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Measurements of particle mass, number and size distribution from light-duty vehicles in conditions of variable terrain topography

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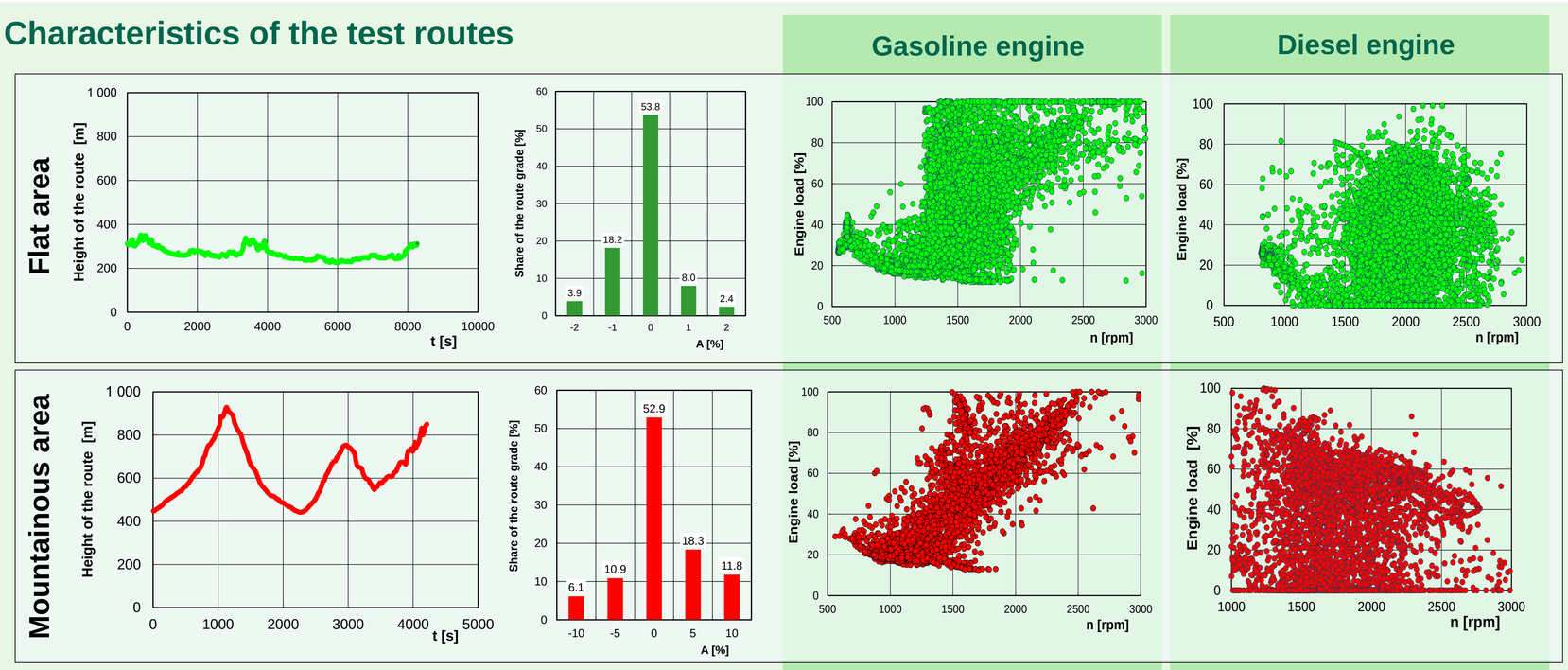
Abstract

This article presents the results of tests conducted in real traffic conditions in a mountainous area, taking into account the natural topography characteristics. The tested vehicle was of SUV type (Sport Utility Vehicle) with gasoline and Diesel engine, complying with emission standard Euro 5. Using the portable system for measurement of harmful substances, measurements of pollution emissions were conducted. The results obtained confirmed the substantial changes in the emission of harmful components of exhaust fumes with the change of the road grade. In all considered cases it was confirmed that with the increasing route grade the road emissions of all harmful components of exhaust fumes increase, however this increase varies for different pollutants. The most sensitive for spark ignition engines is emission of particulate matter, which is associated mainly with the compression ignition engines.

Characteristics of the test routes



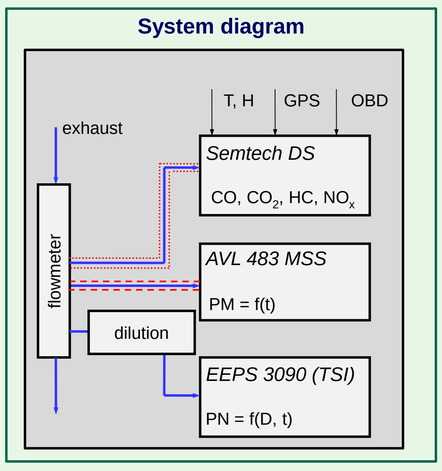
Methodology

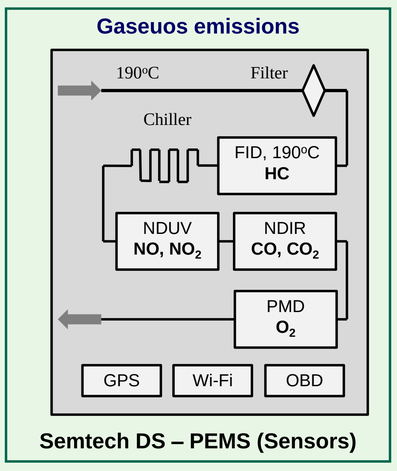
The tested vehicle was of SUV type with automatic gearbox, equipped with gasoline engines (engine displacement of 3.6 dm^3 and the power of 206 kW) and Diesel engine (engine displacement of 2.0 dm^3 and the power of 125 kW). The vehicle used for tests complied with the Euro 5 emission standard.

Test parameters	Total time [s]	Maximum speed [km/h]	Average speed [km/h]	The route length [km]	The share of vehicle operating conditions		
					V = 0 [%]	V = const [%]	a > 0 [%]
Flat route	8224	110	57.5	131.3	32.6	23.8	32.9
Mountainous route	4132	73	39.9	45.8	35.5	24.2	40.1

The selected test routes included different natural topography conditions so as to estimate the influence of the road surface inclination on the values of emissions of pollution in exhaust gases. Two routes varying in terms of average and local road grade were chosen in order to establish the change in pollution emissions for small and large values of the road grade. Grade (slope) of the road (or route incline) in the road transport is defined as a difference in the height between two points of the road related to the distance between these points.

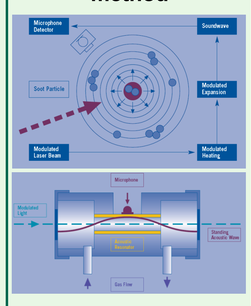
PEMS System





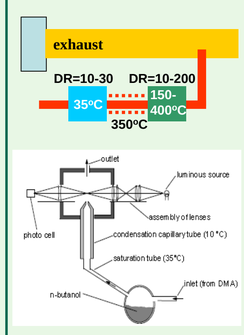
Semtech DS – PEMS (Sensors)

Particulate Mass (PM)
photoacustic method



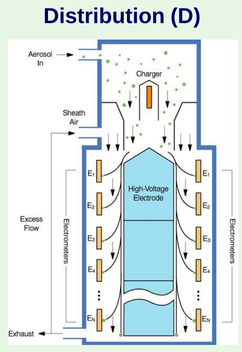
micro soot sensor 483 (AVL)

Particle Number (PN)



particle counter (AVL) according to PMP

Particle Size Distribution (D)



particle sizer EEPS (TSI)

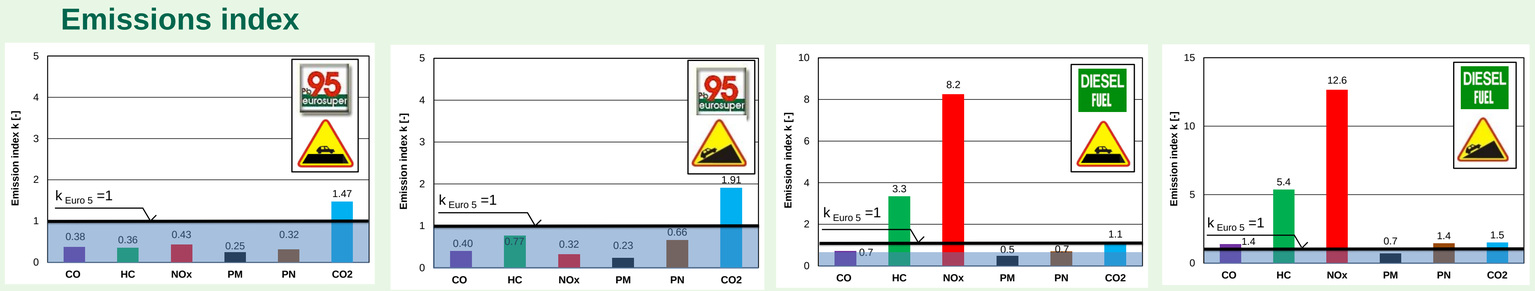
Emissions index

$$k_j = \frac{\sum_0^t E_{real,j}}{E_{normative,j}}$$

j – exhaust component, for which the emission indicator was determined
$E_{real,j}$ – on-road emission under real traffic from the start of the test [g/km]
$E_{normative,j}$ – normative on-road emission according to Euro 5 [g/km]

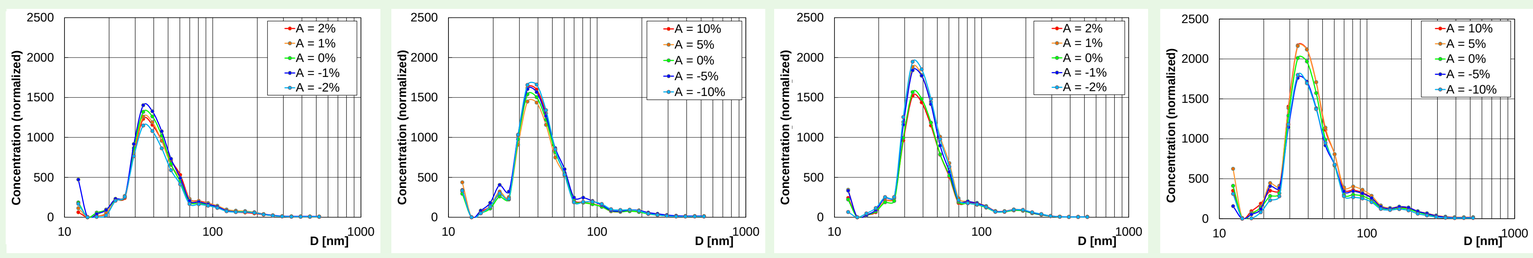
Results

Emissions index



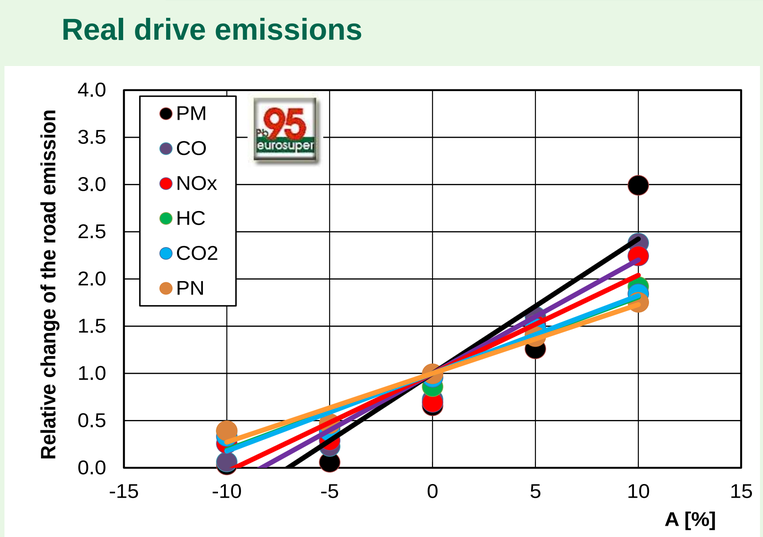
Values of emission factors for vehicles fitted with gasoline and Diesel engine in Euro 5 emission class obtained in emission tests in flat and mountainous terrain

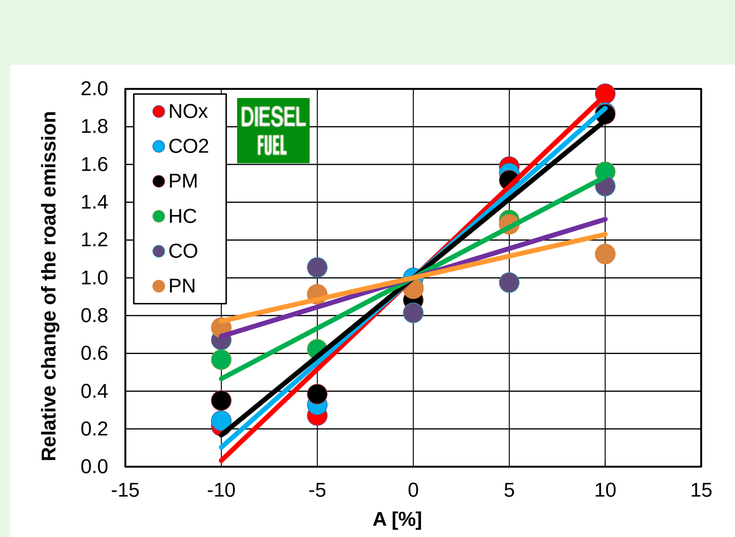
Size distribution



Size distribution change of particle emission with the change of the route grade for vehicles fitted with gasoline and Diesel engine

Real drive emissions





Relative change of the road emission of pollution with the change of the route grade for vehicles fitted with gasoline and Diesel engine

Summary

Comparison of the relative changes of road emissions depending on the road grade shows that for small changes of the road grade the most sensitive seems to be road emission of carbon monoxide. Taking into account bigger grades it turns out that the most sensitive for gasoline engines is emission of particulate matter, which is specific, first of all, to all diesel engines. Studies carried out indicate that the increase of the road grade to 10% caused on average twofold increase in the emission of harmful components of exhaust gases. The obtained results confirmed significant effect of the diversified topography on the emission tests. This influence turned out to be significant enough to justify the need of including in the type-approval tests the coefficients correcting the road emission of pollutions in relation to the site topography.