Consiglio Nazionale delle Ricerche

Comprehensive investigation on the effect of different brake profiles and temperature on the brake wear particle emissions

F. Catapano, S. Di Iorio, A. Magno, B. M. Vaglieco
Institute of Science and Technology for Sustainable Energy and Mobility (STEMS) - CNR

CONTENT

Background

- Issue of particle emissions: non-exhaust emissions due to the brake wear.
- Non-exhaust emissions regulation.

Experimental setup & Methods

- Experimental setup for wear brake particle measure: open & closed configuration.
- Test procedure.

Experimental results

- Particle number concentration at different start temperature of the disk.
- Particle number and size at different braking profiles.
- Particle transport efficiency.

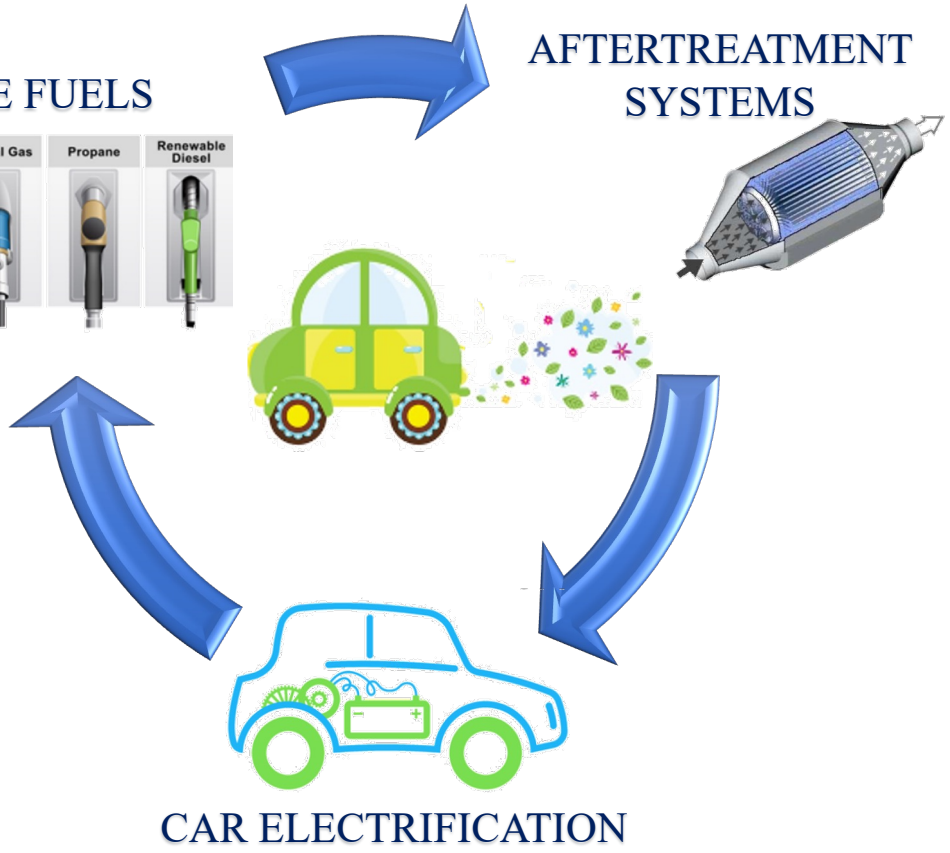
Conclusion & Next steps

- Correlation of wear brake particle emissions with the temperature and the braking intensity.
- Particle transport efficiency affected by the air mass flow rate.

BACKGROUND & MOTIVATION: NON-EXHAUST PARTICLE EMISSIONS

In the urban areas the main contributor of particles in the atmosphere is the road traffic.

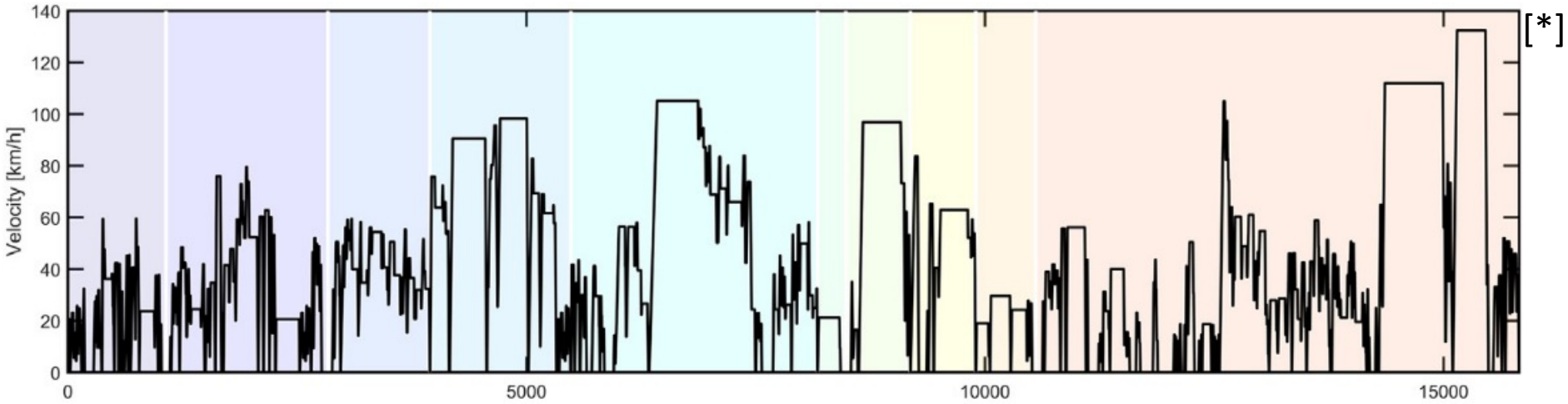
Policy efforts were made to encourage the development and the adoption of solutions to abate the PM exhaust emissions:



Reduction of **exhasut particle** emissions.
Non-exhaust particles due to brake and tyre wear gained more weight.

BACKGROUND & MOTIVATION: NON-EXHAUST PARTICLE EMISSIONS REGULATION

- The Informal Working Group on Particulate Measurement Programme (PMP-IWG) has developed a braking cycle based on real-world driving data to be used as a first step towards a commonly accepted methodology for wear brake particles sampling.
- An initial regulation will be incorporated into the upcoming EURO 7 emission standard.
- A PM_{10} limit will be set. PN emission limits will be introduced later.

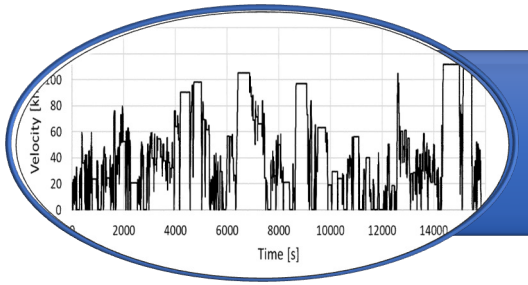


[*]

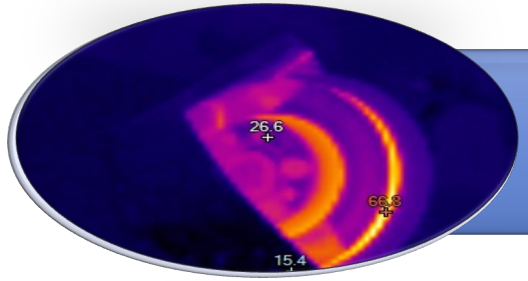
[*] Mathissen M, Grochowicz J, Schmidt C, Vogt R, Farwick zum Hagen FH, Grabiec T, et al. A novel real-world braking cycle for studying brake wear particle emissions. Wear 2018;414–415:219–26. https://doi.org/10.1016/j.wear.2018.07.020.

OBJECTIVES

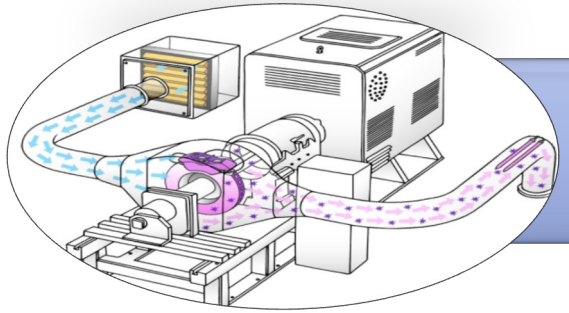
This study aims to provide an overview on non-exhaust particle emissions



Impact of braking profile



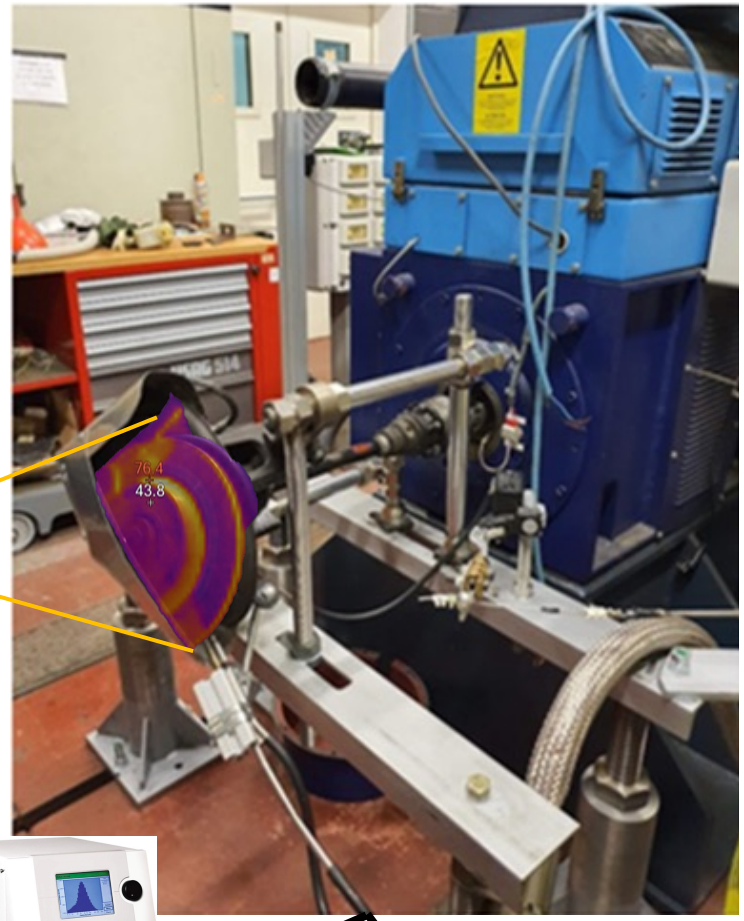
Effect of disk temperature



Transport efficiency

EXPERIMENTAL SETUP AND METHODS: OPEN SAMPLING CONFIGURATION

- An open setup for a preliminary study on wear brake particle emissions was developed.
- The rotor was connected through a drive shaft to an asynchronous dynamometer.
- The probes connected to the particle spectrometers were located near the disk.
- An infrared camera was used to monitor the disk temperature.

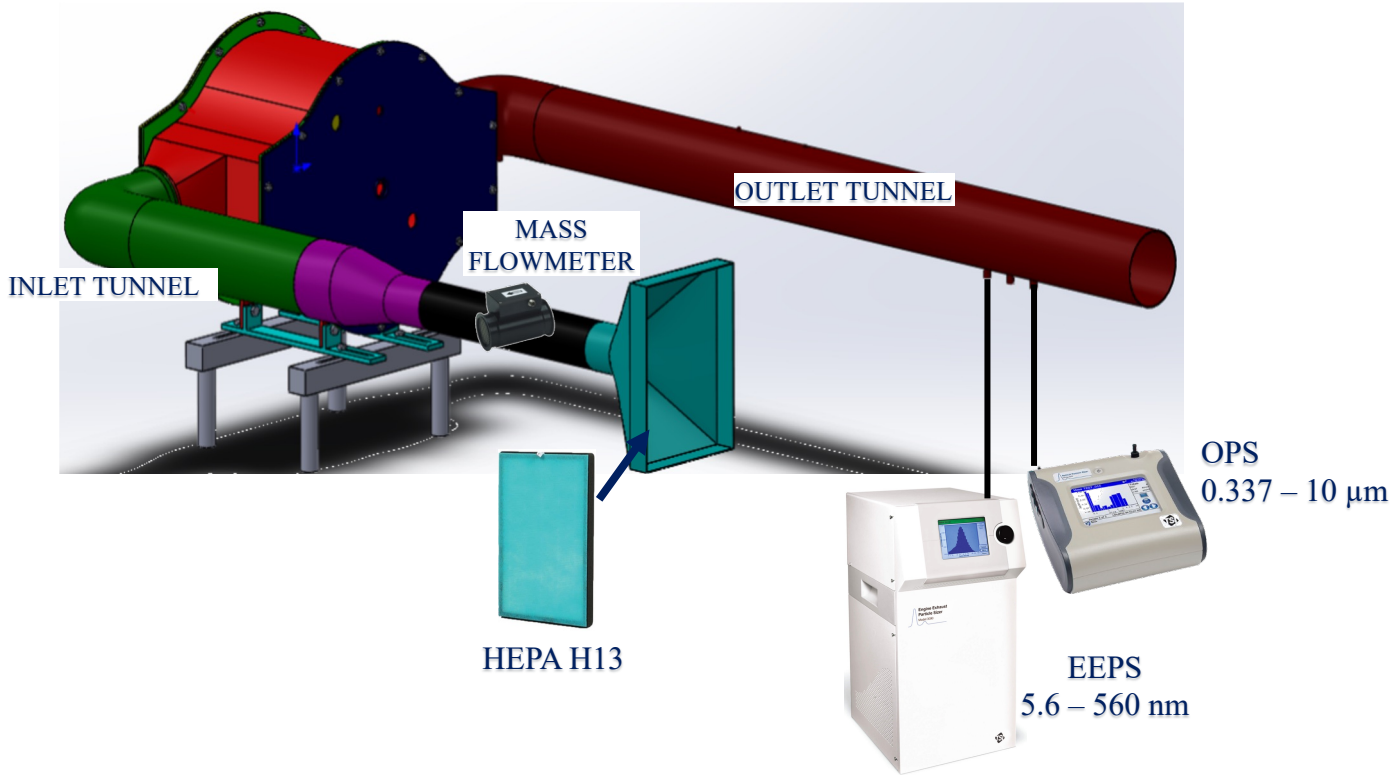


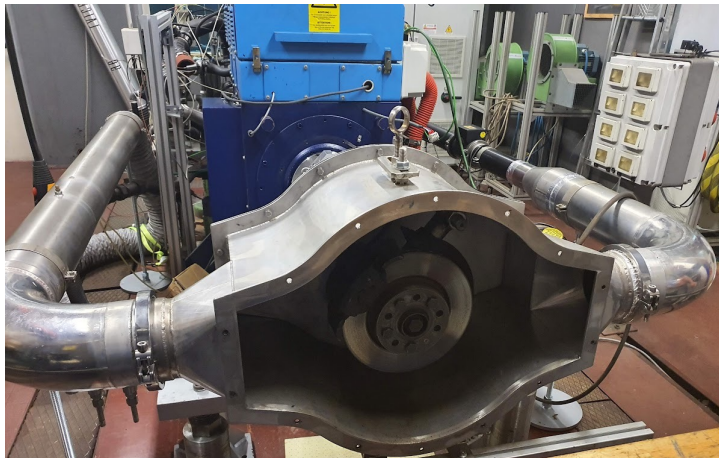
EEPS
5.6 – 560 nm

OPS
0.337 – 10 µm

EXPERIMENTAL SETUP AND METHODS: CLOSED SAMPLING CONFIGURATION

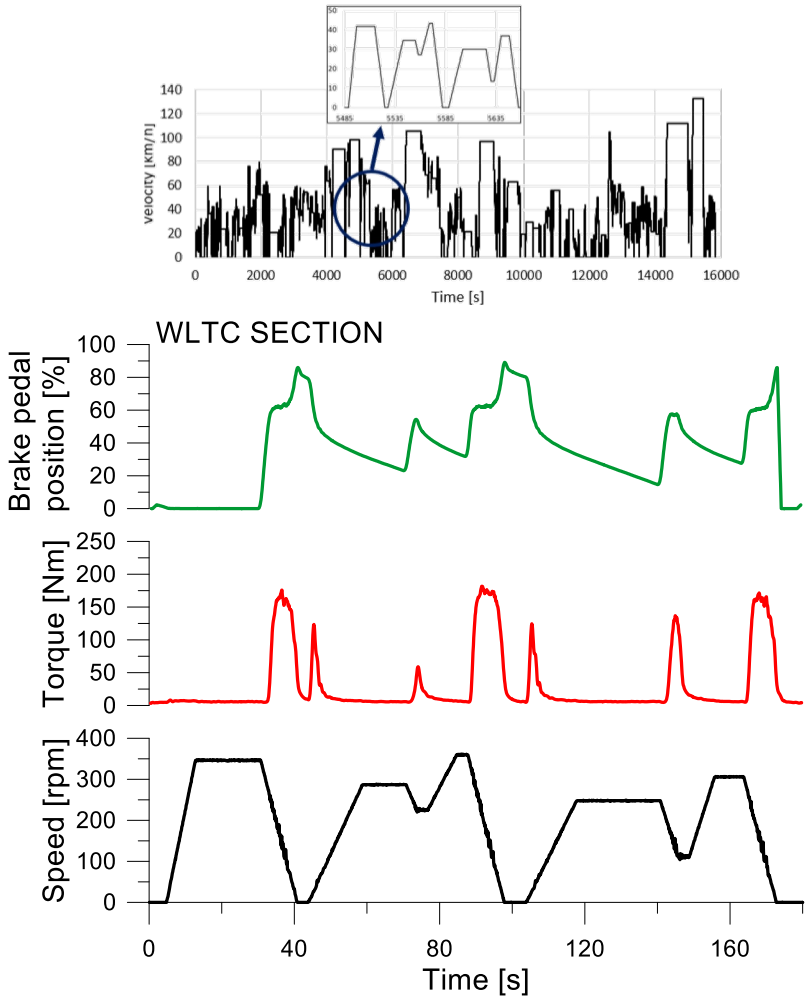
- The basis of a high-quality measurement of the wear brake particles is the repeatable and reproducible sampling.
- A chamber was designed in which the brake system was sealed.
- A particulate air filter was placed on the air-inlet duct of the chamber to avoid contamination due to the ambient particles.
- At the end of the outlet line, a blower created a stable air flow adjustable between 100 and 400 kg/h at negative pressure.
- Continuous flow measurement was performed through a thermal mass flowmeter.



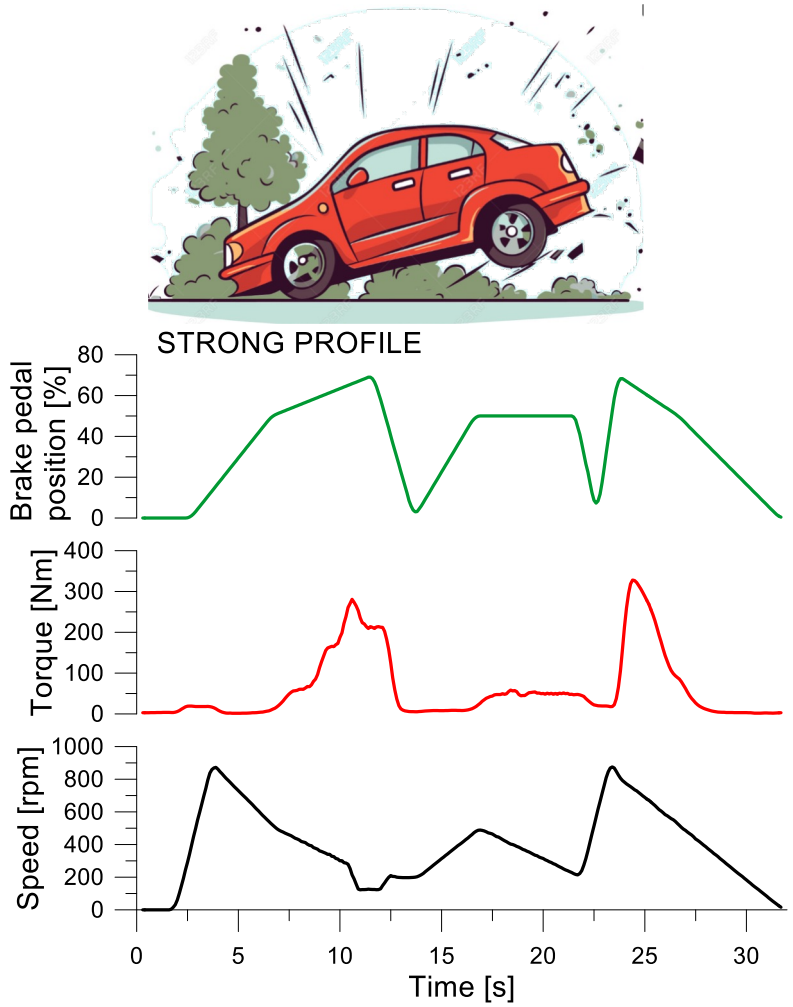


EXPERIMENTAL SETUP AND METHODS: PROCEDURE

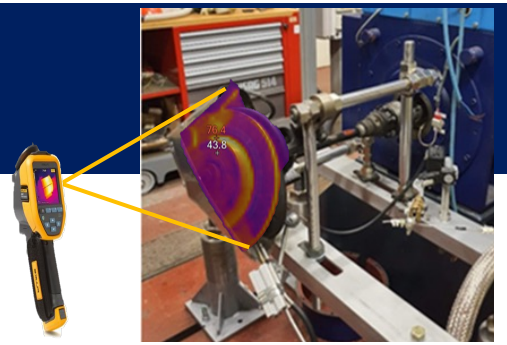
- A section of WLTC included in the PMP regulation was selected to reproduce real-world urban operating conditions at medium speed and torque.



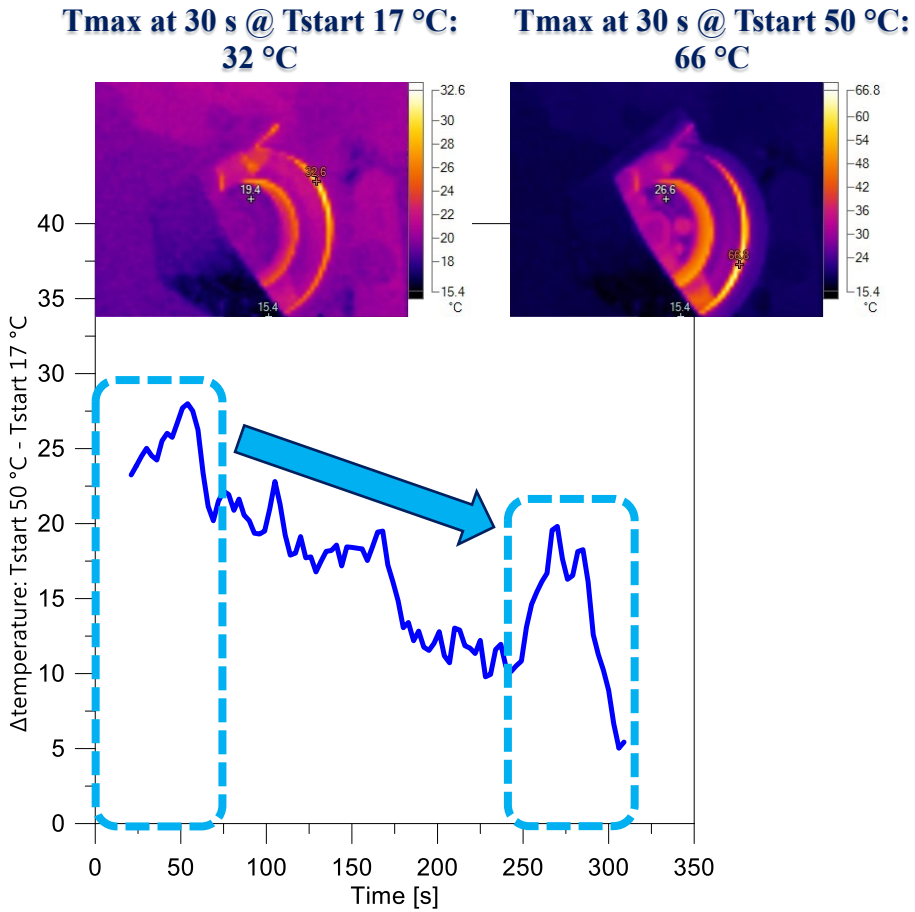
- Tests aimed to evaluate the brake performance during more extreme conditions, rarely occurring during ordinary operation, were also realized.

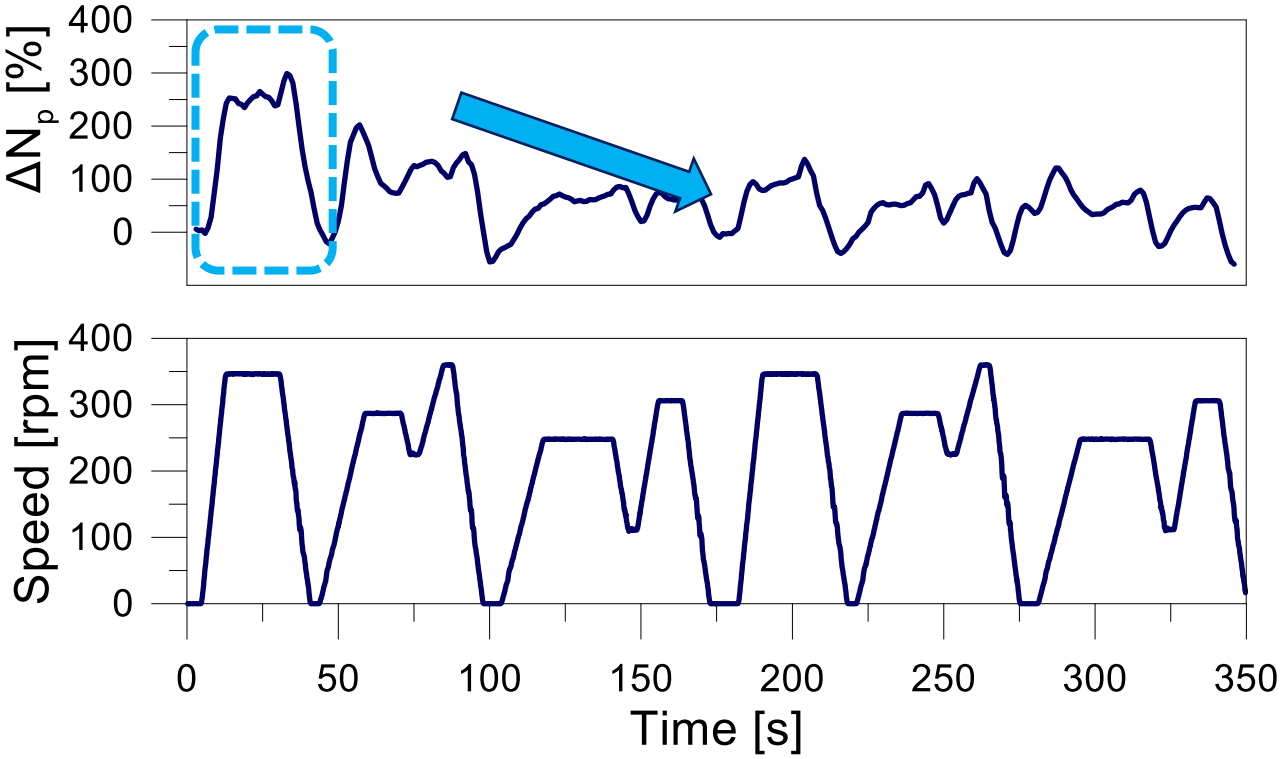


EXPERIMENTAL RESULTS: EFFECT OF DISK TEMPERATURE

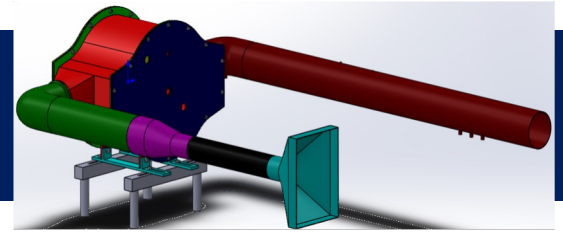


- Test carried out at two different starting temperature of the disk: COLD CONDITION T_{start} 20 °C and HOT CONDITION T_{start} 50 °C.
- The different starting temperature causes high percentage variation in the total particle concentration.
- Along the cycle the temperature differences decrease as well as the differences in the particle emissions.

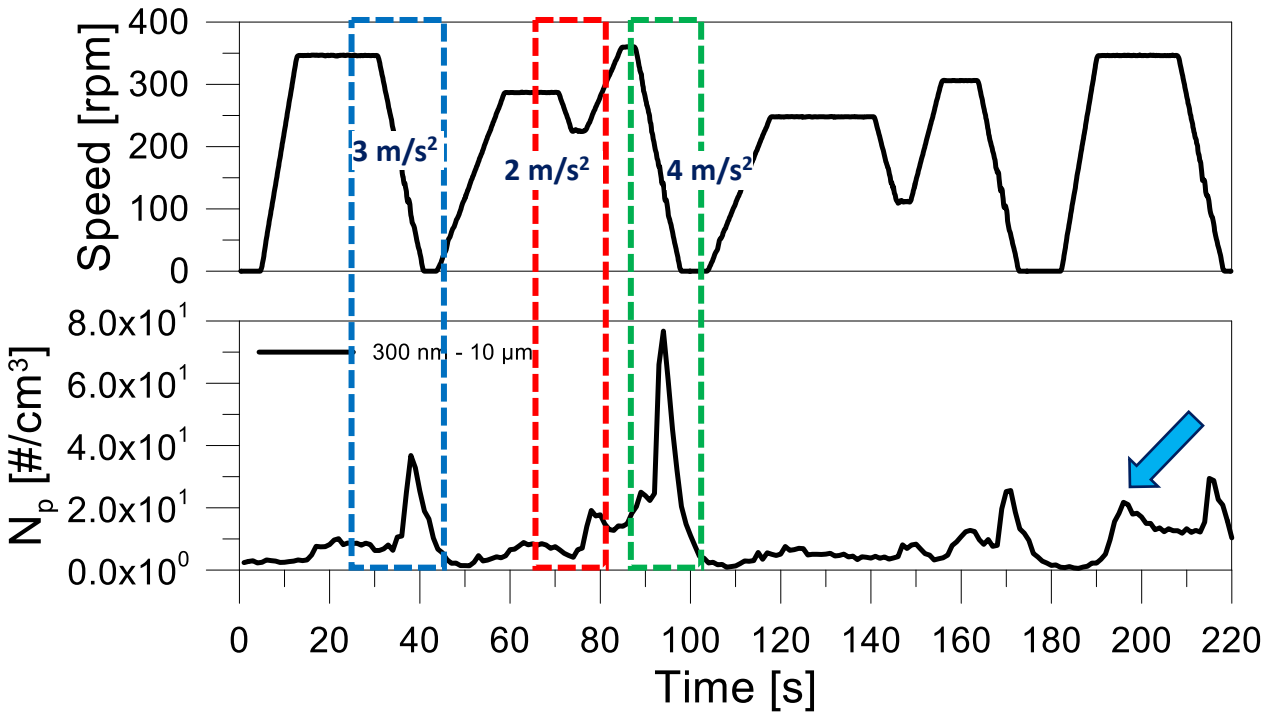


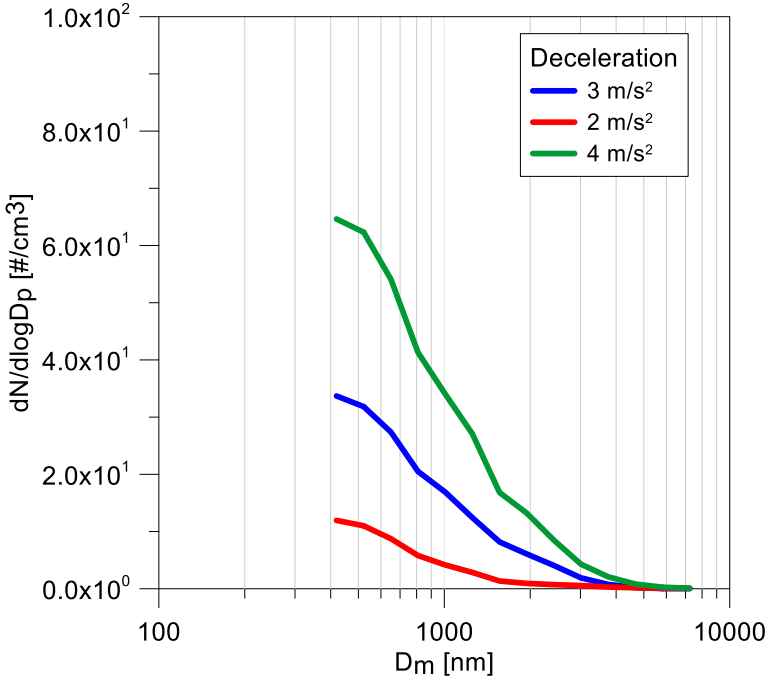


EXPERIMENTAL RESULTS: EFFECT OF BRAKING PROFILE

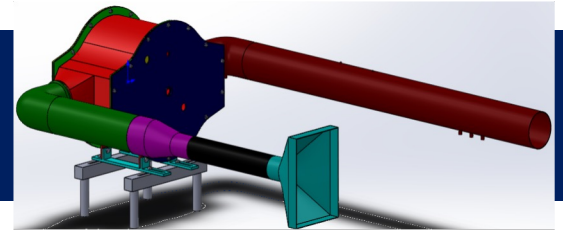


- WLTC section profile: the concentration of the smaller size range, 6 - 300 nm, particles is lower than the low limit of the spectrometer.
- Peak particles are detected in correspondence of braking events.
- Particle peaks also appear when the pad and disk disengage because of the release of particles partially held on the pads-disk interface.
- The particles show a unimodal behavior centered around 300 nm whatever the deceleration.
- The number concentration increases with the deceleration: particles are mainly due to the mechanic abrasion of the components of the pad.

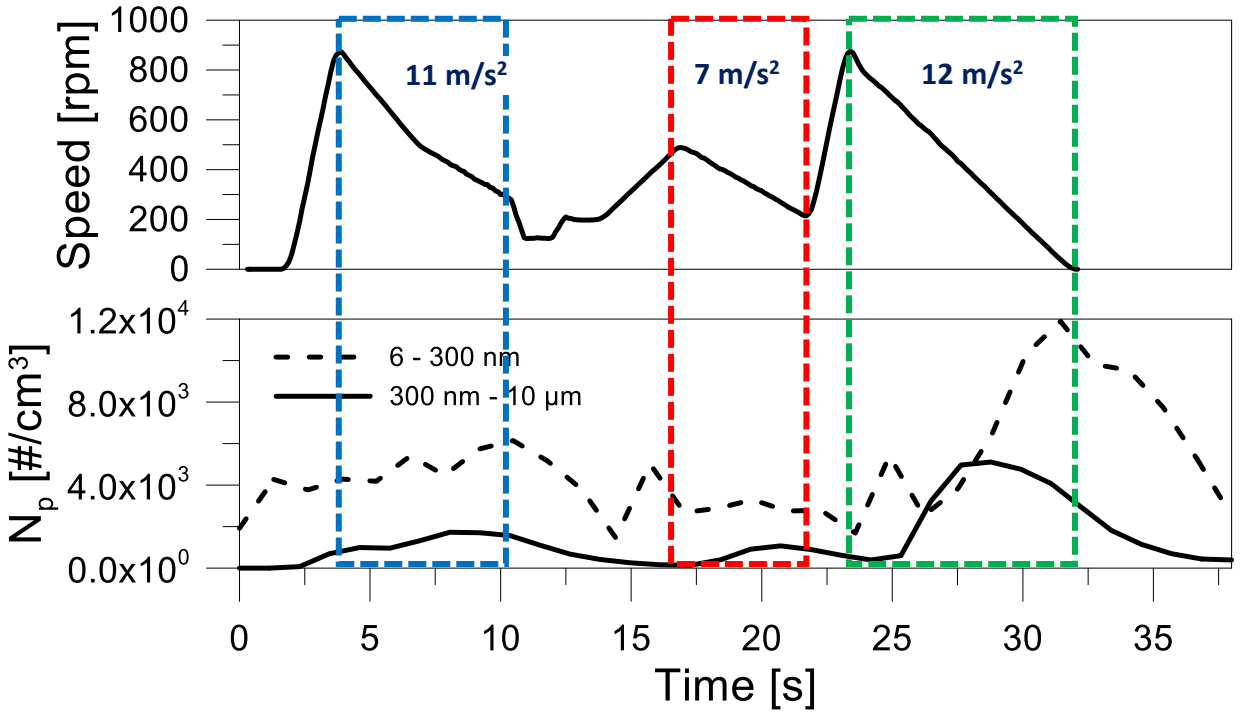


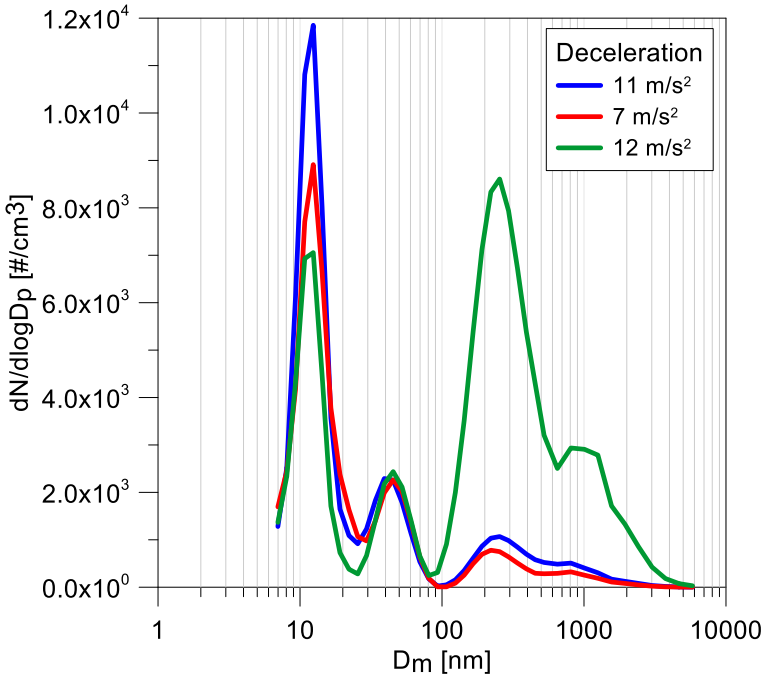


EXPERIMENTAL RESULTS: EFFECT OF BRAKING PROFILE

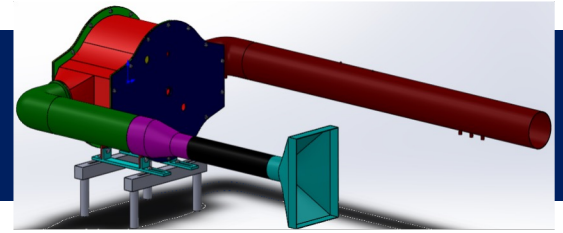


- STRONG profile: emission of particles of about three orders of magnitude higher with respect to the previous case
- The emission of the particles in the size range 6 - 300 nm, represents about 80% of the total emission.
- Particles range between 6 and 3000 nm. PSDs exhibit trimodal size distribution peaked at 10, 200 and 1000 nm.
- With the change of deceleration intensity, the peak values of number concentrations vary significantly but the peak diameters remained relatively stable.
- For the high deceleration, the PSD shows a strong accumulation ascribable to the higher load applied to the bake resulting in a larger friction and a stronger abrasion of the pads.

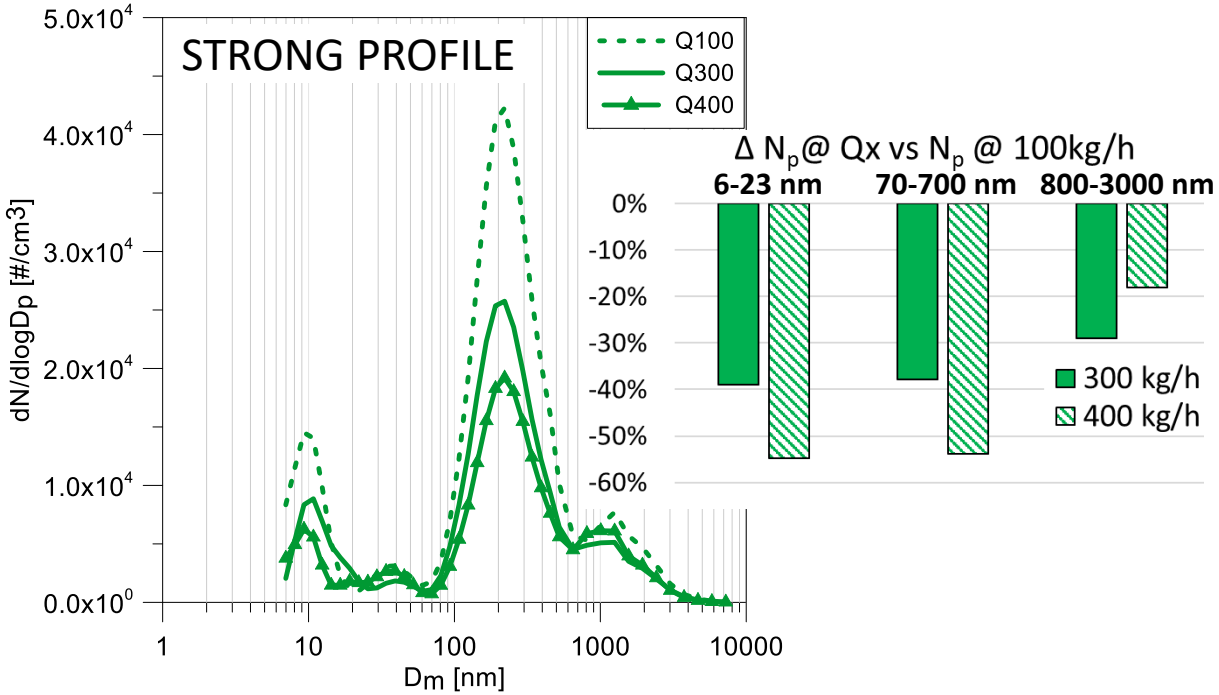




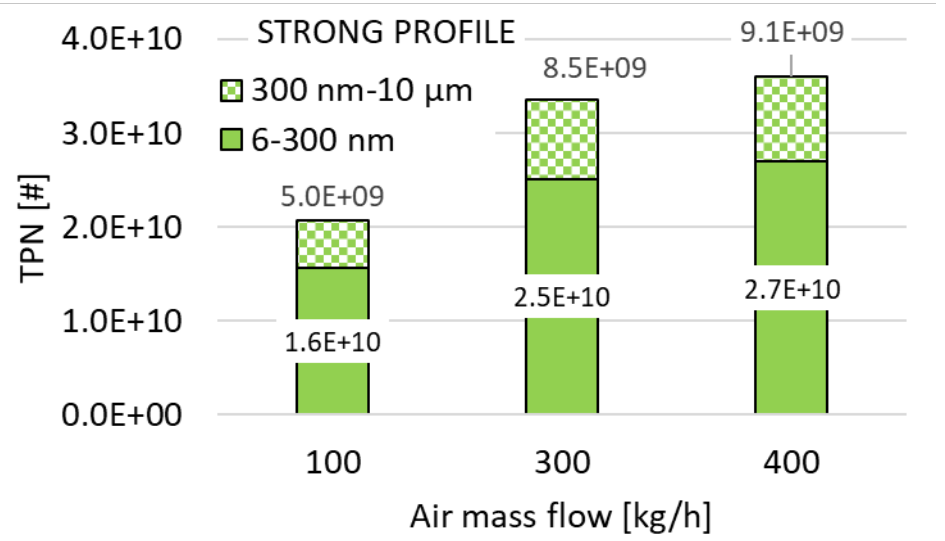
EXPERIMENTAL RESULTS: EFFECT OF AIR MASS FLOW RATE



- The inlet air mass flow does not affect the trimodal behavior of the PSDs.
- The particle concentration decreases with the increase of air mass flow rate due to the dilution effect.
- The influence of the inlet mass flow on the particle measure varies with the particle size.
- Another aspect to consider is the losses of particles that can impact towards the box walls.
- The extent of the effect of the mass flow rate is stronger moving from low to medium mass flow rate. At lower mass flow rate, the particles are not efficiently transported.



$$TPN\ [\#] = N_p \left[\frac{\#}{cm^3}\right] Q \left[\frac{cm^3}{s}\right] T\ [s]$$



CONCLUSIONS

This study focused on the particle emissions due to the brake wear.
A proper system for the sampling and measure of the particles emitted by a brake for light duty application was designed to carry out laboratory experiments.
Following the main results:

- The wear brake particles concentration increases with the disk temperature.
- Higher the deceleration intensity, higher the particle emissions. It is particularly evident for the smaller size particles.
- The PSDs due to the brake wear have a unimodal or trimodal shape depending on the intensity of the brake event.
- An ascending trend of the particle number with the air mass flow rate was observed suggesting that at low flow the particles are not efficiently transported.

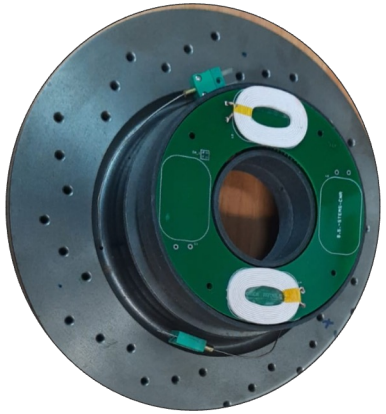
A comprehensive characterization of wear brake particles is crucial to identify the mechanisms of formation of these particles and to develop strategies to mitigate their emission.

Improvement of the brake system material formulation and design

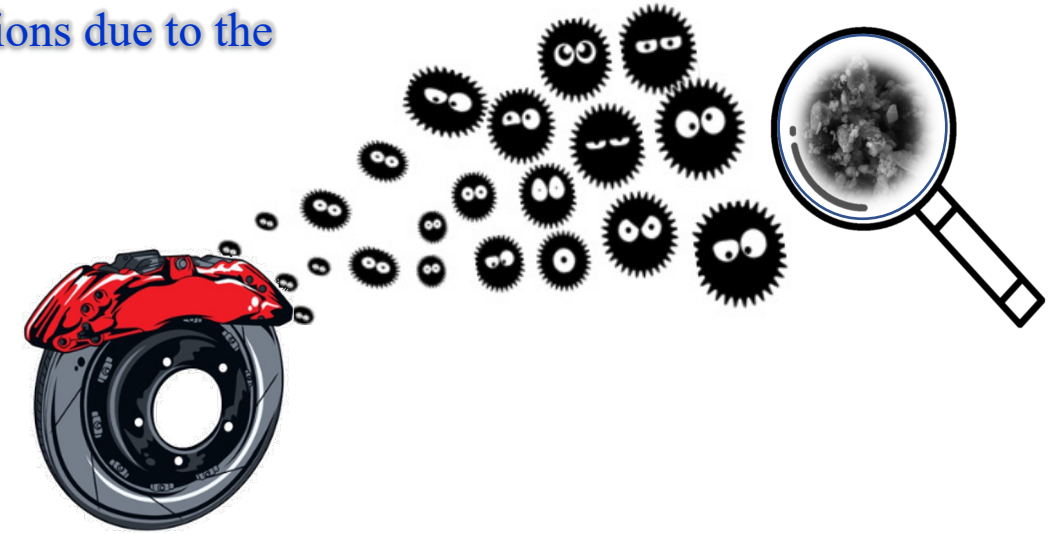
Optimization of the braking profiles through proper control systems to reduce the release of these particles.

NEXT STEPS

Development of a system for a more accurate temperature detection of the disk surface under test in closed system configuration



Measurements aimed to discriminate the nature and the morphology of the particle emissions due to the brake wear.



Consiglio Nazionale delle Ricerche

Agnese Magno
Researcher

Institute of Science and Technology
for Sustainable Energy and Mobility (STEMS) - CNR
agnese.magno@stems.cnr.it

Thanks for your attention