Solid and volatile brake-wear nanoparticles under real-world operating conditions

A. Mamakos[1], M. Arndt[1], K. Kolbeck[2], T. Schroeder[2], M. Bernhard[2], D. Hesse[3], C. Hamatschek[3], K. Augsburg [3]

[1]AVL List GmbH, Hans-List-Platz 1, 8020 Graz, Austria, [2]BMW Group, 80788 München, Germany, [3] Technische Universität Ilmenau, Gustav-Kirchhoff-Platz 3, 98693 Ilmenau, Germany

Recent studies have identified brake-wear as the major contributor to road transport Particulate Matter (PM) emissions, as a result of an efficient implementation of exhaust PM regulation worldwide. Accordingly, there has been a growing interest in the characterization of brake-wear emissions over the last years. In an attempt to establish a standardized test procedure that would facilitate comparison of results from different studies, the United Nations Particle Measurement Programme Informal Working Group (PMP IWG) has been actively working on the development of a harmonized brake-dynamometer methodology, including a novel test cycle (WLTP-Brake).

In this study we have applied the proposed PMP IWG methodology for the characterization of particulate emissions of the same brake system on two different dilution tunnels. The two tunnels were designed to operate at different flowrates (170 to 270 m^3/h compared to 300 to 1800 m^3/h). The brake system was tested under the WLTP-Brake cycle but also under another real-world brake cycle derived within the Lowbrasys European research project from analysis of the Los Angeles City Traffic (3h-LACT). The effect of bending procedure on particle emissions was also evaluated through dedicated tests in which the last and more demanding section of the WLTP-Brake was employed for the conditioning of the brake.

Particulate measurements included $PM_{2.5}$, PM_{10} as well as particle number (PN) following the recently introduced exhaust PN methodology that extended the detector cut-off size to 10 nm. Measurements also included real time size distributions and number concentrations of thermally untreated samples. Disc temperature profiles were investigated with a thermographic camera and an array of thermocouples embedded on the brake disc.

Both PM_{10} and $PM_{2.5}$ emissions were found to agree within 20% at the two facilities, despite the vastly different operating flows of the tunnels. Similarly, no statistically significant effect of the cycle could be identified on the PM emissions despite the nearly two times higher average disc temperatures over the LACT cycle (~110°C compared to 60°C over the WLTP). Most of the airborne PM was larger than 2.5 µm, with the ratio of PM10 to PM2.5 raging between 3.5 and 4.

Elevated concentrations of nanosized particles, thermally stable at a catalyst operating at 350°C, were released over the WLTP-Brake, under specific burnishing procedure. Their nature and formation pathways are currently unclear. Volatile nanoparticles were observed over the 3h-LACT cycle but only at the high tunnel flow. Their relative concentration decreased with increasing tunnel flow. This behavior is in accordance to nucleation theory since increased tunnel flows imply increased dilution of vapor precursors and potentially reduced release of vapors through more efficient cooling of the brake disc.