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APPROVAL TESTS AND EVALUATION OF EMISSION PROPERTIES OF VEHICLE

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Abstract

Operation of vehicles equipped with combustion engines is a source of pollution. That is why the emissions from this source are restricted. The emissions reduction system consists of several steps, whose basic component is a type-approval of vehicle in terms of emissions level and admission to the registration of vehicles that meets the requirements for emissions. It is assumed, that the gradual reduction of emissions limits will improve the emission properties of the vehicles, and gradual withdrawal of used vehicles, will reduce of emissions growth.

The basis for issuing opinions on a vehicle's exhaust emissions is the measurement of emissions performed in the laboratory on a chassis dynamometer in reproducible conditions of preparing the vehicle for testing, test replication, fuel for the engine, and the procedure for collecting the exhaust gas analysis.

Motor Transport Institute conducts the type approval tests, as well as the research on emissions from vehicles in the real traffic conditions, which are used to determine the actual emission from the vehicle population.

Emission tests for applications, that go beyond the application of type approval show, that there are vehicles whose emissions in operation is substantially different from the emissions measured during type approval. It is a natural phenomenon in the case of used vehicles and vehicles with engine malfunctions or exhaust aftertreatment system defect. However, there are vehicles whose emissions under specific operating traffic conditions are significantly different from the values obtained in the course of type approval tests, despite the good properties of emission measured under the conditions provided by the type-approval procedure.

The article discusses the results of the emissions from vehicles, obtained in the tests used to determine the emission factors for vehicles used in real traffic conditions, thus taking into account emissions from vehicles, made under different conditions than the type approval tests, which show that, in terms of driving cycles, which are not covered by the emission test procedure, can multiply and exceed the approved values.. This is particularly true for modern diesel engines.

Keywords: *transport, road transport, combustion engines, air pollution, environmental protection*

1. Introduction

Vehicle type-approval tests of emissions from vehicle exhaust system are made in accordance with Regulations 83 UN-ECE. This provision specifies the required characteristics of equipment used for tests, vehicle preparation, fuel used and method of measurement in the laboratory conditions.

Type approval is part of the emission control system, which aims at the gradual improvement of the emission properties of the population of vehicles through the introduction into service of new vehicles which are characterized by lower emission of the limited exhausts ingredients. According to the intentions, it should result in reducing the mass of pollutants released into the atmosphere.

However, the emission results obtained during the certification tests do not always mean equally low emissions in real traffic conditions.

2. Determining limited components emission during operation

It is well known that in the case of a typical low-emission car fitted with a spark ignition engine, which reached thermal stabilization state, the highest emissions are recorded in transient states of the engine, i.e. during gear changes and vehicle acceleration. However, during replication of the steady speeds the emission often reaches levels below the limit of quantification of the test method.

A high proportion of steady speed and idling characterizes a driving cycle, used in the type approval tests. Accelerations obtained in the test are far lower when compared to those typical of a vehicle operated on public roads. Such test is optimal for obtaining low emissions of limited exhaust gas components.

ITS conducts vehicle emissions tests in real traffic conditions, according to its own measuring methodologies by simulating, at the laboratory, the conditions of the vehicle operation on the road [1-4]. The tests conducted rely on the actual replication of the actual road tests representative to the specific conditions, such as driving in the traffic jam, driving in town, driving outside the town including expressways and motorways (Fig. 1).

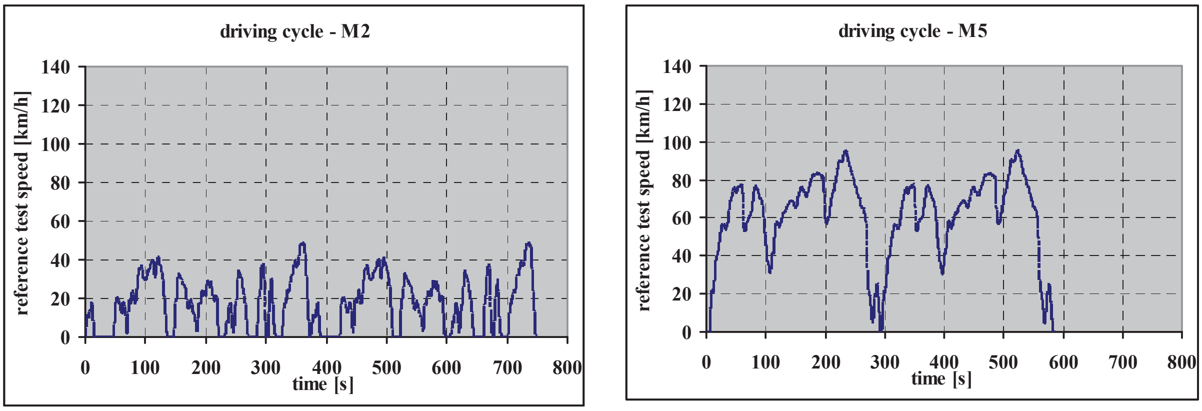

Fig. 1. Examples of ITS driving tests used in the examination of vehicles in traffic conditions

Sample results of carbon monoxide emission tests as a function of the average vehicle speed are shown in Fig. 2.

The black colour denotes ITS road tests: M2, M3, M4, M5, ZW2 and EXP, and green represents urban and extra-urban type approval tests. In order to allow a proper comparison of the results of all tests were performed on the fully warmed-up vehicle.

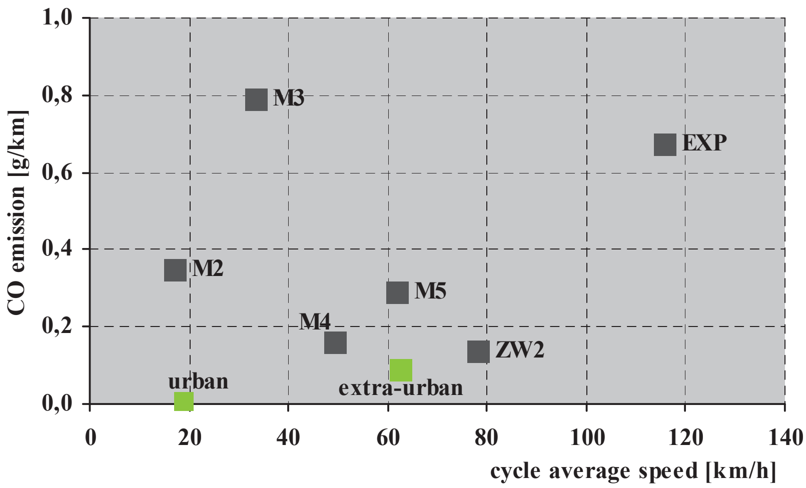

Fig. 2. Example of the results of carbon monoxide emission in the selected driving tests

As it can be seen in the presented case (Fig. 2) the results obtained for the type approval cycles marked in green colour R83 urban and R83 extra-urban are significantly lower than the others.

Identically are presented results for the other pollutions such as nitrogen oxides (NOx), hydrocarbons (CH), particulate matter (PM), which are analysed the same way.

Comparing the results of the individual limited exhausts components emissions for a given vehicle usually is not unequivocal, as usually the results of individual components emissions achieve different values depending on the cycle reproduced on a dynamometer, i.e. the vehicle operating conditions. Thus, the results of the designated emission depend on individual emission properties of the object, such as the emission characteristics of a vehicle, its technical condition, the adaptation of the supply system. The quality of conducting the test by the laboratory also affects the results.

In the presented case the emission in the M2 cycle (Fig. 1), is about 30 times higher than in the urban test and emission in M5 test is three times greater than that obtained in the extra-urban cycle.

ITS's experiences show that in the population of vehicles tested there are those whose emissions in road conditions significantly differ from the results obtained in the course of the type approval tests.

Below are some examples of the measurements results for the two selected vehicles.

3. Testing car equipped with a spark ignition engine

The measurements were conducted in accordance with the type approval procedure after a cold start for the type approved vehicle according to Euro 4 levels, which confirmed the good emission properties of the vehicle. The measured values ranged from 63% to 75% of the admissible values for a new car (Tab. 1).

Tab. 1. Results of the test vehicle pollution measurements

		Mass emission [g/km]		
		CO	NO_x	CH
Cycle	urban	**1.030**	**0.070**	**0.155**
	extra urban	**0.230**	**0.038**	**0.005**
	average value	**0.524**	**0.050**	**0.060**

Then the emissions tests of the fully warmed up vehicle at steady speeds of 80 to 160 km/h at 10 km/h were conducted.

At steady speeds of 80 km/h to 140 km/h NOx emissions ranged from below the quantification limit of measuring method, up to the value of 0.014 g/km. However, for the speed of 130 km/h and 140 km/h NOx emissions increased to 6.4 g/km and 7.1 g/km respectively, so in respect to the emissions determined in the driving tests after a cold start (Tab. 1), more than 100 times and compared to the measured emission values for constant speed of 120 km/h more than 2000 times. With increasing vehicle, speed to over 140 km/h NOx emission was a few hundredths of a gram per kilometre.

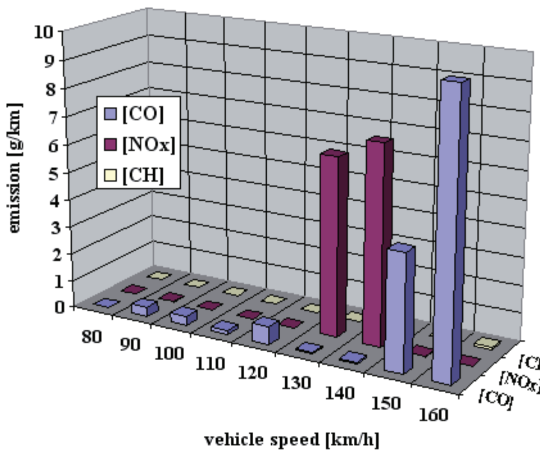

Fig. 3. The CO, NOx and CH emission at steady speeds

At steady speeds of 80 km/h to 140 km CO emission ranged from 0.03 g/km to 0.63 g/km and grew at speeds of 150 and 160 km/h to a value of 4.2 g/km and 9.8 g/km respectively.

The maximum nominal speed of the driving test achieved the type approval driving test is 120 km, thus taking into account the admissible error of performing driving cycle test by the driver, in practice, the maximum speed during driving test should not exceed the speed of 122km/h.

During the operation of a vehicle on the motorway the speeds achieved are higher than those envisaged by homologation tests, but these engine operating conditions do not fall within the scope of the type approval procedure. Thus, despite finding out that the emissions of NOx and CO at steady speeds exceeding 120 km/h exceeds many times the values obtained during the homologation test, the vehicle complies with the requirements of Regulations 83 UN-ECE and is classified as a low emission vehicle.

Changes in the emission of the studied factors by several times, depending on the vehicle operating condition, are a potential source of error for estimating emissions. In the presented case if the vehicle speed on the motorway is limited to 120 km/h the emission of nitrogen oxides should not exceed 0.01 g/km, even taking into account the actual driving cycle on the motorway. If the vehicle is moving at a speed of 130 km/h NOx emissions will increase by no less than 100 times, and will be equivalent to the emissions of four EURO 3 category cars, equipped with compression-ignition engines driving at a moderate speed.

Thus, there are ranges of the engine operation, for which there is no correlation between the emission results under the vehicle type approval conditions and the emission in the actual traffic conditions.

Emission properties at speeds above 120 km/h are characteristic of the vehicle, dependent on the composition of the fuel mixture control. The necessary problem to be solved in the estimation of emissions in certain conditions is to define the emission properties of the vehicle population, which requires conducting tests on a representative sample of vehicles.

4. Testing the vehicle equipped with diesel engine

Measurements were carried out on the popular car equipped with diesel engine and common-rail fuel injection system. The vehicle was type-approved at the EURO 5 level.

The measurements presented were made while conditioning the vehicle before the planned comparative measurements.

The course of conditioning is shown in Fig. 1. The car was started up in about 300-th second from the beginning of the test recording. The driver accelerated and stabilized the speed of the vehicle on a dynamometer at 90 km/h ± 0.3 km/h.

The concentration of the exhaust gas components were measured, such as carbon dioxide, nitrogen oxides (NOx) and hydrocarbons (CH) after dilution in a CVS system. Due to the method of the exhausts dilution in the CVS system, the momentary concentration of the tested agent is proportional to the momentary mass emissions of the exhaust components tested [5]. Thus, Fig. 4 and Fig. 5 show the course over time of the exhausts components concentrations in the CVS sampling system, as a representation of the momentary emission.

As expected, during the vehicle warm up the average carbon dioxide concentration (CO_2), representing fuel consumption, showed a decreasing trend which can be seen between 400-th and 1100–th second of the recording (Fig 4). Visible discrepancies of carbon dioxide concentration from the mean value between 400-th second and 1100-th second of the recording are the result of correcting the vehicle speed on a dynamometer, by the driver who operated the gas pedal to stabilize the vehicle speed at a given level.

In the 1100-th second of the recording the nitrogen oxides concentration grew rapidly from about 8.5 ppm to 104 ppm. This represents an increase of nitrogen oxides emissions from 83.2 mg/km to the level of 1048 mg/km. This increase is correlated with a step change in the

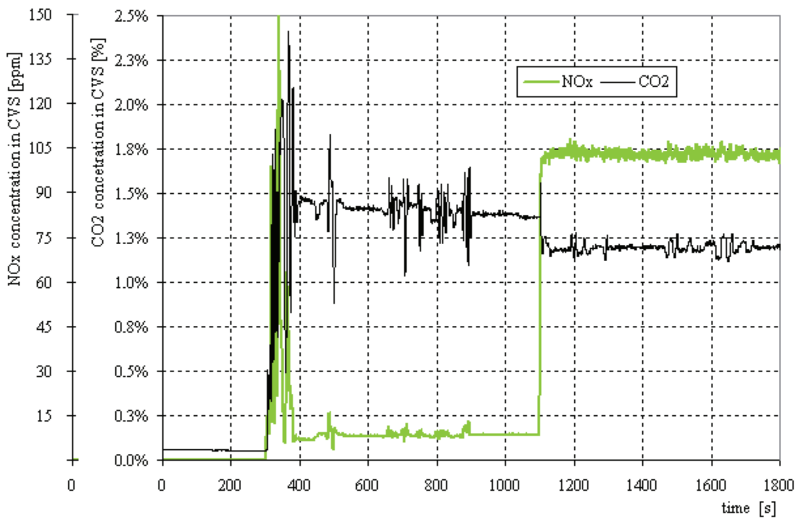

Fig. 4. Recording of the course of the carbon dioxide concentration and nitrogen oxides concentration during the conditioning of the vehicle - Test 1

concentration of carbon dioxide CO_2, which stabilized at 86% of the average concentration between 1060-th and 1100-th second of the conditioning, i.e. the concentration measured for 40 seconds prior to the step change in nitrogen oxides emissions. This corresponds to a reduction of fuel consumption from 5.3 dm^3/100 km to the level of 4.55 dm^3/100 km. Conditioning at a speed of 90 km/h was continued for another few minutes without any visible change in the nitrogen oxides and carbon dioxide concentrations.

The test was continued for another 20 minutes changing the speed of the vehicle. NOx concentration remained constant at above 100 ppm.

Prior to the next test there was a few hours break, during which the engine compartment was cooled down using external fan. Then again, tests were performed at a speed of 90 km/h. The values of nitrogen oxide emissions have stabilized at a low level of about 8 ppm (Fig. 5) the same as at the beginning of the test 1 (Fig. 4). Then, after about 1250 seconds of driving there was an acceleration to 120 km/h and the nitrogen oxides concentration reached the value of about 100 ppm, so the value of the nitrogen oxides emissions (NOx) again increased to a value that is not explicable by a the slight change in driving speed.

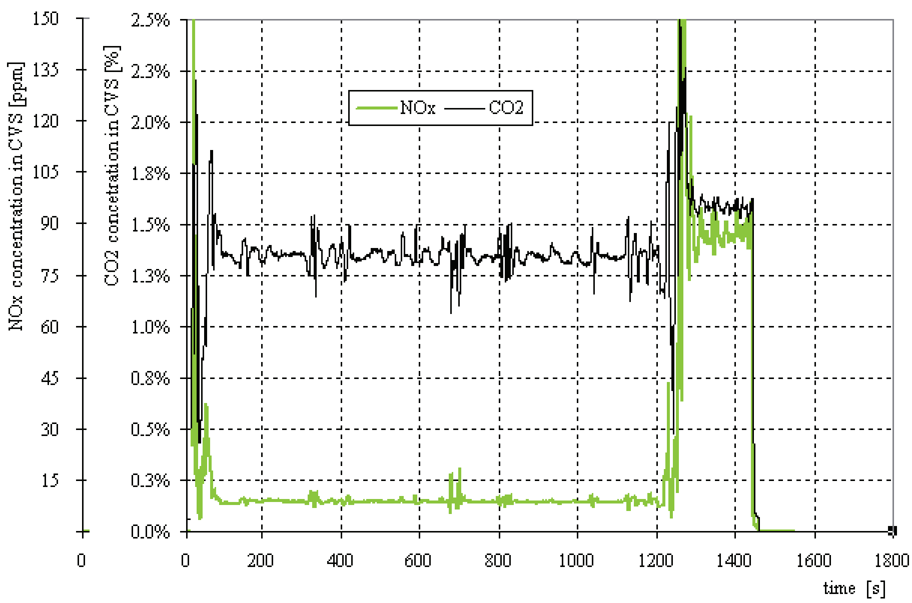

Fig. 5. Recording the course of the carbon dioxide and nitrogen oxide concentrations during vehicle conditioning – test I

Both recordings may suggest that there is a factor, triggered after a specified period after a cold start affecting the change in the emission properties of the test vehicle.

Under the same driving conditions, presented vehicle can emit different amounts of nitrogen oxide. Therefore, if the car is used for a short time after a cold start, the nitrogen oxides emission will be small. If the vehicle will be used extensively the nitrogen oxides emission may increase many times.

5. Reliability of the measurements

Determining the specific emission factor for a specific vehicle with a stable and repeatable emission, driven by the same driver on a uniform stretch of road and driving conditions is a relatively simple task with appropriate measuring equipment and experienced staff.

The problem is much more complicated when it comes to identifying the specific emission factor averaged for a group of vehicles with different emission properties, in real traffic, where vehicles are moving according to the road conditions, rules and preferences of the drivers.

To determine the emission properties of the population of vehicles, one needs to specify the features that significantly affect the emission during the operation and their frequency of their occurrence in the surveyed population of vehicles.

To determine the emission in the operation of the vehicles characterized in section 3, it is important to determine the speed achieved during the driving, and the intensity of accelerations as well as the impact of the driving speed on the emission, particularly in the conditions of the engine load, which is not considered in the type approval tests.

Proper determination of the nitrogen oxides emissions from vehicle in the traffic conditions described in section 4 is associated with establishing the average time after the engine cold start up to an increase of nitrogen oxides emissions. It is also necessary to specify the circumstances of the occurrence of the factor causing the change in nitrogen oxides emissions and frequency of the described feature occurring in the population of vehicles.

Problems with the determination of the influence of various factors are not limited to engines equipped with electronic engine controllers. There were type-approval tests performed on the vehicle equipped with a diesel engine with mechanical injection pump. It was found that the uniqueness of the measurements of particulate matter emission (PM) is associated with the loss of air-tightness of the engine oil dipstick. After the loss of air tightness in the connection, the particulate matter emissions increased about three times in respect to the emission volume with the dipstick properly located in its seat.

The procedure for determining the vehicle population emission coefficients should define the division of vehicles into groups of vehicles with similar emission properties.

In determining the emission of the separate groups of vehicles, it is necessary to first perform preliminary tests to determine factors having decisive influence on the emission during the operation and on that basis to plan future tests. Determining the estimate error of emissions is a problem in itself, because as a rule, the amount of available data is limited. Therefore minimizing the estimate error relies on detailed studies performed on the representatives of these groups of vehicles, whose emissions due to their numbers and the value of emission factors for the exhaust components under scrutiny, is critical for global emissions.

5. Conclusions

It was found that there are engine operating conditions in which serviceable vehicle with a small degree of wear, tested in road tests emits many times more of the exhaust gases limited components than it would appear from the measured values obtained during the type approval tests procedure.

It was also found that, depending on the time of engine operation from a cold start, in the same vehicle operating conditions, the mass of emitted nitrogen oxides may vary over 20-fold.

Carrying out comparative studies involving emission of exhausts components from vehicle exhaust system should be preceded by an analysis of the stability of the test vehicle emissions. This also applies to the engine operating at the constant load conditions.

Changes in the emission test procedures carried out under the type approval procedure should take into account, broader than it currently is, the way the vehicle is used and thereby also limit emissions under conditions of the normal operation, but at present are not covered by the type approval tests procedure.

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