Meeting #3 – Thursday 05 October, 2017, 14:00 – 15:00

Minutes of Meeting – Final Version

1. Tour de table: Participants: AUDI-(SG) Sebastian Gramstat; AVL-(AM) Athanasios Mamakos; AVL-(MA) Michael Arndt; BMW-(RL) Rasmus Leicht; BMW-(UK) Ulrich Kuhn; BREMBO-(FR) Francesco Riccobono; BREMBO-(MA) Mattia Alemani; CARB-(JC) John Collins; CARB-(SC) Sonya Collier; DEKATI-(MMD) Mikko Moisio; FORD-(JG) Jarek Grochowicz; FORD-(MMF) Marcel Mathissen; GM-(MR) Matthew Robere; HORIBA-(DL) Dmytro Lugovyy; ITT-(AS) Agusti Sin; JARI-(HH) Hiro Hagino; LINK-(CA) Carlos Agudelo; LINK-(RM) Radek Markiewicz; OPEL-(MV) Max Votteler; TMD-(IP) Ilja Plenne; TSI-(JS) Jurgen Spielvogel; TU Ilmenau-(DH) David Hesse; TU Ostrava-(MV) Michal Vojtisek

2. Organization of the following presentations: Based on the request of several partners one presentation per meeting will take place from now and on and the schedule based on declared from the TF2 partners is as follows.

- October 19: Presenter FORD;
- November 2: Presenter Brembo

3. Presentation of TU Ostrava: MV presented a set-up for particle measurement very similar to exhaust emissions (gasoline and diesel). Fast Mobility Particle Sizer Spectrometer (FMPS) comes with certain limitations due to sampling rate and braking dynamics. Resin content and volatiles can also impact size distribution and particle count. Particle below 1 µm does not appear to be affected by sampling location.

DL asked about the influence of sampling location to the Particle Size Distribution and total concentration considering that with the application of dilution tunnel we should expect high dilution ratio and we should see some change for both parameters. MV clarified the difference between a typical dilution tunnel and TU Ostrava's configuration. TU Ostrava's setup assumes all air passing around the brake assembly is routed into the tunnel, with no additional air introduced, and thus no dilution (in the form of mixing a flow of sample with a flow of dilution air) taking place.

DL asked if we could interpret TU Ostrava's result as if concentration and particle size distribution will not change within distance x, y meter (distance between 2 sampling points). MV replied that this is not the case. On one hand, there was no dilution taking place between the two sampling points, and therefore, there are no order of magnitude differences. However, there are fairly substantial differences size-dependent. TU Ostrava has identified the following factors:
a) Close to the brake assembly the particle distribution is not yet fully uniform (the sample is not yet fully representative), and the flow is not laminar and therefore sampling cannot be isokinetic - this is less of a problem with nanoparticles, but the magnitude of the problem introduced increases with particle size.
b) Within the tunnel, there are diffusion losses (rather minimal and primarily of very small particles), settling losses (of larger particles, which may or may not be of primary interest to the TF2), and possibly nucleation (formation of particles), coagulation and agglomeration of

particles. Finally chemical processes vaguely described as "particle aging" cannot be excluded.

FR asked about nucleation/coagulation effects due to oxidation perhaps. Sampling points is ~50 cm on a 30 cm duct (8 m/s in the tunnel).

MMF asked about test-to-test repeatability. MV clarified that further testing is required.

4. Presentation of HORIBA/AUDI: DL used AK Master to characterize PM under different conditions and assess different sampling methods. A sampling procedure with emphasis on $PM_{2.5}$ characterization on the dyno was presented. The method will allow to separate exhaust from non-exhaust. Optional sampling at the 90-degree bend. The enclosure around the brake increases the capture of small particles. The housing does not affect the brake temperatures (using AK Master). Airflow may impact coagulation or total particle count. DL suggest including sub-23 nm particle measurement. Significant difference in particle count between CPC and electrometer systems. Please reference actual presentation.

MR asked for a clarification regarding the comment that the enclosure did not have much impact on brake temperature except during the fade sequence. MR mentioned that the AK-master is a temperature controlled test in all sections except the fade (CA mentioned that all parts are temperature controlled). Finally, MR commented that it is perhaps worth further studying the housing effect on temperature in a test environment controlled by cycle time. DL totally agreed with the comment and further advised TF1 to also develop a temperature controlled braking cycle in order to help TF2 in further standardisation of sampling and measurement processes.

MR asked for a clarification on the production of sub-23 nm particles. It seems the sub-23 peaks really show up in the higher speeds and higher pressures so he wanted to know if Horiba also observed this peak in any of the more “typical” braking conditions (1-3 MPa)? DL responded that there is an influence of brake parameters (brake pressure, disk speed, etc.) and composition of lining materials on brake emission including sub-23 nm particles. On one hand, appearance of sub-23 nm particles depends rather on disk temperature and then on other brake parameters. High disk speed and brake pressure will affect disk temperature during brake events and thus induct emission of sub-23 nm particles. For NAO brake pads, sub-23nm emission was observed even at moderate conditions.

AM asked a question regarding the background levels. DL responded that several electrometers from different suppliers were used. AM stated that charging levels may impact count and correlation.

5. Other business:

(MV) and (DL) already provided PDF version of their presentations to (TG) for distribution.