

Researching particulate matter characteristics for mitigating health risks generated by road vehicles

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Abstract. Research of PM (particulate matter) emissions is very important in crowded areas with high values of road traffic and industrial sites because may affect the health significantly. To mitigate the health risks generated by motor vehicles, the present paper shows the applied research on this topic with the practical results. The first important objective of the paper is to study the characteristics related to particulate matter in emissions generated by a car in actual road traffic test. The second objective is to compare the results from cold and warm operation regimes. It is important to know the trendline of PM emissions during operation due to their influence upon health. The PM amount is influenced by engine speed, fuel consumption and other operational factors. High levels of PM were recorded at 1500 rpm because it was the upper point in which the gear ratio has been changed.

1. Introduction

Particles in suspension are entering the body and they are interacting with different physical, chemical, and biological structures generating various phenomena. Some of the particles are toxic, meanwhile some of them may be neutral in relation to the organism. There are studies which undertake the problem of multiple micronized and non-micronized particles into human tissue showing flow characteristics [1].

The problematic contact of particulate matter and other pollutants is with the soft tissues, such as eyes and nose [2]. Operation and its inherent problematic aspects may lead to particulate emissions [3]. These particles are retained by specific filters, in standard systems and solutions, for diminishing the public health risks [4]. There are some store limits and regeneration procedures for such systems [5]. Development of electronic interfaces to improve control and management for supplying the systems is making the operation more efficient [6]. Road cars and conventional transport vehicles are generating emissions of particulate matter in suspension which are impacting the air quality. The latter one is under the control of specialized Management System. Particulate characteristics are generating problems not only for living beings but, in some cases, also for the air quality monitoring equipment [7]. “Suspension” in this case is used to define some fluids which consist of suspended particulate matter (gas bubbles, liquid droplets, and rigid particles) in a liquid mass [8]. Multiple solutions and experimental testing methodologies have been proposed during the last 3 decades to properly manage different types of particles [10, 11, 12]. Experimental research of particulate matter in relation to fuel and engine has led to idea that operation regime and energy source are somewhat influential in determining emissions [13]. From modelling the particle dynamics, through production of particle suspensions, the characteristics and behaviour are studied with nonlinear equations [14, 15, 16]. Flow and displacement of liquid and solid particles, studied by rheology is applicable in food engineering and for characteristics’ definition of multiple nanofluids [17, 18, 19]. Air quality and environment status are influenced by emissions [20].

2. Applied research

Method of research is based on the experiment and recordings with electronic Diesel control system which has the technical data given in table 1.

Main technical specs concerning the tested car are useful to properly identify the powertrain.

Table 1. Practical specifications of the car used during testing

Parameters	Actual value
Propulsion	Diesel 350 CDI / 3.0 L turbo V6 OM642
Energy supply	Common-Rail Injection system with six injectors
Gearbox	7-ratios / 7G-TRONIC
Axles	Classical solution: 4x2 / Front steering / Rear axle drive
Platform	Mercedes-Benz Bluetec E350 CDI/Model W/A207 (2013)

Figure 1 presents the basic steps of the research methodology in approaching the topic of PM risk.

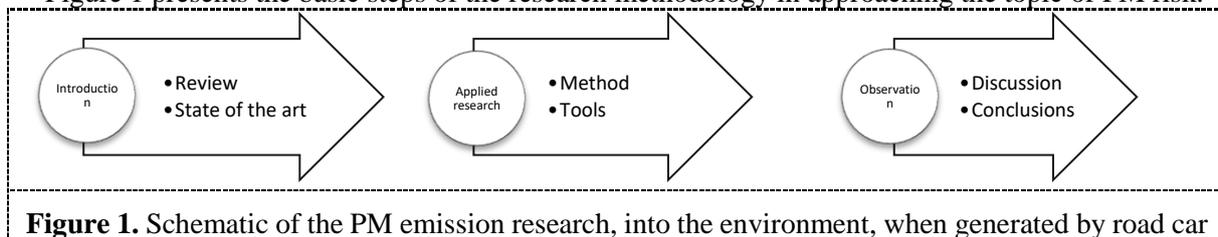


Figure 1. Schematic of the PM emission research, into the environment, when generated by road car

PM assessment starting from air and fuel consumption is based on the instant mixture as shown below:

$$PM = (1 \dots 6) * 10^{-7} n^2 - (0.3 \dots 0.8) * 10^{-4} n + (0.15 \dots 0.3), \text{ [kg/h]} \quad (1)$$

where n is the engine speed, in revolutions per minute [rpm]; PM – particulate matter, in [kg/h].

Figure 2 shows the PM simplified structure in the exhaust gases of a road car. The intake air passes through the front grille 1 to the engine 2. The front axle 3 is used for steering, braking and support, meanwhile the on-board electronic unit 4 allows the control of fuel flow and consumption from tank 5. Soluble organic fraction of hydrocarbons 6 are surrounded by other particles 7 (SO_4) and liquid droplets 8 (HC). Solid carbon 9, combined with soluble fractions 6 and 8, in the presence of vaporised phase 13 of HC, poses a significant carcinogenic health risk due to its specific characteristics. The PM may be produced both by tire 12 friction with the road surface and by exhaust system 11 in the emissions 10.

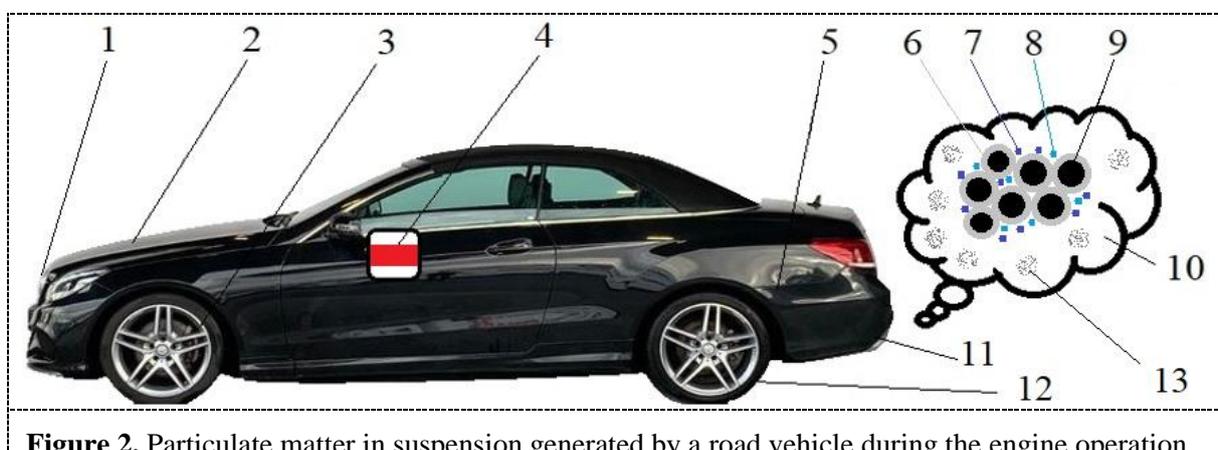
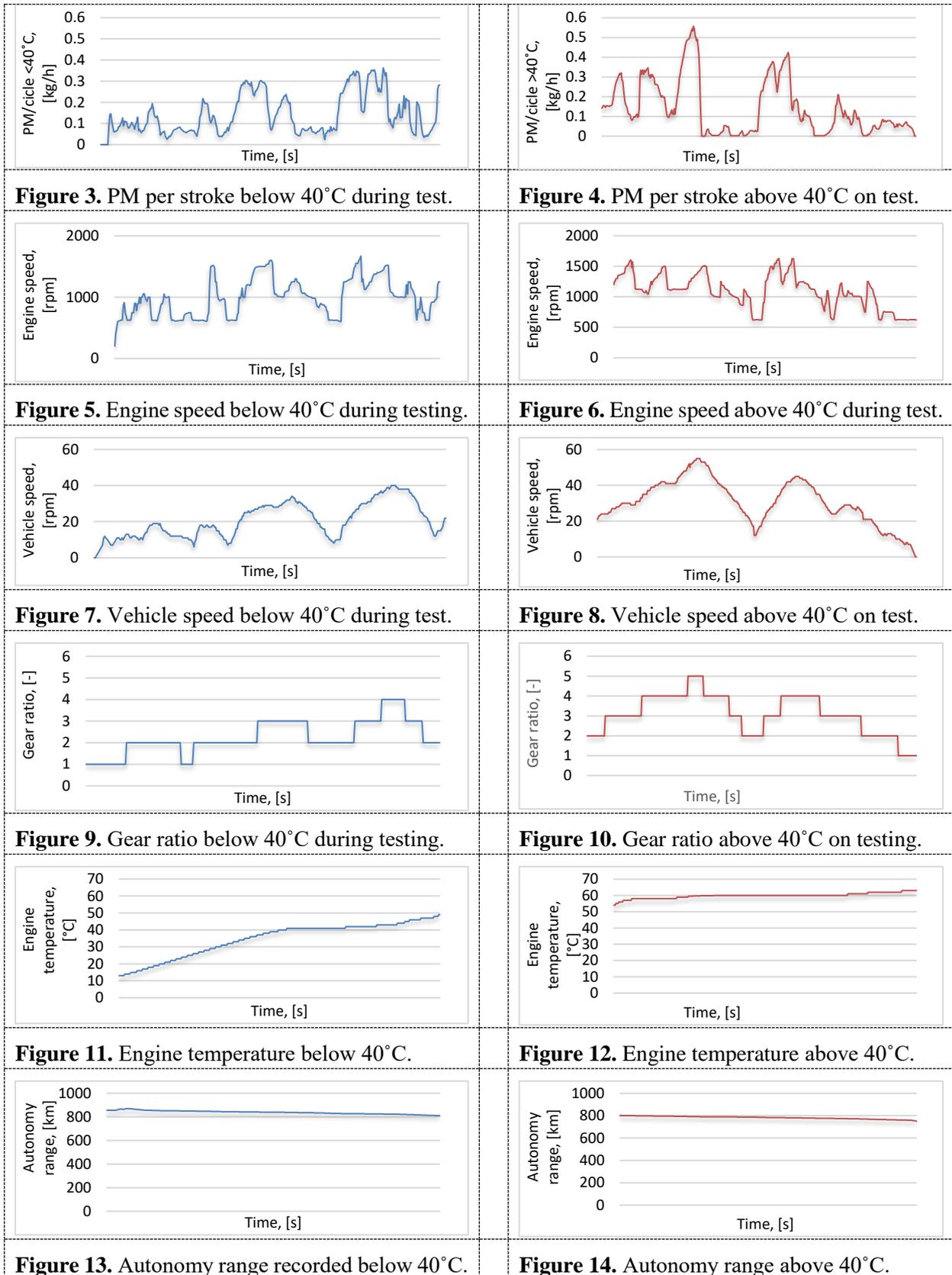
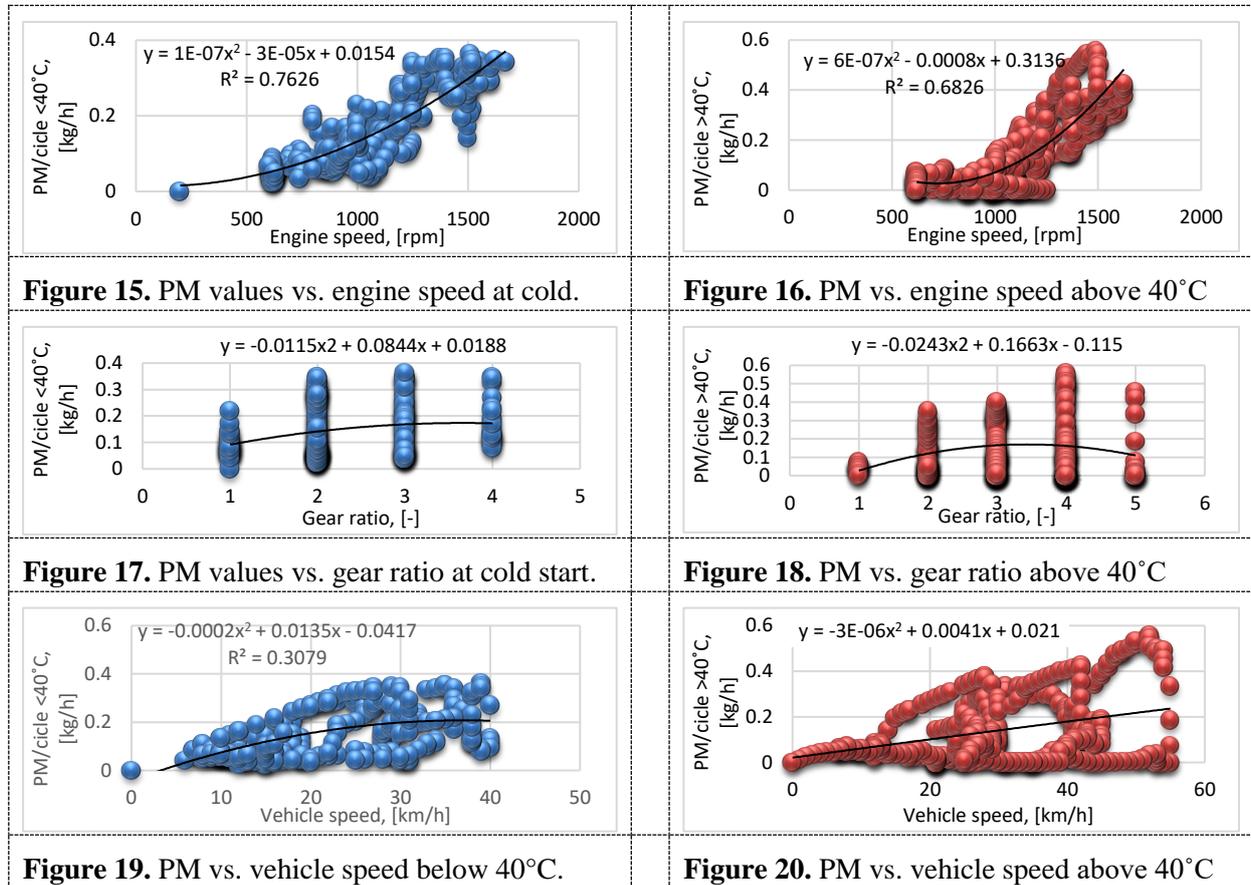


Figure 2. Particulate matter in suspension generated by a road vehicle during the engine operation.

In figures 3 to 14 are shown the graphs for PM variations during the entire transient test cycle of 1800 s duration in conjunction with engine and vehicle speed, gear ratio, engine temperature and autonomy.



The PM emissions were determined through calculus. The latter one is based both on the air intake and fuel consumption. It was divided in two sequences: cold start below 40°C and warm-up phase above it. The hourly PM emission versus the engine/vehicle speed and gear ratio are given in figures 15 to 20.



PM assessment in the relation with consumption, speeds and gear ratios facilitates some observations.

3. Observations and conclusions

Air contamination with particulate matter is nowadays of high concern due to the negative impact on health and climate. Researching and measuring the non-organic solids and soluble organic fractions, and their variation with different parameters are crucial in comprehending the mechanical, thermodynamic, and chemical transformations in environment and influences in health issues. Air temperature during the tests has been 13°C. The vehicle used in tests for the present research has 7+1 transmission ratios, and 3 changing strategies (E-automatic eco-mode; S-sporty; M-manual). In the current investigation the M strategy for gear change was applied. In the present work, cold start and low temperature operation has been investigated to gain insight about the PM variation with the possibility of partial level control of emissions. Elemental and total particulate matter analyses confirmed that level of analysed pollutant reference samples to be influenced by the engine temperature.

In the first step of the experimental research, when the engine temperature ranged between 13 - 40°C, the average PM value was 2.40 g/min. Between 40°C and 63°C, the second phase of the test, PM average emission value was 2.38 g/min. Polluting activity of PM was the highest when the engine speed, vehicle speed, and the number of injections were at peak values. The average number of injections below 40°C was 495 per minute. In the range 40-63, second stage of testing, there were 544 inj/min. Probability theory allows the calculation of the PM levels increase when coolant temperature changes and the vehicle operate in different engine regimes. These aspects, to be highly defined will require further studies.

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