DfT Brake & Tyre Programme Phase 2: Impact of Regenerative Braking and Vehicle Mass on Brake Particle Emissions Across ICE, PHEV & EV Platforms

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Brake and tyre wear are now major contributors to non-exhaust particulate emissions, including PM10, PM2.5, and PN10, which are increasingly relevant for air quality and Euro 7 regulations. This study, part of the UK Department for Transport's Brake and Tyre Programme Phase 2, investigates the influence of regenerative braking and vehicle mass on brake particle emissions from internal combustion engine (ICE), plug-in hybrid (PHEV), and battery electric vehicles (EV). Using a controlled chassis dynamometer environment and common brake hardware across vehicles, emissions were measured under representative drive cycles (PG42 and RDE) at test masses ranging from 1500 kg to 1900 kg. Results show that regenerative braking significantly reduces PM2.5 and PM10 emissions compared to friction-only braking, with EV and PHEV outperforming ICE vehicles even at lighter masses. Conversely, PN10 emissions exhibited minimal sensitivity to either regenerative braking or mass changes, indicating dominance of non-volatile particle sources. The findings suggest that regenerative braking delivers a greater benefit for PM reduction than a ~20% reduction in vehicle mass, primarily through lower brake temperatures and reduced volatile material loss. These insights support the development of effective mitigation strategies and emissions factors for future brake emissions controls.

Session 8: Break wear and Tyre wear, Talk

Non-Exhaust Emissions from Brakes: Comparative Assessment of Physico-Chemical Properties in Nanometric and Micrometric Particulates

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Results from literature review show that specific studies on nanometric particles generated by automotive brakes are extremely limited. Therefore, this contribution focuses on: i) the generation and the physico-chemical properties of nanometric brakes emissions; ii) the correlation of their composition with the materials composing the origin friction pair; and iii) the assessment on eventual compositional differences between nanoparticulates and corresponding coarser particulates. Five different automotive brakes friction pairs are tested following standard procedures for emission assessment of disc brake systems. Nano-particulates are collected and weighed to determine corresponding concentration ranges of 0.0005 and 0.0026 mg m^{-3} at a flow rate of 400 m^3/h. Several analytical techniques are deployed to investigate the physico-chemical characteristics of the collected particulates, including scanning electron microscopy, energy dispersive spectroscopy, mass spectroscopy gas chromatography and X-ray absorption spectroscopy. Main results of this study highlight significant differences in the physico-chemical composition of nanometric particulates compared to coarser ones. Clear increase in carbon content is identified when decreasing particle size distribution. Conversely, the amount of iron decreases in finer particulates, while its oxidation level increases. In addition, several Cr, Cu and Zn compounds are identified in investigated particulates, such as chromite, tenorite and zincite. Finally, for nanoparticulate emissions the polycyclic aromatic hydrocarbons (PAHs) concentrations vary largely ranging from 74 - 1460 µg g^{-1} and the oxygenated polycyclic aromatic hydrocarbons (OPAH) concentrations ranges from 8 to 110 µg g^{-1}. Comparatively, lower PAHs and OPAHs values are measured in particulates from coarser fractions.

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Nanoparticle generation potential of summer and winter tyres at varying ambient temperatures

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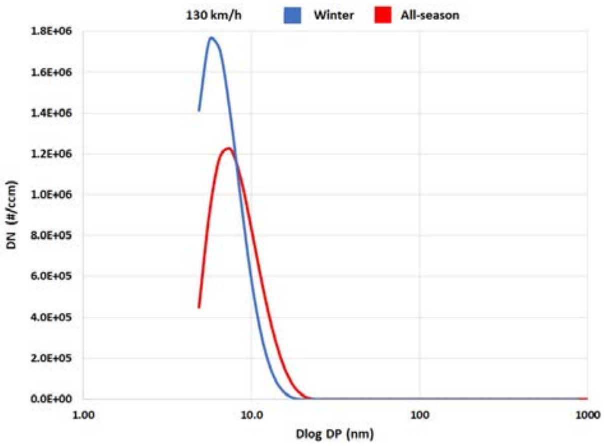
Automotive non-exhaust emissions, such as brake- and tyre wear are of rising interest, since they will be regulated for the first time with the EURO 7 regulation. While the majority of the particle mass of these abrasion derived particles is between 1 and 10 µm, a considerable percentage of the particle number is also generated in the nanoparticle range [1]. These particles can penetrate deep into the lungs, where they deposit in the alveoli and eventually reach the bloodstream via the blood-air barrier [2]. In this study particles generated from summer and winter and all-season tyres measured on a newly developed custom-built dynamometer, which is depicted in figure 1 were characterized.

All tyre types were measured at ambient dynamometer temperatures of 12°C and 23°C and a large change in emitted particle numbers (PN) was observed when changing to warmer temperatures. The large increase in PN was revealed to be in the nanometer size range, which was confirmed simultaneously by a DMS500 and a SMPS. Besides ambient temperatures, the tyres composition played a key role in the nanometer generation potential, with softer winter tyres emitting significantly more nanoparticles than summer tyres. The origin of the emitted nanoparticles was investigated to develop potential mitigation strategies for future policies. Average size distributions of the winter and all-season tyre at 23°C and a steady speed of 130 km/h as measured with the DMS500 are plotted in figure 2.



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Chemical Origin of Tyre Nanoparticles in a Tube Furnace

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Since the 1970s, it has been hypothesised that airborne nanoparticles from tyre wear originate from heat-driven evaporation and condensation of an unidentified tyre component. Tyre extender oil has long been suspected as a source. Here, we revisit this hypothesis and provide a mechanistic characterisation of tyre nanoparticles generated from cryomilled tyre tread under controlled thermal conditions in a tube furnace. Removal of extractable components such as extender oil substantially reduced nanoparticle formation. These results suggest that volatile organic additives, rather than the rubber itself, are the primary source of the tyre nanoparticles in our study. Experiments with tyre extender oil confirmed its ability to emit ultrafine particles when heated to similar temperatures. Nanoparticles collected from both tyre tread and extender oil were chemically characterised using NMR spectroscopy and found to consist predominantly of saturated hydrocarbons, closely matching the pristine extender oil. These findings provide the first experimental confirmation linking tyre nanoparticle chemistry to tyre extender oil, offering a mechanistic basis to interpret tyre nanoparticle emissions and support risk assessments.

Session 8: Break wear and Tyre wear, Talk

Michelin's latest results on quantification of airborne Tire Road Wear Particules, from vehicule usage to micro

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Michelin works since decades to reduce all the environmental impacts of its products, and Tire Road Wear Particles (TRWP) are one of the impacts of tires, intensively studied in our research center. Over almost a decade of research, we have delved ever deeper into this subject, from the nano and micro-scales of these particles to their transport.

This presentation explores the significance of TRWP emissions in the context of sustainable mobility and environmental impact, it will provide insights into the latest research methodologies of Michelin, aimed at accurately measuring TRWP airborne emissions.

Key discussions will include the factors influencing tire abrasion, such as driving style or tire design, highlighting how these elements interact to affect TRWP emission rates. Attendees will learn about cutting-edge analytical technologies being developed to improve the precision of airborne TRWP measurements, including advanced methodologies like Pyrolysis GC-MS. The presentation will also focus on the methodology developed by Michelin for TRWP analysis, the potential biases in this approach and the questions that remain open.

Conflict of interests : the authors declare that this research was funded by Manufacture Française des Pneumatiques Michelin, France