Blowing in the Wind - On the Formation and Physical Properties of Wear Particles We Breathe

Ulf Olofsson[1],

[1]Department of Machine Design, KTH Royal Institute of Technology, SE 100 44 Stockholm Sweden

INTRODUCTION: Emissions are a drawback of road transport. Particles generated by traffic originate not only from the engine exhaust emissions, but also from wear processes occurring in brakes and between tires and the road surface. During the wear process, the contacting bodies generate airborne particles. These particles can penetrate the human body in many ways, including contact with the skin, when breathing, and when eating with potential adverse health effects[1]. Particles smaller than 10 µm in diameter can enter the human body, and the smaller the particle size, the deeper the particle can penetrate. Concentration of particulate matter (PM) continued to exceed the EU limit and target value in large parts of Europe in 2014, for which a total of 16 % of the EU urban population was exposed to PM_{10} (PM fraction consisting of particles with aerodynamic diameter smaller than 10 µm) levels above the daily limit value[2]. Whilst exhaust gases from road transport are monitored and regulated by European legislation, lower concern has been regarded to PM originating from the wear processes. The wear particles generated from the transport sector altogether sum up to 50% by mass of the total ones[3,4], and its relative contribution is expected to increase due to the legislation driven reduction of aerosols from vehicle combustion processes[5]. To get an idea of the importance of the wear generated aerosols, just consider that if emissions from disc brake systems were reduced by 67 wt%, on vehicles circulating in Europe, this would reduce the overall PM_{10} emissions from road traffic by 6–20%[6].

Recent laboratory studies on wear generated particles from disc brake contacts are summarized here.

METHODS: The wear particles were generated by a pin-on-disc machine. The equipment's was in a sealed (clean room) chamber and subsequently analysed using various techniques. The properties investigated include diameter, elemental composition, density, morphology, porosity and volatile fraction. The influence of contact temperature contact pressure and sliding velocity on these properties was systematically investigated.

RESULTS: The data in Figure 1, illustrates a temperature transition for disc brake materials, at which the concentration of the number of particles increase drastically. This temperature transitions, is controlled by effects of contact pressure and sliding velocity[8]. Examples from morphology studies of particles are presented in Figure 2 and illustrate particles of different shape[9]. Most particles have an elongated shape with a breadth-to-length aspect ratio of 0.7. Particle porosity was determined by milling particles with a focused ion beam[9]. Particles with porosity above 20 % were detected using this technique. The presence and number fractions of 1.3−10 nm particles were investigated using an nCN technique[9]. For a disc brake test pair, the presence of particles down to 1.3 nm were noticed. The generation of these particles started at a lower temperature, compared to the previous noticed temperature transition illustrated in Figure 1. On the other end of the scale, airborne wear particles up 32 µm in size have been measured. As for exhaust emissions, part of the wear emissions can be in the volatile fraction. For this reason, a sampling instrument, containing a heated sampling set up was used. The results show a decrease of several decades in the number concentration with a heated sampling line, both for disc brake materials as well as studded tire to road contacts. Also like the exhaust emissions soot particles (black carbon) are present in the emissions from disc brakes and so far measured up to 10 % levels of the total particle mass in the PM2.5 level. Studies of the airborne particles effective density reveals an effective density that is roughly one third of the material density[10]. This difference is due to the porosity and the morphology of the airborne wear particles.

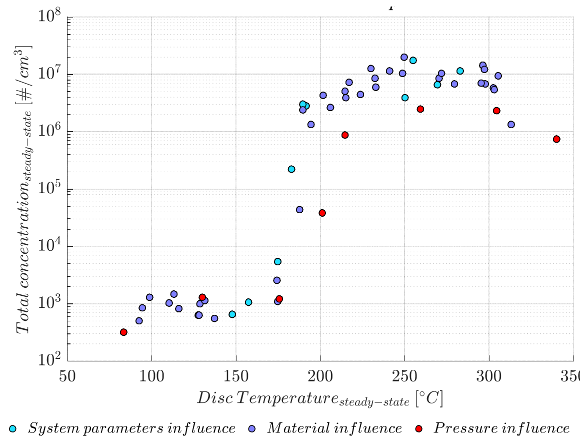

Figure 1 - Transition temperature for different testing conditions[8]

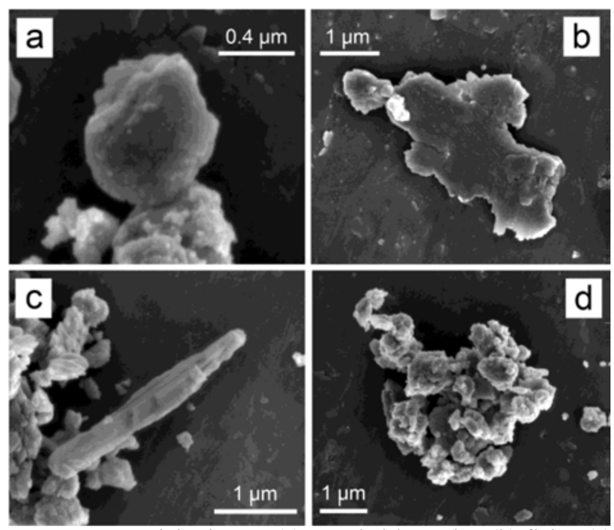

Figure 2 – Particle shapes: (a) rounded / angular; (b) flaky; (c) acicular; (d) agglomerated[9]

DISCUSSION: Just like the more well investigated exhaust emissions, the wear generated aerosols contains nano-sized fractions, but in addition also larger size fractions. The effective density is at the same level that has been previously reported from measurements of street canyons. The volatile part is present for the nano-sized wear particles, but the elemental content of this fraction is not well known. Here, further research is necessary.

REFERENCES: 1.Gasser, *Partic. Fibre Toxicol.* (2009), 2. Indicator CSI 004, European Environment Agency (2016), 3. Grigoratos, *Environ Sci. Pollut. Res*. (2015).4. Larssen, Technical Paper 2009/12, European Topic Centre on Air and Climate Change, 5. European Commission. Directive 2008/50/EC on ambient air quality and cleaner air for Europe. *Off J Eur Union* 2008; L152, 6. Olofsson, J. Tribology (2009), 7. Perricone *WEAR* (2017), 8. Alemani, PhD thesis KTH Sweden (2017), 9. Nosko, *J Aerosol Sci*, (2017), 10. Nosko, *Aerosol Techn* (2017)