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PM EMISSION FROM COMBAT VEHICLE ENGINES DURING START AND WARM-UP

Abstract

The paper presents the results of the investigations of an armored modular vehicle 8x8 Rosomak fitted with a diesel engine during start and warm-up. The analysis of the PM emission was performed based on the measurement of the size of the particulate matter (analyzer 3090 EEPS – Engine Exhaust Particle Sizer™ Spectrometer – by TSI Incorporated) and counting of the particles (analyzer Particle Counter by AVL). The measurements of PM have also been carried out under static conditions, during startup and at constant engine speed without engine load.

Introduction

The tests on the engine emissions of particulate matter and their size distribution are a topic of many scientific publications [3-4, 8-9]. The use of portable exhaust analyzers resulted in a higher interest in the measurement of real traffic conditions of passenger vehicles [6-7]. When it comes to special applications of vehicles (in this case combat vehicles) there are no investigations in this matter. This paper thus, allows the evaluation of the fuel consumption and the determination of the PM emission during start and warm-up.

Research methodology

The object of the investigations was an armored vehicle whose basic technical data and its general overview have been shown in Tab. 1.

For the measurement of the particulate matter a portable Particle Counter analyzer by AVL was used whose basic technical data have been presented in Tab. 2.

Tab. 1. Technical data of the engine and vehicle

Parameter	Value	Photo
Engine	Scania DI1249A03P	
Number of cylinders	6/inline	
Rated power	294 kW @ 2100 rpm	
Maximum torque	1688 N·m @ 1500 rpm	
Maximum power – *overboost*	360 kW @ 2100 rpm	
Maximum torque – *overboost*	1974 N·m @ 1500 rpm	
Vehicle mass	22,000 kg	

Tab. 2. Technical data of AVL Particle Counter [10]

Parameter	Value	Photo
Measuring range	0÷10,000 cm^{-3}	
PNC (t_{90}) rise time	≤ 5 s	
Sample flow rate	1÷5 dm^3/min; adjustable	
Operating temperature	5÷45^{o}C	
Exhaust temperature (inlet)	< 200^{o}C	

Particulate matter emission from the combat vehicle

Research methodology

The characteristics of the gaseous and PM emission was performed taking the gaseous emission and PM number and their size distribution into account. The measurement of PM aimed at determining of the PM number released at a given point of engine work. The measurements (gaseous and PM emission) were performed with no load on a warmed up engine and steady engine speeds – 1000, 1500 and 2000 rpm. This resulted in graphs of ongoing gaseous and PM number measurements and average values obtained from the measurements with admissible errors overlain (marked as a standard deviation).

The PM size distribution was determined for individual points of engine work. The measurements were performed with no load on a warmed up engine and steady engine speeds – 1000, 1500 and 2000 rpm. The results have been presented as spectrum characteristics of the PM size distribution and the averaged values (during the measurement) of the individual distributions of the PM size (their area, volume and mass). The PM mass was calculated according to the relation that the density of the PM is independent of its characteristic diameter (aerodynamic) and amounts to 1 g/cm^3.

PM emission during engine start and variable engine speeds

From these investigations it results that the dominant number of PM falls in the range of 20 nm (Fig. 1a). The PM concentrations are the smallest during the engine start (which results from the exhaust gas flow rate) but almost steady for variable engine speeds (Fig. 1b).

Taking the distributions of PM size into account we should note that changes in the engine operating conditions (from engine start to higher engine speeds) do not result in a change of the PM size distribution. The highest number of PM falls within the size range of approximately 10 nm and amounts to 14,000 cm^{-3}. The influence of the changes in engine speed is noticeable only at n = 2000 rpm: the PM number in the range of 50-100 nm becomes significant (Fig. 2a). The influence of the engine operating conditions on the distribution according to their areas is rather classic i.e. the area grows with the diameter reaching its maximum for PM above 500 nm. Yet, we need to note that as the engine speed grows the PM area (of diameter of 100 nm) begins to grow too (Fig. 2b). Such a high dependence has not been recorded in this size range. The difference between the PM size distribution during engine start and engine speed n = 1000 rpm has not been recorded. In all other cases the growth of the engine speed by 50% (e.g. from 1000 to 1500 rpm) causes the PM area to grow by approximately 160% at a steady diameter in the range of 100 nm. At larger PM diameters the changes do not occur. Much smaller changes occur in the PM volumetric and mass distributions in various engine operating conditions (Fig. 2c-d). Noticeable changes (several per cent) pertain only to PM diameters of 100 nm. In the other ranges no changes in the distributions were recorded at variable engine operating conditions of the armored combat vehicle (Rosomak).

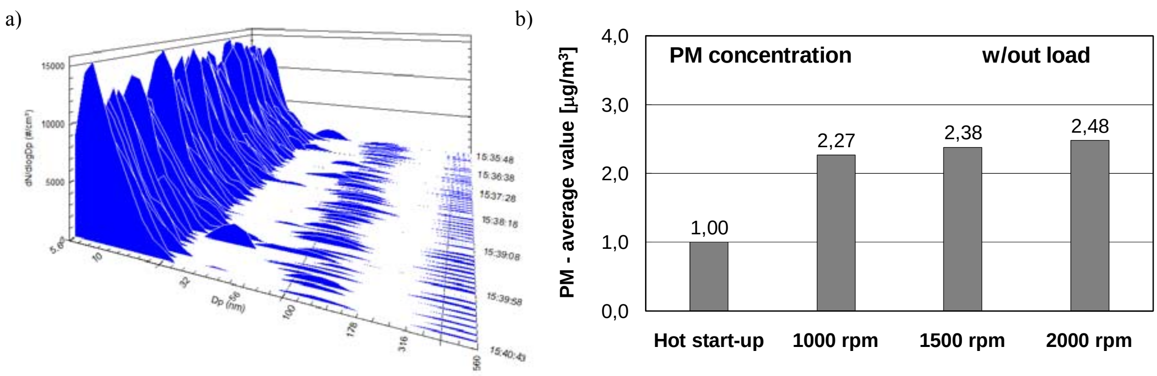

Fig. 1. PM emission: a) PM size distribution during engine start, b) average densities of PM in various measuring points

A growth in the exhaust flow rate at higher engine speeds causes a growth in the mass PM emission (Fig. 3a). The PN number grows almost proportionally to the mass PM emission (Fig. 3b).

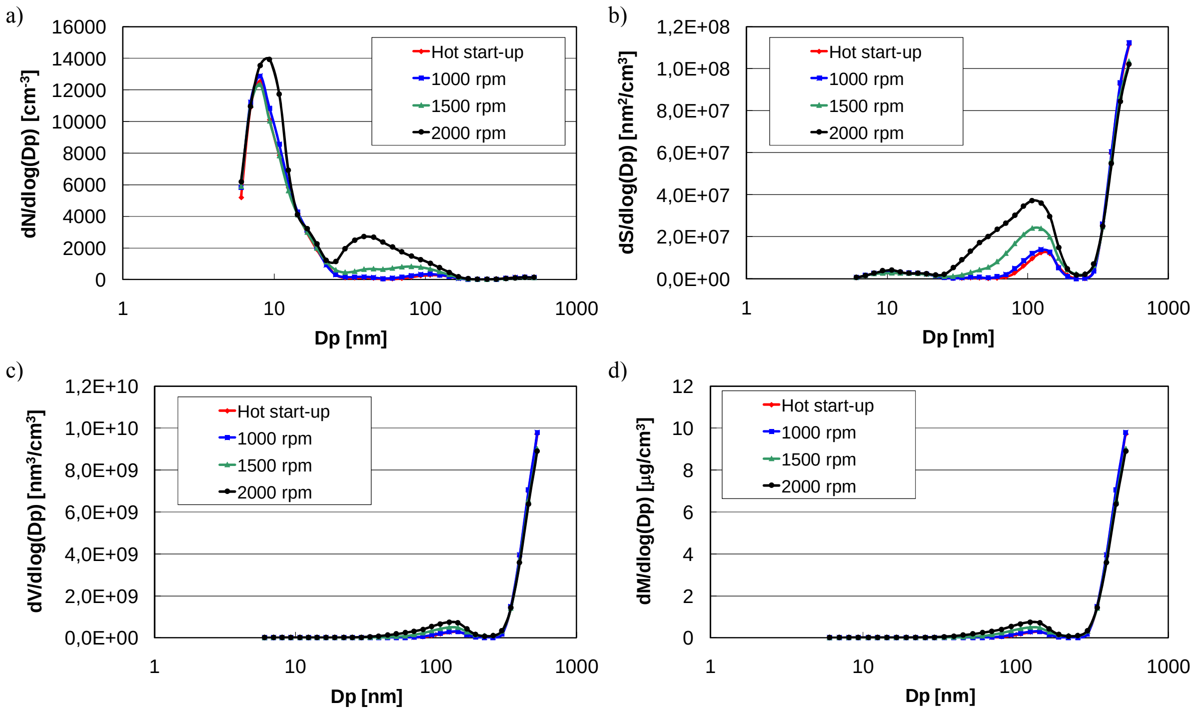

Fig. 2. Distributions of PM size: a) number vs. diameter, b) surface vs. diameter, c) volume vs. diameter, d) mass vs. diameter

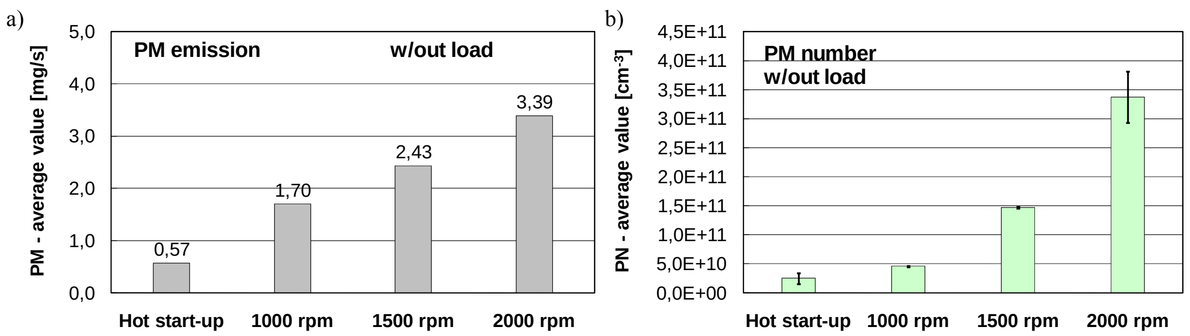

Fig. 3. Average values of PM: a) mass PM emissions in different measuring points, b) values of PN number

Conclusions

A change in the engine speed at small loads significantly influences the concentrations of the exhaust toxic compounds but it does not cause a change in the concentration of the PM (the emission of PM changes though).

The analysis of the PM number in the aspect of changing engine speeds at small loads indicates an occurrence of a maximum PM number of the size of 10 nm for each investigated engine speed.

The characteristics of the PM size distribution indicates an existence of a maximum PM number of a diameter of 100 nm, yet the maximum areas, volume and mass pertain to PM of a diameter of over 500 nm.

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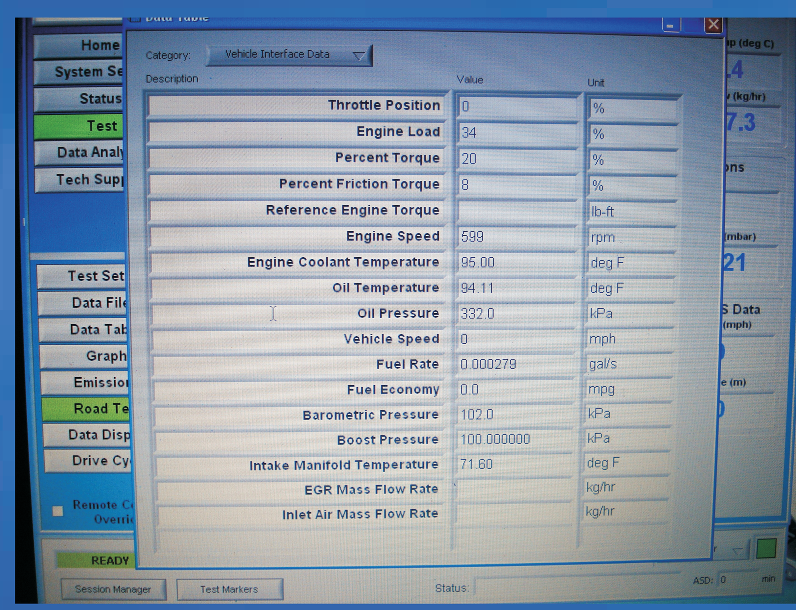
The paper presents the results of the investigations of an armored modular vehicle 8x8 Rosomak fitted with a diesel engine during start and warm-up. The measurements of PM have also been carried out under static conditions, during startup and at constant engine speed without engine load. For the measurement of the engine operating conditions a diagnostic vehicle system was used.

Metodology

Engine	Scania DI1249A03P
Number of cylinder	6/in-line
Rated power	294 kW@2100 rpm
Maximum torque	1688 N·m@1500 rpm
Maximum power – *oveboost*	360 kW@2100 rpm
Maximum torque – *overboost*	1974 N·m@1500 rpm
Vehicle mass	22,000 kg

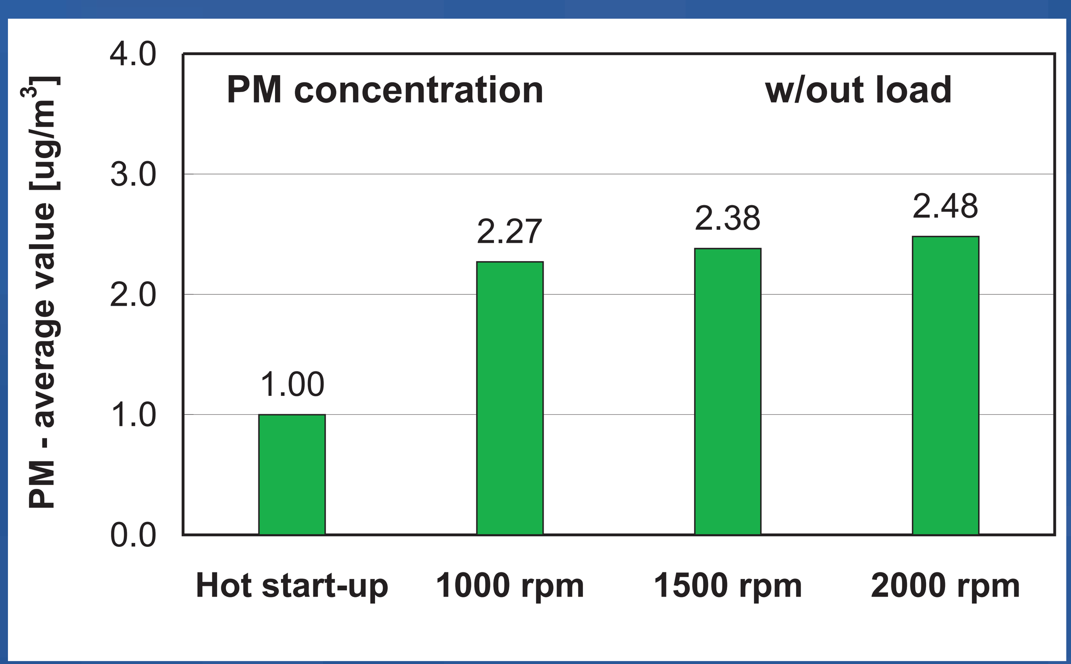
Technical data of the engine

The measurement of the engine operating conditions

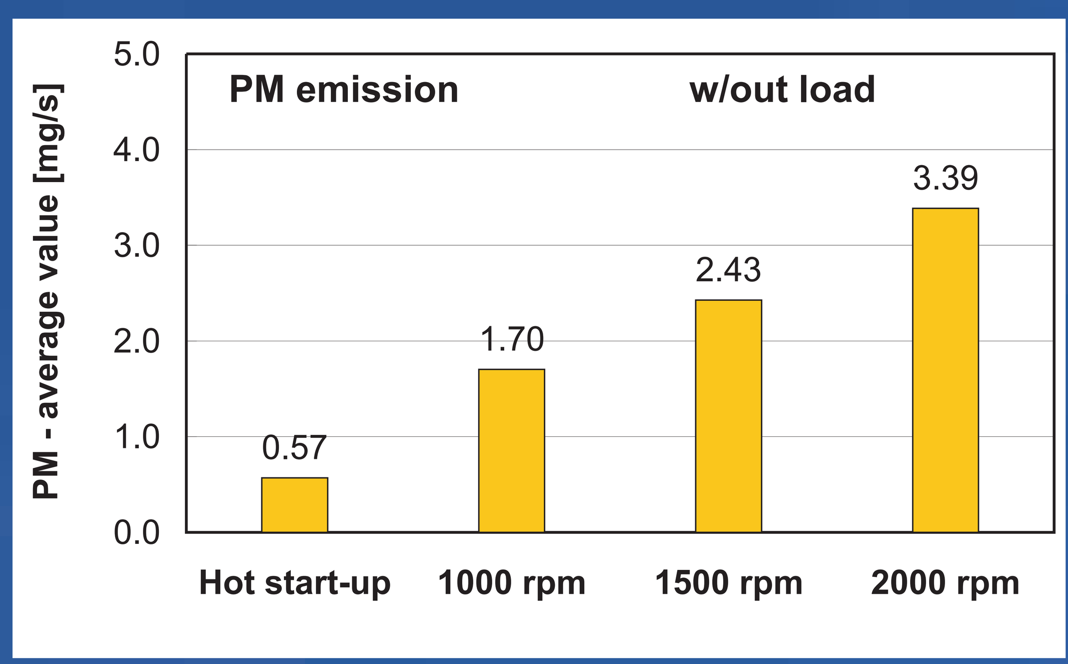


Vehicle onboard diagnostic system (CAN J1939)

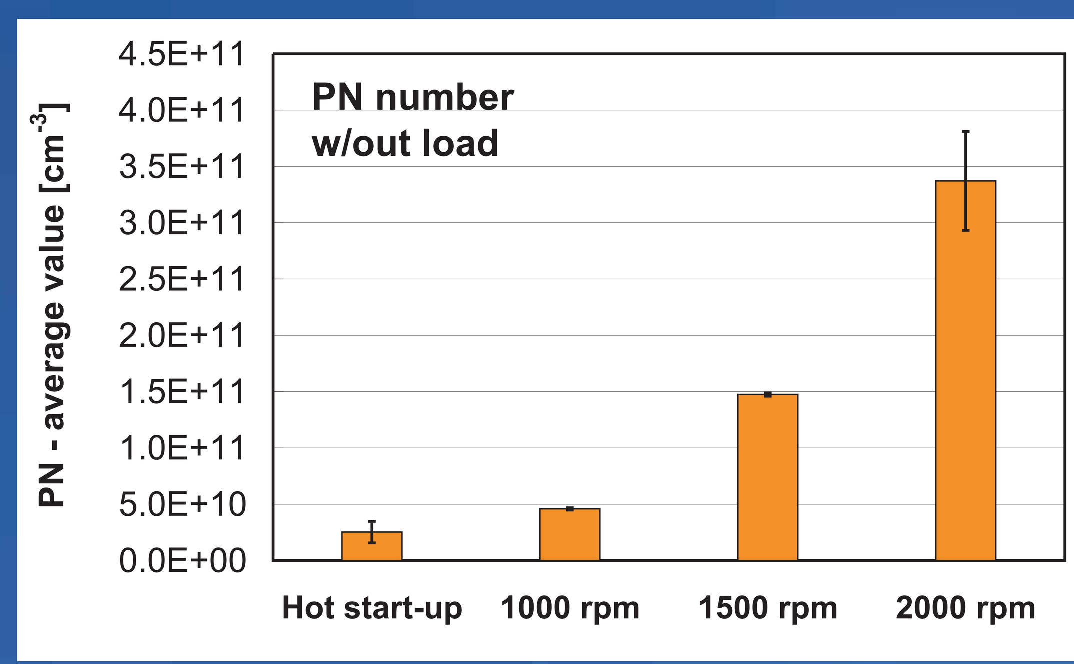
PM concentration



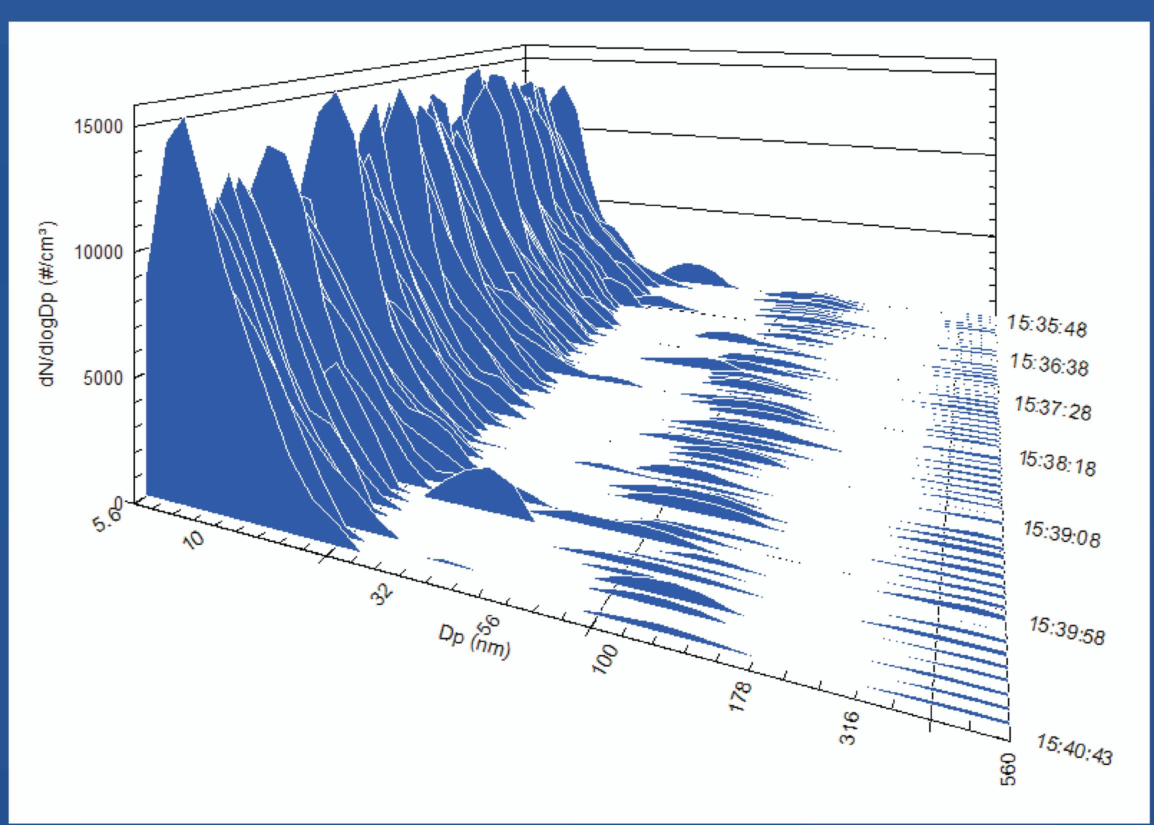
PM mass



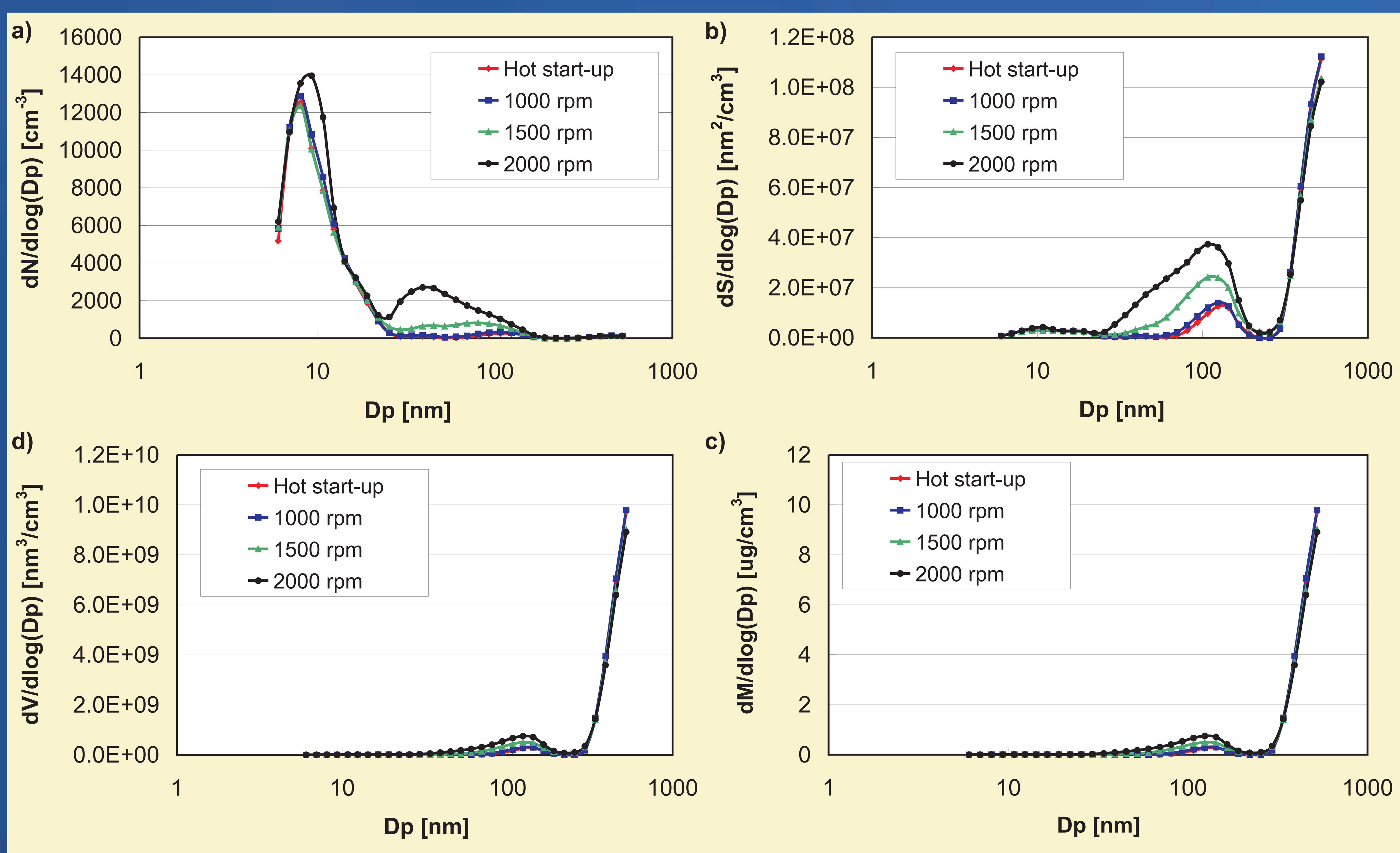
PN number



PM distribution



PM size distribution during engine start



Distributions of PM size: a) number vs. diameter, b) surface vs. diameter, c) volume vs. diameter, d) mass vs. diameter

Conclusions

1. A change in the engine speed at small loads significantly influences the concentrations of the exhaust toxic compounds but it does not cause a change in the concentration of the PM (the emission of PM changes though).
2. The analysis of the PM number in the aspect of changing engine speedsat small loads indicates an occurrence of a maximum PM number of the size of 10 nm for each investigated engine speed.
3. The characteristics of the PM size distribution indicates an existence of a maximum PM number of a diameter of 100 nm, yet the maximum areas, volume and mass pertain to PM of a diameter of over 500 nm.