OICA – Working-Group on *Ducting & Enclosure* for brake emission testing

29.06.2023

Note and Disclaimer

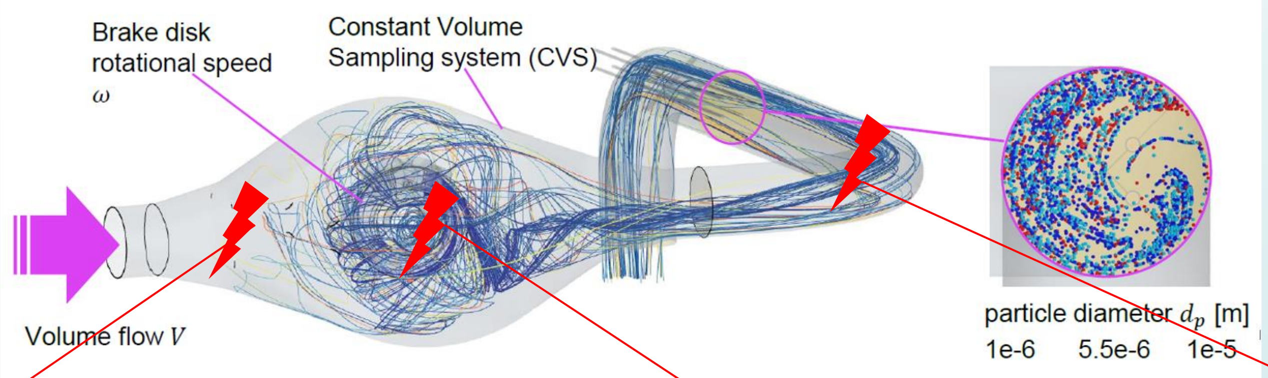
Note: Laboratories with GTR-compliant setups (current or in construction) will not be affected by this proposal, as no restriction on the design of the brake enclosure or limitation of sampling duct is pursued. The herein suggested additions are intended as recommendation and to further harmonize the design across the industry.

Disclaimer: OICA continue to identify technical issues in the draft GTR that are not addressed. Opportunity for more discussion is required.

All OICA-experts working in this group are aware of the *OICA Competition Compliance Anti-trust Guidelines (2019-02-12)* and assure to work within those guidelines from section 1-6. Therefore, every member pursues a lower variability through an addition or a change to the GTR according to a proposal made by OICA. No member holds any interest to find a solution at OICA-level. We strictly reject any notion that would infer an arrangement between the OEMs or a violation to the OICA antitrust-policy in this group. All our work is aimed towards improving regulations through scientific research or qualified discussions concerning the brake-emission-testing subject. In conclusion an improvement of the variability of all testing labs can only be achieved on a regulatory level, which is the common goal of this working group.

Further information regarding the *OICA Competition Compliance Anti-trust Guidelines (2019-02-12)* can be found at the following link: http://secure2.oica.net/media/OICA%20Antitrust%20policy-2019-02-12.pdf

Introduction of the Working-Group *Ducting & Enclosure*



Risks due to high variability in brake emission measurement:

- Unclear situation if two GTR-compliant setup show different values (especially close to a [mg/km] limit emissions factor)
- Legal exposure due to independent labs with unrepresentative sampling (e.g., inhomogeneous particle distribution in sampling duct as only the airflow homogeneity in the enclosure is required)
- Possibly targeted design to create biased particle emissions results
- Difficult framework to develop, evaluate and improve: 1) brake test rigs, 2) mitigation strategies to reduce the particle emissions and 3) particle measurement devices

This sources are interconnected and can not be dealt with using individual measures → system-wide approach is needed to increase comparability and reduce variability, while enabling the required flexibility

[1] Feißel, T. (2023, June 20-23). Regulation of brake particle emissions by Euro 7 [Conference presentation]. Chassis.tech plus 2023, München, Deutschland.

Introduction of the Working-Group *Ducting & Enclosure*

Goals:

A. Find actionable assessment methods for determination of particle distribution, transport efficiency and particle residence time.

B. Generate understanding regarding particle transport and possible source of variability and particle loss

C. Conclude premises for the enclosure and ducting design and further optimization, in order to achieve robust brake emission setup, that is comparable from lab to lab and assures a high particle efficiency.

Methods:

- Literature research
- Numerical simulations (CFD) with/without particle injection
- Design-of-experiments (DOE) to evaluate influence of geometric design with CFD tools
- Experimental investigation and verification in second ILS (expected in the beginning of 2024)

OICA proposes a recommended design within the GTR that increases the comparability and allows enough flexibility to implement in existing test rigs

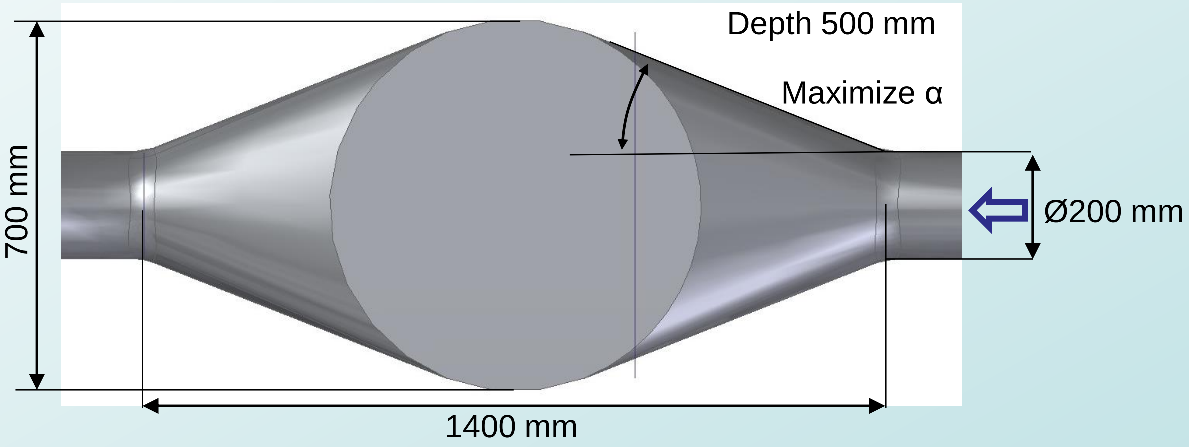
OICA proposal for implementation of recommendations

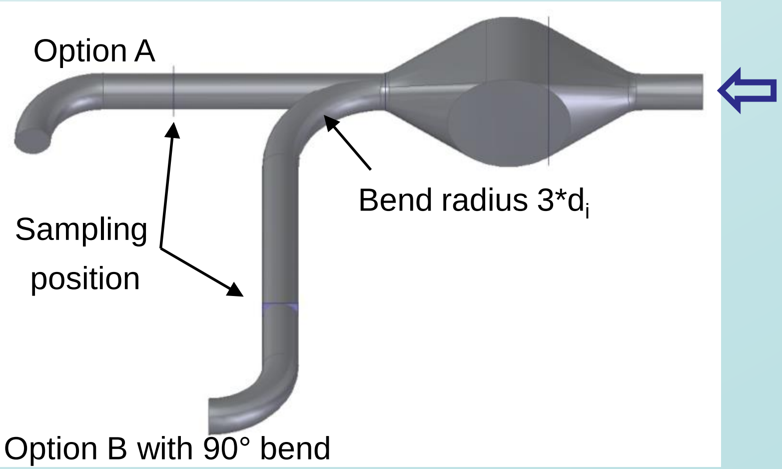
See Annex for full proposal

Overview of the proposal:

- We propose to include a recommendation of fixed values for the brake enclosure to increase comparability between laboratories (within range of UN-GTR)
- Flow homogeneity using 35% is not enough to ensure comparable brake cooling, as laboratories might need to test same brake with different cooling airflow → We propose a change to XX% (to be discussed and to be reduced as experiments show achievability)
- We propose the recommendation of a duct inner diameter of 200 mm
- For the 90° bend we propose a recommendation of $3*d_i$

→ Two possible setups with limited flexibility should be recommended: 1) straight duct and 2) with one 90° bend





Timeline for implementation of recommendations
Urgent need to start ILS 2 → performance check of GTR

Steps for implementation:

Q4 2022-Q2 2023	1. Definition of qualified recommendations within GTR based on literature research, CFD and DOE/CFD
	2. Implementation of proposed design in existing test rigs
Q3 2023	3. Plan of ILS 2 (labs, brakes, etc.)
Q4 2023	4. Proof of GTR-conformity of test rigs with/without recommended design
Q1 2024	5. Calibration of cooling airflow, brake bedding and emissions measurement
Q2 2024	6. Analysis of data
	7. Evaluation of variability (overall and comparison between labs with/without the recommended design)
	• If PM_{10} variability overall is <10%, then no recommended values are needed
Goal: June 2024	• If PM_{10} variability is >10%, but with recommended values is <10% → recommended valued should be in UN-GTR

Steps 3–7: **ILS 2**

- A description of the test rig (enclosure, ducting and sampling) and the results from airflow homogeneity should be given
- Qualified recommendations should be included in ILS 2 to assess their performance and evaluate their possible benefit
- Recommendation will not affect existing setups and are intended to further harmonize the design across the industry

Summary of Proposed Changes

Change no.	Excerpt from	Current text	Discussion Item - Proposed Change
1	7.4.2. (c)	The inlet and outlet cross-sections shall be designed to ensure smooth transition angles (15° ≤ a ≤ 30°) in order to avoid sudden changes in cross-section shape or size;	Request for addition: Recommendation: Angle should be maximized to avoid recirculation areas in the upper and lower part of the enclosure
2	7.4.2. (d)	The transition points between the segments shall not have any imperfections or features that may collect brake particles that could become airborne later during the test;	Request for clarification and addition: Specify what tolerance is permitted.
3	7.4.2. (e)	If fasteners are applied at the transition points, they shall not protrude into the enclosure area;	Request for clarification and addition: Specify what tolerance is permitted.
4	7.4.2. (j)	Plane C is tangential to an arbitrary disc of a diameter of 450 mm. Design the cross-section area at the enclosure inlet so that the airspeed at Plane C remains below the maximum permissible tolerance for speed uniformity defined in point (l) of this paragraph. If necessary, use flow straighteners or diffusion plates at the inlet's side upstream of Plane B to ensure the highest possible level of uniform flow at Plane C;	Request for addition: Add filter meshes as a possibility to achieve flow homogeneity.
5	7.4.2. (l)	Measure the airspeed values at the nine positions of Plane C without a brake assembly or a brake fixture installed. All the cooling air ducting utilized for the brake emissions test shall remain connected to the enclosure during these measurements. Carry out the measurement at the minimum and maximum operational flows of the test system. Let the flow stabilise for at least 2 minutes before conducting each measurement. The airflow is considered stabilized when the average measured flow in the sampling tunnel is within ±5 per cent of the set value. Perform the airspeed measurement for at least 2 minutes after the stabilisation. The measurement time shall be of sufficient duration to detect any instability in the airspeed pattern that may affect the airspeed values. Airspeed at each position shall not vary by more than ±35 per cent of the arithmetic mean of all measurements for a given flow.	Request for addition: Airspeed at each position shall not vary by more than **±XX** per cent of the arithmetic mean of all measurements for a given flow;

Summary of Proposed Changes

Change no.	Excerpt from	Current text	Discussion Item - Proposed Change
6	7.4.3. (a)	Design the brake enclosure symmetrically to Plane A1. The length of Plane A1 (lA1) represents the most extended length of the enclosure along the flow direction. Plane A1's length shall be between 1200 mm and 1400 mm (1200 mm ≤ lA1 ≤ 1400 mm);	Request for addition: It is recommended to design an enclosure with a length close to **1400 mm**;
7	7.4.3. (b)	Design the brake enclosure symmetrically to Plane D. The length of Plane D (hD) represents the longest distance (height) of the enclosure perpendicular to the flow direction. Plane D's height shall be between 600 mm and 750 mm (600 mm ≤ hD ≤ 750 mm);	Request for addition: It is recommended to design an enclosure with a height close to **700 mm**;
8	7.4.3. (g)	The maximum axial depth of the brake enclosure at Plane D (parallel to the brake rotation axis) shall be between 400 mm and 500 mm.	Request for addition: It is recommended to design an enclosure with an axial depth close to **500 mm**;
9	7.5. (d)	Ducts shall have a constant inner diameter di of at least 175 mm and a maximum of 225 mm (175 mm ≤ di ≤ 225 mm). The duct inner diameter di is defined as shown in Figure 7.6.;	Request for addition: It is recommended to implement a duct with an inner diameter of **200 mm**;
10	7.5. (e)	A maximum of one bend of 90° or less may be applied in the sampling tunnel (i.e. downstream of the brake enclosure and upstream of the sampling plane) provided that the specifications described in (f) and (g) are met;	Request for addition: Two configurations (straight and with a 90° bend) with fixed values should be recommended.

Summary of Proposed Changes

Change no.	Excerpt from	Current text	Discussion Item - Proposed Change
11	7.5 (f)	If a bend is applied in the sampling tunnel, the bending radius rb shall be at least two times the duct inner diameter (2·di). The bending radius is defined as shown in Figure 7.6.;	Request for addition: It is recommended to implement a bending radius of three times the duct diameter **(3·di)**;
12	7.6 (b)	Select a three-probe or four-probe configuration depending on the duct diameter as defined in points (e) and (f) of this paragraph. Figure 7.7. illustrates the proper positioning of the PM and PN sampling probes for both the three and four sampling probes layout;	Request for addition: It is recommended to use the position of the four-probe configuration. OPEN POINT TO BE DISCUSSED
13	Figure 7.7		Request for addition: OPEN POINT TO BE DISCUSSED