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THE INFLUENCE OF THE DRIVING STYLE ON THE EXHAUST EMISSION FROM A PASSENGER CAR WITH A EURO 5 DIESEL ENGINE

The article discusses the subject of light duty vehicles exhaust emissions in real driving conditions and their connection with fuel consumption. Tests were carried out in the Poznan agglomeration area on roads with various speed limits. The driver was to drive the same distance first driving in an aggressive manner than normally. Emissions of the following compounds were measured using a SEMTECH analyzer by Sensors Inc.: hydrocarbons, carbon monoxide, nitrogen oxides and carbon dioxide. As a result the tests allowed to evaluate the influence of the driving style on the exhaust emissions and refer it to the currently enforced Euro 6 standard.

Keywords: exhaust emission, driving style, RDE

1. INTRODUCTION

One of the most important issue causing permanent development in engines designing are emission standards, which define permitted amount of harmful compounds allowed in exhaust gases. Recently there is an increase on passenger vehicles sale market. The vehicles equipped with Diesel engine are popular because of the relatively low fuel consumption in comparison with spark-ignition engine. The main goal of the European Union is to reduce CO_2 emission, which is directly connected to fuel consumption. There are many ways to achieve this purpose like eco-driving. The comparison of two different driving styles (aggressive and economic) is present-

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ed in the paper below. There is a Regulation adopted by European Union, which establishes that the CO_2 emission shall be reduced to the level of 95 g/km [Delphi 2016] in the NEDC tests (New European Driving Cycle). The CO_2 emission is equated with fuel consumption to the effect that it also has to be reduced to 4,1 dm^3/100km by 2020. This paper presents a Real Driving Emissions (RDE) driving. Test conditions are significantly different than in case of the test runned on the engine dynamometer [Adamski et al. 2015]. The real emission depends on many factors such as weather, driver and traffic. Unlike Heavy Duty Vehicles, accurate procedures for passenger cars have not been approved yet, but there are proposals being analyzed by several research centers in Europe [Merkisz et.al 2016].

The research described in this article presents Real Driving Emission for Euro V depending on driving style. For example, the CO_2 emissions is at least two times bigger when the driving style is aggressive. The results have been compared to the corresponding standards.

2. RESEARCH OBJECT

The vehicle used in this study was a II generation Fiat Bravo (Fig. 1) from the C segment. It is equipped with Diesel engine characterized by a stroke volume of 1956 cm^3 (Table 1).The year of production is 2009. The vehicle was examined in case of any mechanical defects existence. During the test there were 4 people in the car including driver. Standard equipment of this vehicle features a Particulate Filter and EGR system. The vehicle is shown in Fig. 1.

Fig. 1. The vehicle used in testing with SEMTECH equipment

The main technical parameters of the diesel engine used in the tested vehicle have been presented in Table 1.

Table. 1. Technical parameters of the tested vehicle's engine [Fiat 2010]

Engine type	Diesel
Number and arrangement of cylinders, number of valves	4 cylinders, in-line, 4 valves per cylinder
Displacement	1,956 dm^3
Bore/stroke	83 mm / 90,4 mm
Maximum power	120 kW/4000 rpm
Maximum torque	360 Nm/1750 rpm
Compression ratio	17:1
Fuel injection	Common Rail
Type of charger	VGT Turbocharger
Emission reduction and after treatment systems	EGR, DOC, DPF

3. MEASURING EQUIPMENT AND RESEARCH METHODOLOGY

The tests were conducted with the SEMTECH DS provided by Sensors Inc. This device represent a group of PEMS (Portable Emissions Measurement System) analyzers. It allows to measure the harmful exhaust gas components. The figures below show an appearance and diagram of operation (Fig. 2).

a) b)

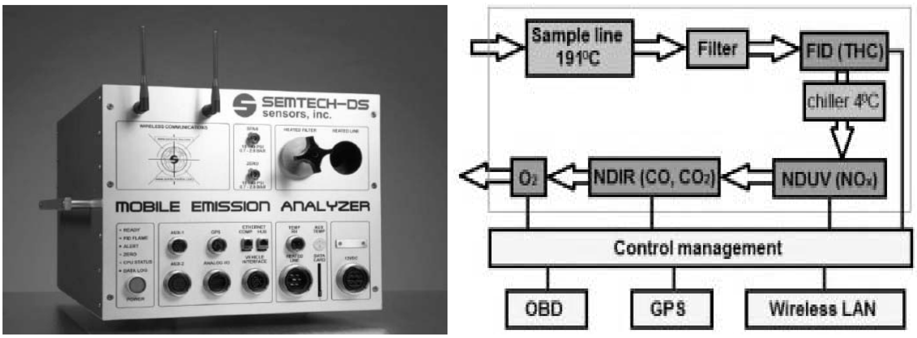

Fig. 2. a) Picture of the SEMTECH DS mobile device for exhaust emissions testing; b) Schematic of operation [Sensor Inc. 2010]

A sample of exhaust gas is collected by the exhaust mass flow rate probe. The test gas swatch is transported by a special tube, which maintains the temperature of 191°C by heating it, to prevent condensation of the hydrocarbons. Otherwise the device could be destroyed, because the filters it contains are fragile and precise [Merkisz, Pielecha, Radzimirski 2014]. The next step is filtrating. It allows to remove particulate matters. Prepared this way gases are ready to be analyzed by the dedicated devices. First the amount of hydrocarbons is examined in the FID analyzer (Flame Ionization Detector). Than the sample is cooled to 4°C and goes to the NDUV analyzer (Non-dispersive Detector Ultra Violet), which examines the concentration of nitrogen oxide and dioxide. The next step is to measure the content of carbon monoxide and carbon dioxide by the NDIR analyzer (Non-Dispersive Infrared Detector). The last step is measuring the oxygen level using the electrochemical sensor. It can store data of the engine speed and load by using the vehicle's OBD system. The position of the vehicle is tracked by the GPS system. It allows to picture the driving path using visualization tools.

Fig. 3. The route chosen for the measurements [done using GPSVisualizer.com]

There are many reasons of choosing this exact path. The point of this research was to examine driving in real conditions. This route contains roads with different maximum speeds, sections with straight lines and also many intersections. The next advantage is the location. The beginning of this route is at the premises of the University, what simplifies technical issues.

4. ANALYSIS AND RESULTS

During the studies the emission of following harmful compounds in the exhaust gas: nitrogen oxides, carbon monoxide and carbon dioxide, have been measured. Because of safety reasons FID analyzer for measuring the concentration of hydrocarbons remained (the tank with hydrogen gas is flammable and the risk of explosion was high). Both of the drives are summarized in table below (Tab. 1). Emissions of various exhaust components emitted during driving are shown in Fig. 4. Figures 10 and 11 show a comparison of fuel consumption and emission levels from both drives in juxtaposition with Euro V standards.

Table 2. Basic parameters recorded for the performed drive tests

Data	Dynamic drive	Economic drive
Travel time [s]	1210	1149
Distance [km]	12,7	12,4
Average speed [km/h]	37,7	38,9
Average acceleration [m/s^2]	0,492	0,129
Average deceleration [m/s^2]	0,452	0,151

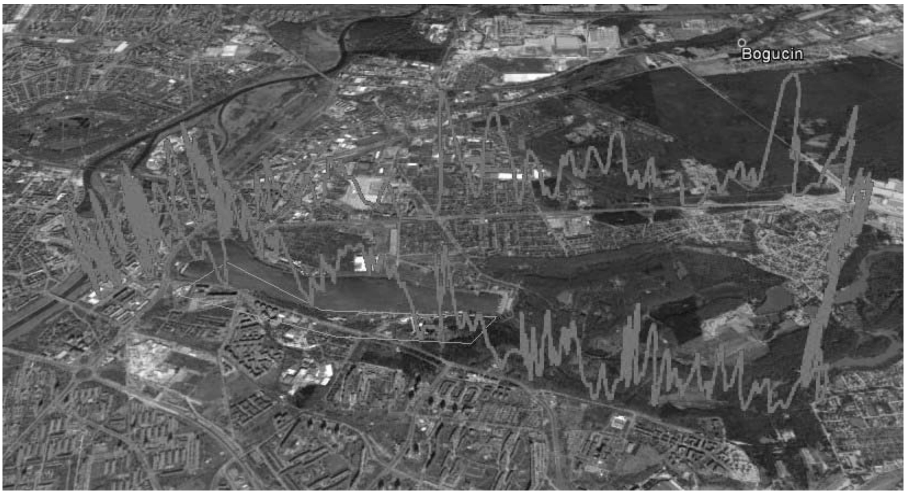

Fig. 4. Results of the CO_2 emissions during dynamic drive

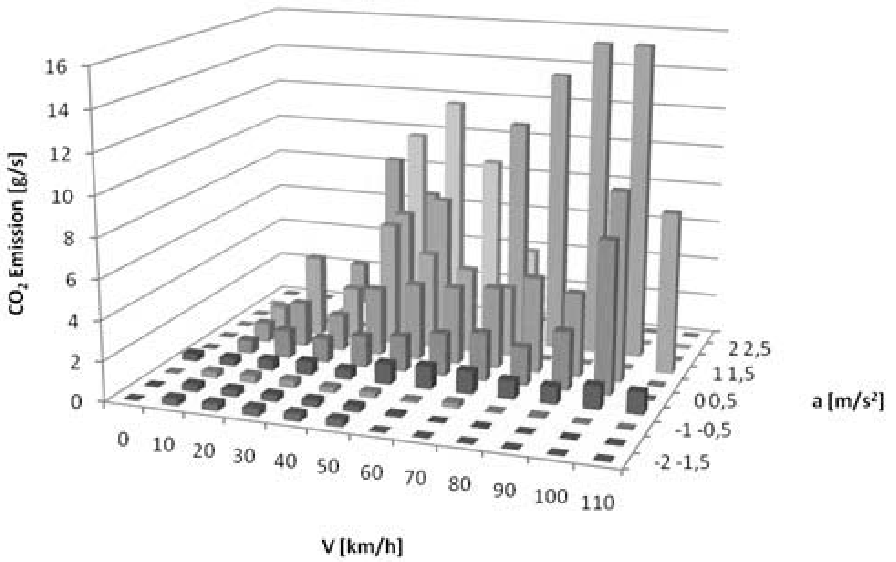

Fig. 5. Characteristics of the CO_2 emission in the range of vehiclespeed and acceleration during dynamic drive

CO_2 emission is directly combined with fuel consumption. The figure above presents the connection between rapid acceleration and fuel consumption. Along with increasing velocity, the CO_2 emission grows. During the stops and decelerating it is around minimum. The highest value is attained between 90–100 km/h.

Fig. 6. Results of the CO emissions during dynamic drive

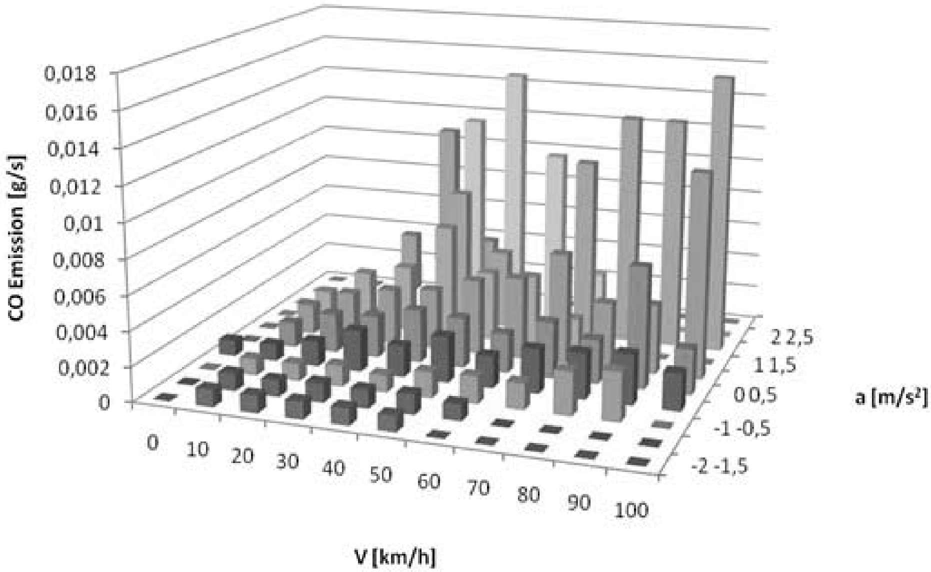

Fig. 7. Characteristics of the CO emission in the range of vehiclespeed and acceleration during dynamic drive

Rapid acceleration causes an injection of escalated dose of fuel. The combustion process can be incomplete, which is the direct cause of CO composing.

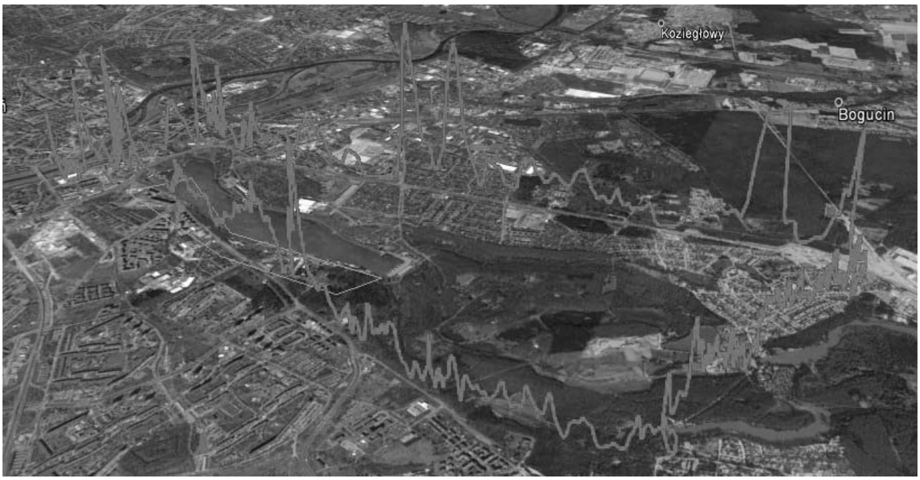

Fig. 8. Results of the NO_x emissions during dynamic drive

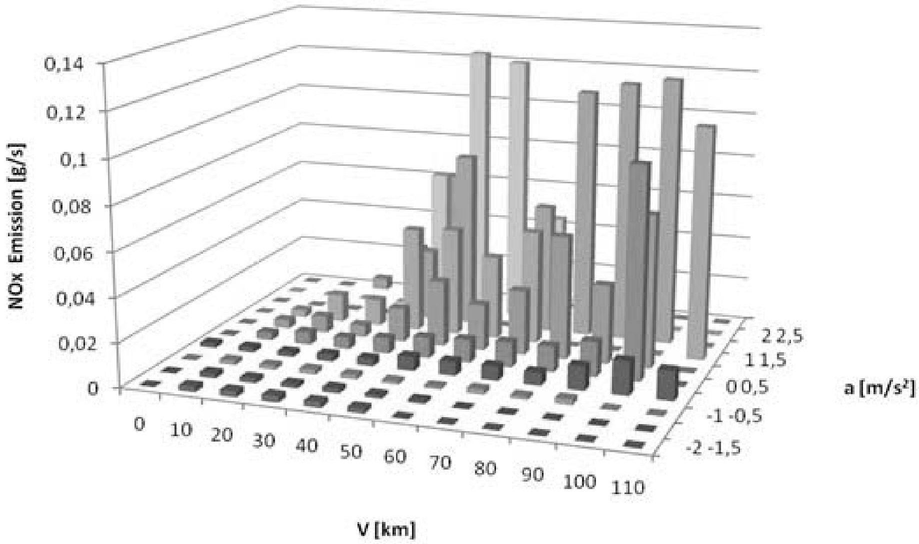

Fig. 9.Characteristics of the NO_x emission in the range of vehiclespeed and acceleration during dynamic drive

The greatest share of NO_x emission is observed in the range of 50–110 km/h. Increased fuel dose and engine speed is directly related to maximum vehicle speeds in this area and also accelerations.

Fig. 10. Results of the CO_2 emission during economic drive

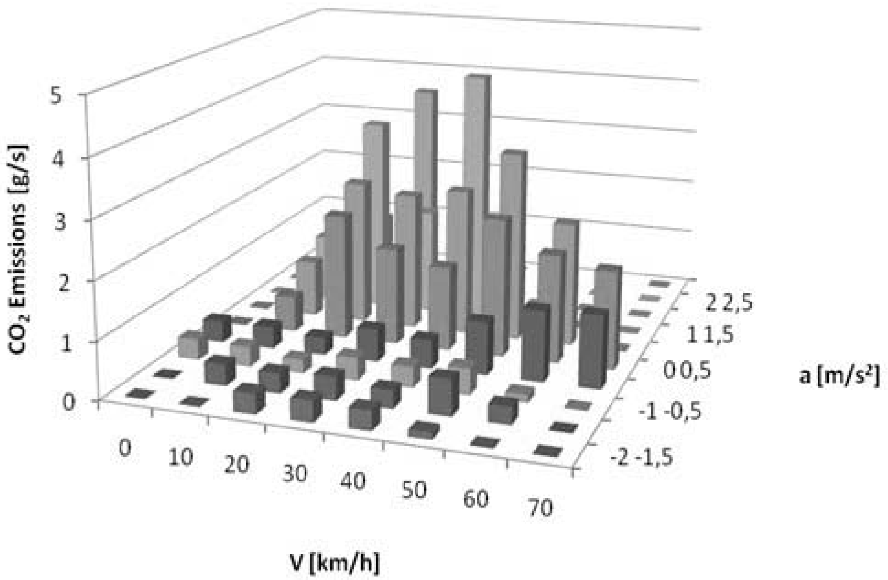

Fig. 11. Characteristics of the CO_2 emission in the range of vehiclespeed and acceleration during economic drive

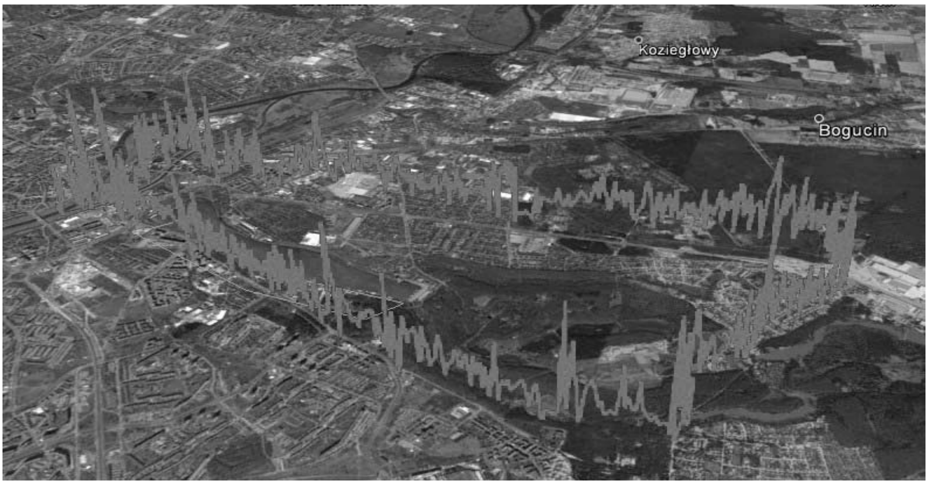

Fig. 12. Results of the CO emissions during economic drive

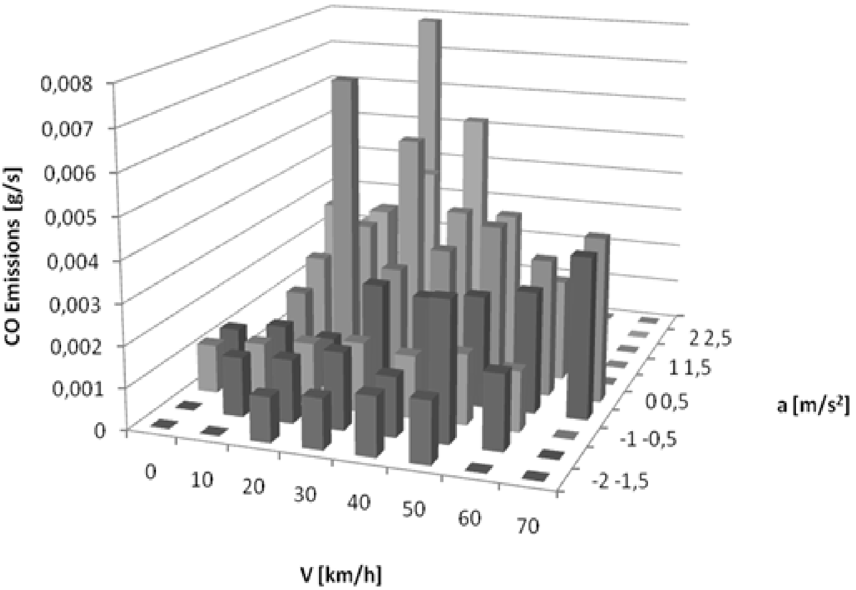

Fig. 13. Characteristics of the CO emission in the range of vehiclespeed and acceleration during economic drive

Fig. 14. Results of the NO_x emission during economic drive

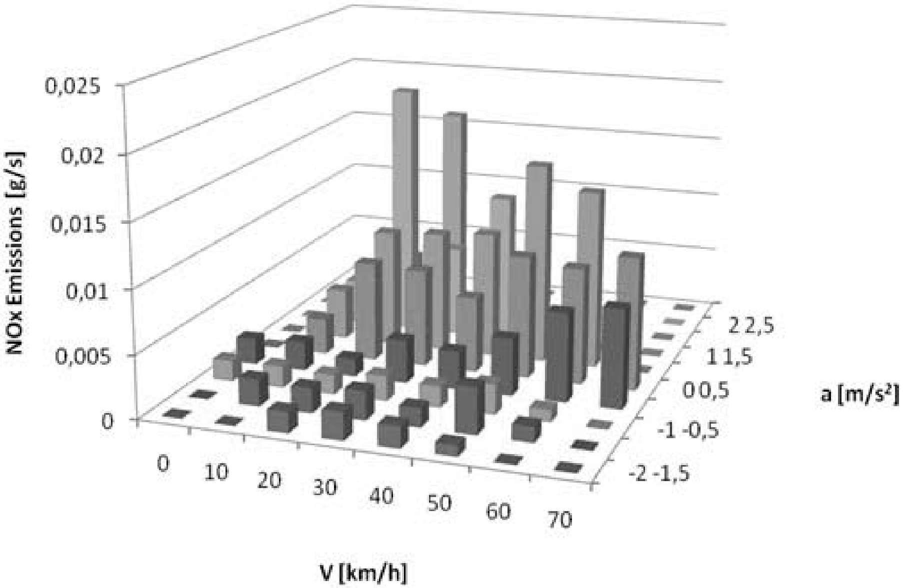

Fig. 15. Characteristics of the NO_x emission in the range of vehiclespeed and acceleration during economic drive

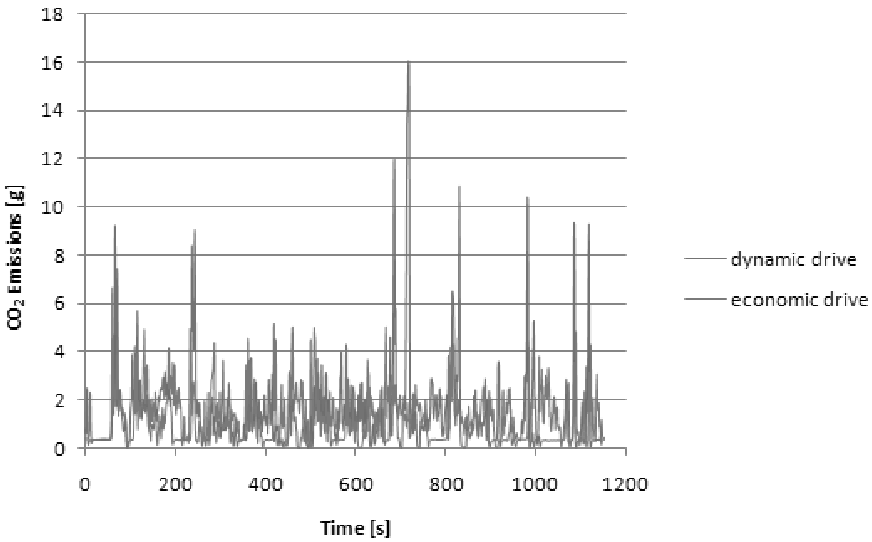

Fig. 16. The tracing of the second-by-second emission of CO_2 obtained during economic and dynamic drive

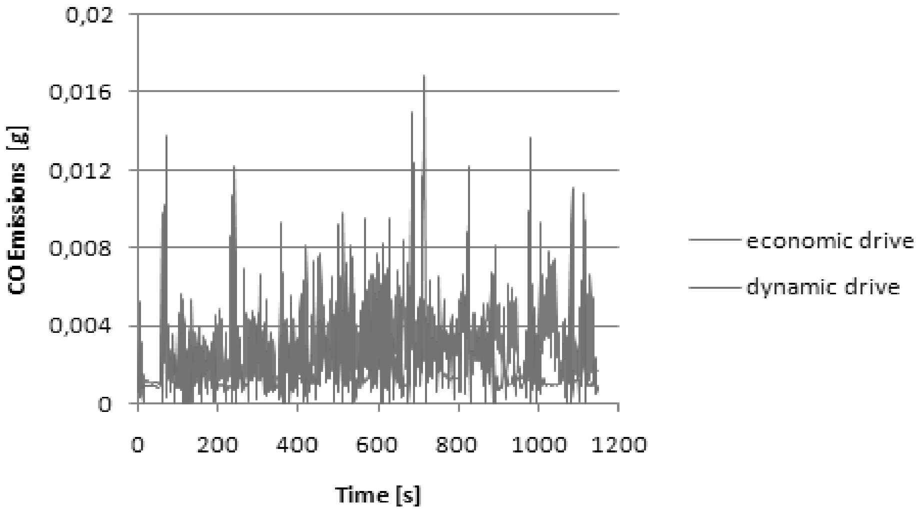

Fig. 17. The tracing of the second-by-second emission of CO obtained during economic and dynamic drive

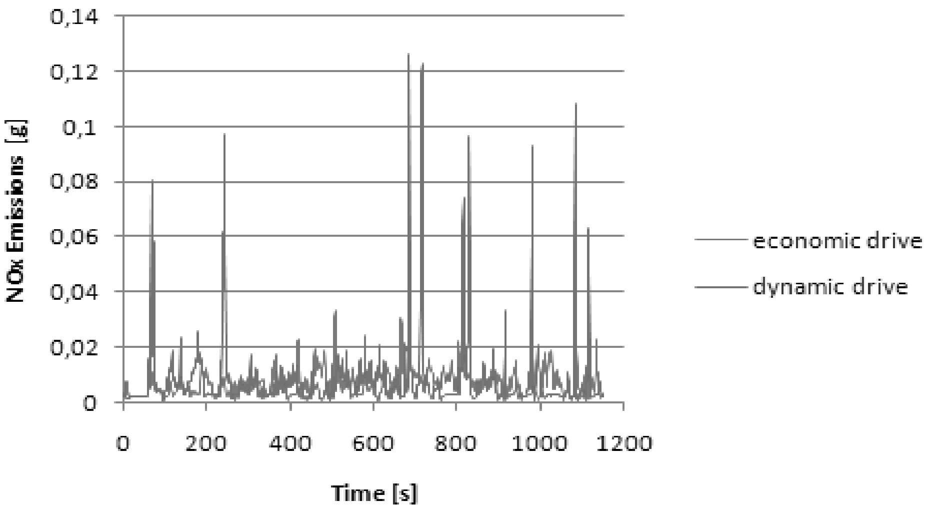

Fig. 18. The tracing of the second-by-second emission of NO_x obtained during economic and dynamic drive

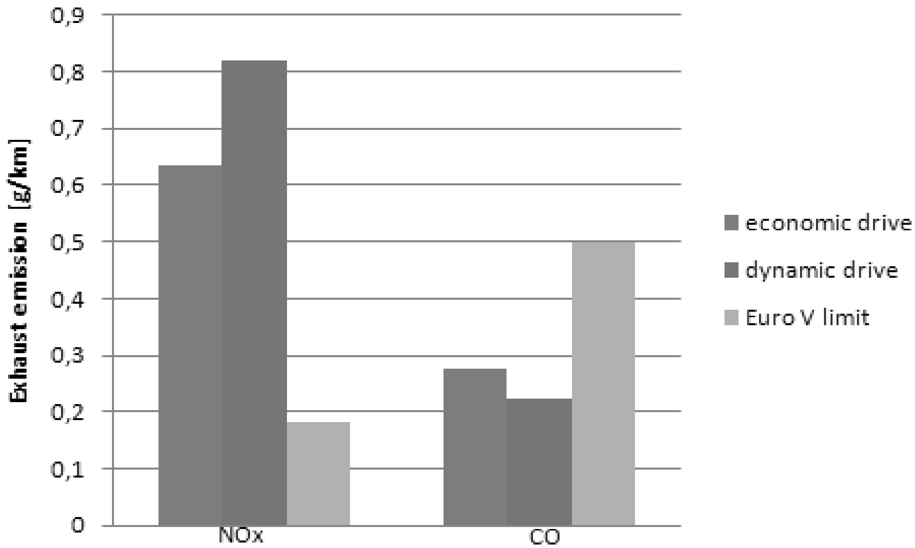

Fig. 19. Comparison of the emission levels of the tested vehicle compared emission Standards

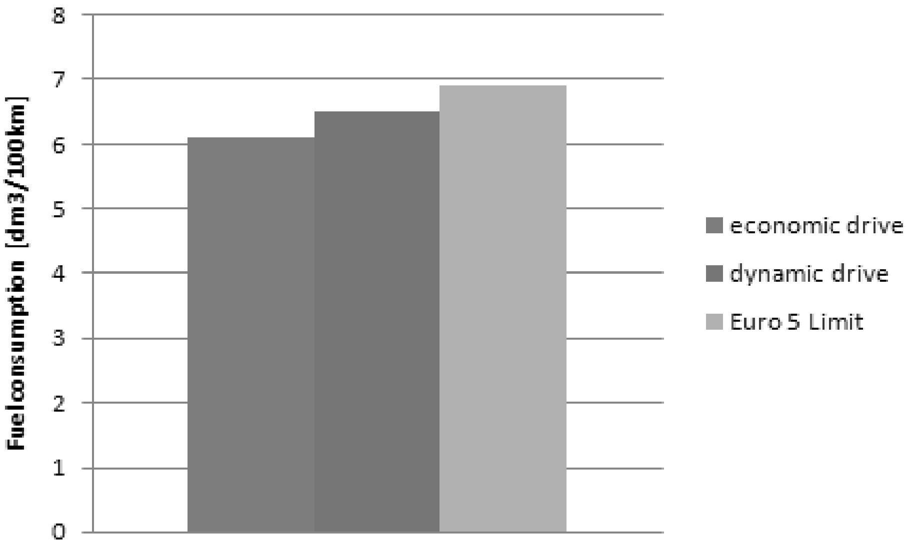

Fig. 20. Comparison of the fuel consumption of the tested vehicle compared emission Standards

Average results of tests with comparison to norms were shown in Table 3.

Table 3. Comparison of the fuel consumption and emission levels of the tested vehicle withemissions standard

Data	Dynamic drive	Economic drive	Euro V limit
Fuel consumption [dm^3/100 km]*	6,52	6,11	6,9
Emission of CO_2 [g/km]	129,1	120,9	160
Emission of CO[g/km]	0,224	0,274	0,5
Emission of NO_x[g/km]	0,775	0,595	0,18

*Fuel consumption was estimated by using the Carbon Balance Method
** Applies to Urban Cycle from NEDC test

5. CONCLUSIONS

RDE test is the only way to determine the real emission obtained during drives under traffic conditions. Unlike the test that were taken at the laboratory there is significant difference in fuel consumption. In real traffic there are situations like congestion and bad weather conditions. Current standards have to be refurbished and thus there will be new test procedures for WLTP and RDE where the Conformity Factor equals 2.1. This solution should cause the emission reduction within the years. Nowadays the vehicles are equipped with SCR system to reduce the NO_x emission, which are believed to be the most harmful because of its toxic influence.

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WPŁYW STYLU JAZDY KIEROWCY NA EMISYJNOŚĆ POJAZDU KATEGORII PC Z SILNIKIEM DIESLA SPEŁNIAJĄCYM NORMĘ EURO 5

Streszczenie

W artykule przedstawiono wyniki emisyjności pojazdu kategorii Passenger Car w rzeczywistych warunkach ruchu, a także obliczono zużycie paliwa metodą bilansu węgla. Badania dotyczyły przejazdu w centrum Poznania na drogach o różnych dopuszczalnych prędkościach poruszania się. Przeprowadzono dwa przejazdy, pierwszy w sposób naturalny, a drugi w agresywny. Emisyjność została zmierzona przy pomocy analizatorów z grupy PEMS. Do mierzonych związków należały: węglowodory, tlenek węgla, tlenki azotu oraz dwutlenek węgla.

Słowa kluczowe: emisja, styl jazdy, RDE, PEMS