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Exhaust Emissions Measured Under Real Traffic Conditions from Vehicles Fitted with Spark Ignition and Compression Ignition Engines

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Abstract

The tests performed under real traffic conditions provide invaluable information on the relations between the engine parameters, vehicle parameters and traffic conditions (traffic congestion) on one side and the exhaust emissions on the other. The paper presents the result of road tests obtained in an urban and extra-urban cycles for vehicles fitted with different engines, spark ignition engine and compression ignition engine. For the tests a portable emission analyzer SEMTECH DS. by SENSORS was used. This analyzer provides online measurement of the concentrations of exhaust emission components on a vehicle in motion under real traffic conditions. The tests were performed in city traffic. A comparative analysis has been presented of the obtained results for vehicles with individual powertrains.

Keywords: exhaust emissions, on-board measurement

1. Introduction

The need to reduce exhaust emission and fuel consumption by transport means has led to development of several concepts of powertrains in recent years. Engineers have pinned their hopes on hybrid powertrains and fuel cells, however, presently

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fuel cells seem impossible to be used on a large scale. It may be estimated that this solution will be in use in approximately 20-30 years. A solution, which is quite commonly used in vehicles now is a hybrid powertrain i.e. a combination of a combustion engine and an electric one. Presently, the majority of car manufacturers in the world offer such vehicles or conduct research on hybrid powertrains and in many cases, the research is considerably advanced. It can be expected that in a few years' time the production and sale of passenger cars equipped with hybrid powertrains will increase significantly. However, one should also note that intensive research is carried out on the improvement of combustion engines with spark ignition and compression ignition which will be probably used for many years to come as the main type of powertrains for passenger cars and other means of transport. A dynamic development of transportation, a quick growth in the number of vehicles in Europe led to changes in the traffic. The cities are getting more congested, driving parameters of vehicle are different (lower average speed, a larger share of the acceleration phase in the total time). In light of the above, tests in real driving cycles under real road conditions gain importance [1-6]. Such tests provide the opportunity to learn the impact of a variety of driving parameters and traffic conditions on the exhaust emissions.

2. Testing Methods

The tests were performed on two passenger cars with different powertrains. The first vehicle was equipped with spark ignition engine, the second was equipped with compression ignition engine. The basic data of the tested cars are given in Table 1 and the view of the car is presented in Figure 1.

Table 1

Characteristics of the vehicles used in tests

	Vehicle 1	Vehicle 2
Data of the power unit	SI engine fuelled with petrol and LPG, 3.3 dm^3, power – 130 kW	CI engine, 2.0 dm^3, power – 137 kW
Mileage	140 000 km	25 000 km
Model year	2000	2009
Exhaust aftertreatment system	TWC	Oxidation catalytic converter +DPF

Exhaust emissions tests (CO, HC, NO_x, PM, CO_2) were performed in real operating conditions of the vehicle in traffic in the city of Poznań. Tests were hot start. The vehicle route during the tests is shown in Figure 2. The length of the route was 12.71 km, it was diversified and included a typical urban section and an extra-urban section, where it was possible to drive at highway speed (with maximum speed of 120 km/h). The extra-urban section was 5.5 km long. As shown in Figure 2, the length of the vehicle route during the road test was similar to the length of the vehicle route in the NEDC test. The time of drive in road tests, approximately 1200 s, was similar to the time of drive in the NEDC test.

Fig. 1. The car with the measurement equipment during test

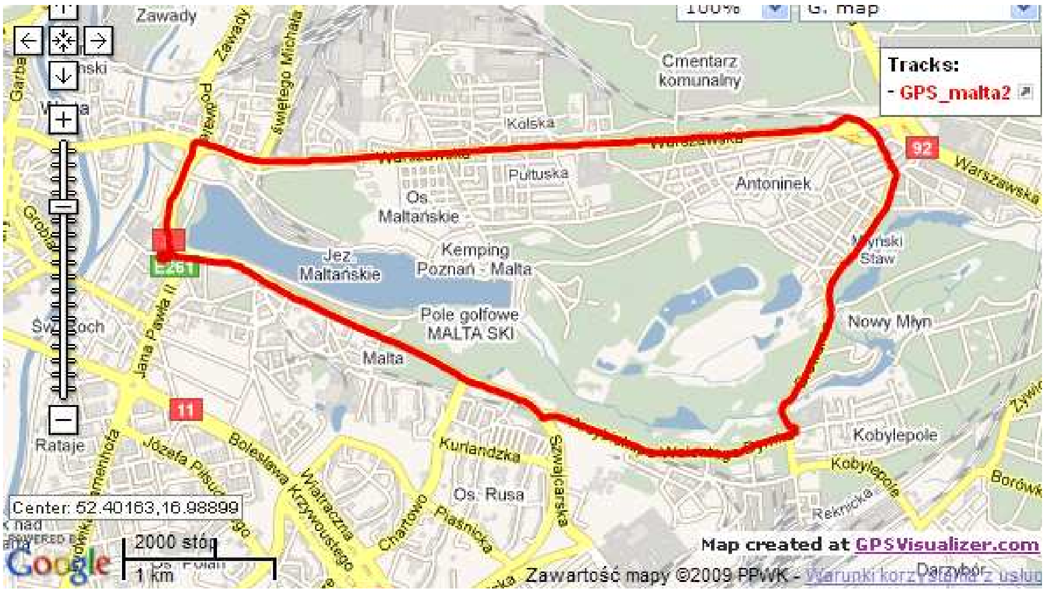

Fig. 2. The marked road used for the testing of exhaust emissions [created by www.GPSVisualizer.com]

3. Experimental Equipment

In order to measure the concentration of toxic compounds in exhaust gases a portable analyzer for exhaust emissions tests SEMTECH DS by SENSORS company was used [7]. The analyzer allowed for the measurement of harmful compounds concentration with the simultaneous measurement of the flow rate of the exhaust gases. Exhaust gases were introduced to the analyzer as a probe maintaining the temperature of 191°C then the particle matter was filtered out (compression ignition engine) and the exhaust probe was directed to the flame-ionizing detector (FID) where HC concentration was measured. Then the exhaust gases were cooled down to temperature of 4°C and the measurement of 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 sent directly from the vehicle diagnostic system to the central unit of the analyzer and make use of localization signal GPS (Table 2). In the tests measurements of emissions were used and also, for the purpose of comparison, signals from an on-board diagnostic system were recorded, e.g. engine speed, load, vehicle speed, temperature of inlet air. Some of these signals served to specify time density maps presenting participation of operating time of the vehicles in real operation conditions.

Table 2

Characteristics of a mobile exhaust analyzer SEMTECH DS

Parameter name	Measurement method	Accuracy
1. Emissions		
CO	NDIR, range 0–8%	±3%
HC	FID, range 0–10.000 ppm	±2%
NOx = (NO + NO2)	NDUV, range 0–2500 ppm	±3%
CO2	NDIR, range 0–20%	±3%
O2	Electrochemical, range 0–25%	±1%
2. Data storage capacity	Over 10 hours at 1 Hz data acquisition rate	
3. Vehicle interface capacity	SAE J1850 (PWM), SAE J1979 (VPW) ISO 14230 (KWP-2000) ISO 15765 (CAN), ISO 11898 (CAN) SAE J1587, SAE J1939 (CAN)	

4. The Test Results

Measurements of exhaust emission (CO, HC, NO_x and CO_2) as well as measurements of the flow rate of the exhaust gases were made with the use of a portable analyzer. Moreover, basic operating parameters of engines of the tested vehicles were recorded (e.g. engine speed, engine load). Figures 4 and 5 present most frequently used ranges of operation of the tested engines, i.e. ranges of the most frequently used engine speeds and engine loads. Figure 4 presents the share of operation of a

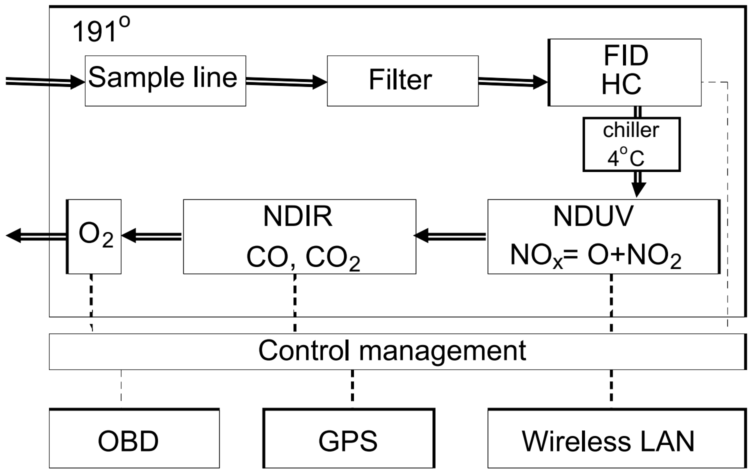

Fig. 3. A diagram of a mobile analyzer SEMTECH DS; exhaust gas flow channels (===) and electrical connections circled (– – –)

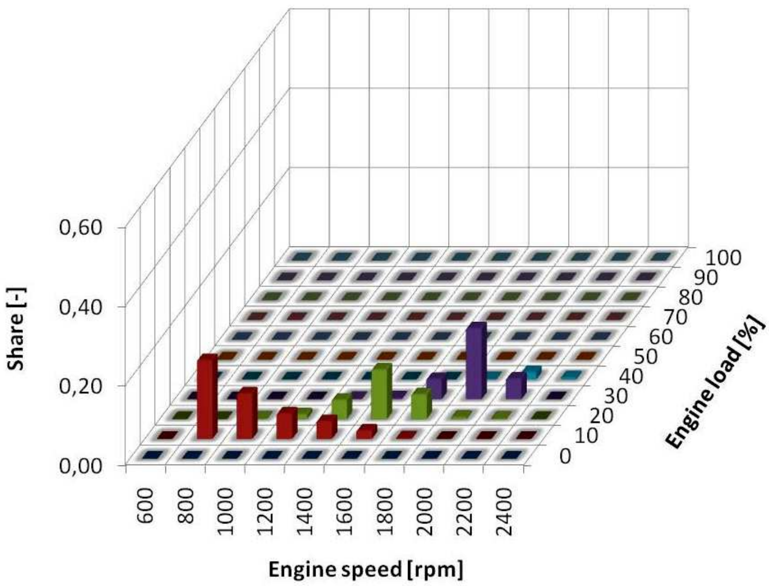

Fig. 4. Characteristics of the share of engine speeds and engine load during the test, spark ignition engine

spark ignition engine during the test and Figure 5 presents the share of operation for a compression ignition engine. In the case of a powertrain with a compression ignition engine, a broader range of the most frequently used engine speeds and loads is visible. In comparing the operation of powertrains equipped with a spark ignition and a compression ignition one may observe that during the test the spark ignition engine operated mainly within the range of low loads (up 40% of maximum load) in the entire range of engine speed, whereas the compression ignition engine operated in a narrower range of engine speed and mainly within the range of medium and low loads (0-70% of maximum load).

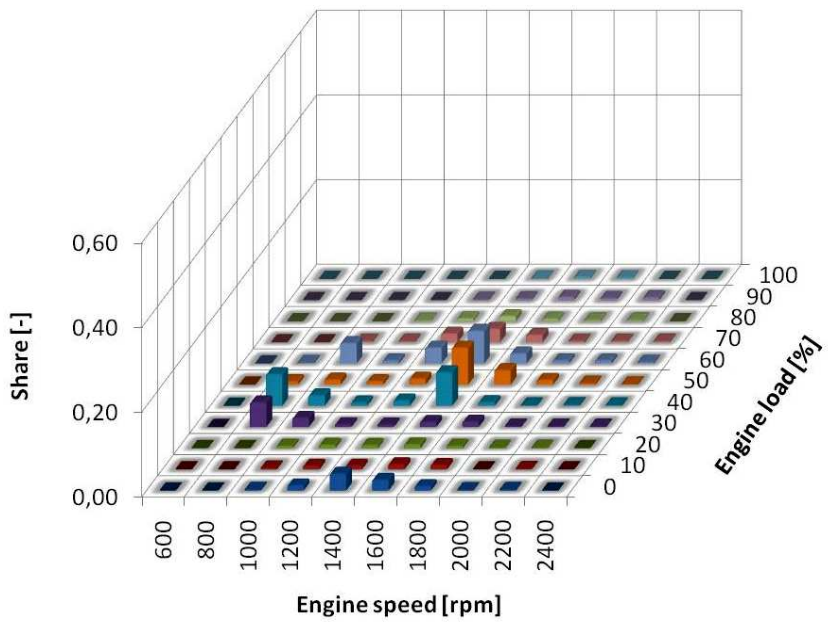

Fig. 5. Characteristics of the share of engine speeds and engine load during the test, compression ignition engine

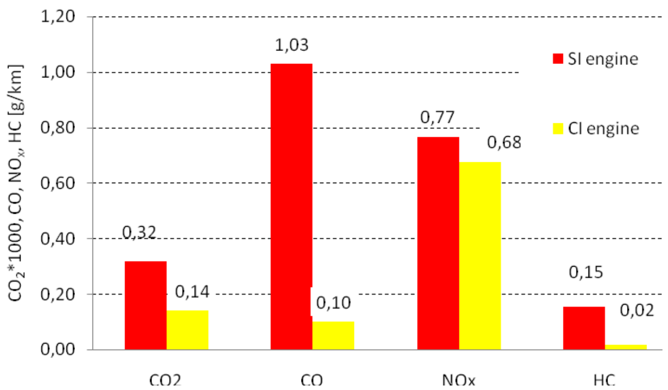

Fig. 6. Exhaust emission in vehicles with different engines during tests under real traffic conditions

Figure 6 presents results of exhaust emission tests for vehicles with different powertrains. The lower value of the CO_2 emissions/fuel consumption was observed for the vehicle with the compression ignition engine, the emission of CO_2 was lower by approximately 50% as compared to the vehicle equipped with a spark ignition engine. In the case of emissions of CO and HC, the higher values were observed for the vehicle with a spark ignition engine. The emissions are considerably higher that for the vehicle with a compression ignition engine.

5. Conclusions

The tests showed differences between exhaust emissions from vehicles with different powertrains under real traffic conditions. As far as the problem of ecology is concerned, most favorable results were obtained for the vehicle with a compression ignition engine, which is characterized by considerably lower exhaust emission as compared to powertrains using spark ignition engines. Presently one may assume that owing to favorable ecological properties, vehicle with compression ignition engine will probably be most frequently used on the roads. Such vehicles should mainly be used in cities, which are characterized by high intensity of traffic. It should be noted that this article presents only selected test results which are a part of a more extensive research project relating to measurement of exhaust emission under real traffic conditions. Further interpretation of the test results is planned in next publications issued upon completion of the project. In authors opinion the test should be completed with PM measurement, it will be next step in research project.

References

1. De Vlieger I.: On-board emission and fuel consumption measurement campaign on petrol-driven passenger cars. Atmospheric Environment, vol. 31.22 1997.
2. Gao Y., Checkel M.D.: Emission Factors Analysis for Multiple Vehicles Using an On-Board, In-Use Emissions Measurement System. SAE Technical Paper Series 2007-01-1327.
3. Merkisz J., Fuć P., Lijewski P.: The Comparison of the Emissions from Light Duty Vehicle in On-road and NEDC Tests, SAE Paper 2010-01-1298.
4. Nelson A.K., Groblicki P.J.: Real world emissions from a modern production vehicle driven in Los Angeles. Journal of Air Waste and Management Association, vol. 43, 1993.
5. Shahinian V.D.: SENSOR tech-ct Update Application Soft-ware for SEMTECH Mobile Emission Analyzers. Sensors 4th Annual SUN (SEMTECH User Network) Conference, 22.10.2007.

ABBREVIATIONS

CLD – Chemiluminescent Detector
DPF – Diesel Particulate Filter
FID – Flame Ionization Detector (HFID – Heated FID)
FTP75 – Federal Test Procedure
GPS – Global Position System
LAN – Local Area Network

LPG – Liquefied Petroleum Gas
NEDC – New European Drive Cycle
NDIR – Non Dispersive Infra Read
NDUV – Non-Dispersive Ultra-Violet
OBD – On Board Diagnostic
TWC – Three Way Catalyst