

Brake Particle Emission Measurements - Testing Method and Results

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ABSTRACT

Brake Particle Emission (BPE) is gaining considerable importance for the friction brake and automotive industry. So far no common approach or legislation for BPE characterization exists although many activities in this field have been started during the last years. Taking this into account, the authors carried out a joint measurement campaign to investigate a new approach regarding the sampling location using a brake dynamometer. During preliminary investigations the influence of the cooling air quality has been examined and a sampling point position validation has been carried out.

At first the stabilization behavior for repeated test cycles and variations of volumetric air flow rates are analyzed. As a next step the role of volatile particle emissions is determined. Subsequently, the influence of load history and friction power is studied. Finally results in terms of the role of high temperature applications are presented.

In summary, it can be stated that a robust measurement method for BPE characterizations, is introduced. Based on the results of this work, further investigation in terms of friction material benchmarking and development of new BPE-optimized friction partners will be done.

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INTRODUCTION

Since particle emissions from the internal combustion engine have been reduced during the last decades significantly, non-exhaust emission sources, such as brake wear particles and tyre wear particles emission, is gaining more interest by environmental organizations and the EU commission. [1]

Unlike the powertrain, a conventional vehicle friction brake is more or less an open system and the sampling of the emitted particles is a very complex process, which is investigated by many researchers. [2]..[4]

The focus of this study is to improve the robustness of the brake particle emission measurement approach. Therefore, some preliminary studies were carried out and the results of these are presented at first. Afterwards various important results are introduced, beginning with an overview of total PN for each test and the role of volatile particles. Further, tribological peculiarities are examined and can be linked with particle emission measurements.

The presented results contribute to a better understanding of brake particle emission measurement and provide an essential base for a standardized test procedure in the future.

EXPERIMENTAL SETUP

A brake dynamometer, used to evaluate the performance of brake systems and test the brake parts under various environments (weight, velocity, brake force, wet-dry conditions), is the experimental base of the investigations. The Horiba GIANT 5200 has a customized design and operates below atmospheric pressure, in order to perform brake tests under specific ambient conditions. The dyno offers an inertia simulation range from 10 kgm² to 200 kgm² with a max. speed of 2500 rpm at a max. power of 190 kW. The subject of the investigations is a front axle passenger car brake with a floating caliper and low steel brake lining material.

One of the key points of BPE investigations is the sampling procedure along with the sampling location. Due to the complexity of the particle emission behavior around the caliper, it was decided to estimate the emitted particles in the exhaust duct. A schematic drawing of the experimental setup is presented in Figure 1.

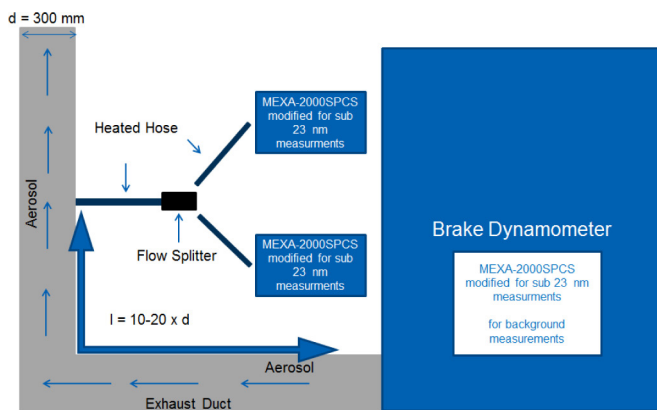


Figure 1. Scheme of the used experimental setup

As background reference an additional sampling location inside the test chamber was chosen as well. Using this setup it is feasible to investigate if the emitted brake particles are removed sufficiently from the brake or if a significant amount of particles remain in the chamber. For further investigations, in terms of the influence of volatile emissions, a flow splitter was installed after the sampling point in the exhaust duct.

In order to provide and ensure a homogenous mixture of the characterized airflow, the distance L from the chamber outlet to the sampling location was defined in dependency to the dilution tunnel diameter D . According to GRPE-48-11 regulation (with $L = 10 \cdot 20 \times D$) the sampling location is defined as $L = 14 \times D$.

Different intake air flow rates were defined-930 m³/h, 2700 m³/h and 3450 m³/h.

Two particle number counting devices were installed into the existing testing environment. Both units are based on the MEXA 2000 SPCS system by HORIBA, but modified to detect sub-23 nm particles. The measurement range was adjusted to detect particles between 10 nm and 2.5 μm.

Due to the experiences from previous investigations a reduced AK Master profile was selected as a suitable test cycle - the sections 1-3, 5-7, 11 and 14-15 were excluded [5]. Even if this cycle creates higher particle emission rates compared to real driving profiles it ensures a sufficient amount of particles for those fundamental characterizations.

In regards of the specimen a 17'' two piston frame-design caliper in combination with cast iron rotors and low steel brake pads were used.

RESULTS

Preliminary Examinations

To investigate the *role of the cooling air quality*, measurements with and without an additional pre-filter system were carried out.

During previous tests it was observed that the particle emissions showed a dependency on time. Since the cooling air was sucked from a workshop next to the dynamometer, particle emissions varied during the day, especially during working hours. In order to stabilize

the background particle level, a H13 filter system was added to the ventilation system for intake air, close to the test chamber. A direct comparison of background particle concentrations (measured in the exhaust duct) is shown in Figure 2.

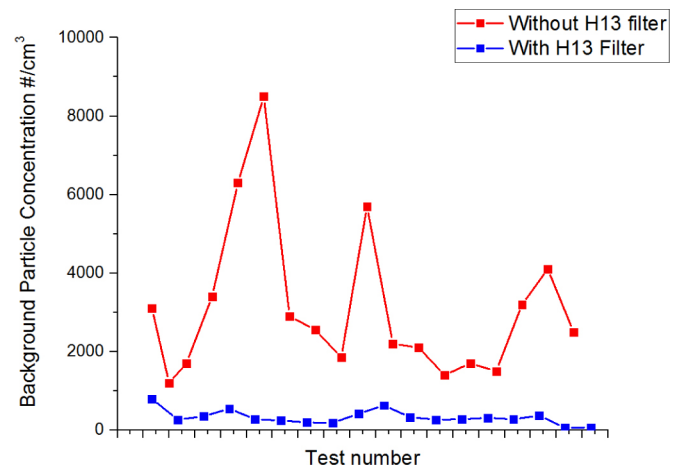


Figure 2. Comparison of background particle concentration with and without H13 filter

It can be observed that the particle concentration in the inlet air without the H13 filter is considerably higher than with the filter. The application of the H13 filter leads to a stabilization of the background level at very low particle concentrations and does reduce the fluctuation during the test series.

The introduced measurement method considers the exhaust duct as a suitable sampling point for brake particle emission investigations. However, it must be confirmed that the majority of relevant particles is sufficiently removed from the test chamber. Therefore, a *direct comparison between the two sampling points* is presented (Figure 3). In order to avoid possible differences, due to a varying air flow rate, several measurements using different flow rates, were carried out.

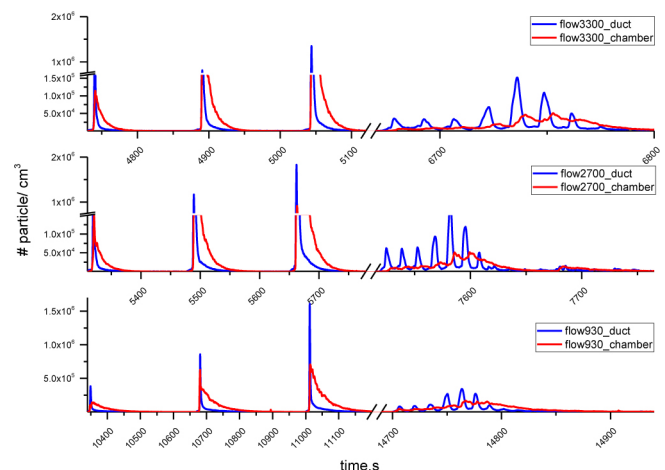


Figure 3. Comparison of particle concentration measured during Sections 4.5 and 9 in exhaust duct (blue) and brake dynamometer chamber (red) at different air flow

The analysis of PN-time-behavior confirms that both sampling points reveal similar qualitative characteristics, where the brake applications mean an increase of emitted PN. Furthermore, it can be stated that the