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PM EMISSION OF DIESEL RAIL-ROAD VEHICLES OPERATED ON POLISH RAIL LINES

Abstract

The paper discusses the use of rail tractors in the aspect of reduction of particulate matter emissions. A fairly new issue, not yet published in Poland is the on-road emission under real operating conditions of these vehicles.

Introduction

The ecological issues related to the reduction of energy and fuel consumption as well as the exhaust emissions are also reflected in works on rail vehicles. Rail vehicles of special application are frequently based on the design of trucks but also agricultural tractors.

A road-rail tractor is a unit designed for works related to shunting rail cars (wide and narrow gauge). The equipment of this tractor is based on Orion Crystal additionally fitted with a gear reducer and a narrower wheel gauge. The vehicle is equipped with a system that enables driving on the rails and towing rail cars (as equipped by Rail Vehicles Institute TABOR in Poznan). The tractor operates both as a locomotive (towing rail cars) and a regular truck towing trailers.

The design features of these vehicles allow:

- entering onto the railroad at any railroad crossing
- easy fixing of the vehicle on the rails
- easy exit from the rails onto a regular road
- operation on railroads of different gauge (1524 and 1435 mm)
- easy change from narrow to wide rail gauge
- access to the destination point through unpaved roads.

Research methodology

The exhaust emission tests were performed on railroad tractors – Crystal Orion C13 fitted with diesel engines. The view of the tractor with the measuring devices fitted has been shown in Fig. 1.

Fig. 1. The tests of Crystal tractor with fitted systems of exhaust emission measurement carried out in RVI Tabor in Poznan

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 analyzer measured the size of the particles from the tested vehicle on a continuous basis. The measurement of the size of the particles was in the range of 5.6 to 560 nm, with the measuring frequency of 10 Hz. Diluted exhaust gases of proper temperature were at the same time directed to a particle counter and mass spectrometer. Hence, two quantities were given at the same time – overall particle number and the size distribution in each size range. The measurements of PM have also been carried out under static conditions, during start-up and at constant engine speed without engine load. The exhaust emission tests were performed at a part and a full load. The PM size distribution was determined for individual points of engine work. The measurements were performed with/without load on a warmed up engine and steady engine speeds – 600, 1000, 1500 and 2000 rpm. The results have been presented as spectral 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-up

The startup measurements of the PM were done within the time period of 90 s from the engine start-up. The values of the PM number during cold- and warm start have been presented in Fig. 2. The PM cold start emission is 25% higher than it is in the case of a warm start (Fig. 3).

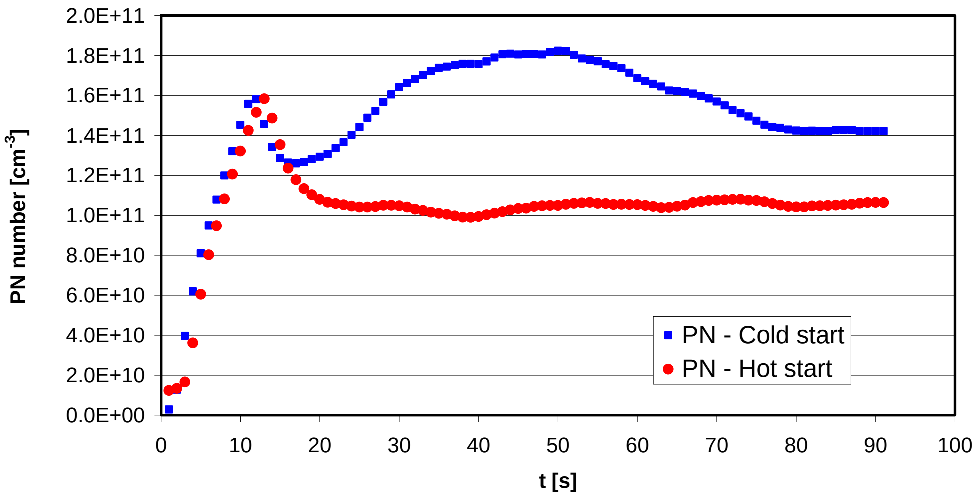

Fig. 2. Values of PN number emitted during start-up

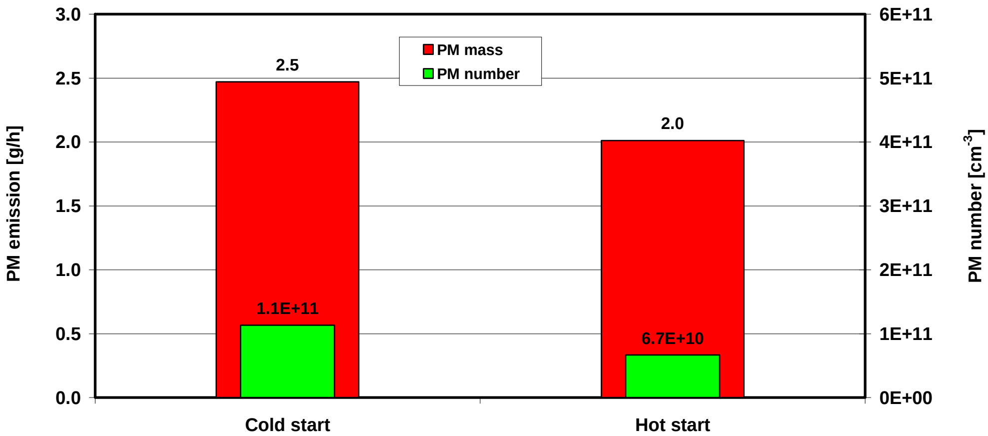

Fig. 3. Average values of mass and PM values emitted during start-up

PM emission during variable engine speeds

The emission of PM from the engine without load was done at steady engine speeds: idle (600 rpm) and the most frequently used engine speeds while operating on the railroad. The increase in the amount of exhaust gas at higher engine speeds results in the growth of the PM emission (Fig. 4). The PM number grows faster than the PM mass emission, which is related to a higher number of smaller particles during the engine acceleration.

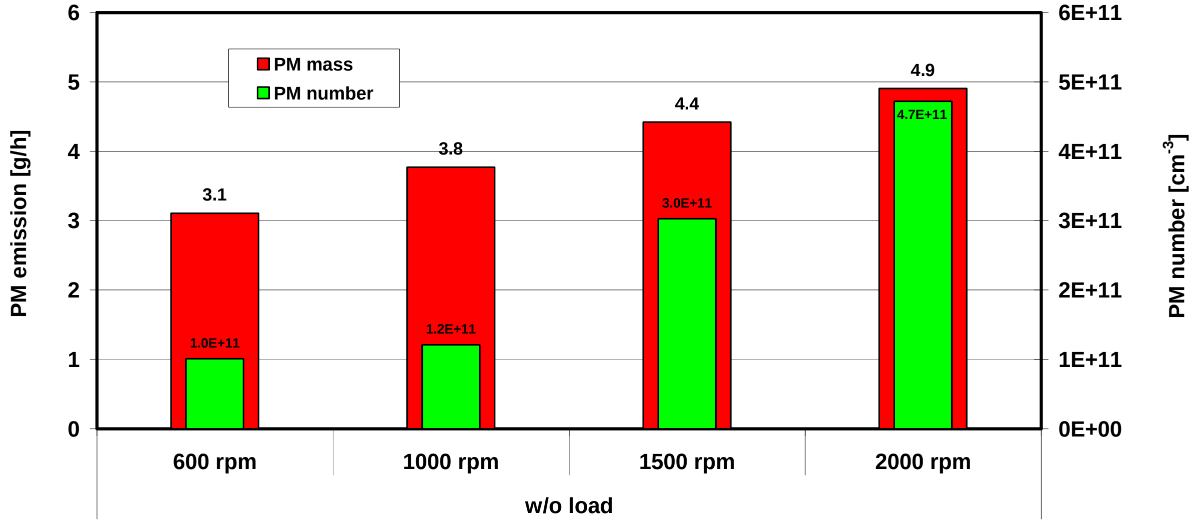

Fig. 4. Average values of mass and PM values emitted during idle run

PM distributions

Taking the PM distributions into account we should note that the change in the engine operating conditions (from startup through increase in the engine speed) does not result in the change of the PM size distribution (Fig. 5). The highest number of PM falls into the range of 10 nm and amounts to approximately 30 000 cm^{-3}. The influence of the change in the engine speed is noticeable only at n = 1000 rpm: the PM number of diameter 50-100 nm gains in importance. The influence of the engine operating conditions on the PM area distribution is typical i.e. as the PM diameter grows its area increases reaching a maximum for the PM of the size of 500 nm. We should note, however that with the increase of the load the area of the 100 nm PM grows as well. Such a clear difference has not been recorded for the PM number in this size range. The differences between the PM area distribution during start-up and steady idle speed (n = 600 rpm) have not been recorded. In the rest of the cases the increase in the engine speed and load results in the increase in the area of the PM by approximately 100% at a steady diameter of the range of 100 nm. At larger PM diameters the changes do not occur. Much smaller changes occur in the volumetric and mass distributions of PM under different engine operating conditions. Noticeable changes (several per cent) pertain only to PM diameters of 100 nm. In the rest of the ranges no changes have been recorded at variable engine operating conditions of a road-rail tractor.

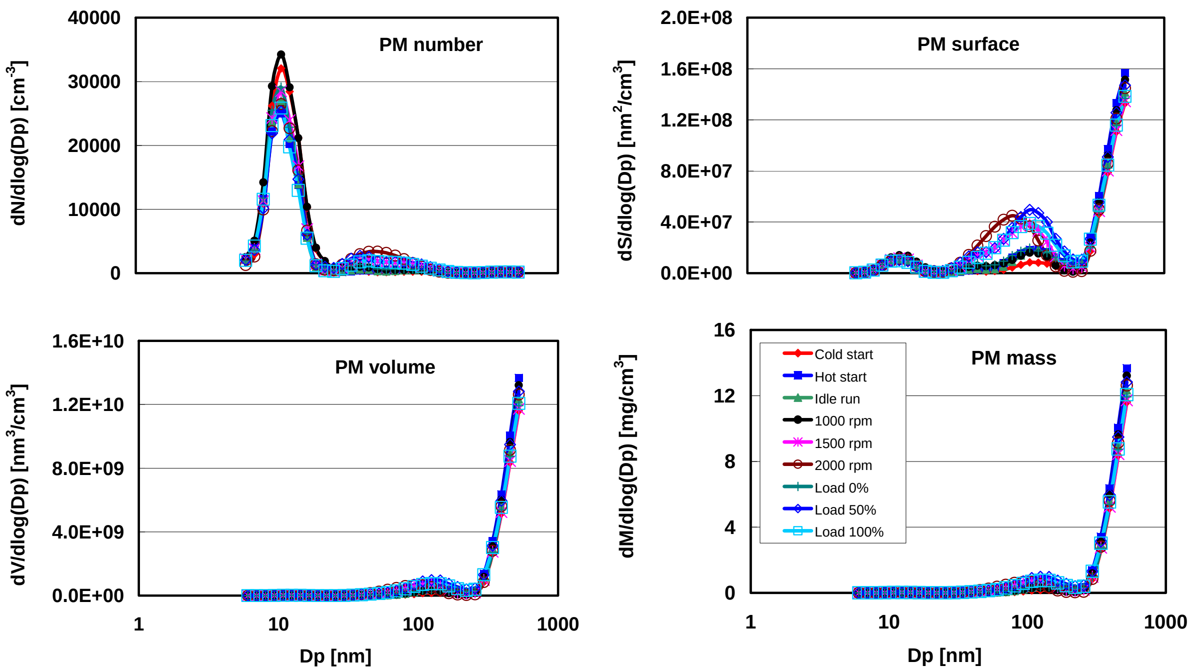

Fig. 5. Distributions of PM size: number, surface, volume and mass

Conclusions

Considering the PM distribution we should note that a change in the engine operating conditions (from start-up to engine acceleration) does not result in a change of the PM size distribution. The highest number of PM falls in the range of approximately 10 nm and amounts to approximately 30 000 cm^{-3}.

The influence of the engine speed is noticeable only at the speed of n = 1000 rpm: the number of PM of diameter of 50-100 nm gains in importance. The influence of the engine operating conditions on the PM area distribution is typical i.e. as the PM diameter grows its area increases reaching a maximum for the PM of the size of 500 nm. We should note, however that with the increase of the load the area of the 100 nm PM grows as well.

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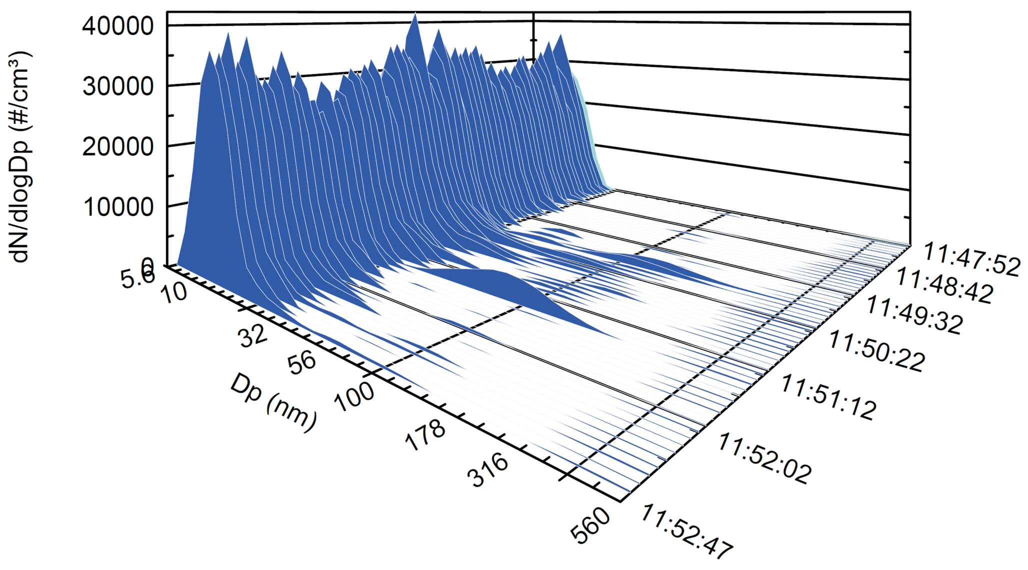
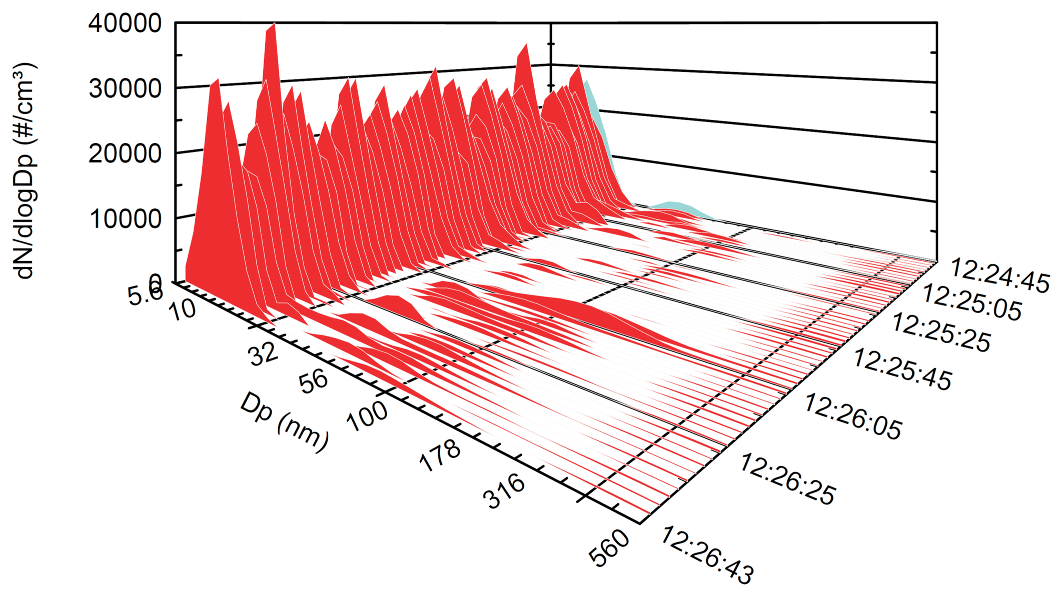
The analyzer measured the size of the particles from the tested vehicle on a continuous basis.

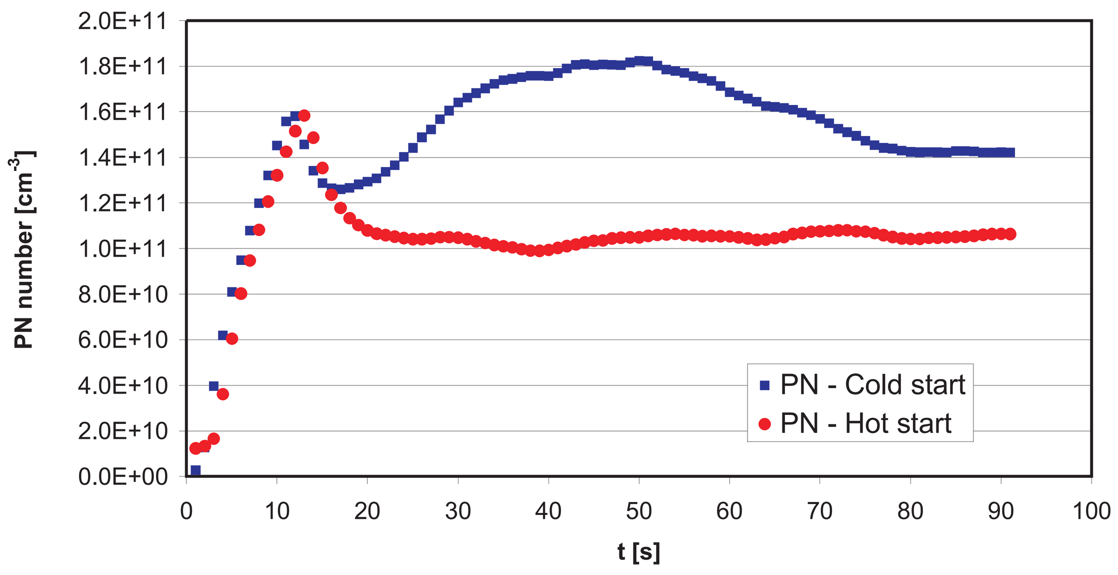
Metodology

The tests of Crystal tractor with fitted systems of exhaust emission measurement

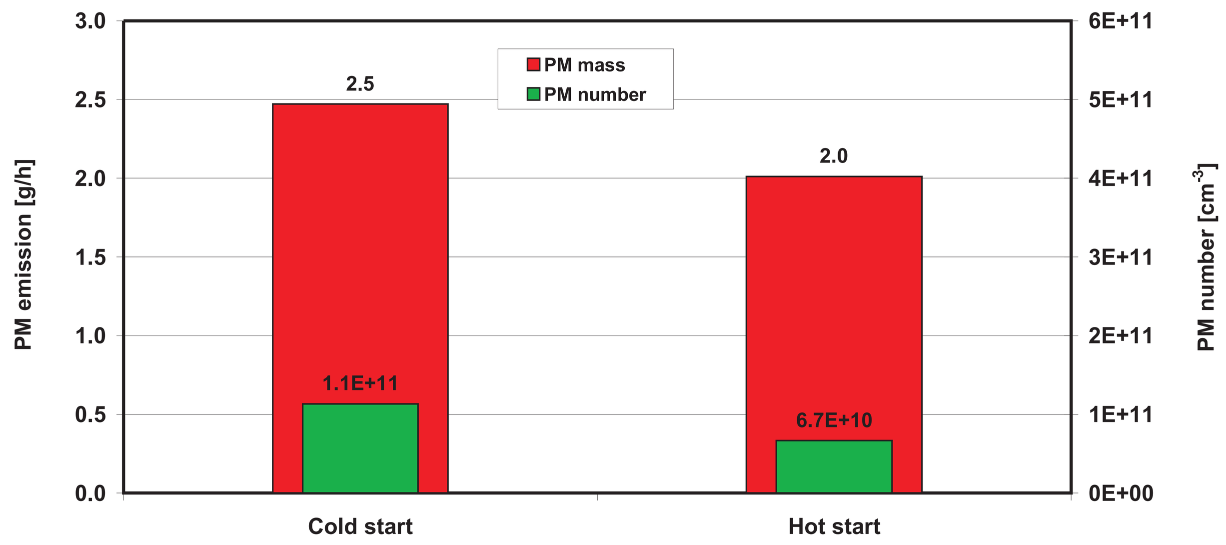
Cold/hot start engine





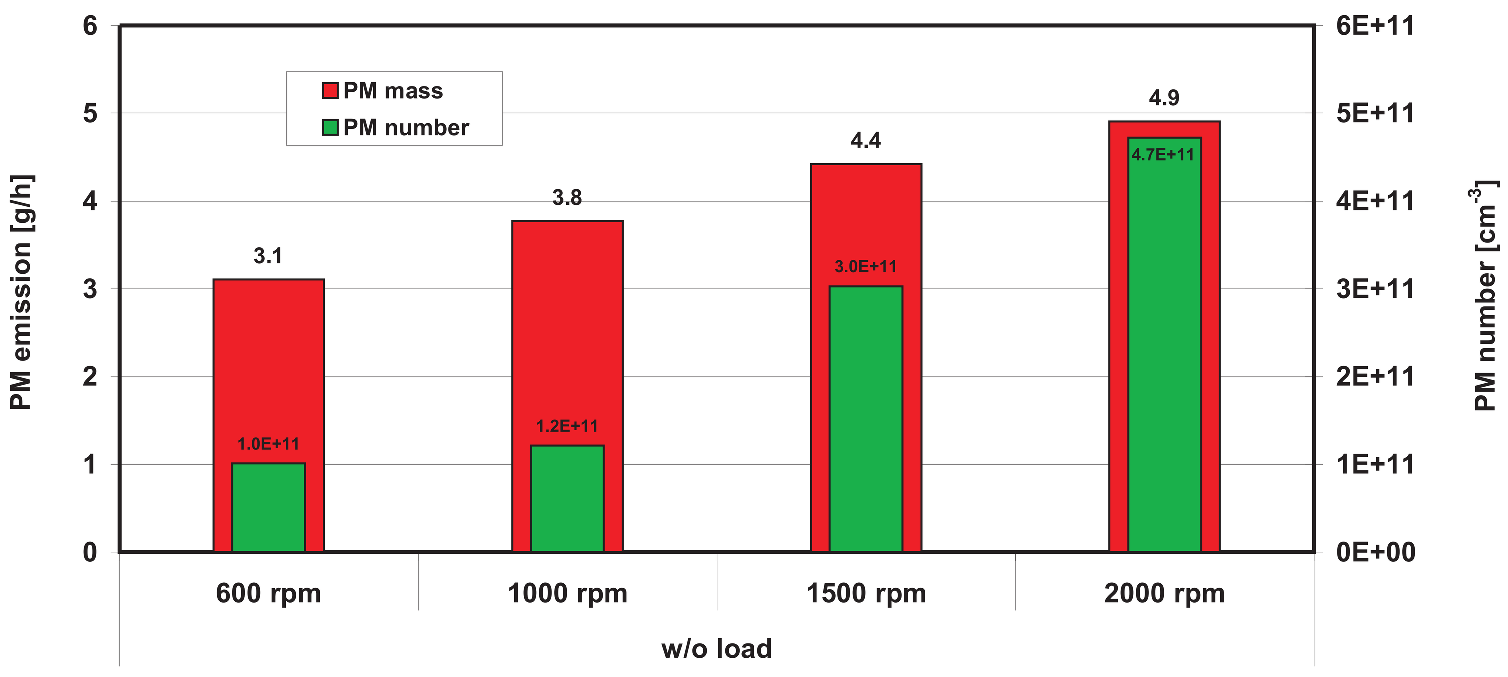


Values of PN number emitted during start-up



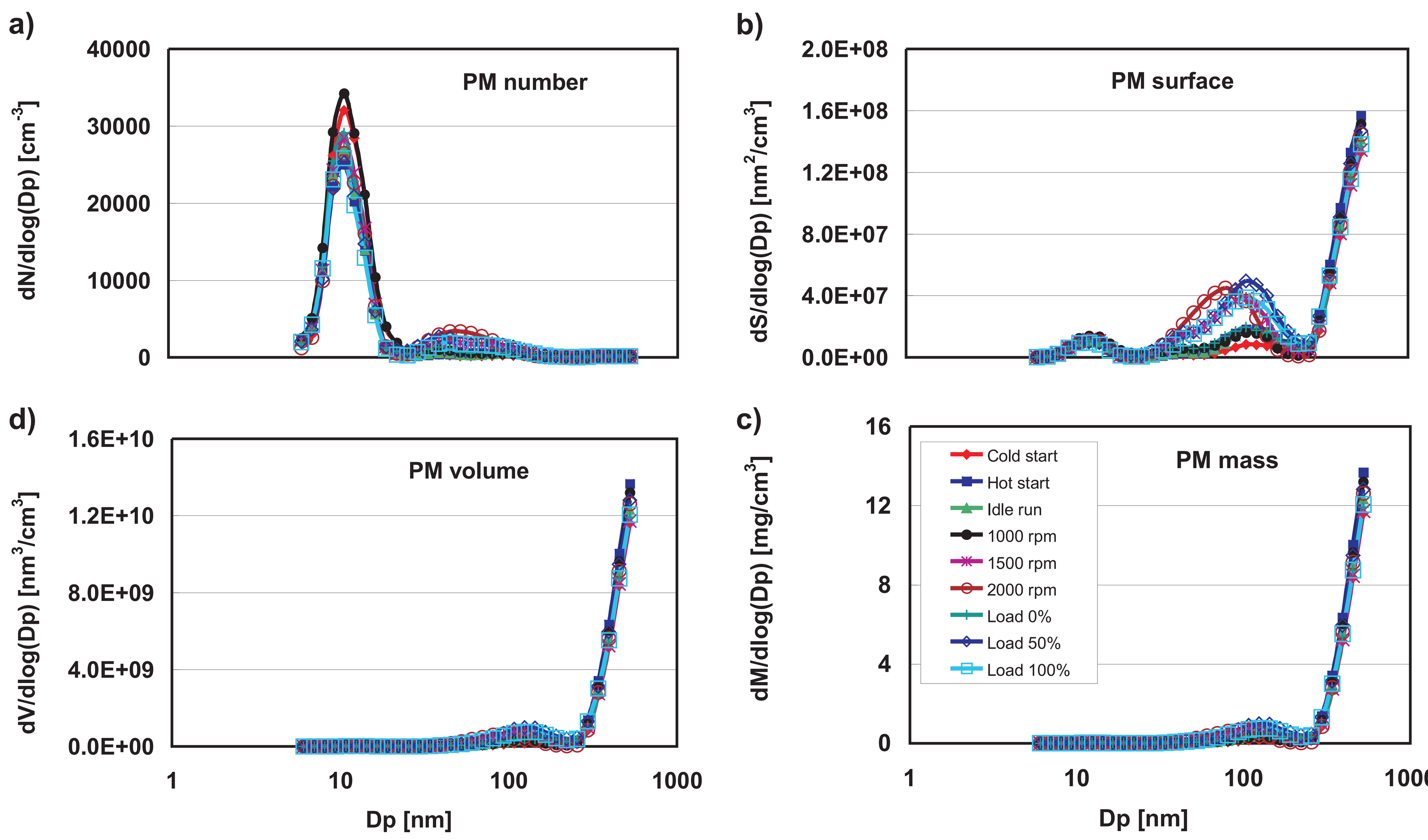
Average values of mass and PM values emitted during start-up

Variable engines speeds



Average values of mass and PM values emitted during idle run

PM distribution



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

Conclusions

1. Considering the PM distribution we should note that a change in the engine operating conditions (from start-up to engine acceleration) does not result in a change of the PM size distribution. The highest number of PM falls on the range of approximately 10 nm and amounts to approximately 30 000 cm^{-3}.
2. The influence of the engine speed is noticeable only at the speed of n = 1000 rpm: the number of PM of diameter of 50-100 nm gains in importance. The influence of the engine operating conditions on the PM area distribution is classic i.e. as the PM diameter grows its area increases reaching a maximum for the PM of the size of 500 nm. We should note, however that with the increase of the load the area of the 100 nm PM grows as well.