ULTRA-FINE PARTICLES FROM TYRE AND PAVEMENT INTERACTION

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ABSTRACT

The ultra-fine airborne particles (particles less than 100 nm) in the ambient air are generally originating from combustion processes and atmospheric reactions. During road wear studies on a road simulator, studded winter tyres were identified to generate considerable amounts of ultra-fine particles. At the Swedish National Road and Transport Research Institute (VTI) a road simulator (PVM) was used to study the characteristics of wear particles. Apart from the expected wear particle size ranges (>1 μm), an ultra-fine (<100 nm) fraction with a number maximum around 20–40 nm was found for studded tyres. No ultra-fine particle emission was detected from friction or summer tires. The composition of the emitted particles is assumed to be winter tyre fillers and softening oils, which differ from summer tyres. For a given tyre the velocity and thereby the tyre temperature was the most significant parameter that affected the amount of generated particles.

1. INTRODUCTION

Wear particles from road pavements, tyres, brakes and road maintenance strongly contribute high concentrations of inhalable particles in many road and street environments (Luhana et al., 2004). In Sweden, these episodes normally occur during dry periods in winter and spring and is mainly caused by road wear from the use of studded tyres and winter gritting (Kupiainen et al., 2003). Wear particles from pavement wear normally range from 1 μm and coarser (Dahl et al., 2006). Tyre wear particles are in some references referred to as bimodal, with a coarse fraction > 7 μm and a fine fraction < 100 nm (Fauser, 1999).

The characteristics, formation processes, emissions and health effects of wear particles are currently a research issue since relatively little is known and the spatial and temporal differences seem considerable. Numerous studies have shown that the concentration of inhalable particles (PM_{10}) in ambient air is associated with mortality and different kinds of respiratory health problems in the population (Schwartz et al. 1996; Schlesinger 2000). Meta analyses indicate that coarser fractions of PM_{10} seem stronger related to respiratory disease while the finer fractions tend to be stronger related to cardiovascular disease and mortality (Brunekreef and Forsberg, 2005). However, the mechanisms and properties that make particles more or less toxic are poorly understood.

In this study a road simulator has been used to study and sample wear particles from pavement and tyre wear without the influence from other ambient particles (exhaust particles, pollen, fibres etc.). Previous studies in the road simulator (Dahl et al., 2006) showed that except for mineral PM_{10} particles, also ultra-fine particles formed during wear tests. These particles are thought to originate from the tyres, why new experiments have been conducted to try to confirm these findings.

2. METHODOLOGY

At the Swedish National Road and Transport Research Institute (VTI) a circular road simulator was used to generate wear particles (Figure 1). Particle sampling in the simulator hall makes it possible to sample pure wear particles, with very low contamination from ambient particles. In the experiments, sub-micron particles from tyre wear of three tyre types (summer, friction and studded) on a typically durable pavement (stone mastic asphalt with quartzite and maximum stone size 16 mm) were studied. The particle generation is described in the paper by Gustafsson et al. (2007:1) in the current proceedings. Coarser particle fractions are described in Gustafsson et al. (2007:2). Size distributions from 10 - 500 nm were studied using SMPS (scanning mobility particle sizer).

Figure 1. The VTI circular road simulator.

Figure 2. Tested tyre types. From left to right: summer, friction (non-studded winter) and studded tyres.

3. RESULTS AND DISCUSSION

Time series for number concentration of particles from the three different tyres are shown in Figure 3. While summer and friction tyres result in very low concentrations, the studded tyres cause formation of ten of thousands ultra-fine particles per cm^{-3}. Number size distributions for summer, friction and studded tyres are shown in Figure 4. The results show a very obvious peak of ultra-fine particles during the studded tyre test. At all speeds a number concentration peak appears at about 20–50 nm. The number concentration increases with speed. On the contrary neither friction nor summer tyres seem to produce this particle mode. The mode around 100 nm probably consists of background particles. For this mode number concentration is reduced with increasing speed for friction and summer tyres, indicating turbulence induced dilution and deposition.

Since pavement and environmental conditions for all tests are equal it seems very likely that the ultra-fine mode originates in the studded tyres. Their heterogeneous morphology (Figure 5) indicate that they originate both from thermal degradation of carbon reinforcing filler material (soot agglomerates) and the volatilisation of softening oils in the ultra-fine mode.

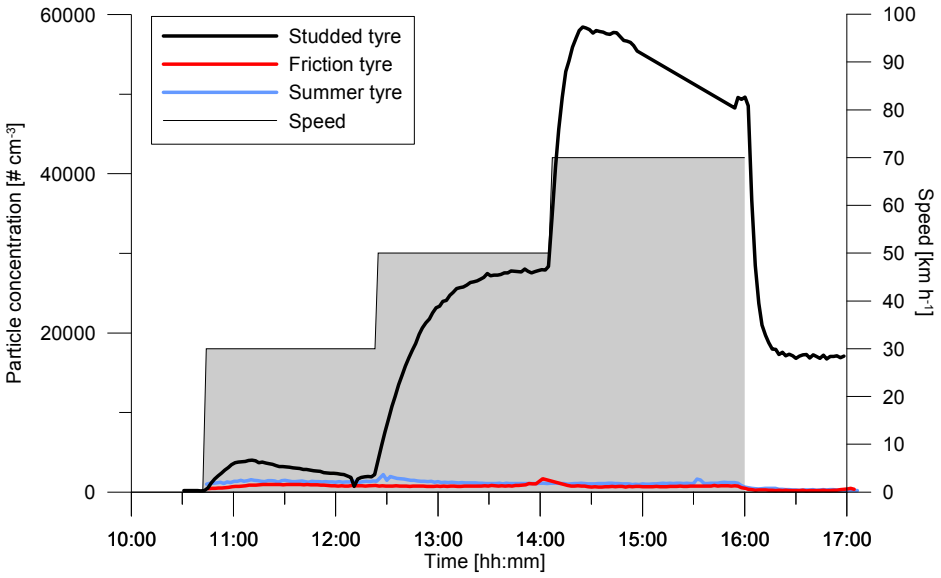

Figure 3. Time series of particle number concentration of particles measured by SMPS system caused by summer, friction and studded tyres at three different speeds.

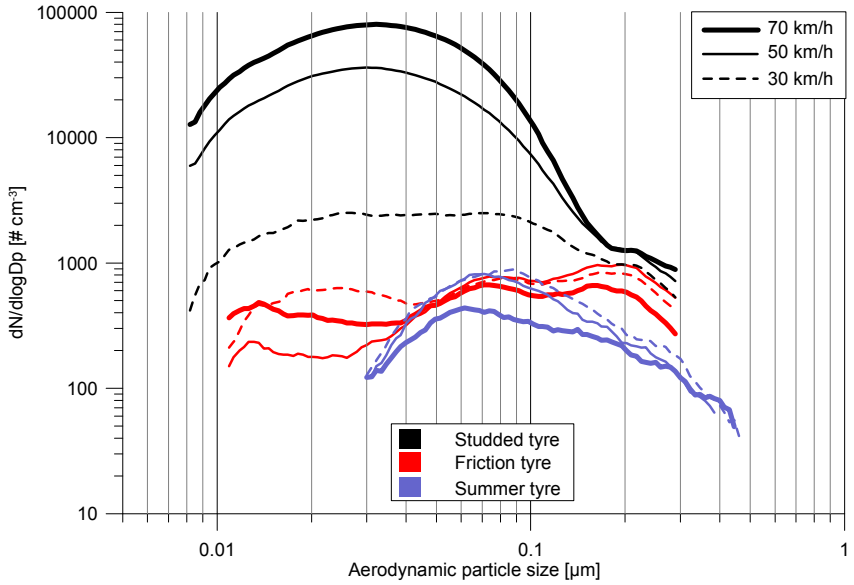

Figure 4. Number size distributions of particles measured by SMPS system caused by summer, friction and studded tyres at three different speeds.

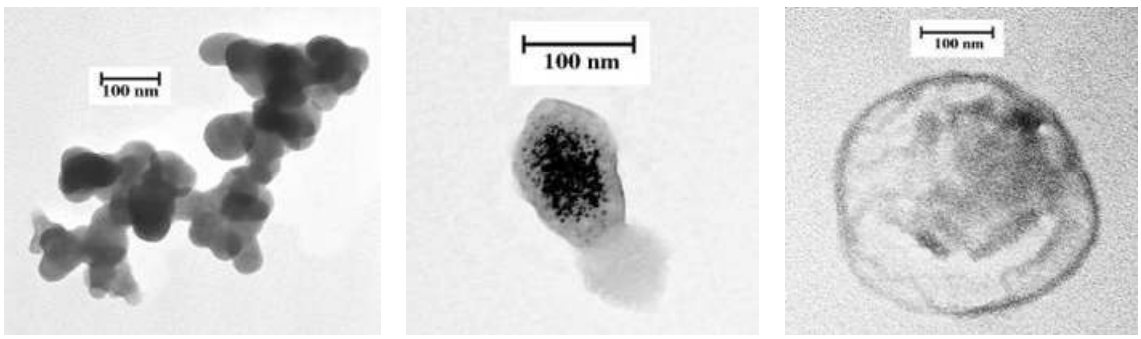

Figure 5. Sub-micron particles formed during wear between studded tyres and pavement. TEM micrographs from Dahl et al. (2006).

Differences in tyre rubber composition are a probable cause to the differences in formation of ultra-fine particles. Winter tyres have softer rubber composition to stay soft during cold weather conditions. Friction tyres are have softer rubber mixes than studded tyres. Summer tyres on the contrary become very hard during cold conditions and instead have rubber composition adjusted to give good friction in higher temperatures. Also the thread patterns differ (Figure 2). Winter tyres have sipes to increase friction on snow, while summer tyres lack sipes. Sipes might both produce particles due to increased tyre surface friction but also act as a sink for particles due to the increased surface.

4. CONCLUSIONS

- Ultra-fine particles form from studded tyre wear of pavement, but does not seem to form from summer and friction tyre wear.
- The origin is likely to be reinforcing filler and volatilisation of softening oils.

5. ACKNOWLEDGEMENTS

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