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PARTICULATE MASS AND NUMBER EMISSION FROM A PICK-UP TRUCK EXHAUST SYSTEM IN REAL OPERATING CONDITIONS

The article presents the particulate matter measurement analysis of a passenger vehicle equipped with diesel particulate filter in real operating conditions. The tests were conducted in the Poznań urban agglomeration on routes with variable speed limits. The procedure included two different driving styles – aggressive and normal. The measurement of particulate matter included their mass, surface area, number and spectral distribution and was performed using a TSI mass spectrometer and an AVL micro soot sensor. The results allowed for determining the impact of the driving style on the particulate matter emissions and allowed for comparison of the outcome relative to the current regulations.

Keywords: exhaust emission, driving style, RDE

1. INTRODUCTION

The awerness of harmful impact of particulate matters on the environment is more prominent. Nowadays administration of countries are forced to tighten up current regulations to prevent further pollution. Natheless poor air quality is noticable. Process of its formation of particulate matter is complicitous. It cosists of two fractions: PM_{SOL} and PM_{INSOL}. It stands for soluble and insoluble fraction. The main cause of PM formation is dissolution of diesel oil in combustion chamber and exhaust system.

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This article presents the results of PM emission during two different driving styles – economic and dynamic drive. Both of drives were conducted by one driver which is an important factor because of various physical conditions and habits. The differences between driving styles applies to acceleretarion and gear changing for distinct velocities.

2. RESEARCH OBJECT

The reaserch object used in study was Nissan Navara from II generation designed to meet Euro 5 requirements which was allowed because of DPF (Diesel Particulate Filter). This type of vehicle is mostly used as a passenger car but its original intended use was to transport goods. In this class of vehicles Nissan Navara is the most popular in Europe. Its weight and length cause escalated fuel consumption. This vehicle is adapted to transport maximum four people. It is equipped with a diesel engine with the maximum power of 140 kW. The vehicle is shown in Fig. 1.

Fig. 1. The vehicle used in testing with PEMS 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 [Nissan 2015]

Engine type	Diesel
Number and arrangement of cylinders, number of valves	4 cylinders, in-line, 4 valves per cylinder
Displacement	2,488 dm^3
Bore/stroke	89 mm / 100 mm
Maximum power	140 kW/4000 rpm
Maximum torque	450 Nm/2000 rpm
Compression ratio	15:1
Fuel injection	Common Rail
Type of charger	VGT Turbocharger
Emission reduction and aftertreatment systems	EGR, DOC, DPF

3. MEASURING EQUIPMENT AND RESEARCH METHODOLOGY

The portable AVL MSS device is used to measure the concentration of PM included in exhaust gases. It also allowes to asses particulate matters mass in mg/m^3 using the PASS method (Photo Acoustic Soot Sensor) [Merkisz et. al 2012]. Size distribution of PM was determined by TSI EEPS MODEL analyzer in range from 5.6 to 560 nm. It shows the dynamic behavior of particle emission during chosen driving cycle. Both analyzers belong to a PEMS group (Portable Emissions Measurement Systems) [Merkisz et. al 2013].

a) b)

Fig. 2. a) Picture of the TSI EEPS model analyzer; b) MSS by AVL sensor [AVL 2017, TSI 2016]

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

The route for tests was chosen on the grounds of localization and variety of speed limits and number of intersections.

4. ANALYSIS AND RESULTS

The studies were based on the results obtained by portable analyzers from PEMS group. Particulate mass and number have been measured in real driving conditions. Results of both drives were compared to current requirements. Driving styles applied in this tests were significantly different. Economic driving is characterized by for example slight acceleration and deceleration, whereas dynamic driving is more aggressive and sudden. Key driving parameters of both drives are presented in Table 2 below.

Table 2. Basic parameters recorded for the performed drive tests

Data	Dynamic drive	Economic drive
Travel time [s]	1131	1274
Average speed [km/h]	37.2	33.1
Average acceleration [m/s^2]	0.452	0.384
Average deceleration [m/s^2]	0.562	0.446

The Figure 4 and 5 present total concentration of particulate mass per kilometer. It was ploted on the map to visualize the areas where the pollution was the most apparent.

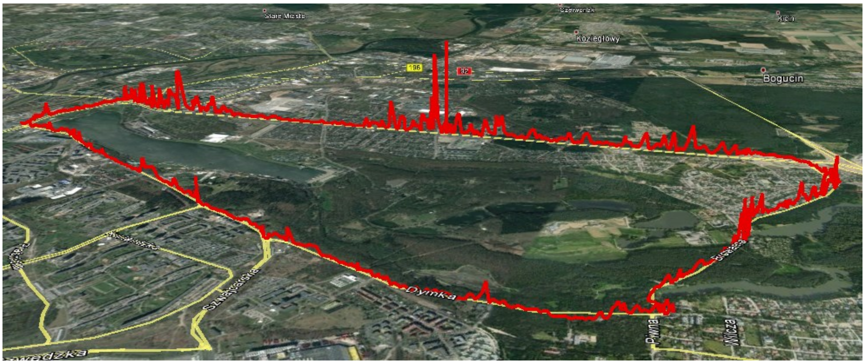

Fig. 4. Total concentration of PM during dynamic drive

The difference between two paths can be seen mostly by the peaks. The route with the highest peaks of the dynamic drive is the main street from the whole circuit. There is the highest risk of congestion occuring.

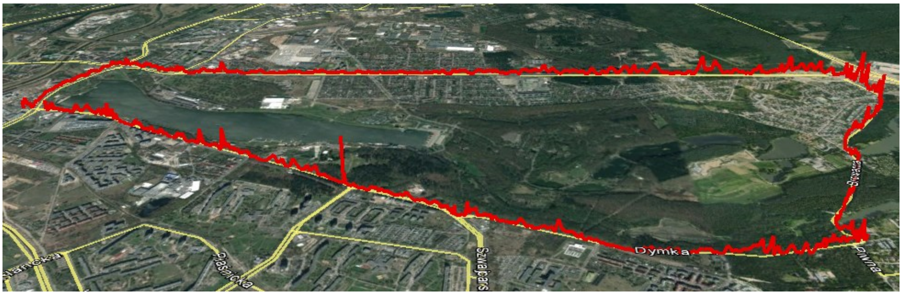

Fig. 5. Total concentration of PM during economic drive

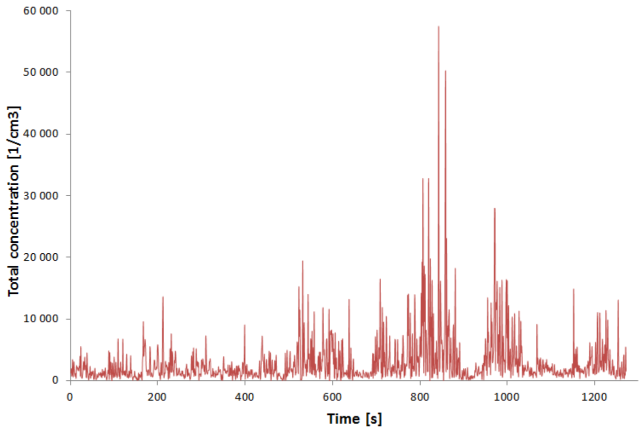

Fig. 6. Total concentration of PM during dynamic drive

The same data were presented in the following charts, but with reference to time. The highest peaks values in dynamic drive are over two times higher than the economic one. The second one is more spread in time, the changes were not sudden which led to fuel consumption reduction.

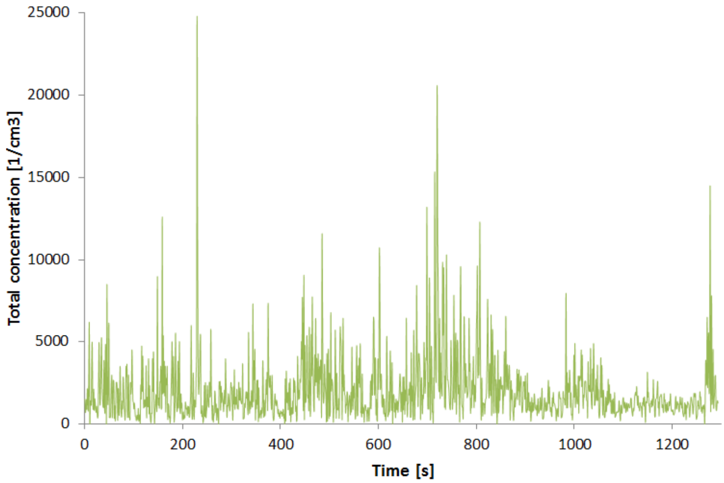

Fig. 7. Total concentration of PM during economic drive

The chart referring to dynamic drive shows that load of vehicle affects on the PM emission. Time lapse from 800–900 s illustrate higher emission caused by abrupt acceleration and deceleration at the main road.

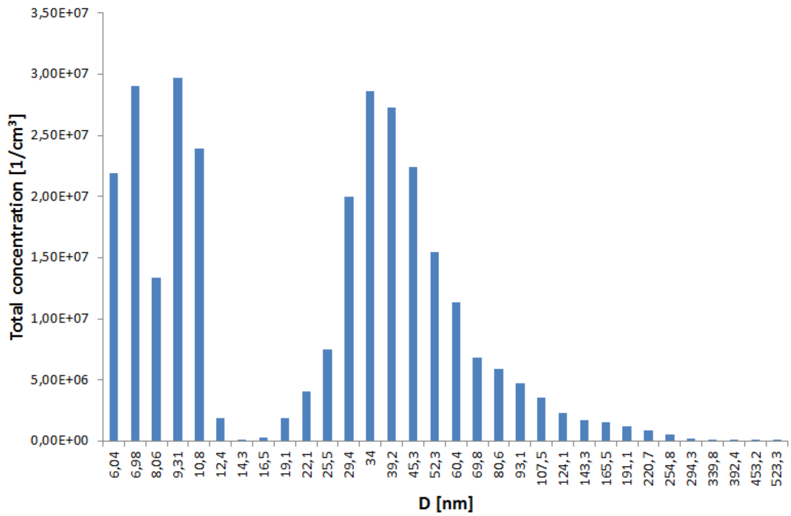

Fig. 8. Dimensional distribution of PN during dynamic drive

Range of dimensional distribution of particulate matters for dynamic drive is two times wider than economic one. Aggressive drive was conducted as a first one. It caused higher emission than the economic one because of cold engine run. In both cases there is a similarity in particulates size. There are mostly the small ones from the range from 6,04 to 10,8 nm and the average ones from 29,4 to 52,3 nm. The difference is in the order of magnitude which is significant.

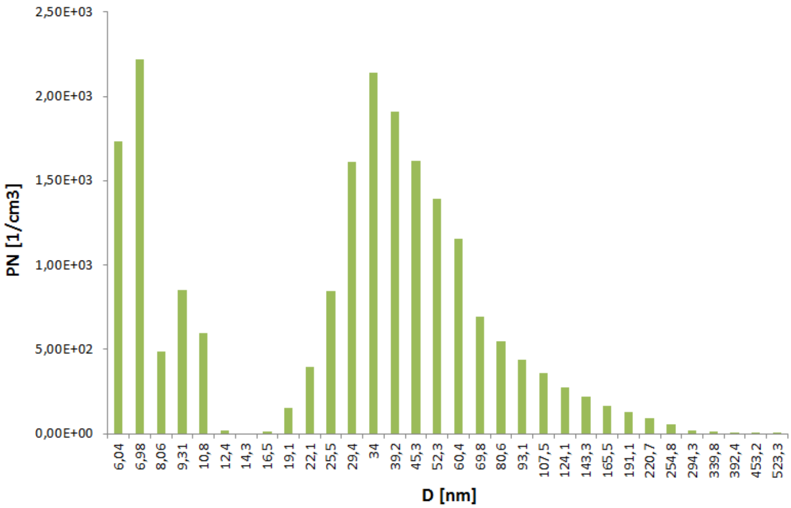

Fig. 9. Dimensional distribution of PN during economic drive

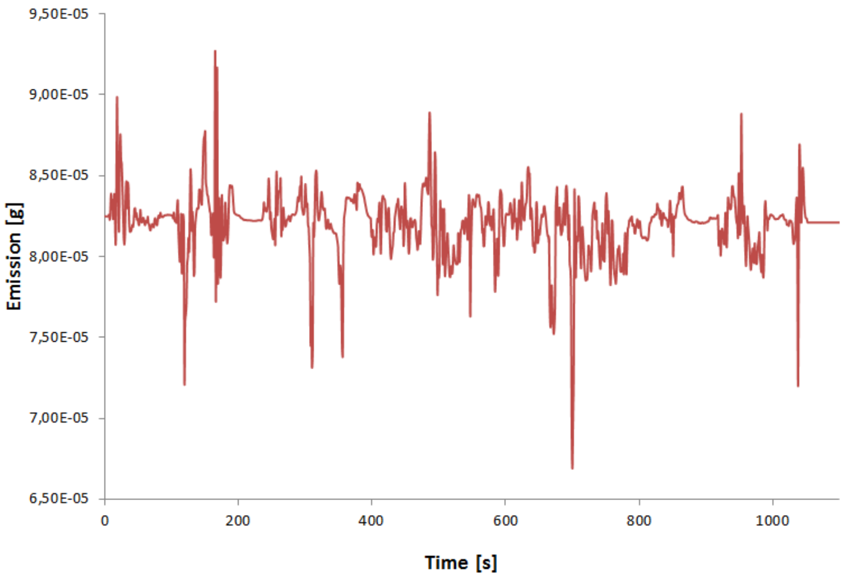

Fig. 10. Particulate matter emission per second obtained during dynamic drive

Emission of particulate matters per second is characterized by fuel dose and engine load which is directly combined with vehicle velocity. During dynamic drive vehicle speed was up to 70 km/h due to rapid acceleration while economic drive is more levelized. Rapid increasing and deacreasing is illustrated by dynamic drive chart.

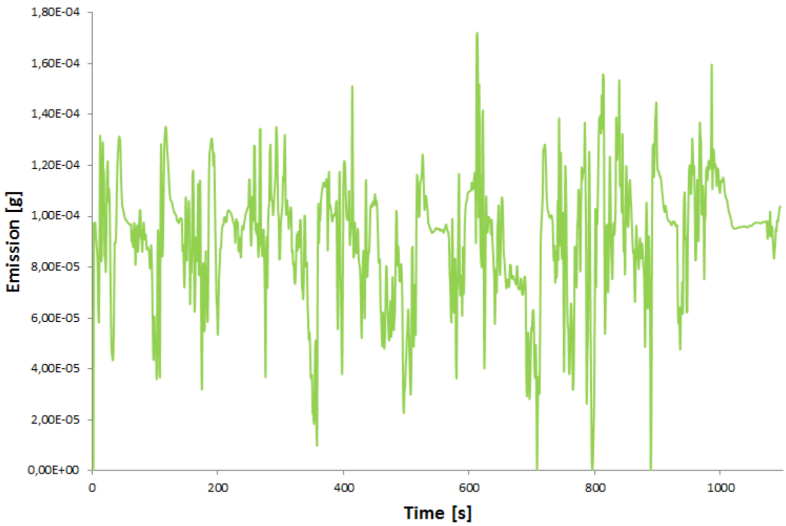

Fig. 11. Particulate matter emission per second obtained during economic drive

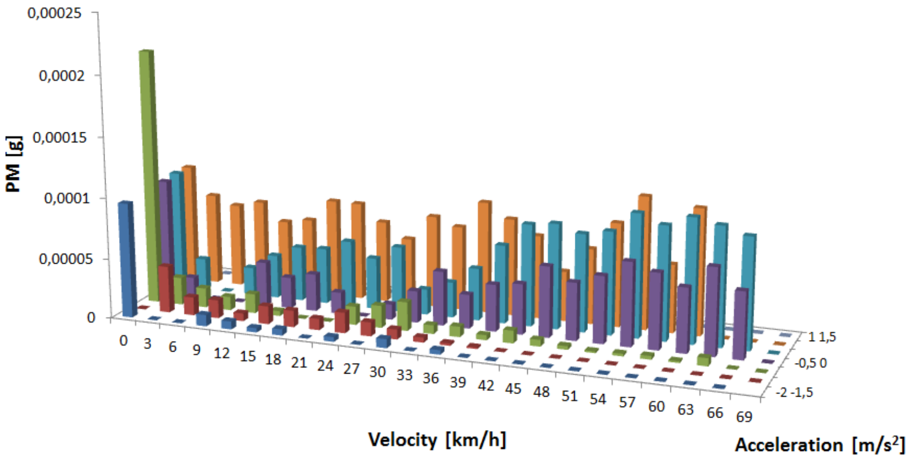

Fig. 12. Emission of PM in the range of vehicle speed and acceleration during dynamic drive

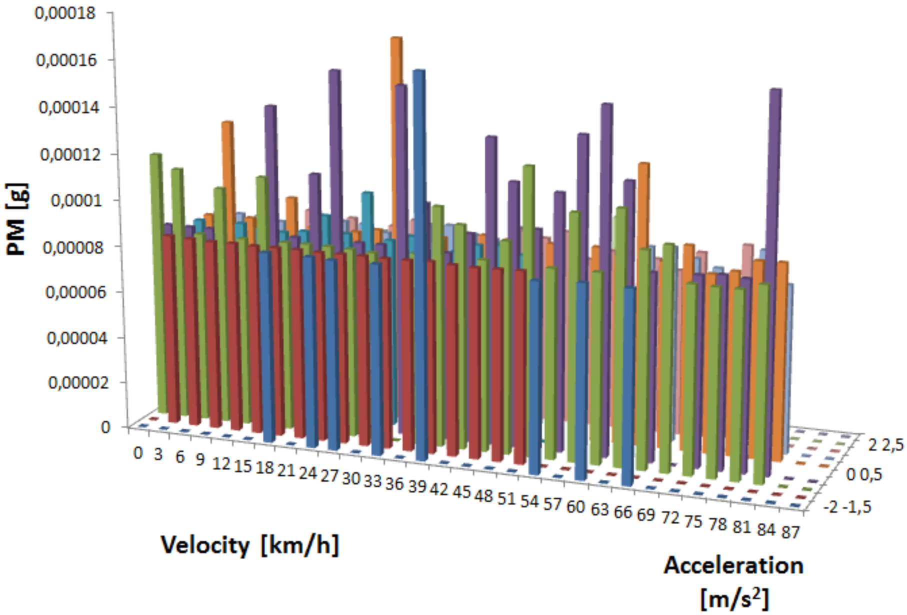

Fig. 13. Emission of PM in the range of vehicle speed and acceleration during economic drive

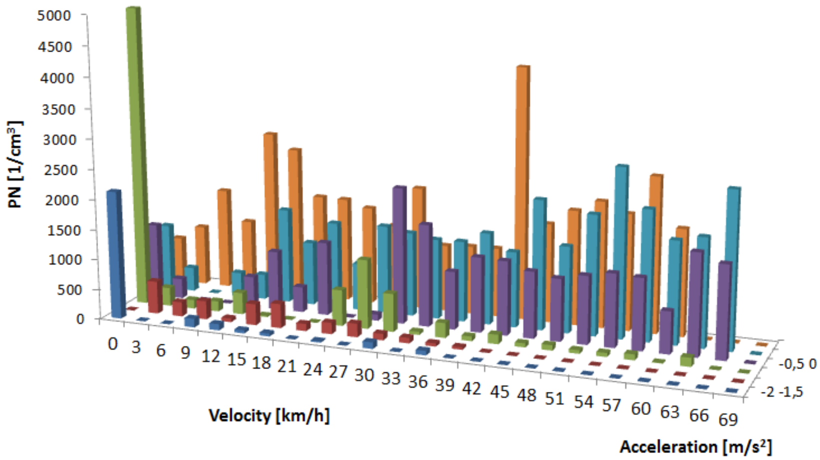

Fig. 14. Emission of PN in the range of vehicle speed and acceleration during economic drive

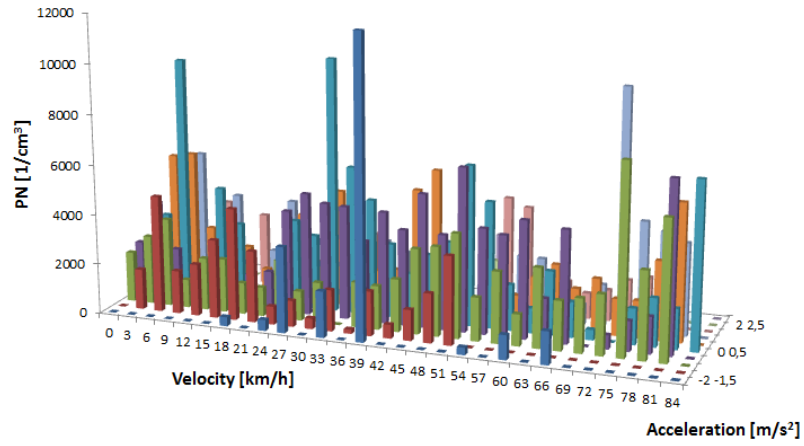

Fig. 15. Emission of PN in the range of vehicle speed and acceleration during economic drive

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

Data	Dynamic drive	Economic drive	Euro V limit
Fuel consumption [dm^3/100 km]	10,8	8,31	10,6
Emission of PM [g/km]	0,03055	0,3034	0,005
Emission of PN [1/km]	1.051×10^{11}	5.196×10^{10}	6.0×10^{11}

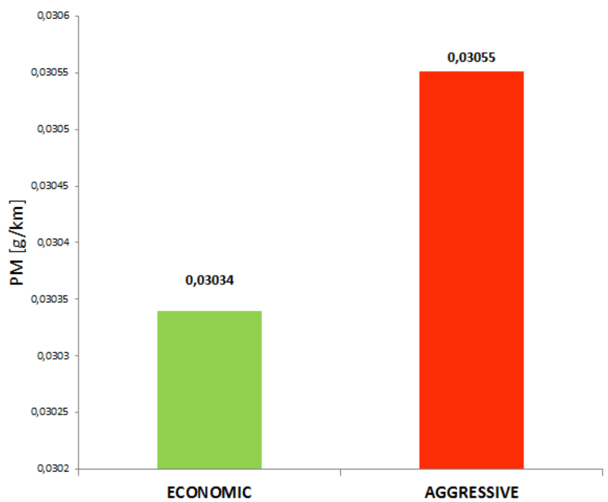

Fig. 16. Emission of PN in the range of vehicle speed and acceleration during economic drive

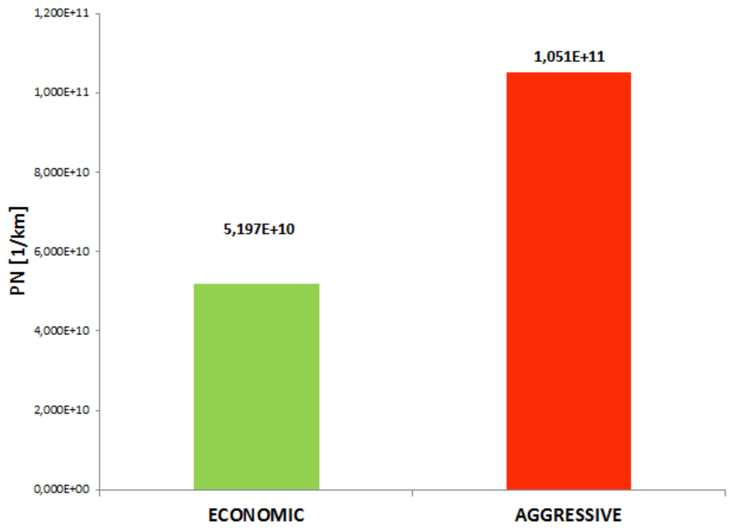

Fig. 17. Emission of PN in the range of vehicle speed and acceleration during economic drive

5. CONCLUSIONS

The Euro 5 limit has a significant impact on the emission reduction. To meet the current requirements vehicles are equipped with DPF which reduced particulate number emission. This issue is important because of harmful influence of small matters which are imposible to remove by human system. Real Driving Emission test procedure is the only way to determine authentic pollution caused by combustion engines. Tests results presented in this article shown that driving style has relevant impact on particulate matter emission. Dynamic driving style caused fuel consumption escalating and PM and PN emission.

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EMISJA MASOWA I LICZBOWA CZĄSTEK STAŁYCH POJAZDU SAMOCHODOWEGO TYPU PICKUP W RZECZYWISTYCH WARUNKACH EKSPLOATACJI

Streszczenie

W artykule przedstawiono wyniki emisji czastek stałych w zakresie masy i liczby z pojazdu typu pickup spełniającego normę emisji EURO 5. Badania przeprowadzono w centrum Poznania, na odcinkach drogi o różnych dopuszczalnych prędkościach poruszania się. Na potrzeby testu jeden przejazdów był ekonomiczny, a drugi agresywny. Pomiarów dokonano za pomocą nowoczesnej aparatury z grupy PEMS – analizatorów TSI 3090 oraz AVL MSS. Pozwoliło to na wyznaczenie rzeczywistego wpływu badanego pojazdu na środowisko. Do mierzonych składników należały: CO_2, HC, NO_x i CO.

Słowa kluczowe: emisja, styl jazdy, RDE, PEMS