equivalent to standard tailpipe emission testing for Euro 6/VI vehicles (Official Journal of the European Union, 2014). Since 2019, OBD testing methods have been performed in Croatia during the PTI (Rešetar et al., 2019). During the OBD test, the following data relating to the proper operation of the emission control system are collected: malfunction indicator lamp (MIL) status, readiness-code status, number of diagnostic trouble codes (DTCs), and others. The MIL status indicates a malfunction of any emission-related component connected to the OBD system or the OBD system itself. Malfunction means the failure of an emission-related component or system that would result in exceeded emissions. The readiness code is a set of 8 bits, each corresponding to one monitored emissions system in a vehicle. It indicates which of the vehicle's systems were checked during the diagnostics procedure. The number of DTCs shows the number of faults that the vehicle's OBD system uses to notify about an issue. When the OBD detects a fault, it will activate the corresponding trouble code. Each code indicates a

specific issue. The DTCs are standardized and explained in ISO 15031-6:2015.

In the Republic of Croatia, the OBD test is currently used as an optional alternative to the tailpipe test for Euro 6/VI vehicles where results indicate MIL OFF and readiness-code status OK. To improve the tailpipe test for Euro 5 and older vehicles with a European on-board diagnostic (EOBD) connection available, coolant temperature and engine speed can be collected via the OBD diagnostic tool. An OBD test is also performed by connecting a diagnostic tool, but it does not have to be accepted as a tailpipe test. By collecting and processing OBD data, it is possible to identify vehicles with potential malfunctions in emission control systems. This study is aimed at developing a method for the detection of such vehicles during the PTI.

2. Method

In order to check the functionality of electronic devices and physically inaccessible components embedded in the vehicle, new inspection methods should be introduced. With the application of vehicle diagnostics, it is possible to easily and quickly determine faults and malfunctions of individual components in the vehicle, and primarily the components of the emission control system. The existing method, self-initiated and introduced by the CVH, was used to collect the OBD data (Rešetar et al, 2019). In this study, data for PCs that underwent PTI in 2020 were collected and processed. Since the OBD test is currently not mandatory, the data of all PCs that attended the OBD test were used.

A new method proposed by this study would include the introduction of a mandatory OBD test for all vehicles equipped with an EOBD system. In addition to the existing OBD data, it is proposed to introduce the number of DTCs as mandatory, and such data should be relevant for passing the roadworthiness test, Figure 1.



EXISTING DATA SET

Optional for emission test (Euro 6)

MIL status
Readiness status

Optional tailpipe test

Coolant temperature
Engine RPM



PROPOSED DATA SET

Mandatory for all PCs equipped with an EOBD system

MIL status
Readiness status
Coolant temperature
Engine RPM
Number of DTCs (VIN)
(IPT data)

- - - data to be collected

Figure 1. The existing and proposed PTI OBD test.

3. Results and discussion

3.1. Results

In 2020, a total of 1.733 million PCs were registered in the Republic of Croatia. Out of the total number of registered PCs, 1.594 million must undergo the emission test. Due to an identified or potential engine failure, 53 thousand PCs were not tested and they failed the PTI. The remaining 1.541 million PCs were tested either through a tailpipe or an OBD test. Out of the total number of PCs tested, 1.365 million passed the tailpipe test, slightly more than 164 thousand Euro 6 PCs passed the OBD test, and almost 12 thousand PCs did not pass the tailpipe test. The number of PCs that passed the tailpipe test, and for which an OBD test was also performed to collect coolant temperature and engine RPM data, is shown in Figure 2.

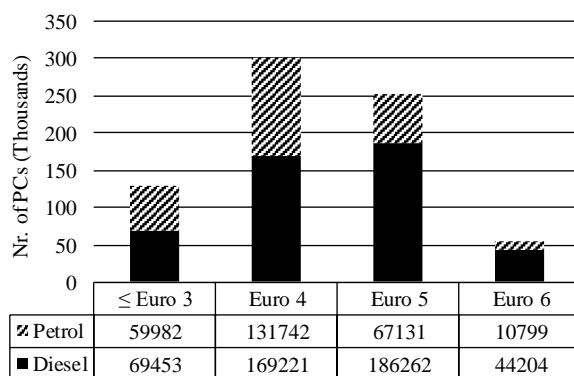


Figure 2. The number of PCs that passed the tailpipe test, and for which an OBD test was also performed.

The total number of PCs in Figure 2 amounts to 738,794, which is only 42,6% of the total PC fleet. Out of the total number of vehicles that passed the tailpipe test, at least 1 DTC was detected in 84,767 vehicles, which is about 11.5%. The number of vehicles with at least 1 DTC according to emission standards and fuel is shown in Figure 3.

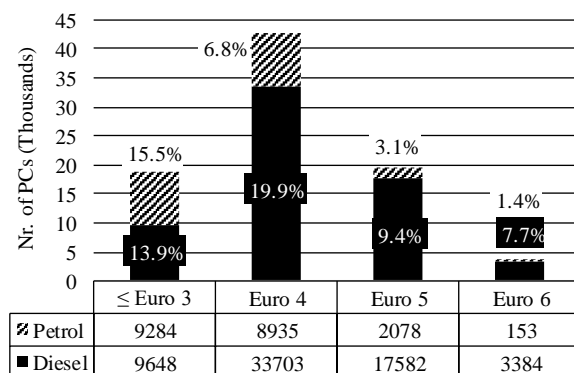


Figure 3. The number of PCs that passed the tailpipe test, for which an OBD test was also performed, and where at least 1 DTC was found.

Figure 3 also shows the percentage of such vehicles concerning the number of vehicles in Figure 2. If the OBD test was performed on all PCs that passed the tailpipe test, the total number of PCs with DTCs could be determined by the extrapolation method, Figure 4.

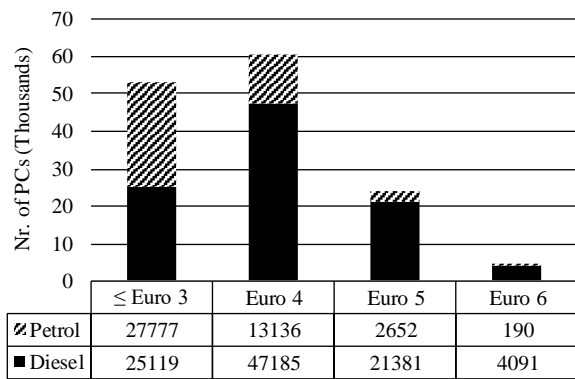


Figure 4. The total number of PCs with identified DTCs extrapolated to the group of PCs that passed the tailpipe test.

The average age of PCs registered in Croatia in 2020 was almost 13 years. Due to this, it is interesting to consider the influence of vehicle age on the PC fleet with identified DTCs. Figures 5 and 6 show the number of PCs that passed the tailpipe test, for which an OBD test was also performed, and the percentage of PCs where at least 1 DTC was found, in relation to vehicle age.

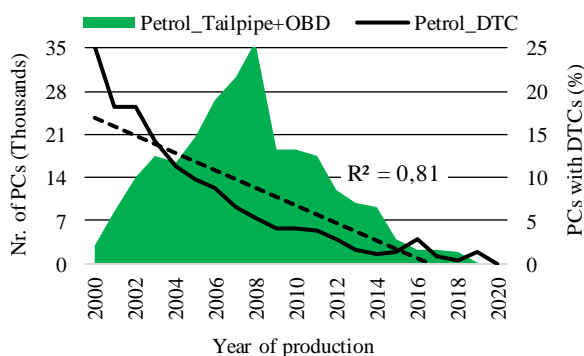


Figure 5. The number of petrol PCs that passed the tailpipe test, for which an OBD test was also performed, and the percentage of petrol PCs where at least 1 DTC was found, in relation to vehicle age.

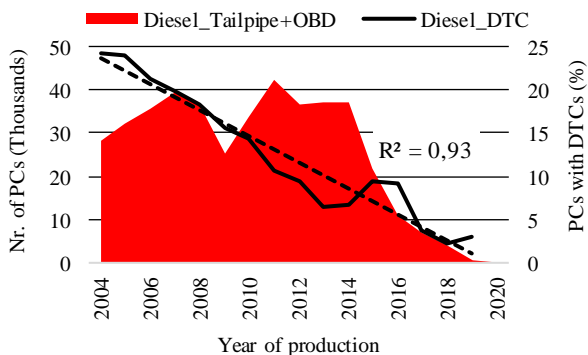


Figure 6. The number of diesel PCs that passed the tailpipe test, for which an OBD test was also performed, and the percentage of diesel PCs where at least 1 DTC was found, in relation to vehicle age.

The OBD test was performed on a total of 918,970 PCs. Of these vehicles, 332,203 were petrol and 586,767 were diesel. The status MIL OFF was recorded in 326,185

petrol and 581,310 diesel PCs. The total number of petrol and diesel PCs with the MIL ON status is shown in Figure 7.

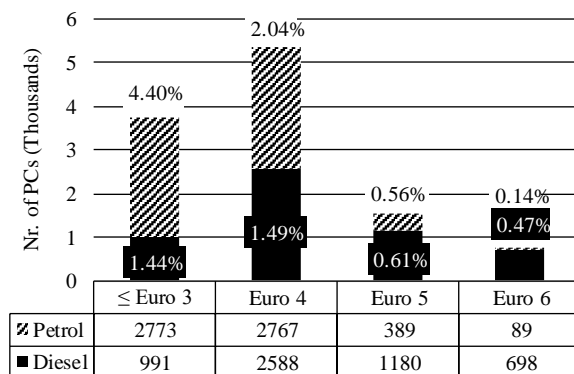


Figure 7. The total number of PCs with the MIL ON status, and the percentage of such vehicles in the PC fleet that took the OBD test.

3.2. Discussion

Although OBD tests are not mandatory, the results of this study indicate that there is a good reason to make them mandatory. By conducting OBD tests, a significant number of vehicles with MIL ON status and stored DTCs were identified, and such vehicles are potentially technically defective. Only 42.6% of the total PC fleet are cars that passed the tailpipe test, and for which an OBD test was also performed. On a sample of 738,794 tested PCs, 84,767 of those with stored DTCs were identified. Thus, 11.5% of vehicles that passed the tailpipe test stored at least one DTC. Although the Euro 3 emission category of vehicles is the second most numerous, a significant number of such vehicles did not take the OBD test. Considering vehicles with emission standards Euro 4, Euro 5, and Euro 6, it was found that the percentage of diesel PCs with stored DTCs is much higher compared to petrol ones, as shown in Figure 3. If all vehicles that passed the tailpipe test also underwent an OBD test, it is estimated that over 140 thousand vehicles would have stored DTCs, as shown in Figure 4. A significant and positive correlation between vehicle age and the percentage of vehicles with identified DTCs is shown in Figures 5 and 6. The older the vehicle is, the more likely it is that DTCs will occur. It can be concluded from Figure 3 and Figure 7 that the number of vehicles with the MIL ON status is much smaller than those with identified DTCs. This difference is to be expected, as not every DTC causes the MIL to activate. However, DTCs indicate a broader picture of possible failures on the body, chassis, powertrain, and other embedded systems. Given the above, the number of DTCs should become mandatory and relevant for passing the roadworthiness test.

4. Conclusion

Based on the results of this study, the introduction of a mandatory OBD test for all vehicles equipped with an EOBD system is proposed. The number of DTCs along with the MIL status should be relevant for passing the roadworthiness test. For emission tests, it is recommended to introduce an additional criterion that the vehicle must not have DTCs. The developed method can be implemented in a much broader set of vehicles and everywhere in the world on vehicles that have a built-in OBD2 system (EOBD for the European market, JOBD for the Japanese market, etc.). In this way, vehicle maintenance would be encouraged, and potential tampering prevented. Such measures would increase traffic safety and reduce the impact of vehicles on the environment and human health.

References

CITA, 2019. CITA SET II Project: Sustainable Emission Test for diesel vehicles involving NO_x measurements.

Official Journal of the European Communities, 1998.
Directive 98/69/EC of the European Parliament and of the Council.

Official Journal of the European Union, 2014. Directive 2014/45/EU of the European Parliament and of the Council.

Official Journal of the European Union, 2007. Regulation (EC) No 715/2007 of the European Parliament and of the Council.

Rešetar, M., Pejić, G., Ilinčić, P., Lulić, Z., 2019. Primary results of OBD tests collected during PTI of vehicles in Croatia, in: 23rd International Transport and Air Pollution Conference. Thessaloniki, Greece, p. 1.

Rešetar, M., Pejić, G., Lulić, Z., 2018. Changes and trends in the Croatian road vehicle fleet – Need for change of policy measures. *Transp. Policy* 71, 92–105.
<https://doi.org/10.1016/J.TRANPOL.2018.08.005>