Advancing the quantification of tyre wear and particulate emissions on an outer drum test bed: challenges and laboratory solutions

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EXTENDED ABSTRACT

Tyre wear is a major source of environmental microplastics and airborne particles smaller than 10 µm, which pose significant health risks by reaching the lungs and other organs [1]. While tyre wear can reach the immediate environment, from roads to the world's oceans, causing pollution, airborne particles can potentially lead to aggravation of asthma, oxidative stress in various organs, Alzheimer's disease and neurodegeneration [2–5]. Accurate quantification and regulatory measures are therefore essential. Together with brake wear, tyre wear itself is already the focus of future regulations (EURO 7), while airborne tyre wear particle (TWP) emissions are not yet considered and are complex to measure. The regulation on brake wear will only focus on the airborne emissions of the brakes, with a limit already set. The regulation work for tyre wear, which is only focussing on the overall mass loss of the tyres, is still ongoing. There is no limit in sight yet. [5]

While the measurement of airborne TWP emissions is difficult in real-world environments due to the high number of background emissions, the measurement on indoor drums is complex due to the need for degumming methods to prevent the tyre from sticking to the drum and to achieve realistic tyre wear behaviour. These degumming methods are usually carried out using talcum powder, which affects the particulate measurements. The airborne talc particles affect the measurement of particle number (PN), particle mass (PM) and size distribution.

https://doi.org/10.25364/978-3-903374-48-5_33

Therefore, this study focuses on the development of a reliable method for the simultaneous quantification of tyre wear and airborne TWPs under realistic laboratory conditions. The test setup at the Institute of Automotive Engineering at the Graz University of Technology consists of an outer drum test bench with a flow-optimised enclosure that minimises the ingress of background particles. The enclosure features a reduced gap baseplate and an airflow system that prevents particle exchange between the enclosure and the environment. This configuration, coupled with a GTR-24 brake wear compliant sampling system, facilitates accurate particle measurements. Key instruments include two AVL particle counters for PN concentration, two samplers for PM, and an ELPI+ (Electrical Low Pressure Impactor) for size distribution analysis. The test cycle used is the so-called JASIC cycle, which has been established by the Task Force on Tyre Abrasion (TFTA) [6] as a future cycle for the regulation of tyre wear. This cycle is a combination of the WLTC and the Japanese Curve and Slope Cycle and consists of two speed sections (60 & 100 km/h) with alternating lateral and longitudinal forces. A single cycle takes 3 hours and 28 minutes to complete, covering a distance of 250 km. Normally this cycle is repeated 20 times for a total of 5,000 km to evaluate tyre wear over distance. [6]

The results show that minimising background emissions is crucial for accurate tyre particle analysis. The air barrier and the flow-optimised base plate significantly reduced background emissions, which is a major advantage compared to real-world measurements. The use of talc powder as a degumming method increased tyre wear rates by a factor of 10 compared to measurements without it: Without talc powder the wear rate of the tyre was around 3 mg/km/tyre. With the use of the degumming method the wear rate increased to more than 30 mg/km/tyre. However, the talc added complexity to the particle measurements by contributing significantly to both PM and PN. Keeping the PN concentration of the talc powder constant helps to distinguish between talc and tyre particles: As TWP emissions are mainly correlating with lateral forces during the test cycle, the PN peaks are clearly visible in the measurement signal. A further distinction is seen in the size distribution analysis, which showed clear differences between talc particles and TWPs, with talc contributing predominantly to the coarser particle fractions (PM10) compared to finer particles (PM2.5). Further studies of PM showed that talc was the major contributor to the mass in the PM filters. Density studies of the filters, as well as mass comparisons with reference filters made with talc powder only, showed that the airborne TWPs contributed only a small percentage of the mass in the filters. This indicated that less than 5% of tyre wear was also airborne TWP emissions. With PM10 values around 1 mg/km/tyre, the airborne mass coming from the tyre is comparable to the airborne mass coming from the brakes. However, the total mass loss of the tyre dominates, contributing to microplastics in the environment.

The study shows that it is possible to measure tyre wear and wear particles in the laboratory under controlled conditions. However, challenges remain. Real-world measurements are hampered by background emissions and resuspension of road dust, while laboratory setups struggle to achieve realistic wear rates without degumming methods. Measurement of tyre PN and PM on the indoor drum is hindered by the high airborne concentration of talcum powder. Investigations of PM filters and PN concentrations showed a clear tendency that only a small number of airborne particles originate from the tyre itself.

For future research, it is essential to find methods that can distinguish between talc powder and TWPs. This is important in order to find a suitable test bench method to measure both tyre wear and TWPs. Ultimately the aim should be to find a correlation between real world measurements and test bench measurements. This will lead to a comparison of real-world events with testbench events, which will lead to a reduction in the burden of tyre testing and regulation. This research highlights the importance of continued efforts to refine tyre wear and TWP measurement techniques. Reliable methods are essential not only for assessing the environmental and health impacts of tyre emissions, but also for informing regulatory frameworks to mitigate these impacts.

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