

Workshop – Towards a regulation on brake wear emissions
82nd GRPE Session – January 13th 2021

Minutes Final

The GRPE Chairman Mr. André Rijnders and the PMP-IWG Chairman Mr. Giorgio Martini introduced the workshop “*Towards a regulation on brake wear emissions*”. Approximately 200 participants, representing stakeholders from all over the world, attended the virtual meeting. The official agenda, the presentations, and the final MoM of the workshop are available on the Particle Measurement Programme Informal Working Group (PMP-IWG) website at <https://wiki.unece.org/display/trans/PMP+Workshop+on+Brake+Emissions++Regulation>.

1. The agenda started with a presentation on the state of play regarding the methodology for sampling and measuring brake wear emissions (Theodoros Grigoratos – JRC). The presentation highlighted the importance of non-exhaust emissions and the challenges that have to be faced when trying to regulate them. It also gave an overview of the background and the main elements of the method and its possible use in a future regulatory framework. Finally, it touched upon the challenges that need to be addressed by the PMP-IWG and the collaborating groups in the months to come. The follow-up discussion touched upon some very important aspects. These can be summarized to the following:

- The first one relates to whether there is evidence that – as it happens for exhaust emissions – extreme braking events might dominate emissions and to what extent these events are taken into account. The WLTP-Brake cycle was designed based on real driving data with the aim to reflect real-world applications. Thus, rare and extreme events have not been included in the cycle. It is not expected that this kind of events will significantly influence PM emissions; however, it is not known how PN emissions will be affected. A study launched by the UK Department of Transport is expected to give concrete answers on this topic and the cycle might be modified accordingly at a second phase.
- Another topic relates to the change of the brake couples’ behavior over time and to what extent it has been taken into account in the method. The method foresees a bedding-in of the brake couple (5 WLTP-Brake cycles – approximately 1500 brake events) during which there is strong evidence that the emission behaviour of most brake couples is stabilized. Alternative options for the definition of the most efficient bedding procedure will be investigated in the upcoming RR exercise. There is still a question regarding the brake pads of EVs and their emission behaviour overtime with relation to corrosion.
- A discussion regarding possible application of chassis dyno measurements instead of brake rig measurements followed. Available data show that chassis dyno measurements have proven more complicated and may introduce unrealistic conditions with respect to the brake temperature profile. Additionally, there is a difficulty in distinguishing between different particle sources (brakes, tires, existing contamination) compared to the test rig method.
- The inclusion of future technologies (i.e. particle filters) to the methodology was discussed. The EC will launch a study on this topic soon. The group was reassured that the method will take into account all important technologies – to the extent possible. For offers of potential brake particle filter technologies please contact: Panagiota.dilara@ec.europa.eu
- Finally, a long discussion regarding health effects and toxicity studies took place. One of the concerns is that lower emissions (in terms of mass or number) may not result in a decrease of toxicity for humans. Not enough data are available to reach sound conclusions. In particular, there is no sufficient knowledge today to establish whether particles with certain chemical compositions

may be more dangerous than others with a different composition or even to identify the size fraction which is responsible for the majority of the adverse health effects. A study currently in place by CARB is expected to give such information in the future. Roy Harrison stated that – according to the WHO – the PM_{2.5} indicator should be adequate to regulate a source. A discussion on the share of PM_{2.5} emissions to the overall PM₁₀ emissions followed. Finally, the group was informed that the method being developed by PMP gives the chance for post-testing chemical analysis through the filters used for the PM₁₀ and PM_{2.5} measurement.

- Due to the COVID pandemic and additional issues the project is currently several months behind schedule.

2. The workshop continued with the industry's point of view. Proposals and considerations for the regulation of brake emissions were presented from the Federation of European Manufacturers of Friction Materials (Andreas Jandl – FEMFM). The FEMFM agreed in regulating non-exhaust emissions but taking into account all non-exhaust sources in a holistic approach at vehicle corner level. FEMFM highlighted that components emitting non-exhaust emissions are by definition sacrificial parts and expressed concerns regarding safety aspects. The actual contribution to air pollution should also be considered taking into consideration that not all wear material becomes airborne. Finally, they consider that additional research for investigating toxicity levels of different components is required.

- A follow-up discussion highlighted the difficulty in considering a testing method – and thus a regulatory approach – from a vehicle corner perspective. This approach would require resources and time-consuming investigations as it would start from scratch as it departs from the method studied thus far. Furthermore, it would complicate the situation as there are many possible brake-tire-road surface combinations. FEMFM clarified that testing methods would apply to the individual components but the regulation should target the whole vehicle.
- The EC objected to the FEMFM statement about brake pads being sacrificial parts and therefore do not count. It was stated clearly that also “sacrificial parts” should be controlled in terms of emissions, and thus regulated. The EC also stated that any possible regulatory approach will have to take into account safety aspects, and added that safety should not be compromised by any means.

A second contribution from the vehicle industry was provided by the International Organization of Motor Vehicle Manufacturers (Sebastian Gramstat – AUDI). OICA supports the development of a robust measurement procedure which could be used in future regulation – and highlighted the need for understanding which vehicle classes are the main contributors to brake emissions. According to OICA, vehicles with zero tailpipe emission contribution (i.e. BEVs) shall be treated separately. A test rig method is considered a viable approach but vehicle-specific parameters shall be considered when applying it. According to OICA, the proposed approach can be extended to HEVs and EVs. Finally, vehicle-based limits are considered as the most suitable approach. The presentation highlighted also the issue of after-market spare parts: Shall be these regulated as well?

- A short discussion on the proposal of vehicle limits (i.e. limits based on brake dyno testing of front and rear brake systems mounted in a specific vehicle and calculated at vehicle level) followed. OICA stated that brake system limits (i.e. limits based on brake dyno testing of a single brake system (disc and pad) taking into account the specific characteristics of the vehicle to be mounted) could also be an acceptable approach considering the difficulty of extrapolating the brake corner's emission values to an overall vehicle limit. The PMP chairman asked whether it would be possible to identify a combination of vehicle parameters and brake system that could represent a “worst-case scenario” covering also the other applications with the same brake system. According to OICA this could be possible and would reduce the testing burden but further investigation is needed. A follow-up discussion on this topic will take place in the next PMP meeting.

- A discussion on emissions from HDVs followed. HDVs feature complicated multiple brake systems that are operated according to priority strategies. It would be very challenging to attribute specific emission cycles. A study already in place by CARB is expected to give some information on HDV brake emissions in the near future.

3. The workshop continued with the regulators' point of view. The European Commission (Panagiota Dilara – DG-GROW) highlighted that all types of vehicles are of concern but LDV should be the starting point. At the same time it is important to consider a solution that takes into account replacement parts. The regulatory approach should ensure that the best possible technologies are used – taking into account cost and safety issues. The EC's first goal is to have as soon as possible a Global Technical Regulation that will a) measure in a repeatable manner and b) limit effectively emissions of brakes at least for LDVs. HDVs and in particular buses could follow in a second phase.

- A discussion on what “best available technologies” means followed. In particular, a question on whether the fact that regenerative braking could significantly cut brake emissions would mean that conventional brake systems might be phased out. OICA pointed out that the measurement methodology should be capable to include the most available technologies; however, more investigations will be required. The EC made clear that an impact assessment study will be required to introduce regulation at the European level. This step will take place independently of the GTR.
- The EC stated – following a comment from OICA that both emissions and safety requirements need to be considered when defining future particulate limits – that any possible regulatory approach will not compromise safety by any means.
- A follow-up discussion on the best available technologies took place. Examples of innovative technologies have been mentioned but also simpler solution that could be already a step forward. The EC mentioned the example of NAO pads which are demonstrated to emit 3-5 times lower PM compared to their LS counterparts.

The presentation “*Regulating brake emissions in a changing vehicle market*” from the UK Department for Transport followed (Duncan Kay and Claudio Chesi – UK DfT). The first part of the presentation focused on the importance and the UK initiatives on non-exhaust emissions. UK stated their commitment to decreasing emissions from road transport and highlighted that the uptake of ZEVs must be supported by regulations on non-exhaust emissions. During the second part, the three-phase project of the UK DfT was presented. This research will focus on on-road measurements and aims in developing recommendations for type-approval and legislation of brake and tyre wear emissions by 2023. It has been clearly mentioned that the project is seen also as a contribution to the PMP process. Knowledge gaps will be evaluated during the project. Finally, preliminary answers to the workshop questions were provided (addressed in the final part of the MoM).

- A question on whether there is the room in the project to address some specific issues to support the PMP activities was raised. It can be the case – if necessary – however the technical specifications drafted for awarding the project may represent a limitation.
- The UK DfT study is expected to provide valuable inputs regarding the importance of extreme braking events to brake PM and PN emissions, the deterioration state and the subsequent emission behaviour of brake parts, and the feasibility of on-road measurement approach.

The last presentation came from the California Air Resources Board (Qi Yao - CARB). CARB highlighted that brake emissions are more a localized rather than regional problem. The current work program includes 4 projects with a view on LDV and HDV brake emissions (conventional and non-conventional vehicles) as well as health and exposure studies. Results from the LDV project show that very fine particles (in the range of a few nm) are emitted under realistic conditions. Also, brake PM_{2.5}

and PM₁₀ EFs are at the level of 1 and 5 mg km⁻¹ veh⁻¹, respectively. Updated EFs for both LDVs and HDVs are expected to be published soon at the EMFAC.

- A discussion on when CARB's projects are expected to deliver followed. The LDV project report will be published soon, while the HDV report is expected to be finalized in 2021.
 - CARB's studies are expected to provide inputs regarding the brake PM and PN EFs, the impact of regenerative braking to emissions, and the importance of HDV brake emissions for air pollution.
4. Based on the input and the discussions during the workshop, the organizers drafted preliminary answers to the questions raised before the workshop. The answers constitute a **first proposal** with the aim of clarifying the way forward within the PMP group.

1. What would be the ideal scheme for regulating brake emissions from conventional ICE Light-Duty vehicles?

a. Type approval/certification at vehicle or component level? Type approval of aftermarket brake products? Type approval of brake drums?

It seems that type approval at the vehicle level (as defined previously) is the preferred option for several stakeholders. However, this solution comes with certain limitations and challenges. Alternatively, a solution of type-approval at the brake system level (as defined previously) – taking into account vehicle parameters – might fit the purpose and may be the most appropriate to also cover aftermarket products. Testing efforts for both options need to be investigated – there are concerns for much higher testing efforts with the second options. Brake drums have not been discussed – any proposal would be welcomed.

b. Emission limit based approach. Application for both brake wear PM and PN? Absolute limits (mg/km and # particles/km) or relative limits (reference system)?

FEMFM suggested a full vehicle approach. OICA suggested individual vehicle-based limits approach but can consider limits at component level with additional discussion/investigation particularly regarding on how to account for performance vehicles and part-to-part variation. EC and UK suggest following an emission limit approach at the brake system level. These limits could be based on the best performing technology available in the market taking into account the impact on different technologies and the cost/benefit ratio. There is an agreement at the PMP level that at least both PM and PN will be considered following the development of the PMP methodology. OICA highlighted that for a measurement procedure the PMP method should be followed.

c. Relationship between laboratory based tests and real world emissions? How to ensure that laboratory measurements are representative of real world applications?

There is a general consensus that a vehicle based approach (either on the chassis dynamometer or on the roads) entails significant technology challenges, starting from how to sample to the quantification of the contribution of each source. The test rig approach is definitely simpler but raises questions on the representativeness of real world emissions. There are concerns, in particular, about aggressive and extreme braking events. Also, there are concerns regarding the evolution of emissions due to aging/corrosion to certain vehicle categories (BEVs) which will not be reflected on a test rig method. Despite the given limitations, the method seems to reflect real-world applications and testing conditions to a good extent. Adaptations might take place in the cycle in a second phase if data show that extreme events should be considered.

d. Feasibility of classification/labeling on top of type approval. Should it rely only on PM emissions or PN emissions should be considered, too?

The question is obsolete based on the feedback on the previous questions.

2. How should non-conventional Light-Duty vehicles (i.e. HEVs, EVs) be handled in a future regulatory approach?

e. Importance of brake PM and PN emissions from non-conventional Light-Duty vehicles?

There is evidence that non-conventional LDVs emit lower than ICE LDVs. However, the EC wishes to include non-conventional LDVs in the regulatory scheme. According to OICA, further investigations are required and vehicle types with minor emission contribution shall be treated separately. Expected results from the UK and the CARB project will provide inputs on how to adjust/improve the procedure to properly consider these new technologies.

f. Feasibility of following a similar approach to that of conventional ICE LDVs?

From the available preliminary data, it seems that the test rig based approach being developed within the PMP may be extended to cover HEV and BEV. However, more complex equipment than is readily available on the market today would be necessary. There are certain elements that need to be further investigated and elaborated (i.e. different regenerative strategies, confidentiality issues when third parties are involved).

g. How could other innovative technologies (car-to-car communication, ADAS systems, etc.) be assessed and considered in possible future regulation?

Topic not discussed in detail. With appropriate adjustment of the test based rig approach it could be still possible to assess these technologies. However, specific adjustments could be required for each different technology.

3. How should HD vehicle brake emissions be handled?

h. Importance of brake PM and PN emissions from Heavy-Duty vehicles?

Topic not discussed in detail. Updated emission factors from on-going projects (CARB) are expected. There seems to be consensus to give priority to LDV. HDV emissions representing urban applications might need to be prioritized within the HD sector.

i. Feasibility of following a similar approach to that of conventional ICE LDVs?

It has been clearly highlighted that HDV are equipped with very sophisticated multiple brake systems with different priority. In general the friction brake has the lower priority. The application range of HDV is very wide and this may lead to the necessity of respective HDV brake cycles. Data from on-going projects (CARB) are expected to provide an insight on the role of different applications.

j. Other possible approaches?

Topic not discussed at all – any proposal would be welcomed.