AVL List GmbH (Headquarters)

Particle emissions from different types of brake pads – PM results

Mamakos A., Arndt M. (AVL)

Augsburg K., Hesse D. & Wenzel F. (TUI)

Experimental - Setup

Campaign results on Particle Number (PN) emissions have been presented during last PMP meeting

Presentation covers some of Particulate Mass (PM) results

Instruments used:

- AVL PM PEMS for collecting filter samples and additional time-resolved bC measurement (light absorption / photoacoustic)
- Filter conditioning and handling according to UNECE R83 (TX40)
- While no pre-cut was used, the setup is designed for 2.5 µm measurements, so results should be considered as indicative of PM2.5

AVL PM-PEMS

Tunnel flow 800m³/h
for all tests

Sample point

TSI 3708
4-way splitter

Other instruments
for some tests

Experimental – Brake pads tested

Three different types of commercial brake pads were tested. Two of them were series-production pads from European market (ECE) and one was of non-asbestos organic (NAO) type (US market). One of the ECE pads had no copper in its formulation. They will be abbreviated herewith as:

- NAO
- ECE
- ECE Cufree

Dyno setting: Left front wheel of an entry-level luxury car

- Inertia: 60.4 kgm^2
- Effective radius: 126 mm
- Rotor size: 278 mm

Experimental - Test procedure

Test cycles:

- WLTC
- AK-master μ-green sequence: 18 × [80 to 30 km/h] [30 bar] [start at 100°C]
- AK-master fade sequence: 15 × [100 to 0 km/h] [40%g] [100-550°C]
- AK-master pressure row:
  - 8 × [40 to 5 km/h] [10 to 80 bar] [start at 100°C]
  - 8 × [120 to 80 km/h] [10 to 80 bar] [start at 100°C]
  - 8 × [200 to 170 km/h] [10 to 80 bar] [start at 100°C]

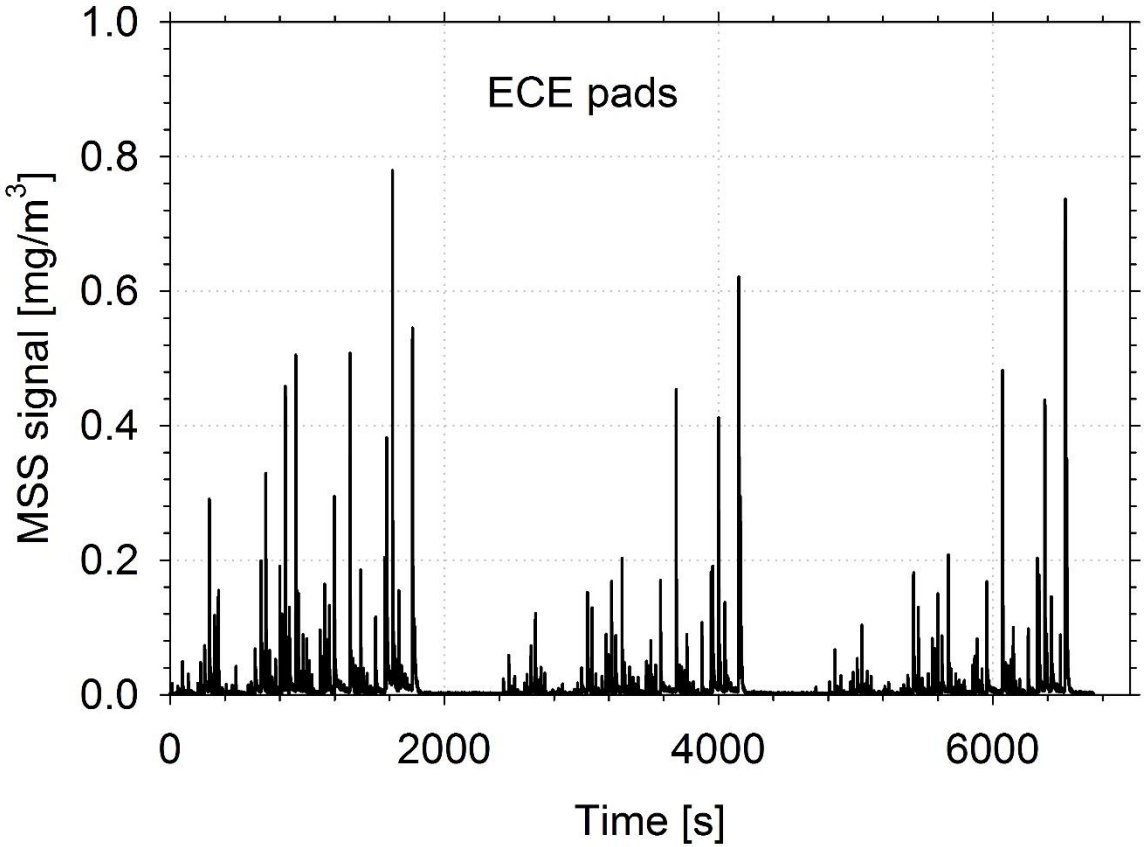
All pads were first conditioned with a μ-green.

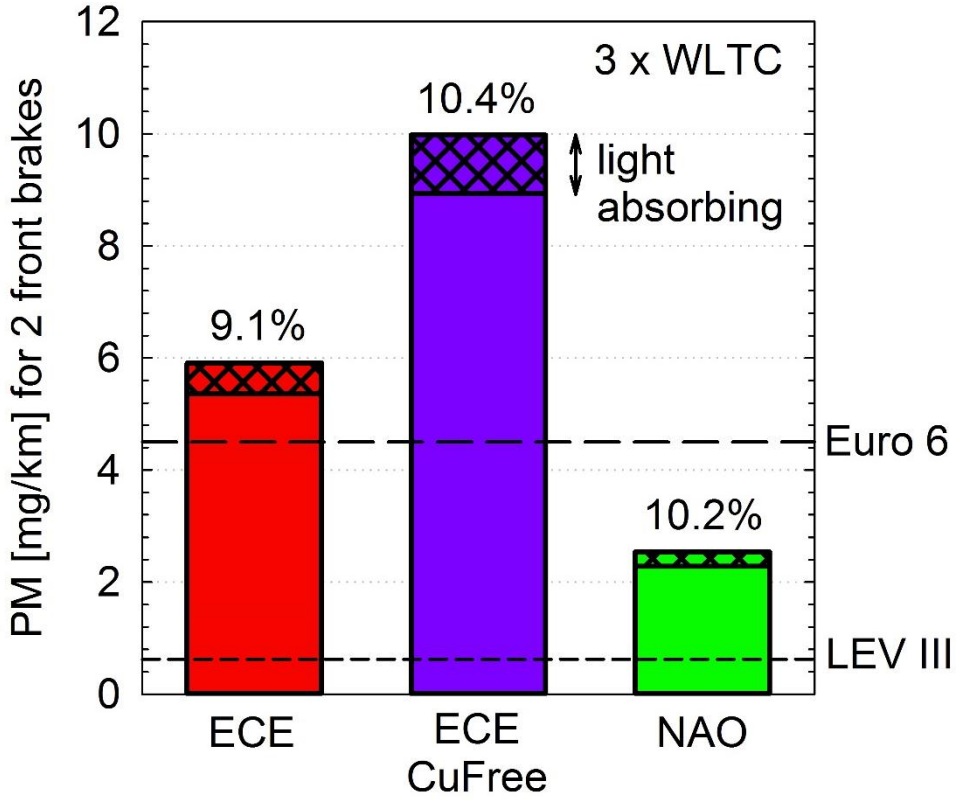
Repeated tests for each of the above cycles were performed to collect more mass on the filter.

AK master fade sequence was performed at the end.

Focus was on chemical analysis and not that much on repeatability.

PM results - WLTC

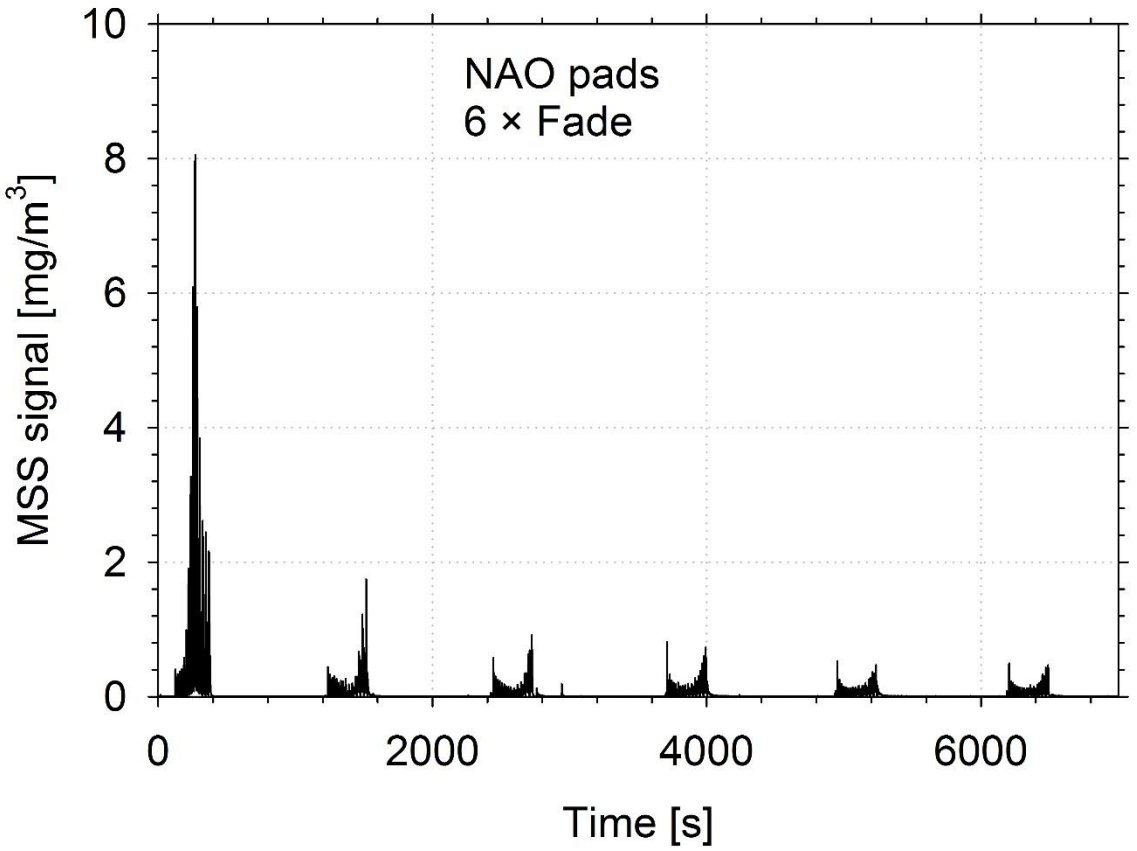


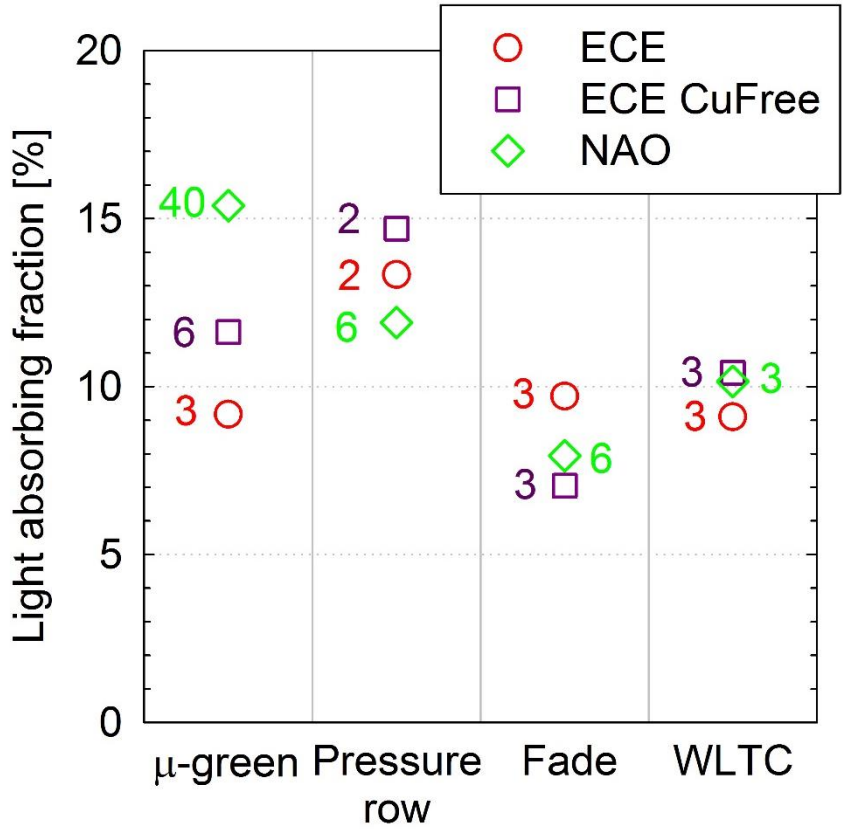


Large differences in PM emissions between pads.

Fraction of light absorbing species was very similar though for the WLTC tests: 9.1% for ECE, 10.4% for ECE CuFree and 10.2% for NAO.

Light absorbing fraction of PM



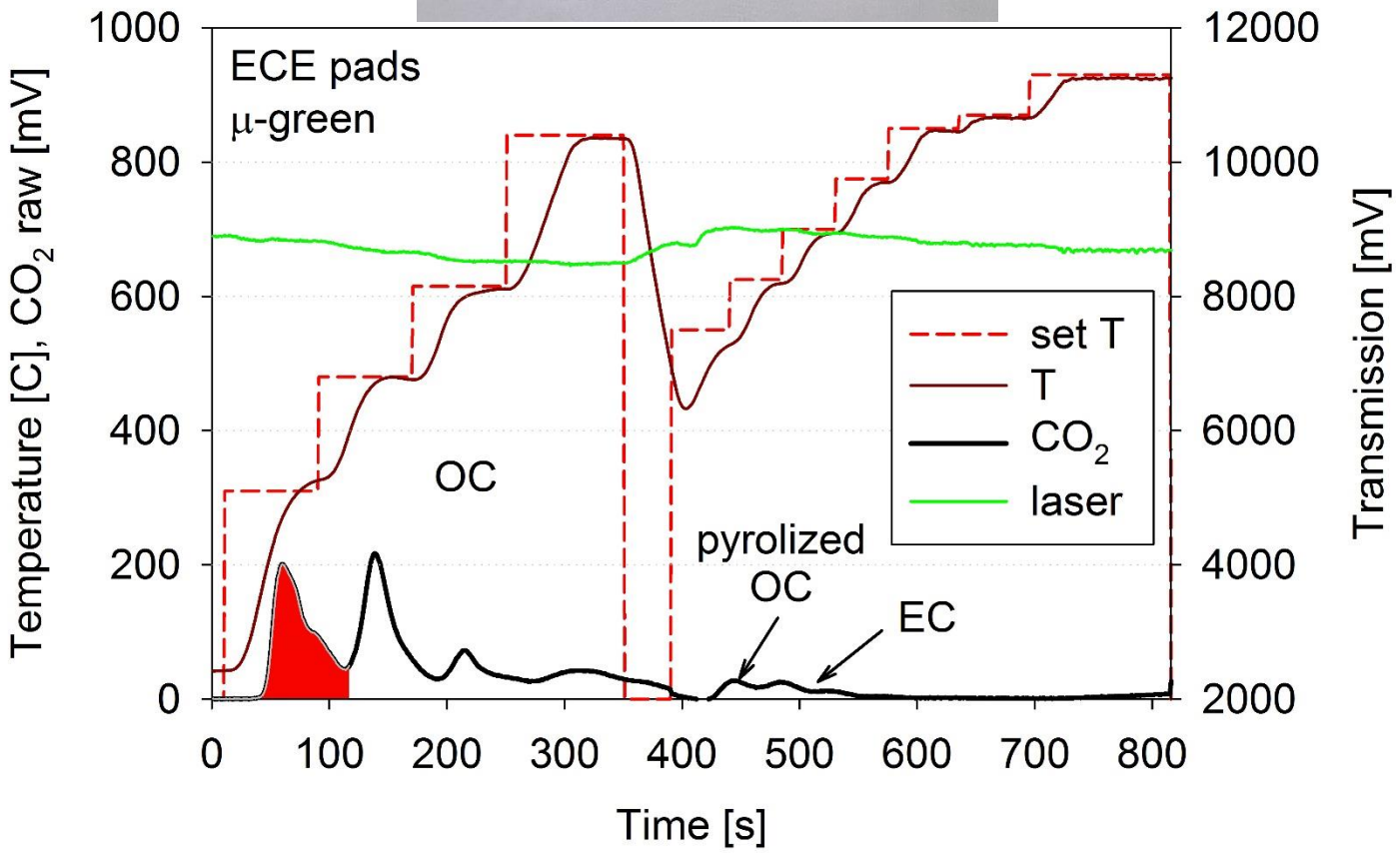


Emissions were not so stable during the AK-master sections, and the use of different number of repetitions could have some effect since it is possible that the chemistry of particle changes.

Nevertheless, under all operating conditions, the light absorbing fraction of PM was found to range between 7 and 15%.

Chemical Properties of Brake Dust OC/EC

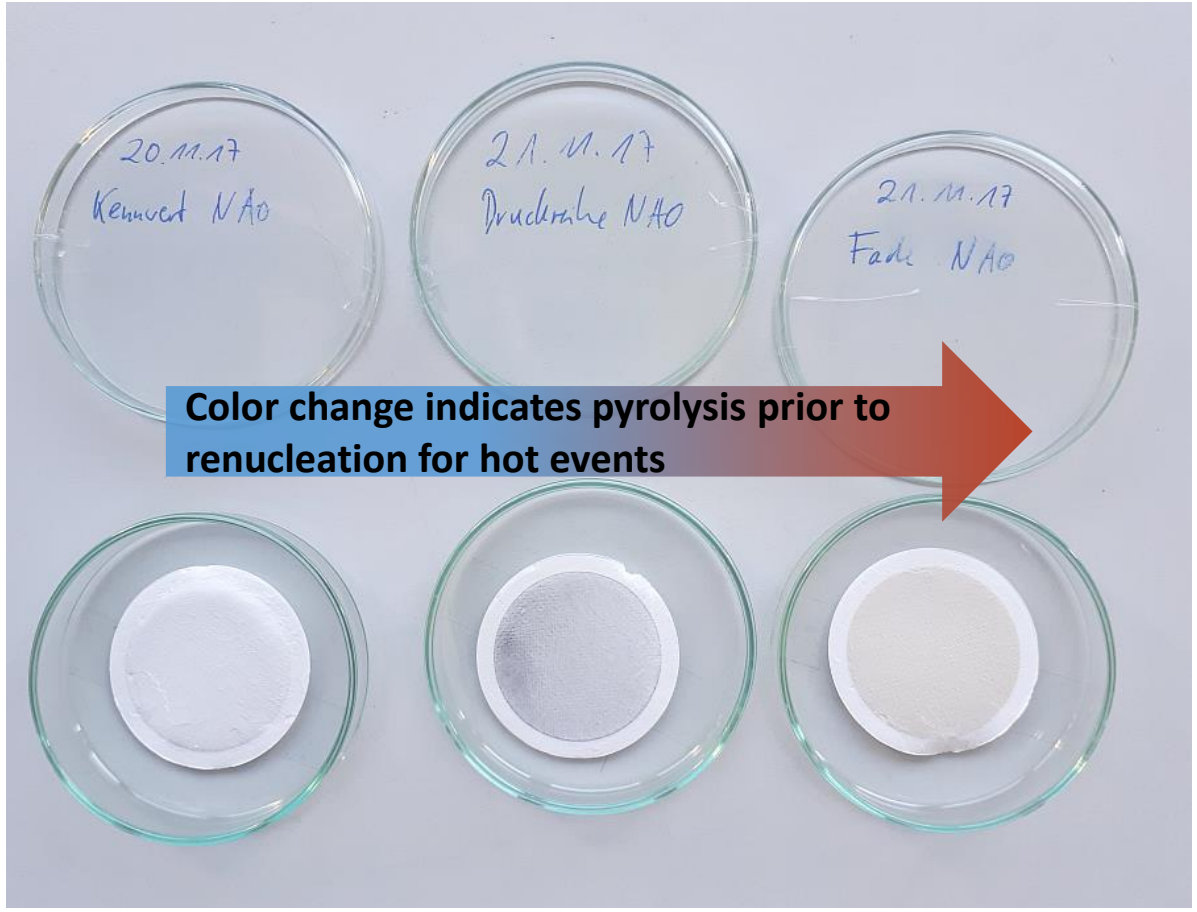
- Analysis of the EC/OC thermograms is complicated due to large background metal content as evident from the filter colour change (FE/Cu oxides). This colour change could also affect laser transmission that is based on visible red light.
- The only safe conclusion we could reach is that for all pads and conditions tested, the majority of carbonaceous compounds seems to be volatile.
- A large fraction of OC is released at temperatures below 400 C.



The plotted laser transmission is the raw signal not corrected for temperature

Chemical Properties of Brake Dust

- Filter samples collected and analyzed with different approaches
- ICP-OES for ions (metals and others)
- OC/EC for elemental and organic carbon
- GC-MS for organic compounds
- Chemical composition for different pressure / temperature events



Conclusions

- Employed exhaust regulation PM procedures were successfully employed but rather capture the PM2.5 fraction. More work is needed to properly quantify PM10.
- PM2.5 emissions are relatively high (compared to current and exhaust PM standards) even under moderate conditions (WLTC).
- Real time measurement of the light absorbing fraction of PM yielded useful insights on the stability of the PM emissions. The light absorbing fraction of PM was found to range within 7 to 15% for all pads and braking events considered.
- Analysis of EC/OC thermograms was not successful as of yet due to the complex PM matrix. More research is needed to establish proper EC/OC procedures for brake dust.
- The carbonaceous fraction of PM was dominated by OC, a large fraction of which was released at temperature lower than 400°C for all pads and conditions tested.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