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THE COMPARISON OF HARMFUL EXHAUST COMPONENTS FROM 1.9 AND 2.0 JTD ENGINES IN REAL OPERATING CONDITIONS

This article presents a comparison of CO_2, CO and NO_x emission from Saab 9-3 1.9 JTD and Fiat Bravo 2.0 JTD engines. The tests were conducted on the same route and reflect real driving emission from following passenger cars. Fiat Bravo engine is an evolution of 1.9 engine redeveloped to meet EURO 5 requirements. Despite cylinder diameter enlargement and increased fuel consumption harmful exhaust gases components were significantly reduced. Both of the engines had not exceeded the considered regulations. The results were obtained using SEMTECH DS device from PEMS (*Portable Emissions Measurement System*).

Keywords: exhaust emission, JTD engine, SEMTECH DS, RDE

1. INTRODUCTION

Combustion engines remain a major propulsion of motor vehicles despite pervasive electrification [Bajerlein, Rymaniak 2014]. Advantages of fuel like energy density and fast replenishing induces manufacturers to develop existing units so as to be marked by better utility and economic properties. With the aim of costs reducing the older engine designs with a minor changes are being used. The example is 1.9 JTD engine presented in 1997 in Alfa Romeo 156 as a first engine equipped with a common-rail system [Jost, 1998]. The engine remained in offer until the end of EURO 4 remaining in effect [Fiat materials 2009]. The next step was meeting the EURO 5 requirements which involved engine redevelopment and the 2.0 JTD engine was created [Fiat materials 2008].

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The difference between two norms is mostly in nitrogen oxides emission (fourfold emission) and particulate matters emission (Diesel Particulate Filter using necessity) [EC Regulation, 2007]. Main modifications concerned enlargement of cylinder diameter by 1 mm, applying II generation of Common Rail fuel injection and liquid cooling EGR (Exhaust Recirculation System) [Fiat materials 2008]. It also had an impact on fuel consumption reducing. Those changes should cause toxic compounds emission decreasing. The purpose of this article is to analyze real emission of vehicles equipped with the following engines 1.9 and 2.0 JTD. The measuring equipment used in this study was PEMS (Portable Emissions Measurement System). At the moment it is the only way to verify virtual impact of vehicles exploitation on the environment. The measurement include road emission of harmful gas components from exhaust gases during the drive on the Poznan agglomeration streets. The following components were analyzed: carbon dioxide, carbon monoxide, hydrocarbons and nitrogen oxides. The results were compared to each other and referred to current regulations.

2. RESEARCH OBJECTS

Vehicles used for the tests are Fiat Bravo II generation produced in 2009 and Saab 9-3 produced in 2007. Cars belong to the C segment. Both of the vehicles are equipped with EGR system and DPF (*Diesel Particulate Filter*). The engine of Fiat Bravo is an improved version of Saab 9-3 engine. The vehicles are shown in Fig. 1.

a) b)

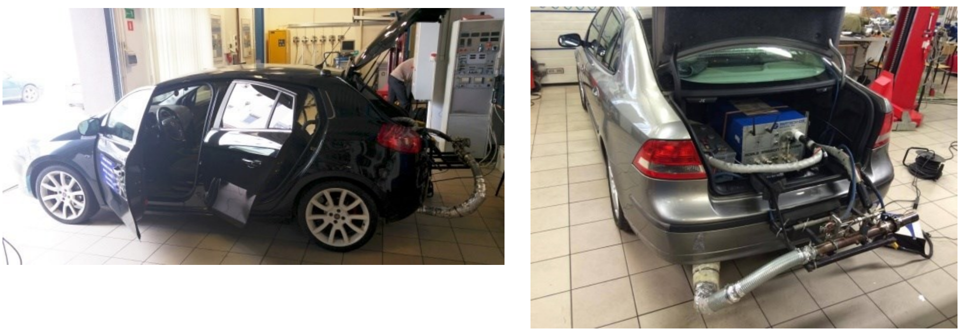

Fig. 1. Vehicles used in testing with PEMS equipment: a) Fiat Bravo, b) Saab 9-3

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, Saab 2015]

	Fiat Bravo 2.0 JTD	Saab 9-3 JTD
Engine type	Diesel	Diesel
Number and arrangement of cylinders, number of valves	4 cylinders, in-line, 4 valves per cylinder	4 cylinders, in-line, 4 valves per cylinder
Displacement	1,956 dm^3	1,920 dm^3
Bore/stroke	83 mm/90,4 mm	82 mm/90,4 mm
Maximum power	120 kW/4000 rpm	110 kW/4000 rpm
Maximum torque	360 Nm/1750 rpm	320 Nm/2000 rpm
Compression ratio	17:1	18:1
Fuel injection	Common Rail	Common Rail
Type of charger	VGT Turbocharger	VGT Turbocharger
Emission reduction and after-treatment systems	EGR, DOC, DPF	EGR, DOC, DPF

3. MEASURING EQUIPMENT AND RESEARCH METHODOLOGY

The test were carried out by SEMTECH DS device manufactured by Sensors Inc. belonging to PEMS group (*Portable Emissions Measurement System*). This apparatus was used to measure the emissions of CO_2, CO and NO_x ($NO+NO_2$) and exhaust mass flow (Fig. 2a). The operation diagram illustrate which units analyze following components. Carbon mono- and dioxide was scrutinized by NDIR (*Non-Dispersive Infrared*) analyzer. while NO and NO_2 were measured by NDUV (*Non-Dispersive Ultraviolet*) device (Fig. 2b) (Sensors, 2009).

SEMTECH analyzer is equipped with communication unit which allows to obtain data from vehicle OBD (*On-Board Diagnostic System)* system. [Merkisz, et. al 2015]. Registered data refer to basic engine parameters such as engine load and speed. The vehicle velocity and current position were gained by GPS (*Global Positioning System*) system. All of the input data were set using a laptop computer.

a) b)

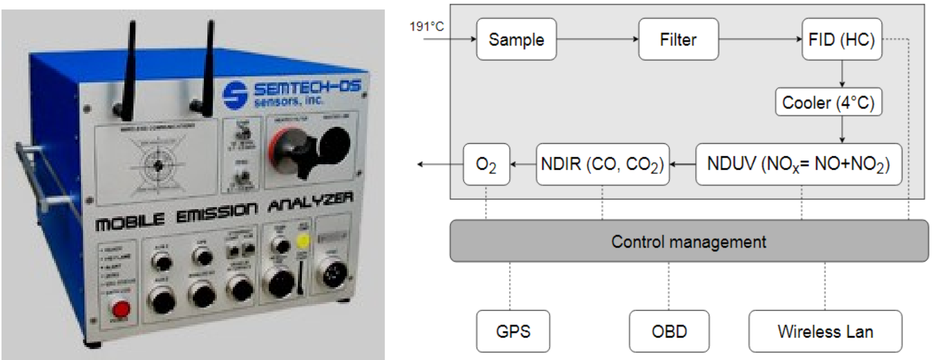

Fig. 2. Picture of the SEMTECH DS: a) mobile device for exhaust emissions testing; b) schematic of operation [Sensors, 2009]

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

Length of the route (Fig. 3) chosen for the tests was 12,5 km. The quality of the roads was fine. Moreover location of the route was chosen because of its situation nearby the research unit. The path contains roads with variety speed limits and few intersections with and without traffic lights.

4. ANALYSIS AND RESULTS

The tests results show a comparison of two drives conducted using two different vehicles. Both of them represent the same car segment but two different engines were used. Saab 9-3 is equipped with 1.9 JTD engine which is an older version of Fiat Bravo 2.0 JTD [Picccone and Rinolfi 1998]. The main difference is modification of fuel injection system and cylinder diameter enlargement. Another significant improvement involves the aftertreatment system. EGR (*Exhaust Gas Recirculation*) valve is more complex and it eventuated in NO_x emission reducing. From harmful compounds of the exhaust gases only hydrocarbons have not been measured because of safety reasons Container with reference gas is flammable and explosive and it is safe only in laboratory conditions. Table 2 illustrates basic driving parameters of both vehicles.

The CO_2 emission for both vehicles has a similar trajectory (Fig. 4–5). Increased emission can be seen for the same areas. It can arise from intersections and traffic lights occurring. Fuel consumption for Fiat Bravo was higher because of enlarged cylinder diameter and bigger fuel dose but redeveloped EGR system caused lower emission of harmful components.

Table 2. Basic parameters recorded for the performed drive tests

Data	Fiat Bravo	Saab 9-3	Percentage ratio Fiat Bravo/ Saab 9-3 [%]
Travel time [s]	1210	1526	79,29
Distance [km]	12,7	12,4	102,42
Average speed [km/h]	37,7	29,2	129,11
Average acceleration [m/s^2]	0,492	0,51	96,47
Average deceleration [m/s^2]	0,452	0,548	82,48

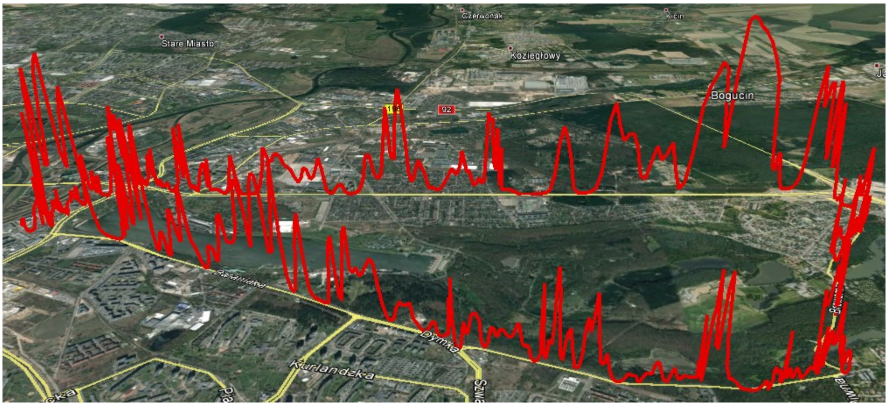

Fig. 4. Results of the CO_2 emissions during Saab 9-3 drive

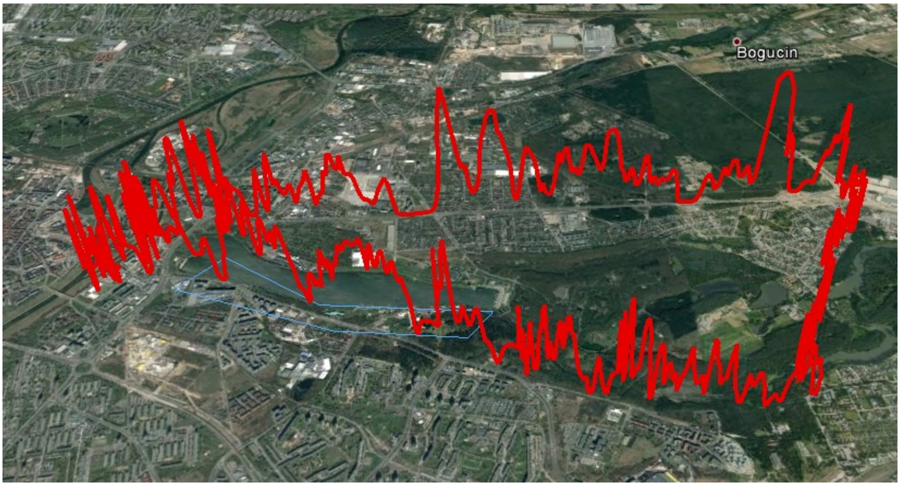

Fig. 5. Results of the CO_2 emissions during Fiat Bravo drive

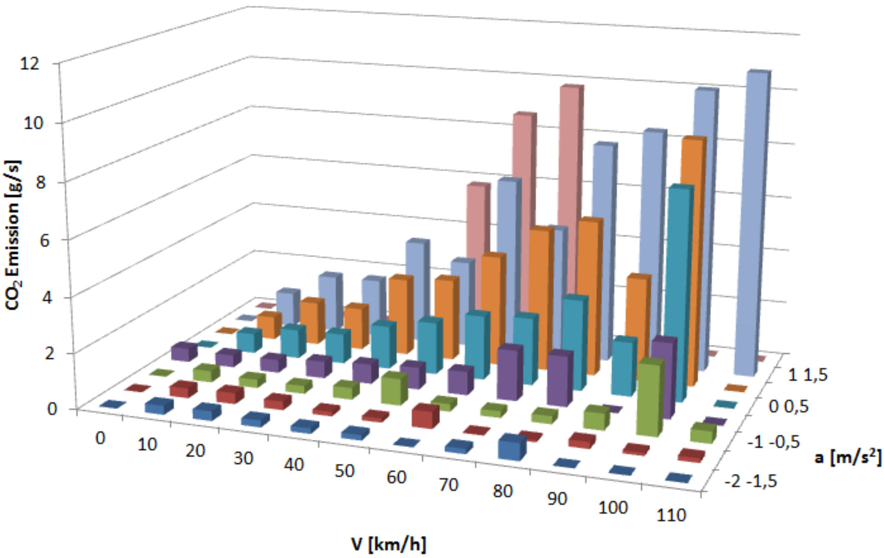

Fig. 6. Characteristics of the CO_2 emission in the range of vehicle speed and acceleration during Saab 9-3 drive

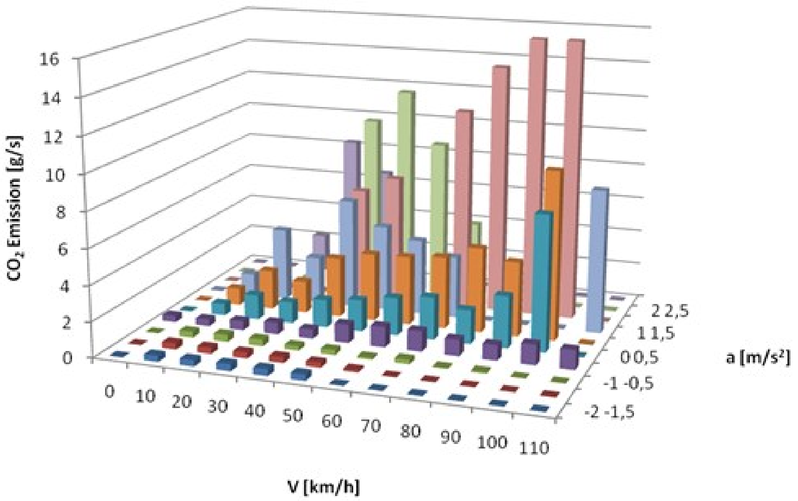

Fig. 7. Characteristics of the CO_2 emission in the range of vehicle speed and acceleration during Fiat Bravo drive

Higher pollution was registered from Fiat Bravo during acceleration in range of 1,5 to 2 m/s^2 (Fig. 7). Saab 9-3 caused less emission during deceleration. CO_2 emission is naturally higher for Saab 9-3 because CO_2 emission is directly proportional to fuel consumption (Fig. 6).

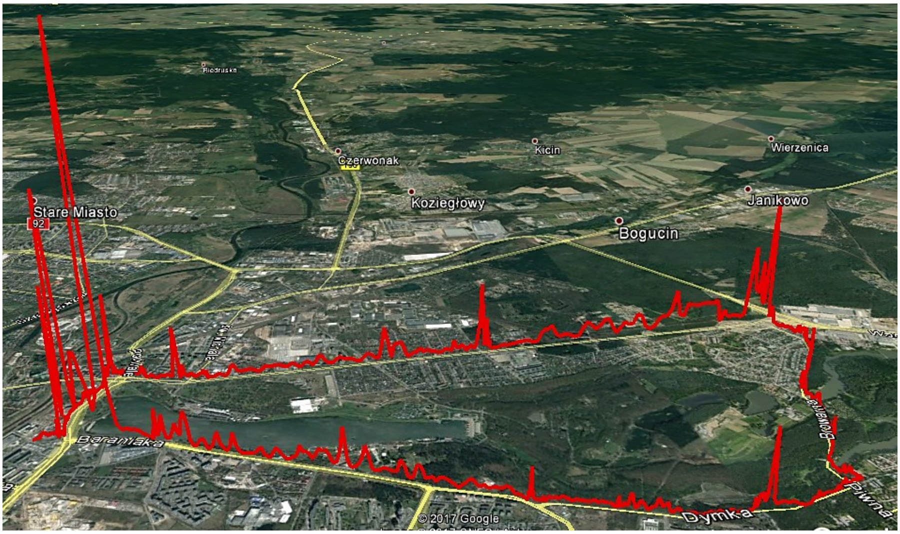

Fig. 8. Results of the CO emissions during Saab 9-3 drive

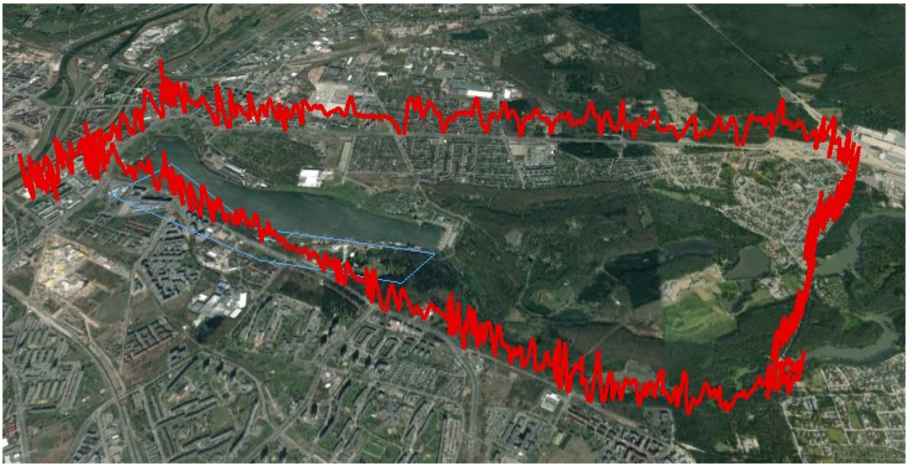

Fig. 9. Results of the CO emissions during Fiat Bravo drive

CO emission has a steady trajectory for Fiat Bravo (Fig. 9). Saab 9-3 drive has few clear peaks which could be caused by sudden acceleration and deceleration (Fig. 8). The 3D charts show what impact had the aggressive acceleration on the CO emission. Saab 9-3 driver had been decelerating more rapidly (Fig. 10–11).

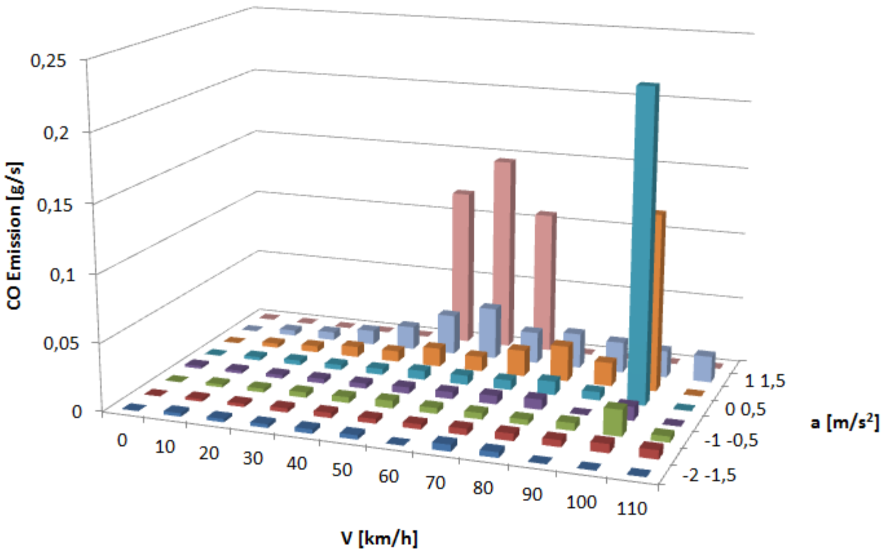

Fig. 10. Characteristics of the CO emission in the range of vehicle speed and acceleration during Saab 9-3 drive

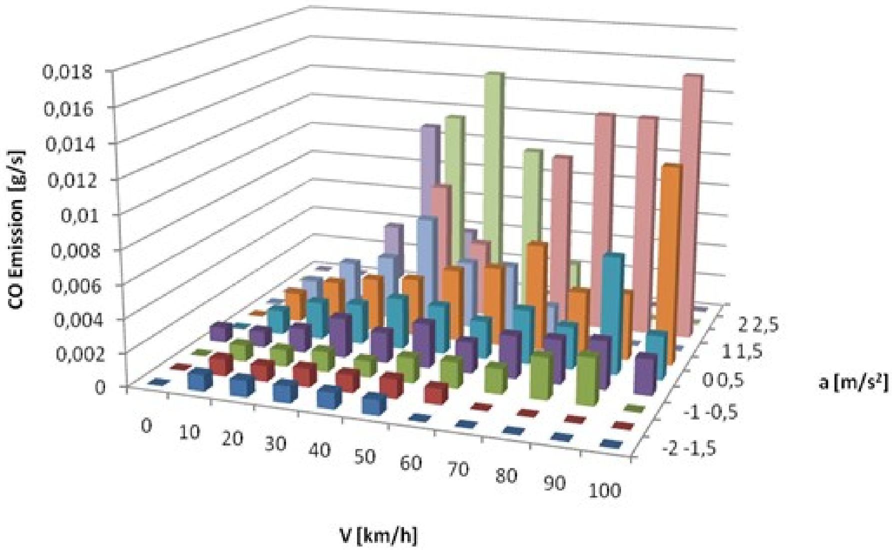

Fig. 11. Characteristics of the CO emission in the range of vehicle speed and acceleration during Fiat Bravo drive

Sudden acceleration caused around 12% higher NO_x emission from Saab 9-3 than Fiat Bravo (Fig.12–13). Engine thermal state is important factor for nitrogen oxides reducing. Fiat Bravo is equipped with more complex EGR system than Saab 9-3 which led to mentioned reducing. In case of NO_x emission the peaks occur in similar areas.

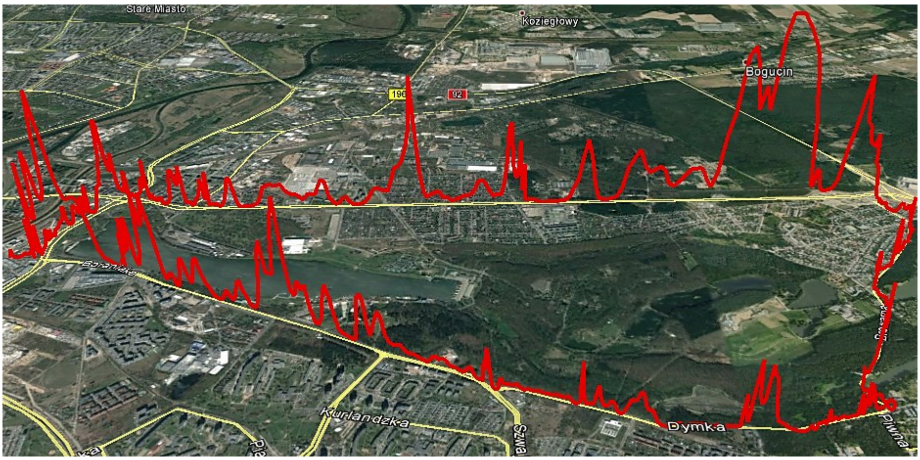

Fig. 12. Results of the NO_x emissions during Saab 9-3 drive

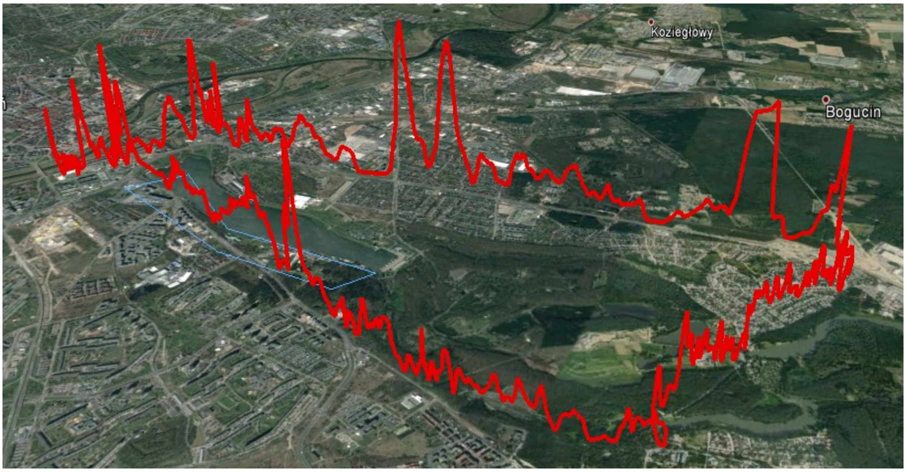

Fig. 13. Results of the NO_x emissions during Fiat Bravo drive

The 3D diagrams prove that Saab 9-3 generate pollution also during deceleration opposite to Fiat Bravo. The highest values of NO_x emission occur in the range of 90 to 110 km/h for Saab 9-3 (Fig. 14) and 50–110 for Fiat Bravo (Fig. 15). The highest value of NO_x emission was registered for Fiat Bravo but in a total amount Saab 9-3 was characterized by 0,189 g/s higher emission.

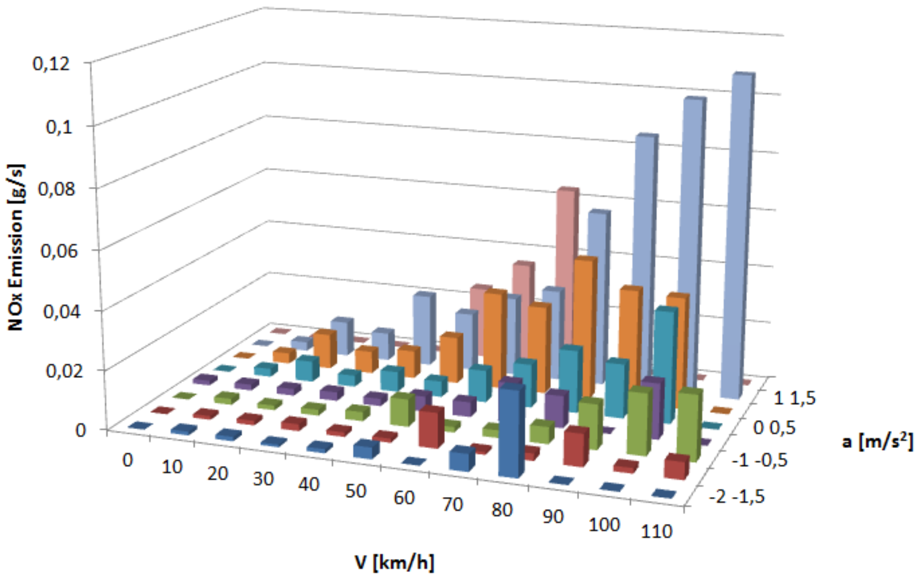

Fig. 14. Characteristics of the NO_x emission in the range of vehicle speed and acceleration during Saab 9-3 drive

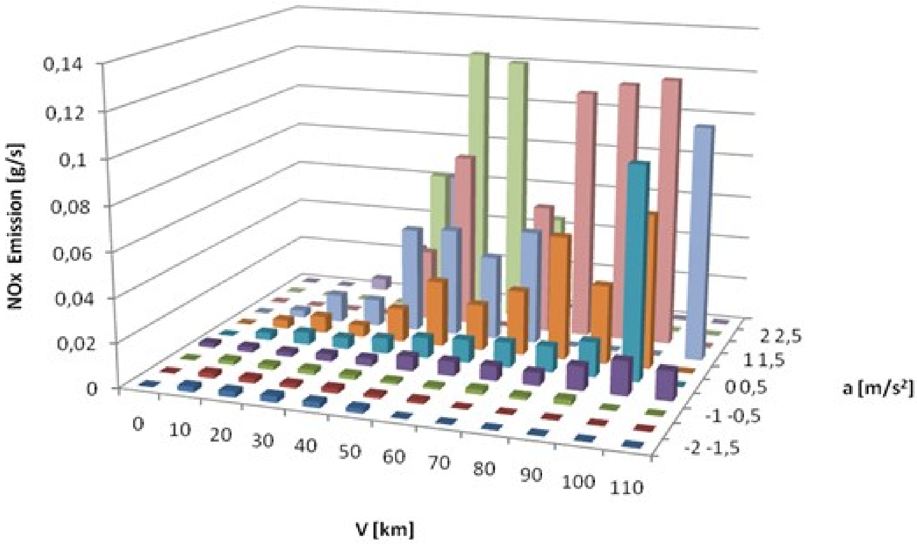

Fig. 15. Characteristics of the NO_x emission in the range of vehicle speed and acceleration during Fiat Bravo drive

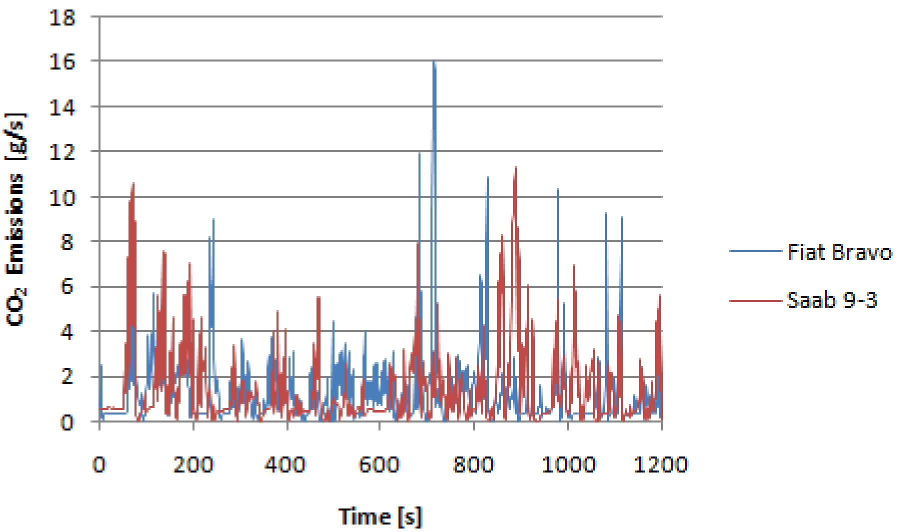

Fig. 16. The tracing of the second-by-second emission of CO_2 obtained during Fiat Bravo and Saab 9-3 drive

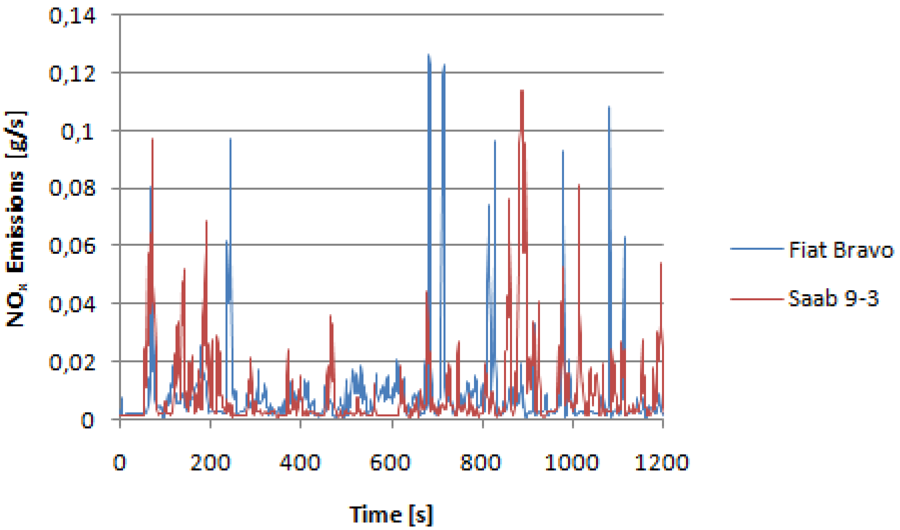

Fig. 17. The tracing of the second-by-second emission of NO_x obtained during Fiat Bravo and Saab 9-3 drive

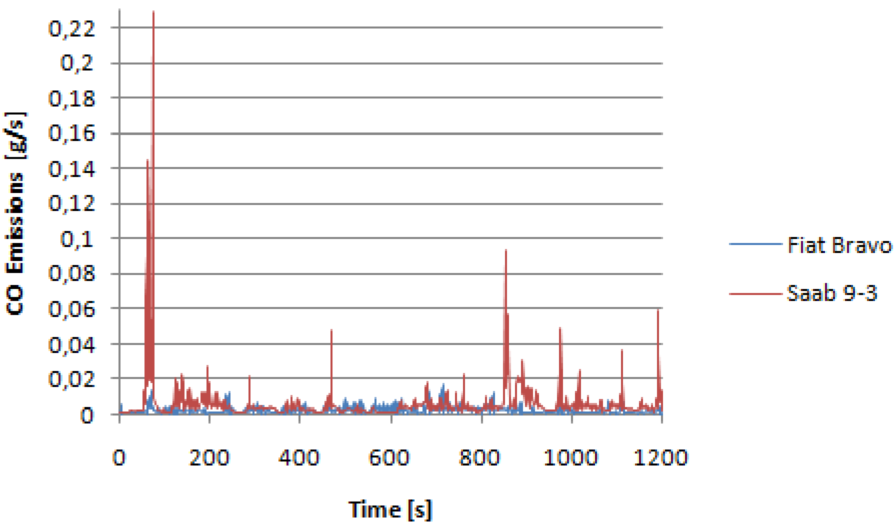

Fig. 18. The tracing of the second-by-second emission of CO obtained during Fiat Bravo and Saab 9-3 drive

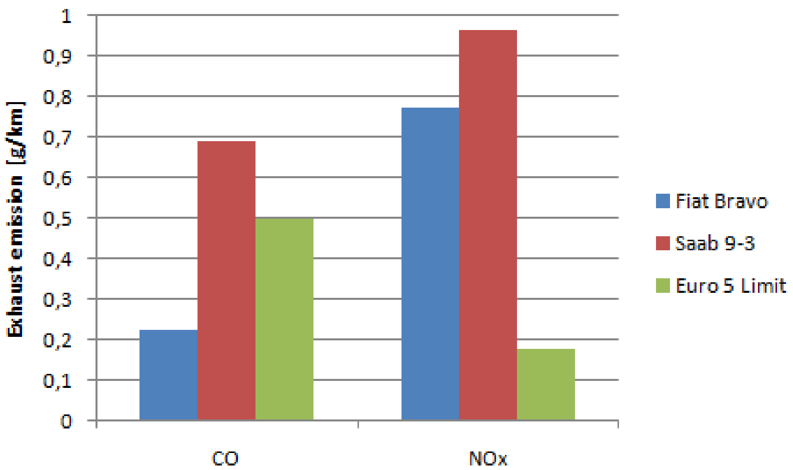

Fig.19. Comparison of CO and NO_x emission for Fiat Bravo, Saab 9-3 and EURO 5 limit

Fuel consumption was calculated using Carbon Balance method (Table 3). Average results of tests with comparison to norms were shown in Table 3. Figure shows a comparison of particular exhaust gases components for both vehicles. In both cases higher emission was caused by Saab 9-3 with 1.9 JTD engine and also the current limit was exceeded (Fig. 19).

Table 3. Comparison of the fuel consumption and emission levels of the tested vehicle compared emission standards

Data	Fiat Bravo	Saab 9-3	EURO 5 limit	Percentage ratio Fiat /Saab [%]
Fuel consumption [dm^3/100km]*	5,5	5,9	6,9	93,22
Emission of CO_2 [g/km]	129,1	160,2	16	80,59
Emission of CO [g/km]	0,224	0,692	0,5	32,37
Emission of NO_x[g/km]	0,775	0,964	0,18	78,32

5. CONCLUSIONS

From the conducted tests it is known that the Fiat Bravo 2.0 JTD engine characterized by lower emission of harmful exhaust gases compounds emission despite higher fuel consumption. 1.9 JTD engine improvement was the only way to meet EURO 5 regulations. The drives were performed by two different drivers which could have an influence on the results because driving style can reduce emission relevantly. Nitrogen oxides limit for EURO 5 was exceeded for both vehicles despite improved EGR system in 2.0 JTD engine. To meet the EURO 6 requirements vehicles are being equipped with SCR (*Selective Catalyst Reduction*) system what has a significant impact on NO_x reduction. Real Driving Emission tests are the best option to show authentic impact on the environment. Nowadays engines are more and more improved and efficient. The comparison of 1.9 JTD and 2.0 JTD engine shows that even a small improvement can significantly reduce harmful exhaust gases components even by 76% like CO.

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PORÓWNANIE EMISJI ZWIĄZKÓW SZKODLIWYCH Z SILNIKÓW 1.9 I 2.0 JTD W RZECZYWISTYCH WARUNKACH EKSPLOATACJI

Streszczenie

W artykule przedstawiono porównanie emisji CO, CO_2 oraz NO_x dla dwóch pojazdów: Saab 9-3 z silnikiem 1.9 JTD oraz Fiat Bravo, którego silnik 2.0 JTD jest ewolucją wymienionego powyżej. Testy przeprowadzone zostały na tej samej trasie i odzwierciedlają rzeczywiste warunki ruchu dla danych pojazdów osobowych. Oprócz powiększenia średnicy cylindra o 1 mm innowacji poddano także zawór recyrkulacji spalin w celu spełnienia wymagań normy EURO 5. Oprócz limitu emisji NO_x przekroczonej przez silnik Saaba pozostałe składniki pozostały w normie. Wyniki uzyskano za pośrednictwem aparatury SEMTECH DS z grupy PEMS (*Portable Emissions Measurement System*).

Słowa kluczowe: RDE, PEMS, normy EURO, emisja