

The Exhaust Emission from Light Duty Vehicles in Road Test in Urban Traffic

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ABSTRACT

The investigations into the emissions from light-duty vehicles are carried out on a chassis dynamometer in the NEDC test in Europe and FTP75 test in the US. Such tests do not entirely reflect the real road conditions. It should be noted that the changes in the methodology of emissions testing should go in the direction where they get closer to the actual road conditions. The paper presents the road test results obtained in an urban congested areas. The analysis of the road tests results (exhaust emissions and fuel consumption) was carried out considering the road conditions (vehicle speed and acceleration). The obtained data were used to specify the dependence characteristics for the influence of the dynamic engine properties on the exhaust emissions. For these measurements a portable SEMTECH DS analyzer by SENSORS, Particle Counter by AVL and Particle Seizer EEPS by TSI has been used. The device is an analyzer enabling an on-line measurement of the concentration of toxic compounds in a real driving cycle under real road conditions.

INTRODUCTION

The advancement of road transportation as well as the necessity to protect natural environment require constant efforts to improve combustion engines and the measurement methodology of their emissions. The advancement in the combustion engines technology seen in recent years forces an introduction of new measurement methods i.g. PM measurement is not limited to the determination of their mass. Currently the engineers want to know their physical and chemical properties in order to minimize their negative impact on the man and his environment. Recently the scientists have begun a discussion on the conditions of measurement of the exhaust emissions. They keep asking themselves whether the conditions of the currently applicable

homologation test fully reflect the actual operating conditions of LDV vehicles. The applicable European test with tiny subsequent modification has been used in the tests for a long time. 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 [2,3,4,5,6,7, 9, 10]. Such tests provide the opportunity to learn the impact of a variety of driving parameters and traffic conditions on the exhaust emissions.

TESTING METHODS

Exhaust emissions test (CO, HC, NO_x, PM, CO₂) were performed in real operating conditions of the vehicle in traffic in the city of Poznań (approx. 700 thousand inhabitants). The tests were performed by noon, i.e. not during the peak traffic. The tests used a vehicle with CI engine with the capacity of 2 dm³. The vehicle route during the test was shown in [Fig. 1](#). The length of the route was 12.71 km, it was diversified and included a typical urban section and extra-urban section, where it was possible to drive with highway speed (with maximum speed of 120 km/h). The extra-urban section was 5.5 km long. The similarity of the length of the vehicle route during the road test to the length of the vehicle route in NEDC test is visible. The time of drive in road tests, i.e. 1254 s, is similar to the time of drive in NEDC test. The average speed of drive in road tests was 34.9 km/h, whereas in NEDC test it was 40.1 km/h.

See [Figure 1](#) after last section of paper

EXPERIMENTAL EQUIPMENT

The object of the tests was Skoda Octavia fitted with a CI engine; automatic transmission, 4 cylinder, engine volume 2.0 liters, diesel particulate filter (DPF), mileage - 25000 km, OBD II protocol ISO-9141-2 (Fig. 2). In order to measure concentration of toxic compounds a mobile analyzer for exhaust emissions tests SEMTECH DS by SENSORS company was used [8]. The analyzer allowed for the measurement of harmful compounds concentration with the simultaneous measurement of exhaust flow. Exhaust gas introduced to the analyzer by means of a probe maintaining temperature of 191°C was then filtered out of particle matter (CI engine) and directed to the flame-ionizing detector (FID) where HC concentration was measured. Then fumes were cooled down to temperature of 4°C and the measurement of concentration of NO_x (NDUV analyzer), CO, CO₂ (NDIR analyzer) and O₂ 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 1). In the tests measurements of emissions were used and also, for the purpose of comparison, signals from an on-board diagnostic system were registered, 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 a vehicle in real operating conditions. GPS localization signal was used in further visualization of the obtained data (Fig. 3).

See Figure 2 after last section of paper

See Table 1 after last section of paper

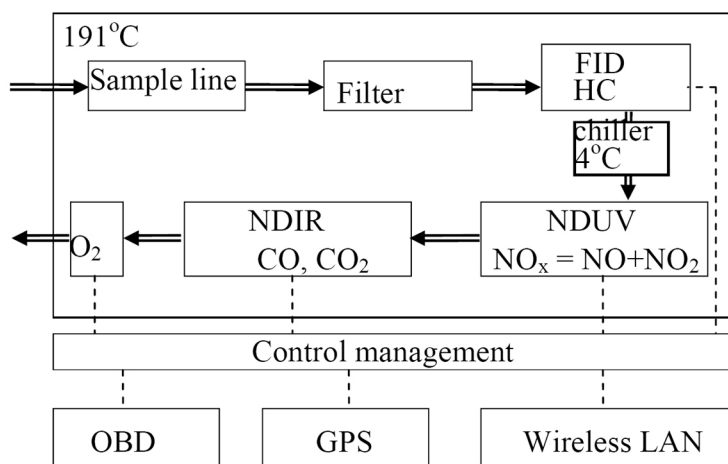


Fig. 3. A diagram of a mobile analyzer SEMTECH DS; exhaust gas flow channels (====) and electrical connections circled (---)

In order to measure number of PM analyzer AVL Particle Counter was used (Fig. 4, Table 2). AVL Particle Counter is a compact device for reliably and accurately measuring particle

number concentrations of diluted exhaust gas. The AVL Particle Counter measures the number concentration of all non-volatile particles in the exhaust gas. The APC consists of a conditioning component (volatile particle remover VPR) and the actual particle number counter (PNC). The VPR consists of the first dilution step (particle number diluter 1 PND1), an evaporation tube (evaporation tube ET), and a secondary dilution (particle number diluter 2 PND2). The PNC is an n-butanol based condensation particle counter with a cut-off diameter of 23 nm.

See Figure 4 after last section of paper

See Table 2 after last section of paper

In order to measure size of PM the Engine Exhaust Particle Seizer (EEPS) was used. The EEPS spectrometer measures the size distribution of engine-exhaust particle emissions in the range from 5.6 to 560 nm with the fastest time resolution available, 10-Hz data collection captures transient events in real time. Users can visualize and study the dynamic behavior of particle emissions that occur during transient test cycles, during the first few seconds of a cold start, or during regeneration of a particle trap or diesel particulate filter (DPF). The EEPS spectrometer displays measurements in 32 channels total (16 channels per decade). It operates at ambient pressure to prevent evaporation of volatile and semi-volatile particles, and it requires no consumables. A microprocessor measures temperature and barometric pressure automatically to convert to volumetric flow. The instrument includes features for remote operation and includes software that is unmatched in the industry.

TEST RESULTS AND ANALYSIS

Measurements of the exhaust emissions such as CO, HC, NO_x, CO₂ and PM were performed with the use of the above-mentioned analyzers. In the case of PM, measurements of the number of PM and their diameter sizes were performed. Basic operating parameters were recorded (e.g. engine speed, load) of the engine and vehicle cruise (speed, acceleration) were recorded. Detailed information concerning the relation between the emissions and vehicle drive parameters as well as engine operation may be concluded on the basis of the relations presented in Fig. 5,6,7,8. The figures are also limited to the presentation of changes in emissions depending only on the engine load and vehicle drive speed. The concentration of CO₂ (fuel consumption) increases with the increase of vehicle speed and is maintained at a high level during high speed drive. The concentration of HC (Fig. 6) decreases considerably upon driving on the high speed road section, which probably results from an increase of the temperature of oxidizing catalytic converter and, consequently, increase of its efficiency. The concentration of CO increases several times during the vehicle acceleration and the increase of the level of CO is also visible for high

speed drive (Fig. 7). The concentration of NO_x increases considerably during the vehicle acceleration and decreases for constant speed drive.

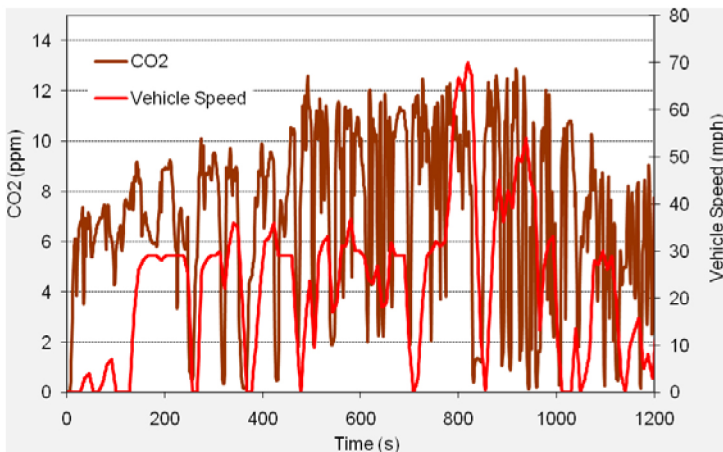


Fig. 5. Concentration of CO_2 and vehicle speed during road tests

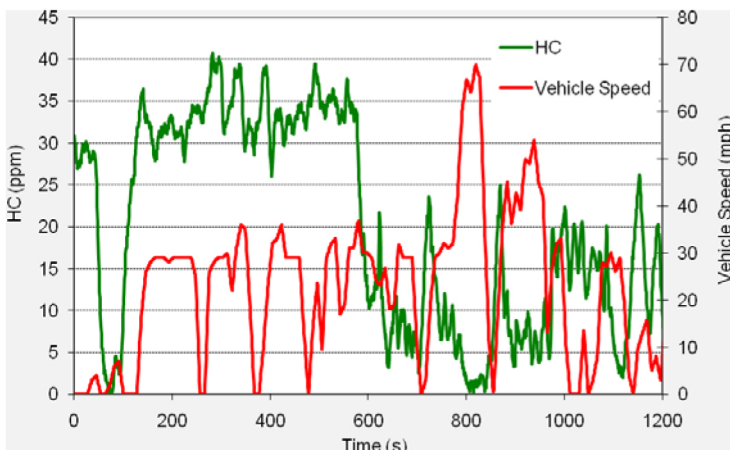


Fig. 6. Concentration of HC and vehicle speed during road tests

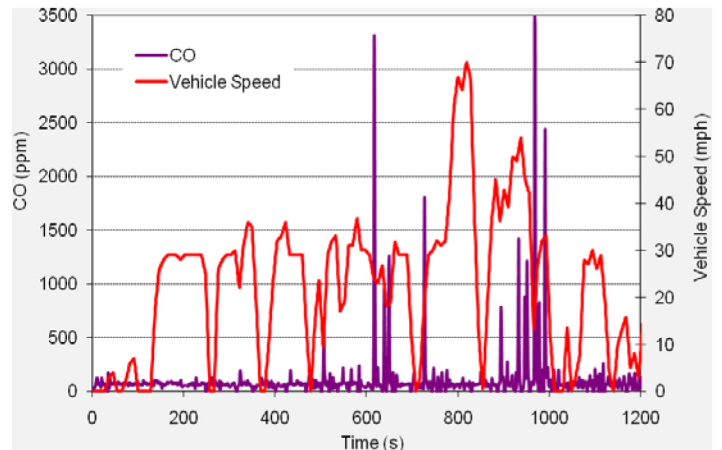


Fig. 7. Concentration of CO and vehicle speed during road tests

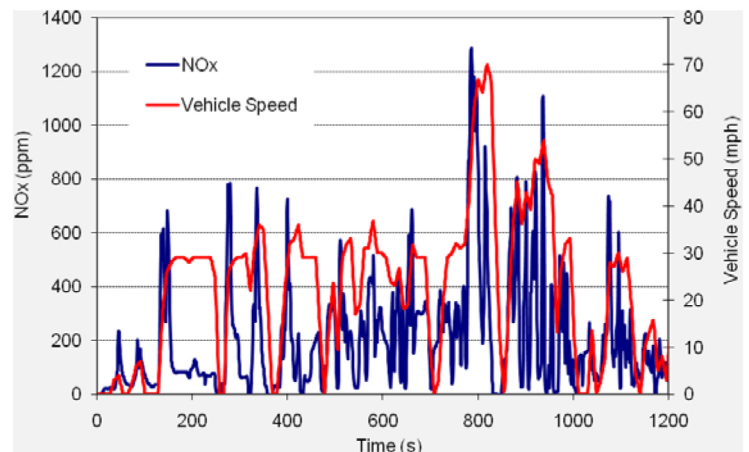


Fig. 8. Concentration of NO_x and vehicle speed during road tests

Fig. 9 presents changes in the quantity of the emitted PM and vehicle speed during road tests. Similarly to gaseous compounds, the relation between the count of the solid compounds, acceleration and vehicle speed is visible. During acceleration sudden increases of PM count are visible, whereas while driving with constant speed, the count decreases. In comparing PM count in relation to the vehicle speed, PM count decreases with the speed increase. The tested vehicle was fitted with a diesel particulate filter and the filter was not regenerated during the test.

See Figure 9 after last section of paper

The changes in PM count depending on its volume during road tests were shown in Fig. 10, whereas the spectre of PM concentrations depending on their diameters during the entire road test, was shown in Fig. 11. It is visible that the engine emitted PM mostly for two diameter ranges, namely 8-12 and 27-65 nm. The first range is characterized by higher