Characterization of Brake Wear Particles: Influence of Pad Material and Braking Conditions of Particle Charging State

S. BENGTSDOTTER[1], J. HOIVALA[2], Y. LYU[3], V. MALMBORG[1], P. WACKER[1], T. RÖNKKÖ[2], J. WAHLSTRÖM[3], J. PAGELS[1]

[1]Ergonomics And Aerosol Technology, LTH, Lund University, Lund, Sweden, [2]Aerosol Physics Laboratory, Physics Unit, Tampere University, [3]Machine Elements, LTH, Lund University, Lund, Sweden

Summary

We studied the electrical properties of brake wear particles (BWP) generated from a pin-on-disc tribometer (PoD) using two different pad materials, non-asbestos organic (NAO) and low-metallic (LM), towards a gray cast iron disc [1]. Two breaking conditions, “mild” and “harsh”, were studied by varying the disc speed and the pressure between the pin and the disc.

→ Preliminary results show that BWP particles are heavily charged, and that pad material and braking condition influence the net polarity and number of charges per particle

→ Knowing the charging state of BWP can help predict their deposition onto surfaces (including the human lung) [2] and aid in development of emission control technologies.

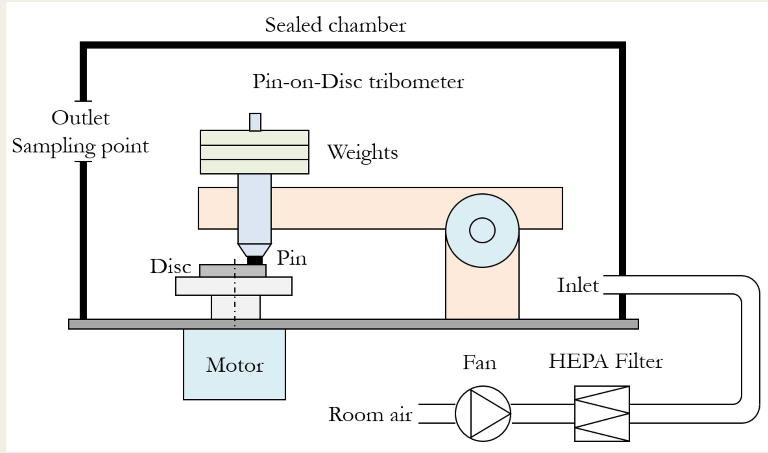


Figure 1: Pin-on-disc tribometer

Net current though the aerosol sample

METHOD: We measured the aerosol current with an electrometer.

RESULTS: The electrometer shows a net negative current for both materials during mild braking conditions. During harsh breaking conditions (Figure 1) there is a significant negative ”dip” for all materials during the ”running in” phase, correlating well with the peak in particle number associated with the running in phase. During ”steady state” conditions, the net current though the aerosol is negative for the LM pad material and positive for the NAO pad material. A net negative current indicates either a higher number of negatively charged particles or that negatively charged particles generally has a higher number of charges per particle compared to positively charged particles.

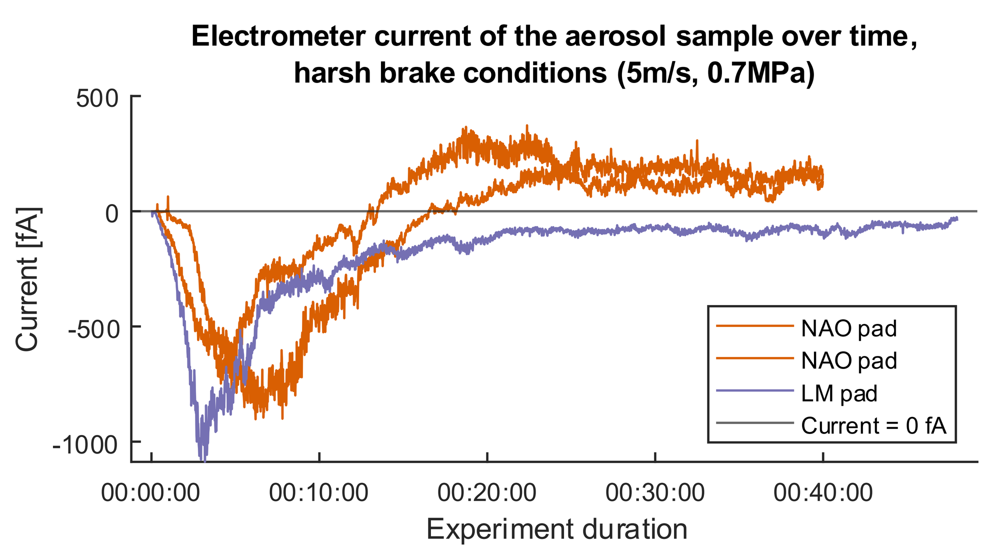
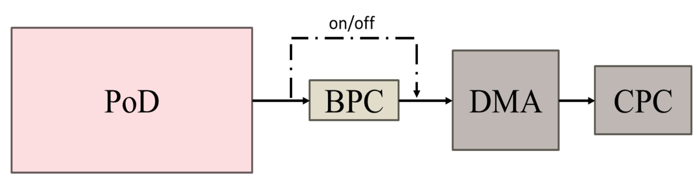


Figure 2: Aerosol current over time.

Charges per particle from distribution peaks



METHOD: We used a SMPS system with the bipolar charger (BPC) on and off, to scan the electrical mobility diameter distribution of singly charged particles (BPC on) and with the natural charging state retained (BPC off).

RESULTS: The size distribution varies significantly when measuring with and without the BPC (Figure 2), meaning that without the BPC, larger particles appear smaller due to an excess of charges. By converting the measured peak mobility diameters to electrical mobility (Z), the average number of charges per particle can be approximated to be ~28 for the example plot shown below (LM mild, negative particles).

$$\frac{n_{bpc\,off}}{n_{bpc\,on\,(=1)}} = \frac{Z_{bpc\,off}}{Z_{bpc\,on}}$$

	BPC off	BPC on
mode [nm]	~60	~510
Z [$m^2 V^{-1} s^{-1}$]	~6.8· 10^{-9}	~2.4· 10^{-8}

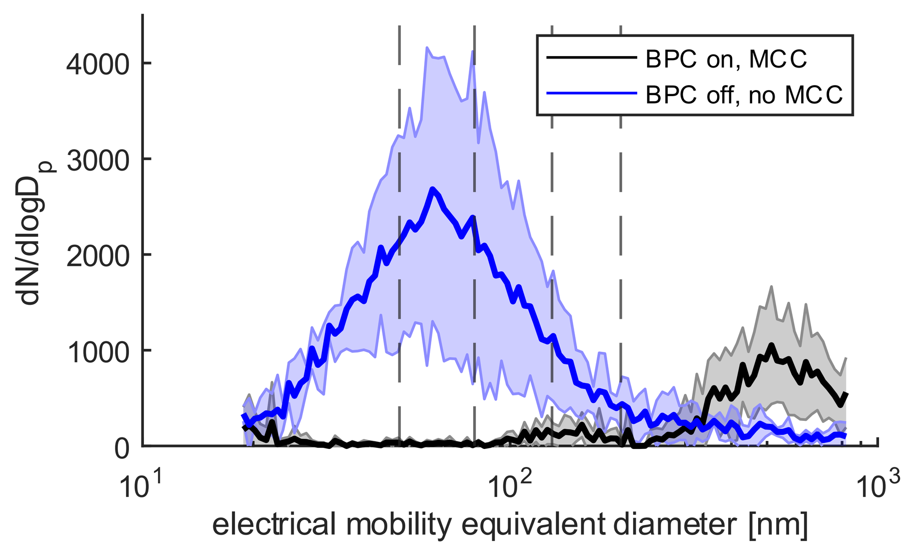
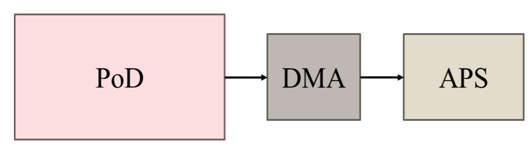


Figure 3: SMPS size distribution of negatively charged particles (LM, mild conditions) with the bipolar charger turned on and off. Vertical lines indicate the particle diameters: 50, 80, 130 and 200 nm.

Charges per particle vs electrical mobility diameter

METHOD: We used a DMA to select BWP particles (BPC off) with electrical mobility corresponding to diameters of 50, 80 130 and 200 nm, which were then scanned with an APS to determine the aerodynamic equivalent diameter.



RESULTS: Preliminary results indicate that particles <1000 nm have a high electrical mobility due to electrical charge, making them appear smaller in the DMA. The aerodynamic geometric diameter increases slightly with decreasing electrical mobility. These results support that particles are highly charged and suggest that the number of charges per particle increase with decreasing electrical mobility diameter.

DMA size [nm]	Z [$m^2 V^{-1} s^{-1}$]	APS Geo. Mean [nm]	Std [nm]
50	0.93 · 10^{-7}	1550	27
80	0.39 · 10^{-7}	1480	43
130	0.17 · 10^{-7}	1410	25
200	0.08 · 10^{-7}	1400	25
no DMA	-	1480	38

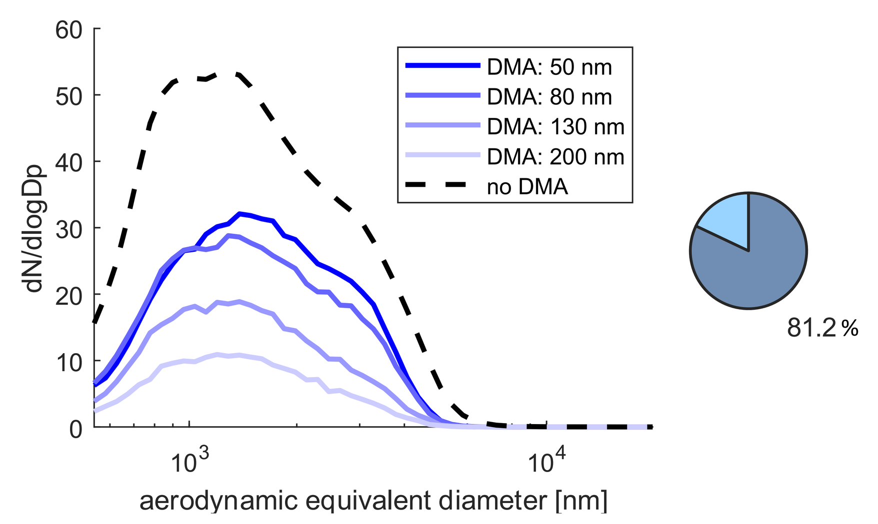


Figure 4: Aerodynamic particle size distribution of negatively charged particles (LM, mild conditions) selected with the DMA (no BPC). The mean APS size distribution for the same material and condition is shown for comparison (black, dashed line), and the percentage of particles detected with an APS (dark blue) compared to a CPC is shown in the pie chart show.

References

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[2] Thomas, A. E., Bauer, P. S., Dam, M., Perraud, V., Wingen, L. M., & Smith, J. N. (2024). Automotive braking is a source of highly charged aerosol particles. Proceedings of the National Academy of Sciences, 121(13), e2313897121.

Contact

Sara Bengtsdotter, Division of Ergonomics and Aerosol Technology, Department of design sciences, LTH. sara.bengtsdotter@deisgn.lth.se.

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