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Influence of Driving Cycles on Emission Parameters of Vehicles

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Abstract: The vehicle emissions tests, which are performed using the Portable Emissions Measurement Systems (PEMS), indicate that the diesel cars produce several times more NOx emissions on the road than during certification realised according to the methodology New European Driving Cycle (NEDC). This fact initiated the infamous "dieselgate" affair. It is a well-known reality that the current emission limits are very strict and therefore a serious problem arises for the motor car producers to meet the demanding emission requirements. The main task of the presented research work was testing of 10 passenger cars with regard to true values of their exhaust gas emissions. These cars were equipped with the diesel engines and gasoline engines that officially meet the Euro 4-6 standards. Based on the measured results it was found that the real NOx emissions of the diesel engines significantly exceed the values measured by NEDC. The results obtained using the NEDC cycle also contradict the findings from two alternative driving cycles: CADC (Common Artemis Driving Cycle; Artemis - Assessment and Reliability of Transport Emission Models and Inventory Systems) and WLTC (Worldwide harmonized Light vehicles Test Cycle).

Keywords: driving cycles; emission; NEDC; CADC; WLTC

1. Introduction

Investigation of the "dieselgate" affair, concerning fraudulent manipulation in measuring of the NOx emissions produced by the diesel combustion engines installed in the passenger cars, opened a professional discussion focused on effectiveness of the emission laboratory testing. Taking into consideration the growing air pollution in many European cities, it is necessary to ensure the reliable procedures for exact measuring of the gaseous emissions, which are generated in the real road traffic. [1-5]

Testing of the vehicles using the Portable Emissions Measurement Systems (PEMS) in Europe since 2007 has shown that the light diesel vehicles, which were certified according to the Euro 4-6 standards, produce many times more NOx emissions than is allowed by the given emission limit. These exceedances were caused due to shortcomings in the approval process, namely due to low vehicle accelerations as well as due to a narrow temperature range from 20 to 30°C, which was applied during the NEDC certification. These issues are currently being addressed through the Worldwide harmonized Light vehicles Test Procedure (WLTP) and using the supplementary Real-Driving Emissions (RDE) test. [3-7]

Within the above-mentioned measuring processes, which are on the verge of implementation, only a little attention is paid to understand the true reason, which causes increasing of the NO_x emissions produced by the diesel vehicles in real operation. It can be stated that the insufficient driving dynamics and too narrow temperature range of the NEDC testing may not be the main cause of the NO_x problems in the case of diesel engines. A large volume of the increased NO_x emissions produced in

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road transport may be caused due to usage of disturbing strategies. A disturbing device is any hardware, software or design of a motor vehicle, which interferes or deactivates the emission control performed under actual driving conditions, even if the vehicle undergoes formal emission testing. The presented analysis covers 10 passenger cars tested by NEDC on the laboratory conditions and also on various routes in the real transport. This research provides an alternative how to verify the vehicles and it may be targeted on those vehicles that require an in-depth assessment of their operational ability. [6,7]

2. Methodology and Conditions

It was already mentioned that there were tested 10 passenger cars as the experimental models, whereby 3 of them were equipped with the gasoline engines fulfilling Euro 5 and other 7 vehicles had installed the diesel engines fulfilling Euro 4-6 (Fig. 1-4). The laboratory tests as well as the road tests were realised using the standard engine fuels that comply with the Direction 2009/30/EC and with the manufacturer's specifications determined for operation of the given vehicle. The emission tests were performed on a laboratory test stand. Emissions produced by mentioned tested vehicles should not be effected by excessive wear due to low mileage (between 80 000 and 150 000 km). The NO_x and CO_2 emissions were measured by the emission analyser. On the road, i.e. in the real transport, these emissions were measured using PEMS. The ambient temperature was measured at the frequency 1 Hz and the atmospheric probe was a part of the measuring device. According to the Regulation 2016/427 (EC, 2016), the instantaneous NO_x and CO_2 emissions on the roads are calculated using the frequency 1 Hz by multiplying of the pollutant concentration with the exhaust mass flow. The distance-specific emissions [mg/km] are then calculated as the sum of the instantaneous emissions during the assessed time interval divided by the distance in that time interval. [2-5]

The testing conditions similar to those for NEDC were selected for the PEMS road tests. This means that the combination of the vehicle speed and acceleration was in accordance with NEDC, the ambient temperature was in the range of homologation, i.e. from 20 to 30°C and it was driven in a flat terrain with slope gradient up to 0.1%. The results obtained from the analysis are presented in the form of bar graphs. The differences between the laboratory values of the NO_x emissions and the emission values obtained in the real traffic may be caused due to a different driving dynamics. [6-10]

3. Results and Discussion

The diesel and gasoline vehicles tend to meet the requirements of the relevant emission standards when they are tested by NEDC. Consistent with this observation, most of the instantaneous NOx emissions of all vehicles during the NEDC testing are below the emission limit (Fig.1, first column). The graph values differ for the road data, where most of the instantaneous NOx emissions of the diesel vehicles are located high above the limit (Fig.1, last column). [10-12]

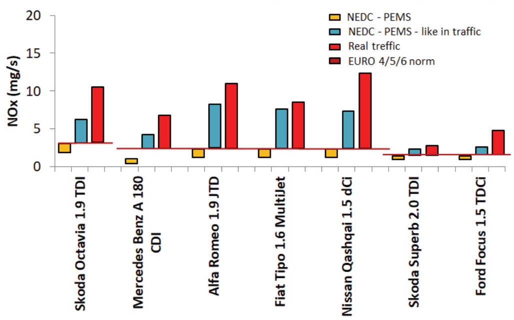

Figure 1: Bar graphs of the NO_x emissions (mg/s) for diesel vehicles

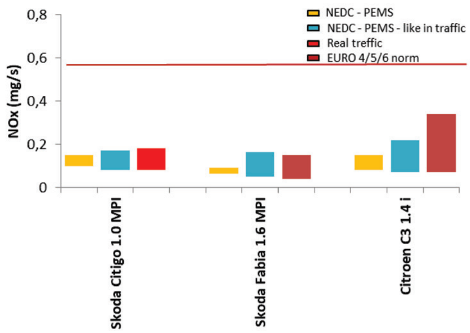

Figure 2: Bar graphs of the NO_x emissions (mg/s) for gasoline vehicles.

In the case of gasoline vehicles, the values of the road NO_x emissions are also higher than the NEDC emissions, but they are still below the emission limit. If only the NEDC-like driving conditions are selected, the graphs (median values) mostly overlap the NEDC fields (Fig. 2, middle column). This part of the analysis points to a significantly different behaviour of the diesel vehicles at NEDC testing and on the road in conditions similar to certification.

The second part of this work analyses the engine gaseous emissions as a function of the distance travelled (Fig. 3). When the NO_x emissions are analysed by NEDC on the test stand under different driving conditions, there are again significant differences between the diesel and gasoline vehicles. For the diesel vehicles, the real NO_x emissions significantly exceed the values measured by NEDC. When changing the ambient temperature, the results are not changed. When all the PEMS data are taken into account, the diesel cars exceed the NEDC emissions by several times. However, for the gasoline vehicles, the real NO_x emissions exceed the NEDC values only in a lesser extent, being deep below the valid emission standard. [10-13]

The results obtained using the NEDC cycle also contradict the findings for two alternative driving cycles, i.e. for CADC and WLTC (Fig.4). For the diesel vehicles, the average values of the NO_x emissions in the real road traffic exceed the average values measured in the laboratory by only 5%. These results confirm application validity of the new driving cycle for a generally mandatory testing of the motor cars. [13-14]

4. Environmental risks

Nowadays, the nitrogen oxide emissions mean a serious problem with a direct impact on public health and on overall air quality in the urban areas. The urban areas are characterized by increased traffic density, which is furthermore complicated due to creation of the so-called Low-Emission Zones (LEZ). These zones create an obstacle, mainly for the city centre visitors, because they complicate transfer of people within the intra-city area.

The low emission zones are such urban areas in which is limited or charged entry of those vehicles, which do not meet the defined exhaust emission limits. At present, there is more than 270 low-emission zones established within Europe, above-all in Germany and Italy.

It is possible, in some European countries, to see also other designations of the low-emission zones, for example Umweltzonen, Milieuzones, Lavutslippssone, Miljozone, Miljözon etc. The

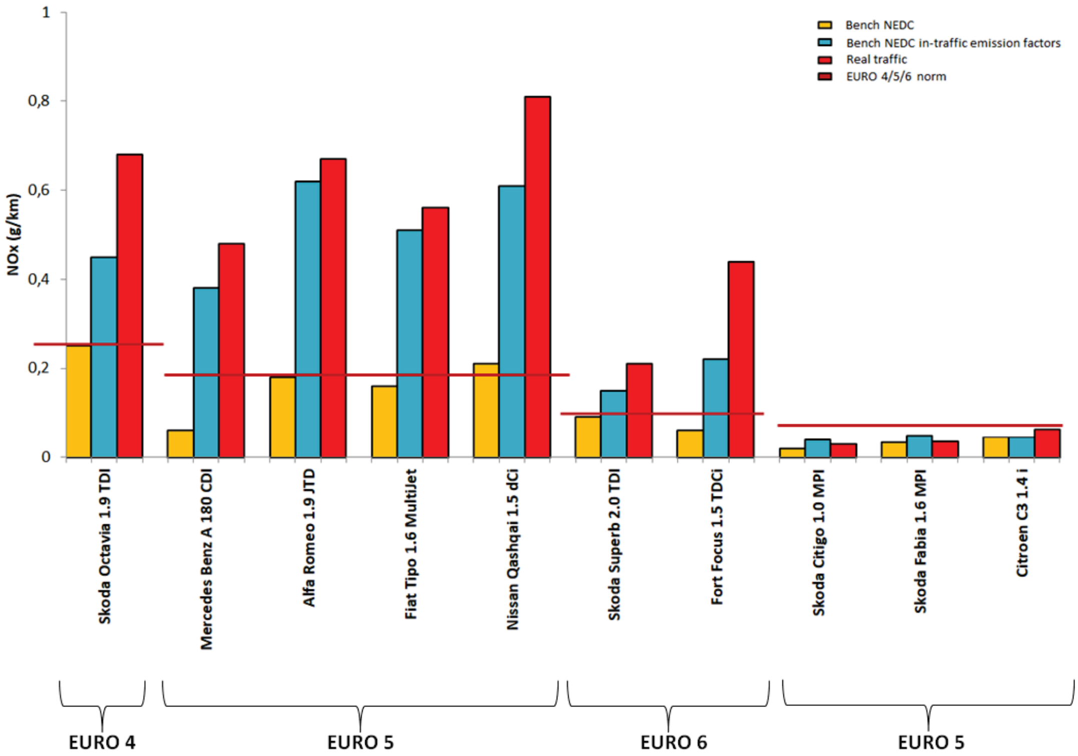

Figure 3: Bar graphs of the NO_x emissions (g/km) for diesel and gasoline vehicles.

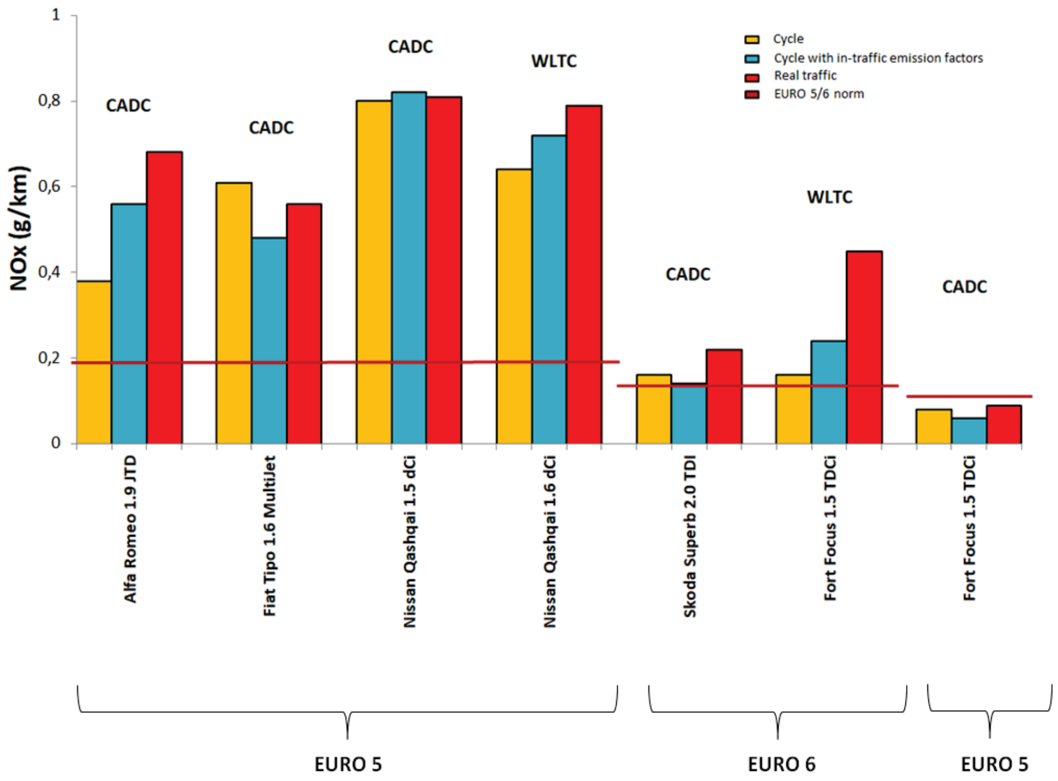

Figure 4: Bar graphs of the NO_x emissions (g/km) for diesel and gasoline vehicles using CADC and WLTC cycles.

purpose of the LEZ is to eliminate entry to the restricted area of those vehicles that do not meet a certain limit of the vehicle's emission class, or the entry of such vehicles into the defined area is subject of a fee, what is preferred especially in North European countries (e.g. Sweden). Since January 2012, there were implemented another important changes in requirements valid for the low emission zones in Europe. Especially the forwarders have to consider these new rules when planning transportation routes. The most important change is usually a total restriction of entering a vehicle into the low-emission zone territory, violation of which could result in a penalty of hundreds of Euros for the driver. A possible solution of this unfavourable situation is development of a mobile application, which will be able to plan an optimal route according to the vehicle type, emission standard and additional information about the actual traffic conditions and changes in the low-emission zones.

5. Conclusions

Finally, all the above-mentioned facts can be summarized into the following items:

– *The tested vehicles equipped with the diesel engines, which officially meet the Euro 4 - 6 standards, in reality exceed the NOx emission limit when driving in the road traffic several times. This observation is in a contradiction with situation in the case of the gasoline vehicles, for which the real on-road NO_x emissions remain below the applicable limit.*

– *A large part of the increased NO_x emissions of the diesel cars on real roads cannot be justified by the insufficient dynamics of the NEDC methodology, nor by the narrow temperature range during the testing procedure. This result calls into question the official opinion that the insufficient NEDC testing is the main cause of the "diesel-NO_x" problem.*

– *The type approval authorities recently tested the NO_x emissions using NEDC on road. At normal temperatures in Europe, they found that the average exceedances reached about 4.5 times higher values than the given emission limit.*

– *This presented research work provides an alternative to testing of the vehicle emissions, whereby it can be focused on those vehicles that require an in-depth assessment of their capability.*

It is possible to say, according to the results obtained from this research, that certification of the vehicle gaseous emissions according to NEDC could be acceptable, provided that the specific provisions are strictly kept. This is not just a matter of the measurement itself. The current free rules make it possible artificially to reduce the measured values, for example using special tires determined for minimization of the rolling resistance or by means of special software tools and others.

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