PMP – Particle Measurement Program Informal Working Group
Task Force 2– Brake Dust Sampling and Measurement

Meeting #42 – Wednesday 04 MAY 2022 15:00 – 17:00 CEST

Minutes of Meeting – Final Version

1. Participants: As in the file ***"42nd TF2 Meeting Attendance"*** uploaded in TEAMS.

2. Introduction: Theo Grigoratos (TG) welcomed the TF2 members and summarized the status of the various documents. A clean version of Clauses 3, 5, and 6 will probably become available by the end of Week 18. Comments on Clause 7 have been received – TG requested the rest of the members to provide their feedback until Wednesday 11.05. Today's discussion was dedicated to the PM measurement and all relevant topics.

3. Clause 9 presentations: Marcel Mathissen (MM) presented a Ford's analysis regarding possible particle losses in the ducts focusing in the area between the exit of the enclosure and the sampling plane. A summary of the layouts in terms of their duct diameters and the applied airflows was initially presented. Losses were modelled for three different layouts including a 90° and a 180° bend and always assuming a distance to the sampling plane with 5 diameters straight tube. The overall duct losses are low for all scenarios. Larger ducts and lower speeds are generally slightly more favourable. At a given diameter of 150 mm very high flows can result in higher particle losses of almost 30% for 10.7 µm particles. The estimated impact of the losses on PM emissions is low (2.5%).

During the follow-up discussion TG asked if the takeaway message would be that losses in the duct are expected to be negligible under the "ILS conditions" – MM confirmed. Carlos Agudelo (CA) asked about the density of the particles – MM replied that a density of 1 kg/m^3 was assumed. CA asked about the impact of bigger diameters on losses – MM replied that ducts with bigger diameters might come with other issues (spacing) but are not expected to result in high gravitational or inertial losses. Dmytro Lugovyy (DL) asked about the distance that was considered between the enclosure/bend and the sampling line and if a homogenous flow is expected in only 5 diameters – MM replied that there are not experimental data with other distances. Heinz Bacher (HB) commented that the differences in the layouts and the different curvatures seem to contribute more than the duct diameter itself to the losses – MM replied that losses are generally low and that inertial deposition seems to dominate over gravitational losses. Stefan Carli (SC) asked if the Reynolds/Stokes numbers are available – MM replied that they can become available. TG complemented that a further analysis on the flows (turbulent or not) will be presented later.

TG provided a presentation related to the PM measurement protocol. The details of the proposal and the data-supported evidence are summarized in the attached presentation "GTR - Clause 9". The amended text is available in the submitted document "PMP Brake Protocol - Clause 9 Clean". Five different sub-clauses have been introduced in the newly formulated Clause 9; however, this might be further amended.

Clause 9.1 – Describes the general elements related to the particle transport in the ducts focusing in the area between the enclosure exit and the sampling plane;

Clause 9.2 – Describes the general elements related to the particle extraction and restricts duct dimensions. Specifications about the probe and nozzles are provided;

Clause 9.3 – Discusses the selection of the cyclones as a PM separation device. Specifications about the cyclone, the sampling tubes and the sampling volumetric flow are provided;

Clause 9.4 – Describes the general specifications for the sampling filters for the PM measurements following the GTR15;

Clause 9.5 – Describes the general specifications for the weighing procedure following the GTR15 specifications.

TG presented a PM sampling setup for illustration purposes. Then, the main sources of error were introduced based on a presentation provided by AVL at the 28th TF2 meeting. The most important factors are: anisokinetic sampling, anisoaxial sampling, gravitational deposition, and inertial impaction.

Regarding isokinetic sampling, TG initially presented the expected losses for the two PM fractions at different ratios, and explained how the TF2 agreed to apply the 0.9-1.15 window for the ILS. ILS data show that most labs managed to stay within this window; however, calculations come with certain assumptions and risk of errors in both the tunnel and sample flows. TG concluded that isokinetic sampling shall be ensured through the accurate control of the cooling air flow and the PM sampling flow. Regarding anisoaxial sampling, TG highlighted that if an isokinetic sampling is assumed the effect of anisoaxial sampling is expected to be negligible for aspiration angles smaller than 15°. TG suggested sticking with this specification as it seems not to have created any issue during the ILS exercise.

TG discussed in detail the possible gravitational and inertial losses in both ducts and bends. 1m long ducts and tubes have been considered for the gravitational losses calculation, whereas inertial losses were checked against one 90° bend. The gravitational losses in the tunnel are expected to be very low at the typical ILS operating conditions and this is expected also for longer ducts. Gravitational losses can become more critical in tubes compared to the ducts; however, the overall influence to the PM_{10} fraction is expected to be lower. ***A combination of long lines with large diameters with low flows can result in high losses.*** Inertial losses in the tunnel are expected to be low at the typical ILS operating conditions; however, they can become high at very high air tunnel speeds. Inertial losses can become very much critical in tubes even with one bend only. ***Combinations of low diameters with very high flows shall be avoided*** and optimization taking into account also gravitational losses is needed.

A presentation of the proposal regarding particle transfer and extraction followed. The most important highlights are: Bends in the setup shall come with a bending radius of at least two times the duct diameter. The inner diameter of the ducts shall be constant for a given setup and may vary between 175 mm and 250 mm in different setups. The sampling plane shall be located at least 6 diameters downstream and 2 diameters upstream of any flow disturbance. A minimum of three and a maximum of four extraction points with corresponding probes are required – two of them will be used for the PM measurements. Specifications about the probes have also been proposed – TG specifically asked for the feedback of the group and mainly the instrument manufacturers regarding the probe's specs. Finally, specifications about the nozzles were also presented mainly following the ISO 9096.

CA asked if the plan would be to limit the flow speeds between 15-45 kph – TG replied negatively and explained that this is the window where the minimum losses are expected; however, there is no intention to limit air speed because this might create cooling issues with certain brakes. Bob Anderson (BA) commented on the positioning of the probes in the duct. Certain orientations (i.e. PM probes in diagonal positions) might penalize the PM_{10} measurement – TG welcomed the comment and asked for further feedback to better define the positions. Christophe Jouy (CJ) asked about the probes orientation and the possible positioning of stage impactors – TG replied that the proposed separation method is cyclones (explanation on this choice presented later). DL asked about the definition of thin wall nozzles and if the ratio of 1.1 is necessary – This is an ISO 9096 specification and TG invited the group to comment on the necessity of keeping the specification. DL asked if we shall be worried about losses in setups with 1 bend – TG explained that based on the analysis of MM and TG there is not a big risk under normal operating conditions. CA added that nozzles will need to be better defined following the ISO 9096 specifications and commented that the proposal for the different dimensions needs to be checked against all proposed specifications. Ravi Vedula (RV) highlighted that the nomenclature needs to be accurately defined in the GTR.

A discussion on the separation device followed. TG presented ILS data and highlighted that in 65% of the tests with impactors, the PM_{10} filter load was higher than the recommended 1 mg. This might create clogging and bouncing problems and renders the method questionable for brake emissions measurement. On the other hand, six out of eight labs that measured without obvious errors applied cyclones for the PM_{10} measurement. The proposed specifications for the cyclones were presented and a proposal for sampling lines has been submitted – TG again specifically asked for the feedback of the group regarding the separation device and the sampling tubes specifications. TG closed the presentation with the specifications for the filters and the weighing method following the GTR15 specs.

CA asked if the accuracy requirement for the sample flow refers to the average or the instantaneous values – TG clarified that it is for the average. Michael Arndt (MA) stated that probably a specification for the isokinetic ratio will be required and we shall not leave it upon the compliance of the two involved flows. BA commented about the no-need of monitoring the isokinetic ratio in real-time – TG confirmed that there is a typo and the intention is to check the isokinetic ratio of the test as a whole and not instantaneously. Heinz Bacher (HB) commented that pre-conditioning of 1h is too short and we probably need 24h. CJ asked about sampling during the cooling sections – TG replied that data did not show towards one or another direction. The most convenient approach shall be followed.

4. Next Meeting: The next meeting will take place on Wednesday 11.05.2022 from 15.00-17.00. The topic will be related to reporting.