REAL ROAD TESTS – EXHAUST EMISSION RESULTS FROM PASSENGER CARS

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Abstract

The paper presents the results of on-road exhaust emission tests of passenger car fitted with diesel engine, and a DPF (diesel particulate filter). Under such conditions the author could determine the actual vehicle emissions. The tests were performed on a road portion of a fifty kilometres or so – these tests provide information on the on-road emissions and are a basis for their ecological evaluation. For the measurement of the exhaust emissions the authors used a portable exhaust emissions analyzer SEMTECH DS by Sensors Inc. The analyzer measured the concentration of the exhaust components at the same time measuring the exhaust mass flow. The measurements of the particulate matter (mass) were done with the use of particle analyzer by AVL. The obtained data were used to calculate the relations that characterize the influence of the dynamic engine parameters on the exhaust emissions. These properties were taken into account indirectly using the whole range of speeds and accelerations of the vehicle (engine speeds and loads of the engine) for the preparation of the matrices of the emissions rate. The used data were averaged within individual speed and acceleration ranges thus obtaining the characteristics of the share of operation in individual ranges and the characteristics of the emission matrices of the individual emission components. The above results served for defining of the emission level indicator of the vehicles that can be used for classification of vehicle fleet in terms of their emission level.

Keywords: *exhaust emission, road tests, Diesel engines, Diesel particulate filters*

1. Introduction

Currently a trend has been seen of global treatment of the environmental perils from the automotive industry. The regulations permitting the vehicle to drive on roads periodical inspections of the vehicle technical condition and other legal acts directly or indirectly related to the production, use and disposal of used up civilization products treat the environmental issues in a complex way. In the previous years in individual countries there were different inspection and testing systems related to the exhaust emissions yet for some time now there has been a far reaching unification going on [4, 8, 11].

These days one can observe a strong tendency to deal with environmental perils from the automotive industry in global terms. The regulations that allow the operation of vehicles (homologation tests and production conformity tests), periodical technical check-ups and other laws directly and indirectly related to the production, operation and management of products of civilization treat the problem of environmental protection on a full scale [6]. Over the years in each country there were different systems of tests and vehicle exhaust emission control, however, for some time there has been a well-developed unification. A growing number of cars in the world and the pollution of the environment result in higher requirements as far as the emission of exhaust components are concerned. The present level of technical and technological advancement in all the branches of industry, including all types of transport, causes increased requirements for production of tools for emission measurement. In order for these requirements to be fulfilled to the necessary extent according to the regulations which change from time to time, it was necessary for the industry to concentrate on this issue. The studies on the emission of toxic components are a complex process. Contemporary emission analyzers require special laboratory conditions and the homologation procedures include engine and chassis dynamometer tests which do not reflect the real on-road emissions. The latest results of studies conducted in the real conditions show that in the case of some emission components certain emissions are higher by several hundred per cent. Thus, there is a tendency to legitimize the measurement of the emission in the real conditions of vehicle operation [3].

2. Testing methods

The purpose of the research was to verify the emission characteristics of a vehicle with a Diesel (meeting Euro 5 standard) in the real traffic conditions. The research was at the same time an attempt at creating an on-board system for measuring the level of exhaust emission. The determination of emission characteristics in on-road conditions and comparing it with the results obtained on a test-bed in a type-approval test allowed for the determination of emission factor. The emission factor obtained was used to answer the question: Is emission in on-road conditions comparable with the emission obtained during a type-approval test? It is simultaneously a verification of driving conditions in a type-approval test (developed several decades ago) and the real traffic conditions [5, 7].

The measurement of emissivity was carried out in the road conditions in the city of Poznan (length road – 50 km). The tests were conducted on the main the roads of the city in the afternoon, with a moderate traffic. The conditions were selected in a way enabling to compare the tests results with the NEDC homologation test – with reference to which the emissivity indicators were introduced.

3. Experimental set up

Vehicle – The object of the tests was passenger car fuelled with diesel (European standard, Sulphur < 10 ppm); manual transmission, 4 cylinder, volume: 2.0 dm^3, power: 125 kW@4200 rpm, torque: 350 Nm@2000 rpm, catalytic converter, diesel particle filter, OBD II protocol, mileage: 12,000 km, car weight: 1410 kg. The tested vehicle was homologated according to Euro 5 standard.

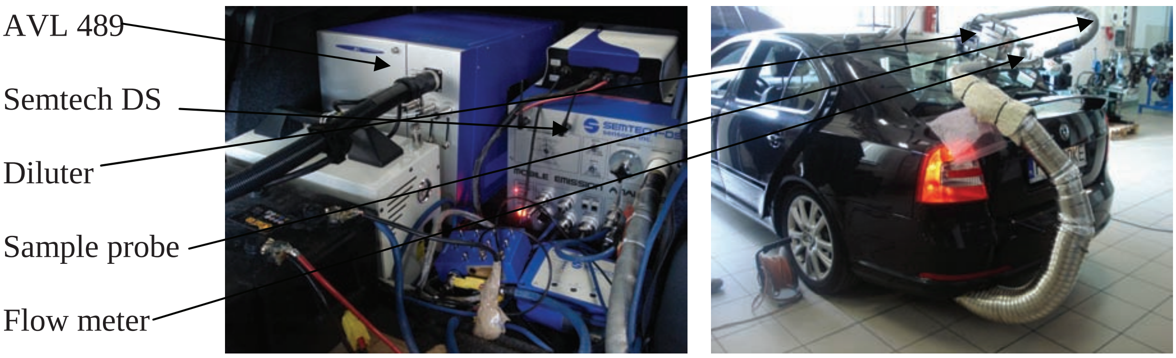


Fig. 1. View of SEMTECH DS analyzer fitted in a vehicle

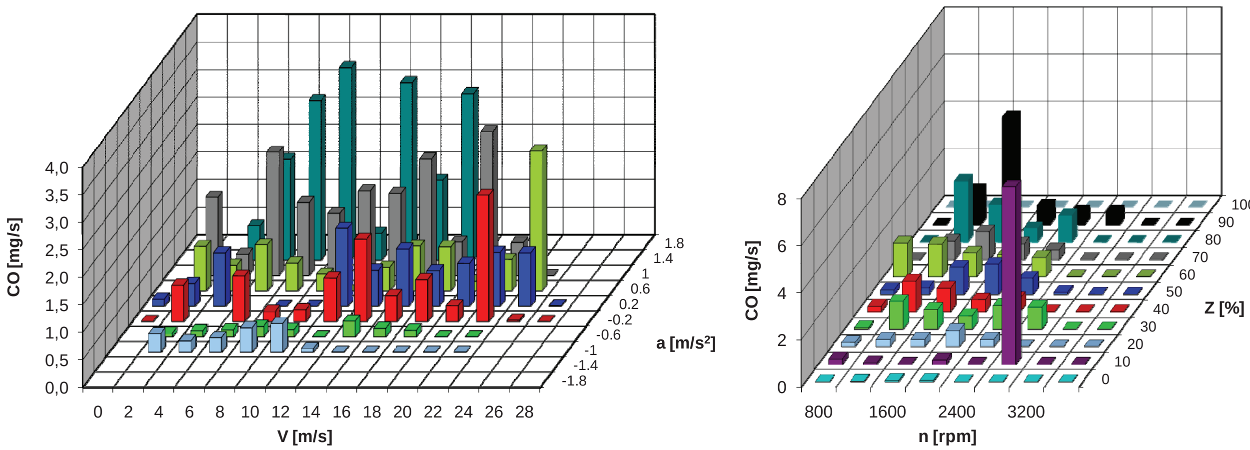
4. Measurement instruments

Mobile gas analyzer – Semtech DS. In order to measure the concentration of toxic compounds a mobile analyzer for toxicity tests SEMTECH DS by SENSORS Inc. [9, 10] was used. The analyzer allowed the measurement of harmful compounds concentration with the simultaneous measurement of mass intensity of exhaust gases. The exhaust gas introduced to the analyzer through a probe maintaining the temperature of 191°C was then filtered out of particle matter (Diesel engine) and directed to the flame-ionizing detector (FID) where hydrocarbons concentration was measured. Then the exhaust gas was cooled down to the temperature of 4°C and the measurement of the concentration of NO_x (NDUV analyzer), CO, CO_2 (NDIR analyzer) and O_2 followed in the listed order. It is possible to add data acquired directly from the vehicle diagnostic system to the central unit of the analyzer and make use of the GPS signal. In the tests the measurements of toxic compounds emission were performed and, for comparison, signals from an on-board diagnostic system were registered [6, 7], as well, e.g. engine speed, load, vehicle speed, engine temperature. Some of these signals served to specify the time density maps presenting the share of the operating time of a vehicle in the real operation.

AVL Particle Counter 489. Condensation particle counters (CPCs) accurately measure PN concentration of exhaust emissions. In fact, the GRPE Particle Measurement Program (PMP) recently completed the light-duty, inter-laboratory correlation exercise (LD ILCE) and concluded that PN measurements using a CPC plus thermodilution are 20 times more sensitive and much less variable than the traditional method (i.e., gravimetric filter analysis). As a result, the measurement of solid PN emissions has been proposed for Euro 5 Regulation 83. Proposed ECE Regulations 83 and 49 mandate that only the number concentrations of solid particles are measured. Therefore, nucleation mode particles (i.e., nanoparticles) formed by the condensation of volatile compounds found in engine exhaust must be suppressed or eliminated [2].

5. Experimental results

The obtained data were used to specify dependence characteristics for the influence of dynamic engine properties on exhaust emissions. The dynamic engine properties were indirectly taken into account, using all the speed range and the range of acceleration calculated for city traffic to prepare a matrix of emission intensity. The data used were averaged within each speed and acceleration range, which generated characteristics of vehicle operation in each range and characteristics of emission matrices of exhaust. The greatest share of the engine operation in the studied traffic conditions was obtained for minimum and medium speed and zero vehicle acceleration. Maximum intensity of emission of carbon monoxide and hydrocarbons (Fig. 2 and 3) expressed in grams per second falls within the area of maximum vehicle speeds and accelerations within the range of 0.0 to 1.2 m/s^2 which are convergent for the both exhaust compounds. The area of an increased emission of NOx (Fig. 4) falls within the range of increased speeds of a vehicle and increased acceleration of a vehicle i.e. a considerable load of an engine. This is related to the enhanced dose of fuel and the increase of an engine speed at the same time.



a) b)

Fig. 2. Characteristics of CO emission in each speed and acceleration range in city traffic conditions

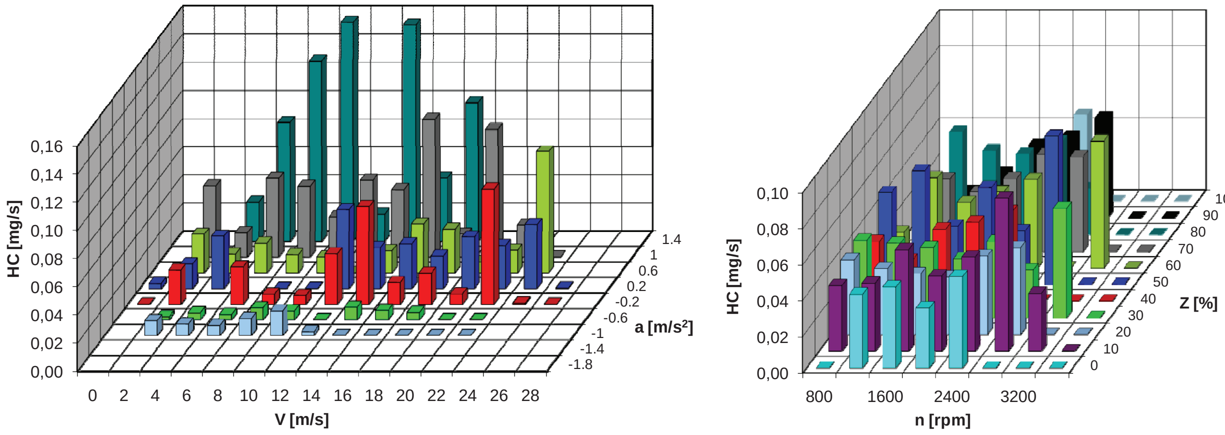


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Fig. 3. Characteristics of HC emission in each speed and acceleration range in city traffic conditions

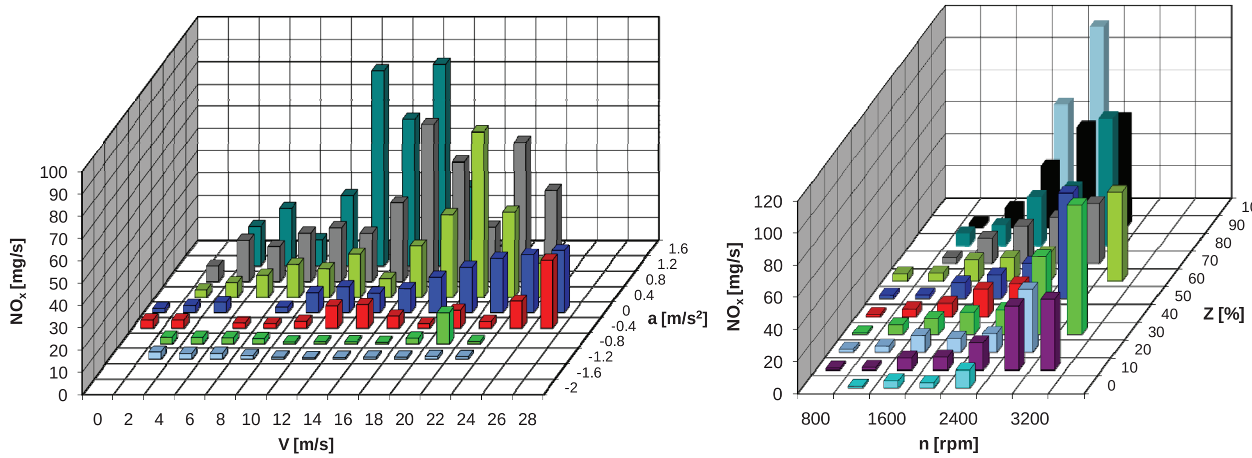

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Fig. 4. Characteristics of NO_x emission in each speed and acceleration range in city traffic conditions

The mass emission of particles (Fig. 5) is ambiguous – for minimum vehicle speed the emission amounts to 15 mg/m^3 and decreases along with the increase of vehicle speed (5–10 μg/m^3), and then for high speed values (above 20 m/s) it increases to 15-20 μg/m^3 again. The measurements of particle quantity showed a different distribution than particle mass. The highest quantity of particles (Fig. 6) was generated in the vehicle operating conditions of rather low driving speed (2–6 m/s) and average acceleration (0–1 m/s^2) and with the increasing speed the quantity of particles was decreasing. Such distribution of particle mass and quantity is characteristic of vehicles equipped with diesel particulate filter that can be subject to periodic regeneration. In the tests conducted over the specific road section partial regeneration was not activated. It resulted mainly from the short distance covered by the vehicle as well as from the high performance of the diesel particulate filter. Too low temperature of exhaust gases (in the exhaust gas measurement point it did not exceed 250^{o}C) was the reason of the lack of diesel particulate filter regeneration.

The obtained results of a vehicle driving time in the conditions determined by its speed, acceleration and intensity of harmful compounds were verified in the European homologation test NEDC. Having compared the participation of driving time of a vehicle within the areas of a vehicle speed and acceleration in the road and homologation test a similarity of both the obtained characteristics can be observed. Compatibility of the compared characteristics for a breakdown of the occurrence of a vehicle driving time share has been maintained. In the NEDC test the share of a vehicle drive at minimum speed and zero acceleration is bigger. However, for real conditions the area of the used speeds and acceleration of a vehicle is bigger. However, the relative comparison of the values reveals the discrepancies which reach the values above 100% for the same ranges of speed and acceleration of a vehicle.

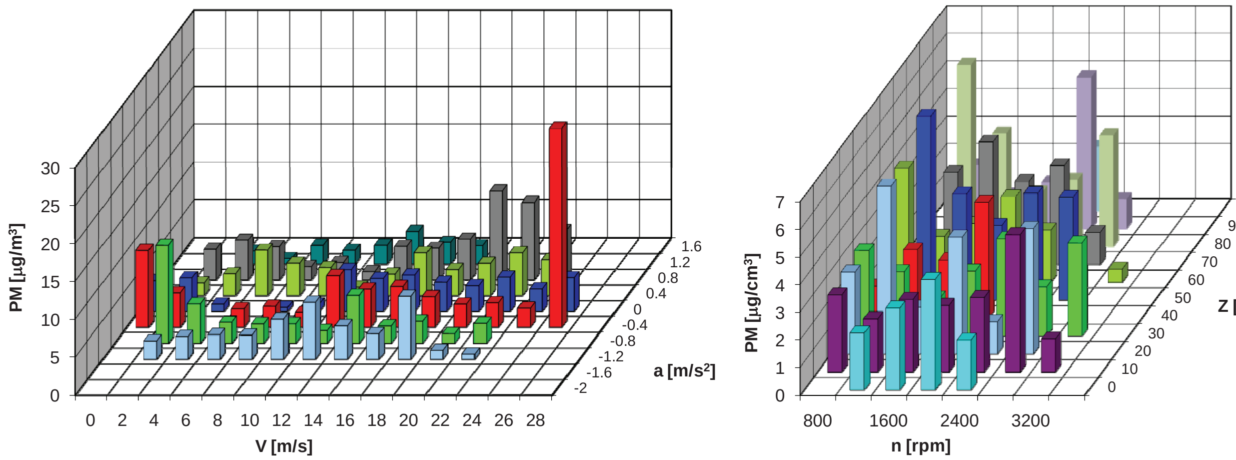

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Fig. 5. Characteristics of PM emission in each speed and acceleration range in city traffic conditions

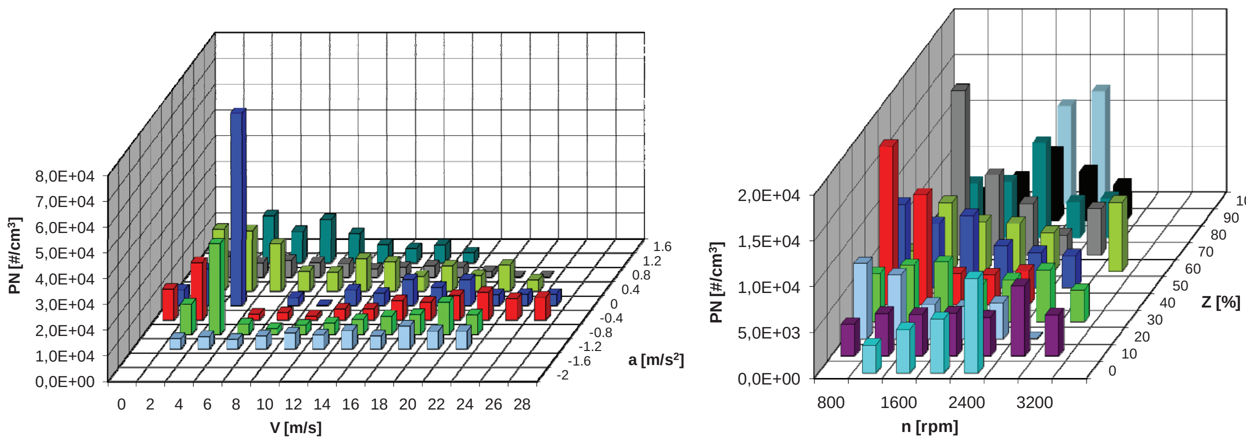

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Fig. 6. Characteristics of PN emission in each speed and acceleration range in city traffic conditions

6. Quantity indicators of emissivity

Based on the presented information, e.g. the characteristics of share of a vehicle operating time in each section of speed and acceleration and the characteristics of emission intensity, a multiplication factor of the emission increase (or decrease) in the real traffic conditions can be calculated in relation to the homologation test. The indicator of a vehicle emissivity (for a given harmful compound) was defined as follows:

$$k_j = \frac{E_{road,\,j}}{E_{NEDC,\,j}}, \tag{1}$$

where:

j – exhaust compound for which emissivity indicator was set forth,

$E_{road,j}$ – emission intensity obtained in the real conditions ([g/s] or [g/km]),

$E_{NEDC,j}$ – emission intensity obtained in the NEDC test ([g/s] or [g/km]) (emission limits: [1, 11]).

The emission intensity in the real conditions can be calculated by means of the characteristics of a vehicle driving time breakdown ($u_{a,V}$) and the characteristics of emission intensity for j-this exhaust compound $e_{j(a,V)}$ expressed in grams per second:

$$E_{road,j} = \sum_a \sum_V \left(u_{a,V} \cdot e_{j(a,V)}\right). \qquad (2)$$

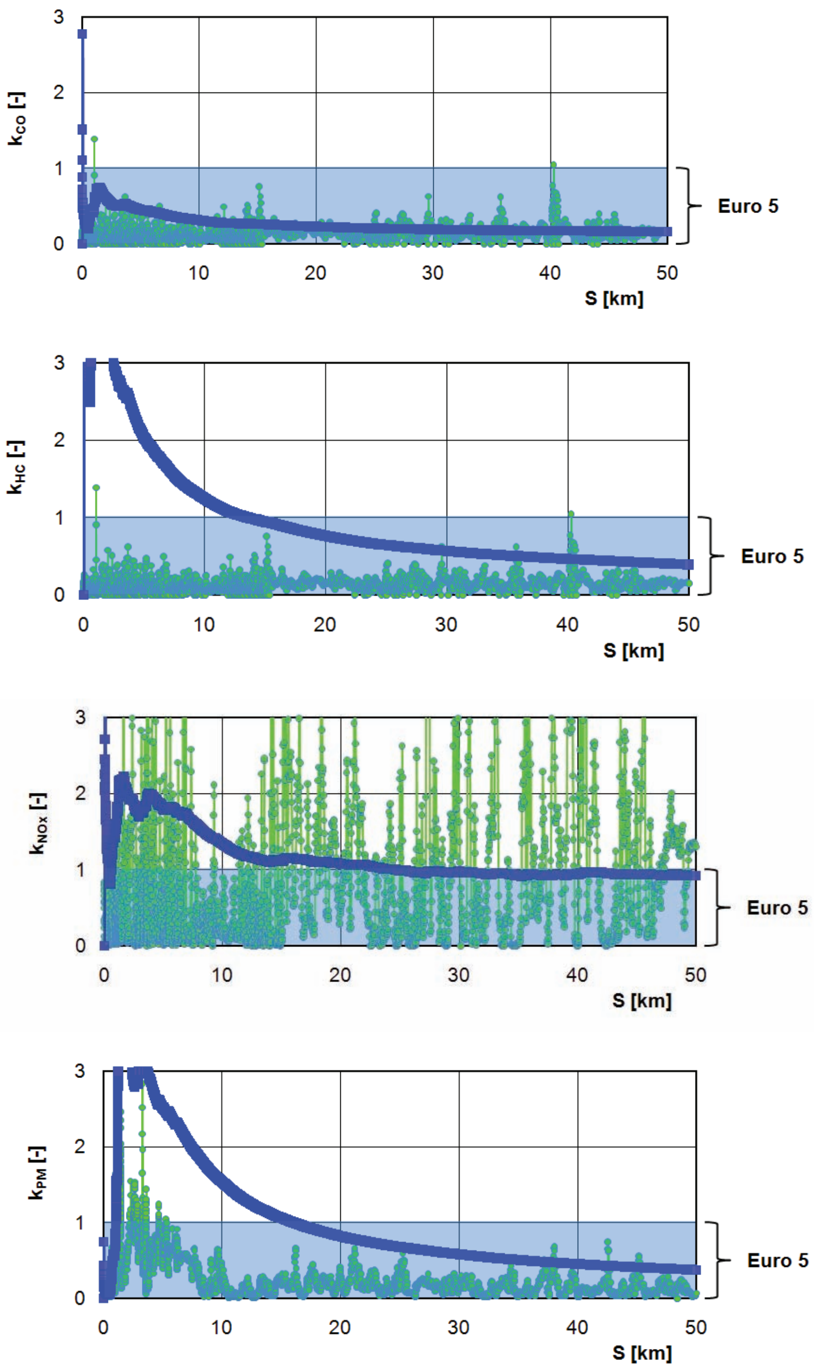

Fig. 7. The comparison of the emission indicators from SUV vehicles meeting different Euro emission standards

In the graphs from Fig. 7 for each exhaust component (for which the normative limit is fulfilled) the change of the emission indicator has been presented (gray). Despite high momentary variability of the emission indicator its value determined in an incrementing way is characterized as follows:

– for carbon monoxide – abrupt growth during engine start and then lowering of its value; under traffic conditions in a short time a reduction of this emission is obtained below the required standard (Fig. 7);

– for hydrocarbons – the course of the changes of the indicator is similar to that recorded for carbon monoxide; the value of the indicator below 1 this distance was approximately 12 km (Fig. 7b);

– for the nitrogen oxides – no normative requirement fulfilled – this results from the fact that there is a difference in the engine operation under the NEDC test and in the real traffic; a small distance in the test results in an incomplete warming up of the engine, which leads to a small emission of the nitrogen oxides for vehicle. The value of the emission indicator is greater than 1 (Fig. 7c);

– for the particulate matter – the indicator lower than 1 was reached after approximately 13 km despite the fact that the vehicle was fitted with DPF (Fig. 7d).

The obtained emission indicators for the whole test characterize the vehicle on-road emission level against the emission standards that applied to a given vehicle (Fig. 8). The emission indicator of carbon monoxide (k_{CO} = 0.2), hydrocarbons (k_{HC} = 0.4), hydrocarbons (k_{HC} = 0.4) and PM (k_{PM} = 0.4) for the tested vehicle confirms that the vehicles do not exceed the average emissions in the on-road operation against the emission standards. The situation is quite contrary for the nitrogen oxides: for vehicle Euro 5 compliant, the emission indicator is 1.1, which confirms a higher emission against the emission standard.

If the information concerning the exhaust emission in the NEDC test is missing, acceptable values according to the Euro norm of emissions toxicity can be assumed which is binding for a specific vehicle. The acceptable emission values for a specific compound expressed in g/km can be recalculated for the emission intensity values (in g/s) if the duration and the distance covered in the homologation test are known. Such relations served to establish the emissivity indicators for the harmful compounds of a tested vehicle (Fig. 8).

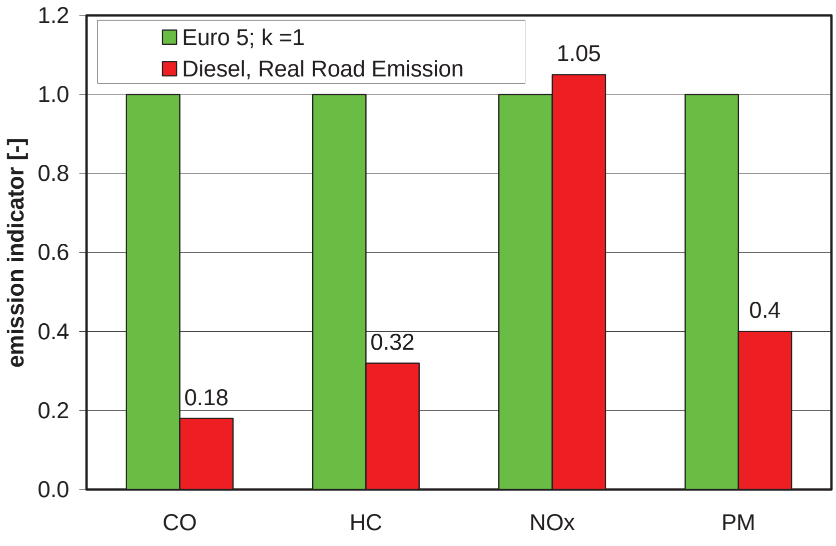

Fig. 8. Comparison of vehicle emission indicator

Conclusion

The analysis of the data proves that the emission values obtained in the NEDC homologation test for a tested vehicle (in accordance with Euro 4 standard) and the values in the real operation differ from each other. These differences in the case of some compounds are significant and amount to:

– CO emission is 80% lower,
– emission of hydrocarbons is 70% lower,
– emission of nitrogen oxides is 5–10% higher,
– emission of particle matter is 60% lower.

The obtained data enabled to define the vehicle emission factor which can be used to classify fleets of vehicles in relation to toxic compounds emissions that differ e.g. in production date (limits of exhaust toxicity, mileage of vehicles or operating conditions).

The results of the tests carried out in the real conditions show that in the case of some exhaust toxic compounds this emission is several hundred per cent higher. Therefore, one can observe a tendency to legitimize the emission measurement of harmful compounds in the real operation conditions of vehicles in Europe.

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