OICA contribution to PMP

27.04.2023

Version 26.04.2023

Outline

- Methods introduction
- Alternative use of individual friction share method or Table 5.1
- Master Method B
- Test cycle (WLTP-Brake, WLTP-Trip 10, or WLTP-Exhaust) and correlation
- Alternative Method(s)
- Timing Plan

Non-friction energy share methods

For Reference

- **Method A (Brake torque measurements)** could help to verify other methods
  - on its own it is not suitable for homologation, because of the instrumentation effort needed?
  - Not "first choice" due to issues with direct torque measurement for drum brakes and potentially disc brakes with sliding calipers

Master

- **Method B (Brake torque calculation (pressure) equivalent signal for EMB (electromechanical brakes) needed**
  - Need to agree on the Method for friction coefficient estimation/measurement
  - seems to be a workable approach

Alternative

- **Method D (Brake torque on CAN)**
  CAN values have to be available for the front and back axel for every vehicle
- **Method C Calculation from E-motor and engine drag**
  - Other losses will be neglected
  - Powertrain Efficiency has to be estimated/calculated
- **Method E Calculation from electric energy (battery)**
  - For pure BEV this method could be easy and suitable

Alternative use of individual method or Tab 5.1.

- In order to avoid excessive testing requirements and due to the very strict timeline OICA needs clarity on the continuation of Table 5.1 (fall back solution)
- individual friction share method or values in Table 5.1. may be used
- in case the individual friction share would be higher than Table 5.1., the individual value counts
- With this proposal, no cherry picking is possible with current Table 5.1 values
- The following text is proposed for the GTR revision:

5.2.2. Brake Emissions Family Parent

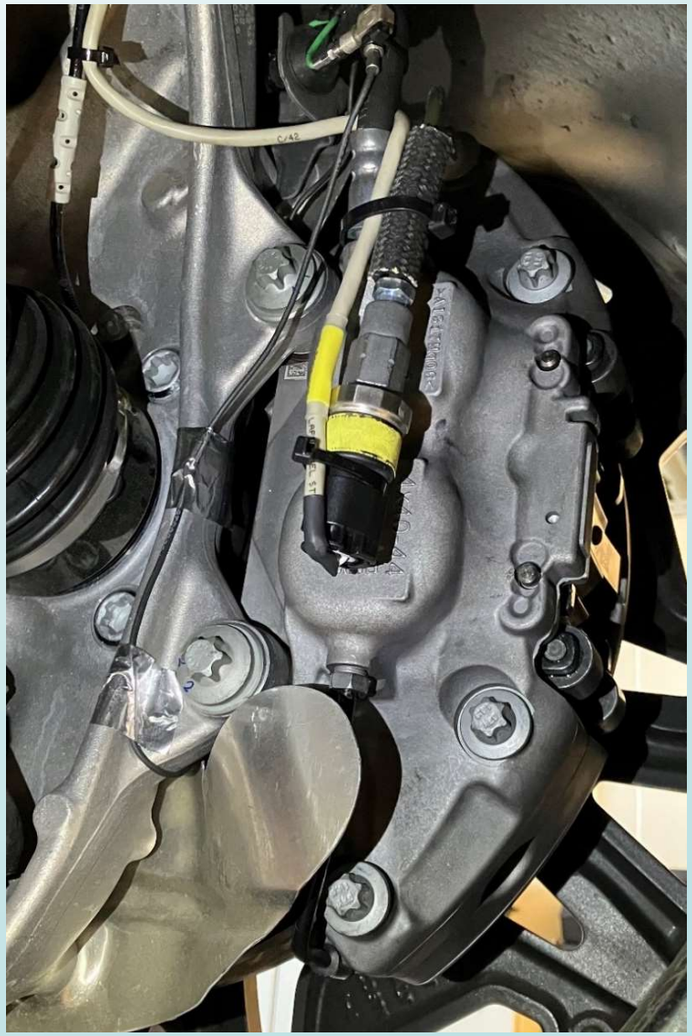
….

[Manufacturers can use the assigned friction braking share co-efficient from Table 5.1, or as an option may demonstrate own tests to determine the vehicle specific friction braking share co-efficient via the methodology described in Annex C. If the vehicle specific friction braking share determined by Annex C is higher than Table 5.1, the individual number of Annex C is used to determine the vehicle's emission as described in paragraph 12.1.5 and paragraph 12.2.4.

A detailed testing methodology to determine vehicle-specific friction braking share coefficients is described in Annex C.]

Description of Method B

Method B	
Measurement technology	External brake pressure measurement
Hardware	Pressure-sensor external at vent screw Measuring tolerance: ±0,1% (range: 0 – 200bar) Calibration via hardware manufacturer
Calculation C-factor	Measured → pressure in Pa $= \sum_{i=1}^{N} \frac{C_{p,i}}{r_i} \int p_{brake,\mathrm{i}} \cdot \mathrm{v}\, dt$ W_{brake} = sum of energy dissipated at the foundation brak s during all braking events in N; p_{brake} = brake pressure measured in Pa; Cp = Pressure to To que ratio in Nm/Pa; v = vehicle speed as given by the drive curve in m/s; r = tire dynamic rolling radius in m;
Advantages	+ Standard measurement technology for brake development + Easy way to determined friction brake share also for 3rd parties to verify + No necessity of calliper re-machining
Disadvantages	- External measurement necessary - Zero point calibration - c_p variation (friction coefficient uncertainty) (see next slides)
Price	~XXX € for sensors (1 vehicle)



Calculation of Friction share Method B

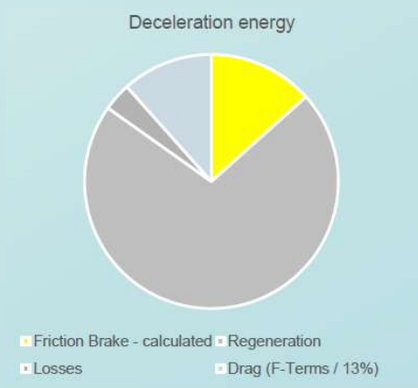
- Separate calculation for the front and rear axle

$$W_{Brake} = \int_{t=0}^{End} if\left(a_{target}(t) < 0\right) then \left(BrakeTorque_{FA}(t) \times \omega_{FA}(t) + BrakeTorque_{RA}(t) \times \omega_{RA}(t)\right) dt$$

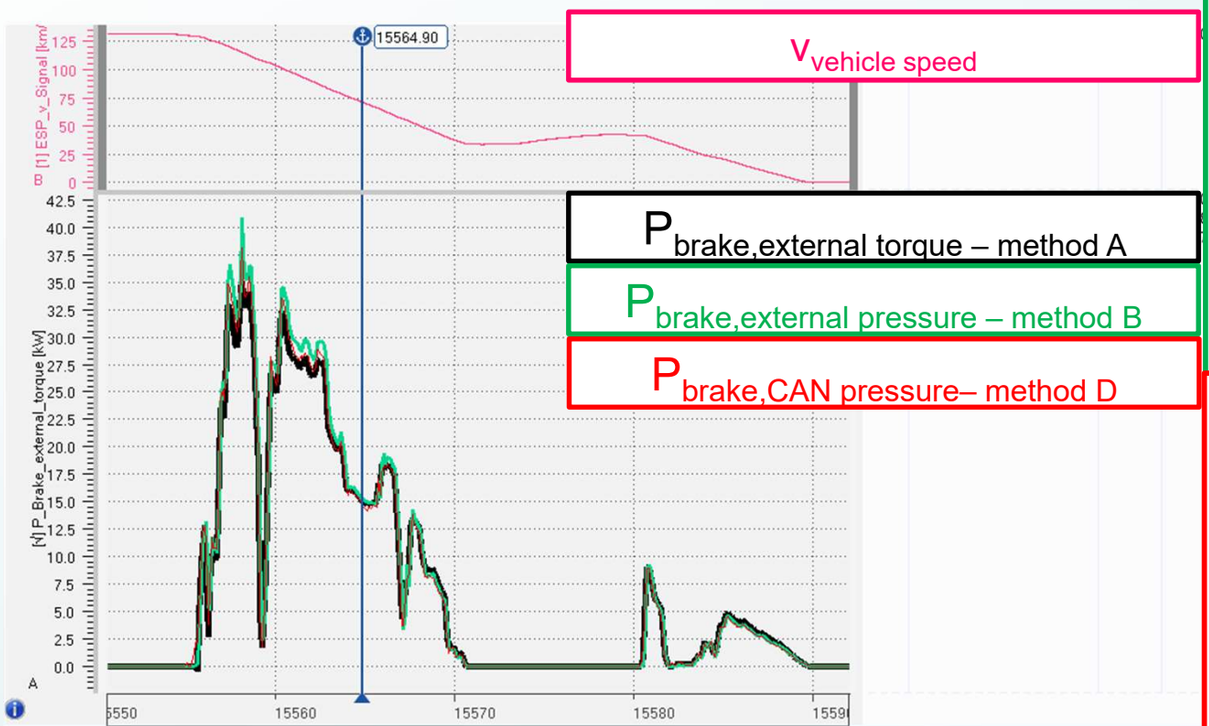
$$W_{Brake} = \int_{t=0}^{End} if\left(a_{target}(t) < 0\right) then \left(p_{FA}(t) \times 2 \times c_{p,FA} \times \omega_{FA}(t) + p_{RA}(t) \times 2 \times c_{p,RA} \times \omega_{RA}(t)\right) dt$$

- Total vehicle energy as sum of the front and rear axle

$$c = \frac{W_{\text{brake}}}{W_{\text{ref}}} = \frac{W_{\text{brake}}}{0.87 \cdot W_{\text{total,brake}}}$$



Brake pressure (B), CAN (D) and torque (A) (OEM-2)

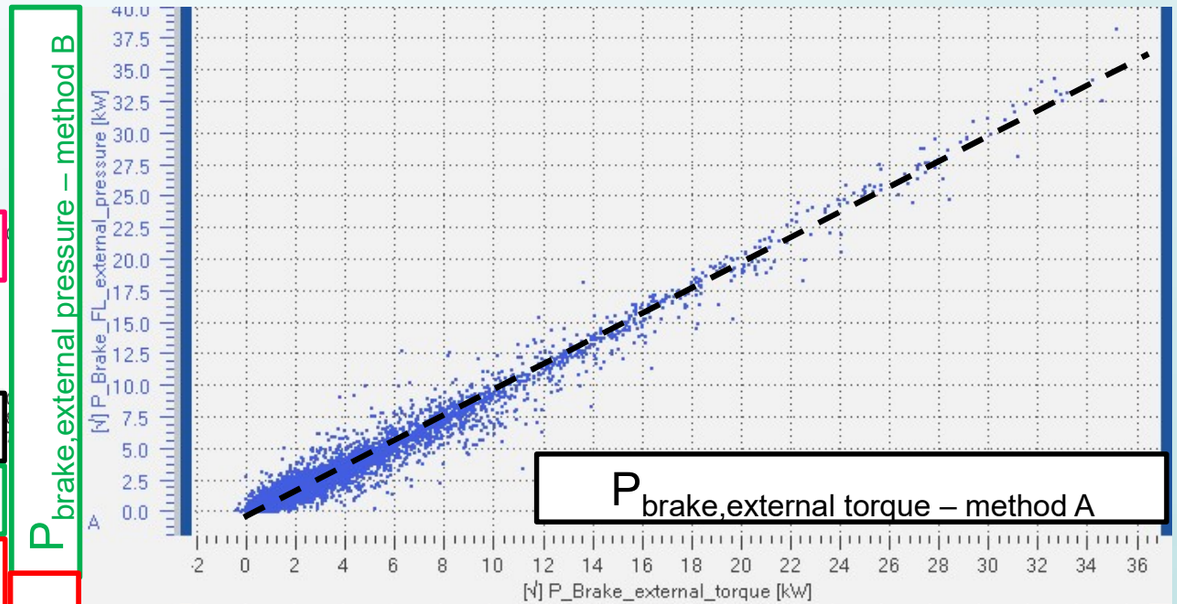


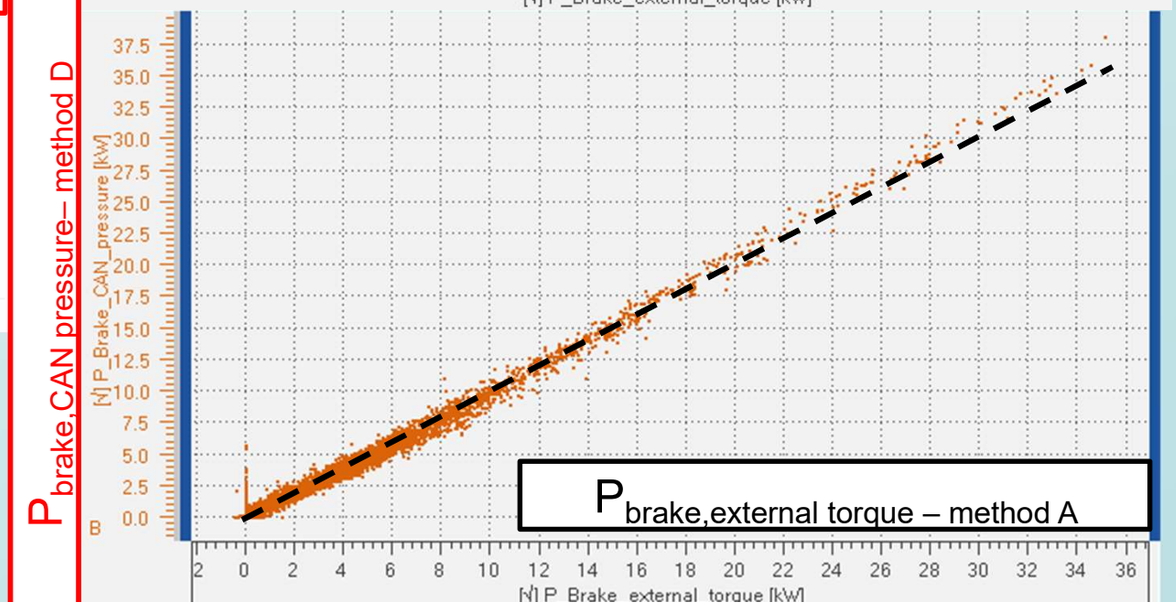
$v_{vehicle\ speed}$

$P_{brake,external\ torque\ –\ method\ A}$

$P_{brake,external\ pressure\ –\ method\ B}$

$P_{brake,CAN\ pressure–\ method\ D}$

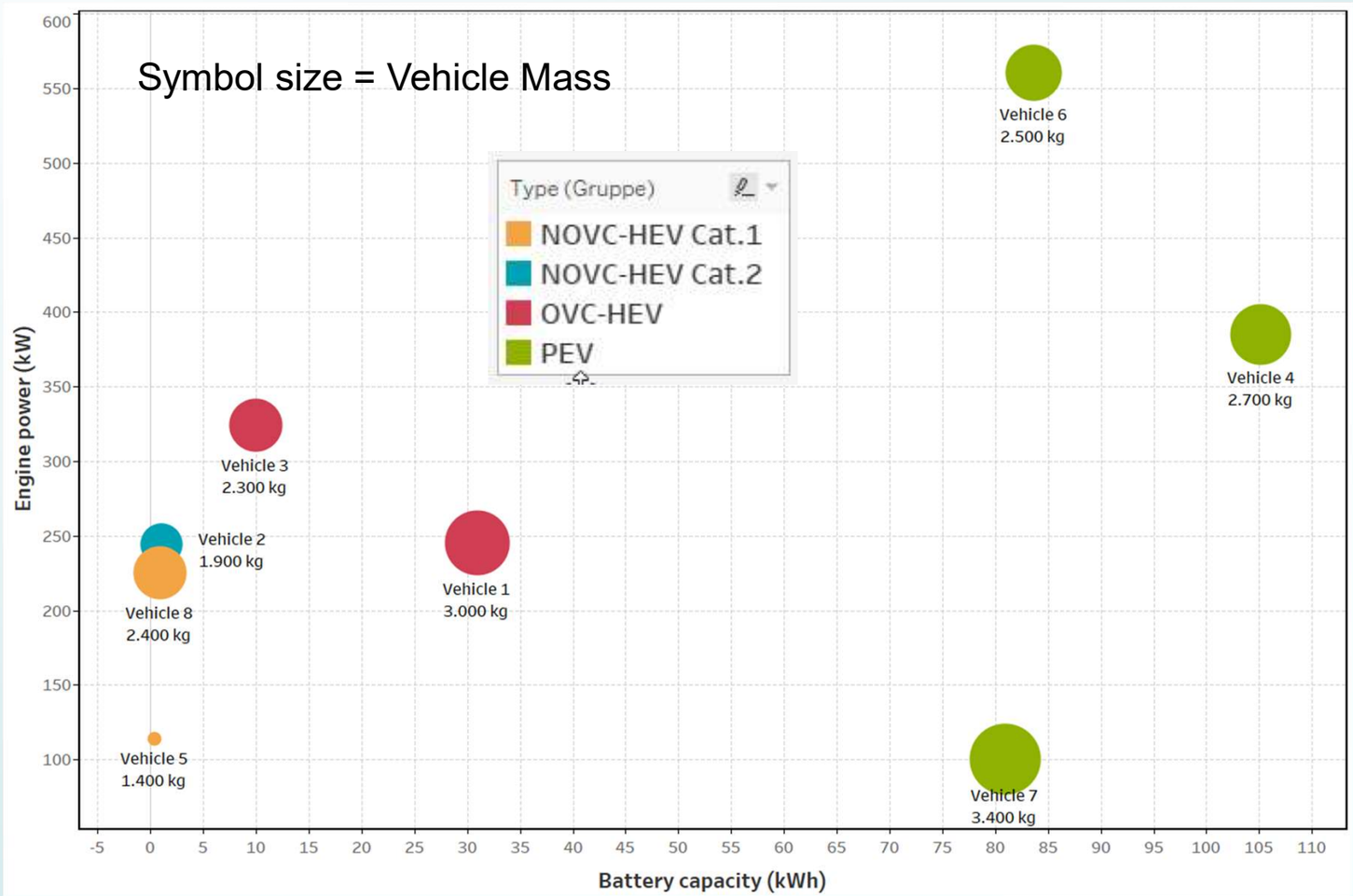




- Brake torque from external sensor and Brake torque from pressure (external sensor AND CAN) correlate well

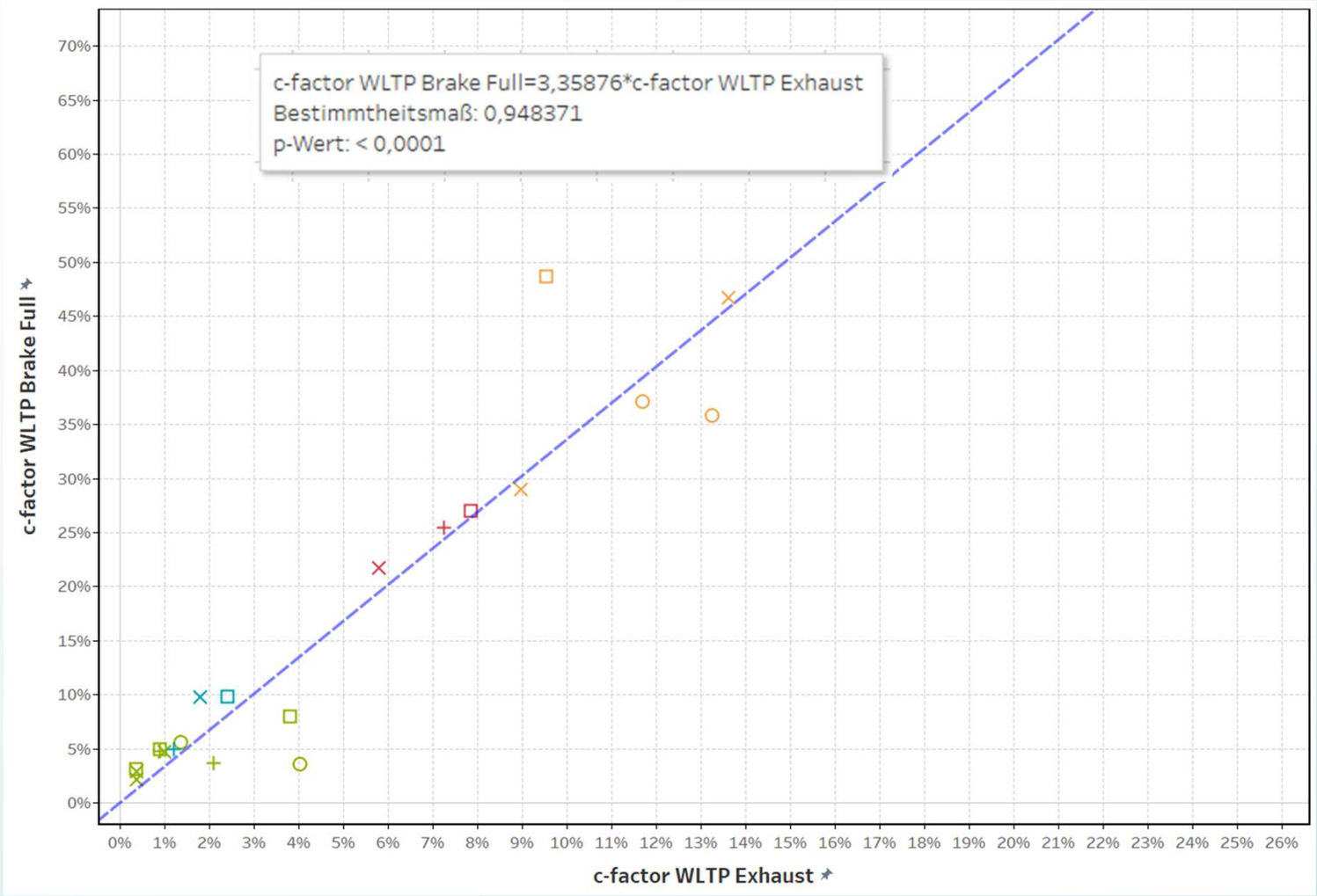
Data comparison Method B

Vehicle	Type	Engine power [kW]	Battery capacity [kWh] netto
Vehicle 1	OVC-HEV	145+100	31
Vehicle 2	NOV-HEV Cat2	109+135	1.1
Vehicle 3	OVC-HEV	324	10
Vehicle 4	PEV	385	105.2
Vehicle 5	NOVC-HEV Cat.1	114	0.45
Vehicle 6	PEV	560	83.7
Vehicle 7	PEV	100	81
Vehicle 8	NOVC-HEV Cat.1	225	0.92



- All electrification types were tested: 3x PEVs, 2x OVC-HEV, 2x NOVC-HEV-cat-1, 1x NOVC-HEV cat-2
- More vehicles to be tested

Correlation: WLTP Brake / WLTP-Exhaust

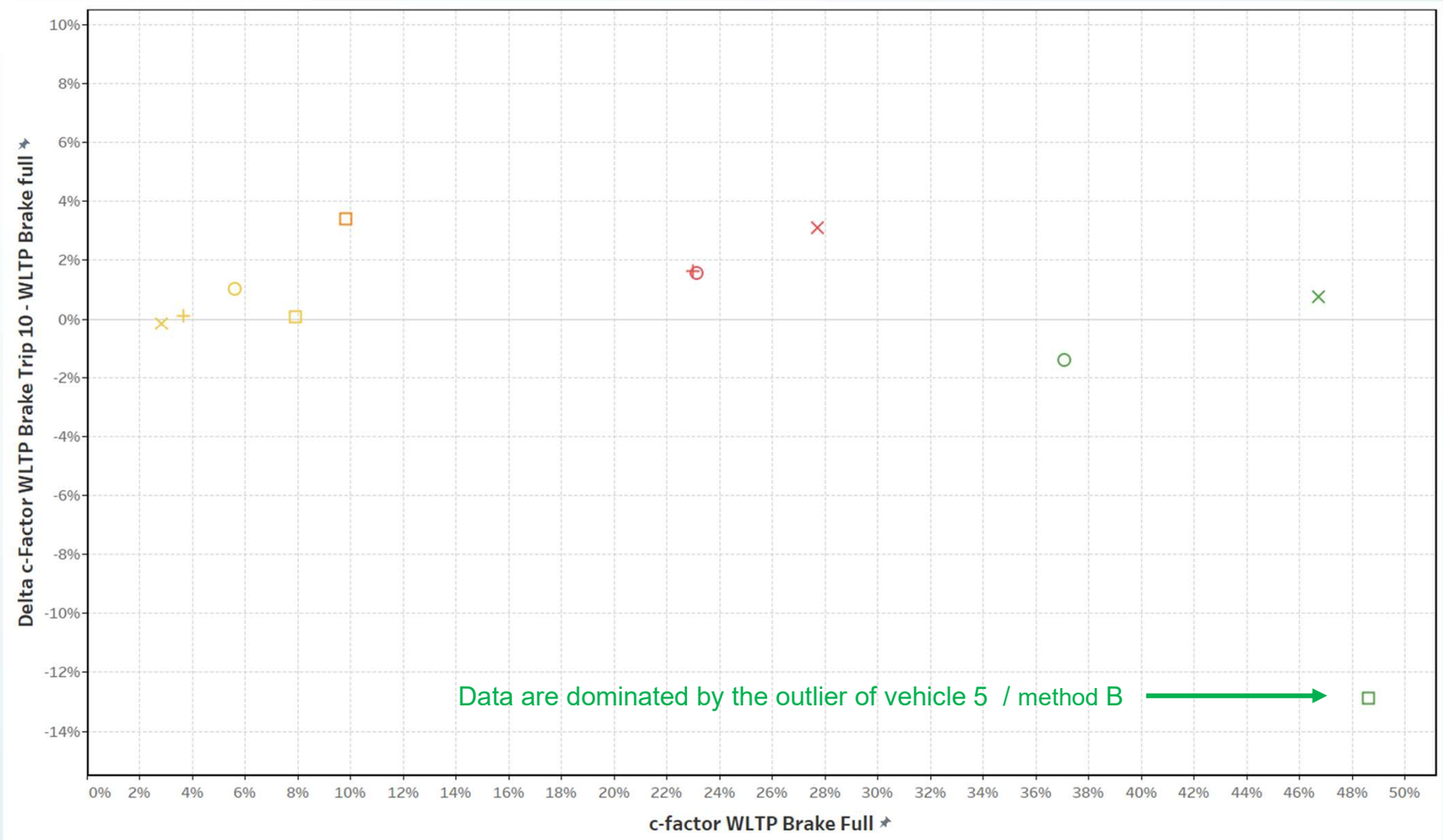


Type (Gruppe)
- NOVC-HEV Cat.1
- NOVC-HEV Cat.2
- OVC-HEV
- PEV

Method
- A: direct torque
- B: pressure w/o cons..
- B: pressure with con..
- D: CAN-signals

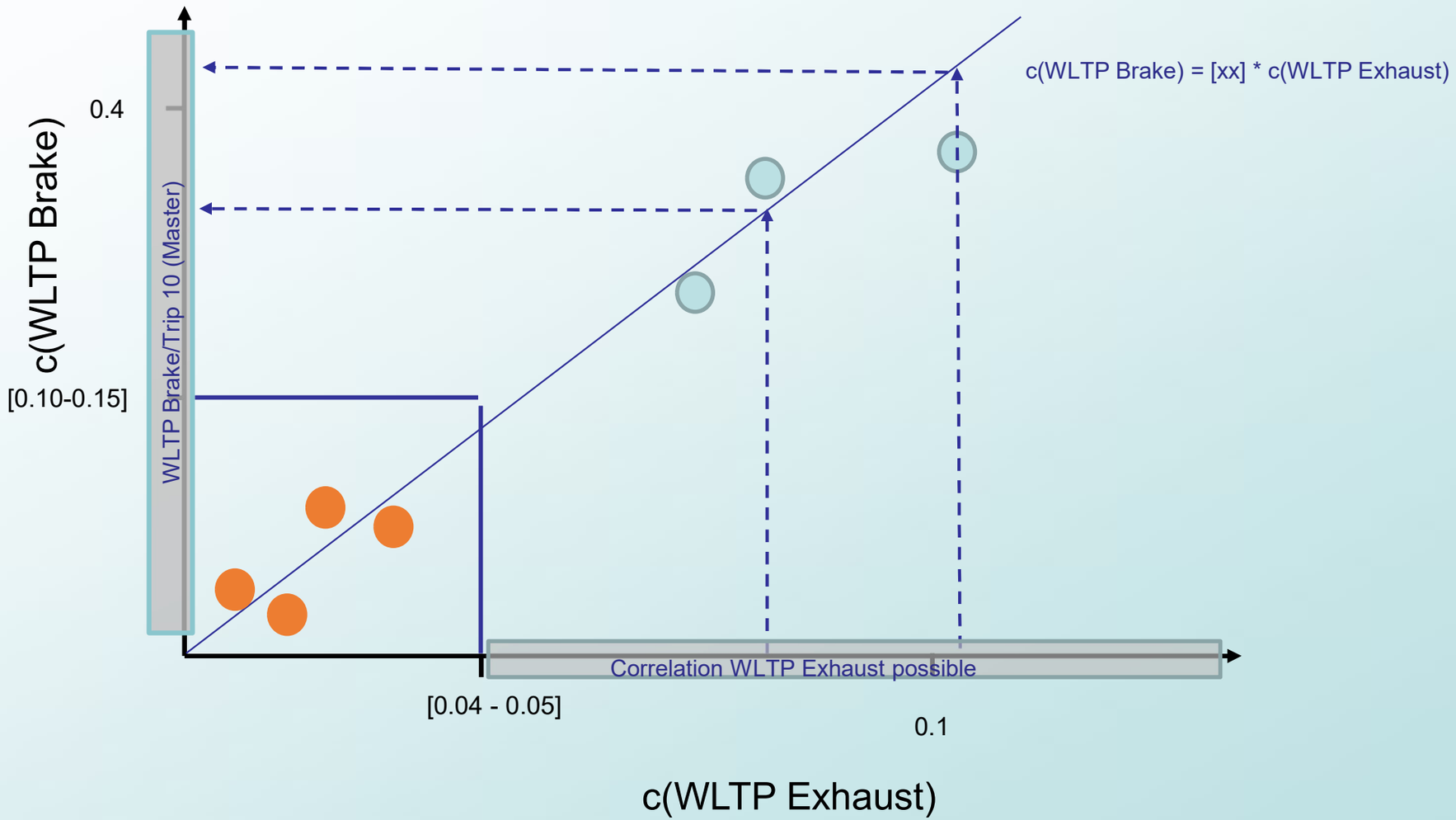
- Raw OICA data – outliers need to be investigated
- WLTP Brake / WLTP Exhaust correlation factor needs to be determined by further data

Correlation plot c-Factor WLTP Brake Full vs Trip 10

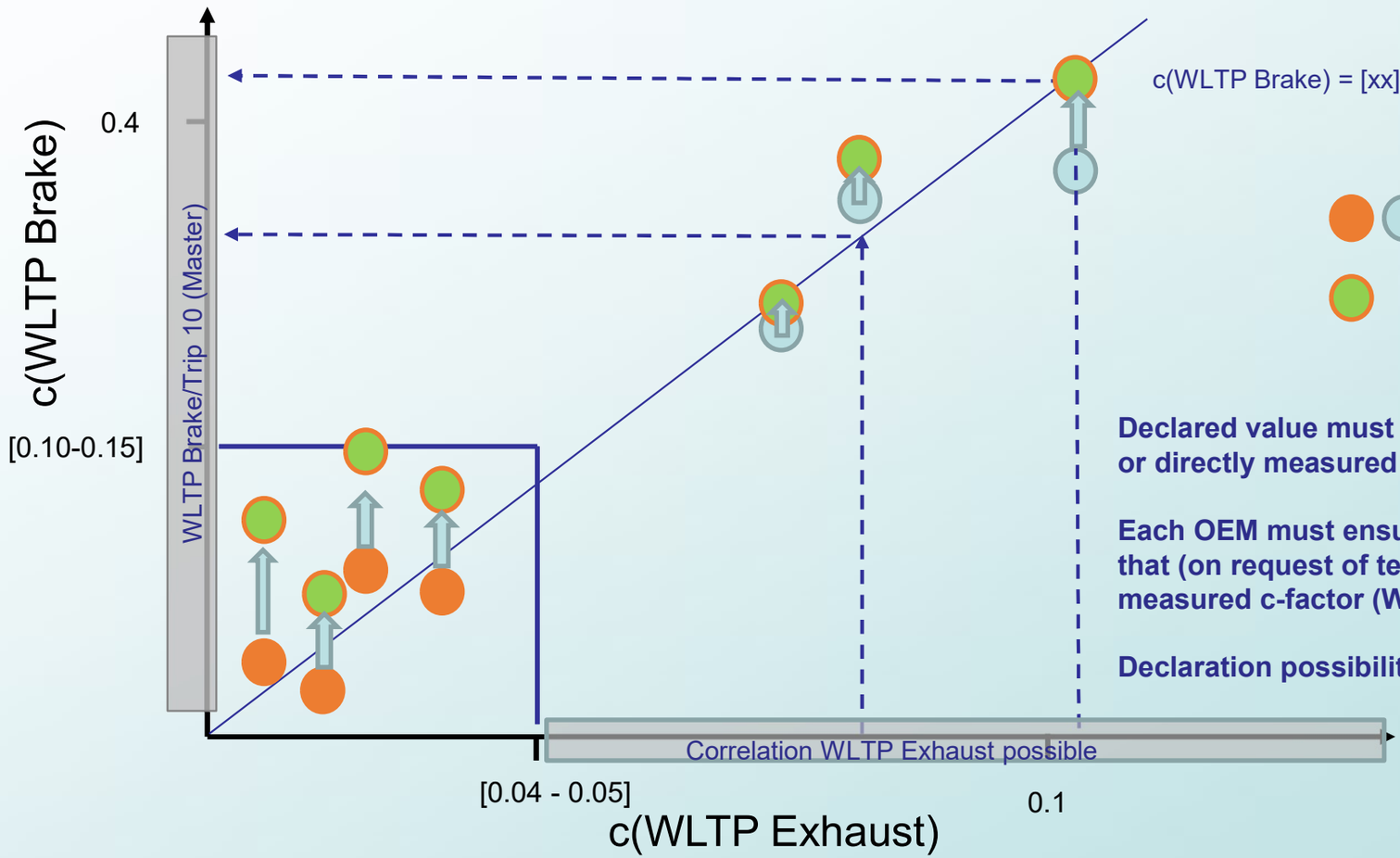


- c-factor determined on Trip 10 tends to show somewhat higher values ➔ Δ (WLTP Brake Trip10 – Full) > 0
- to be confirmed by further data

Correlation from WLTP Exhaust data – Proposal



Correlation from WLTP Exhaust data – Proposal



Declared value must always be >= correlated (WLTP Exhaust) or directly measured (WLTP Brake) value

Each OEM must ensure individually, that (on request of technical service or authority) measured c-factor (WLTP Brake) is < declared value

Declaration possibility must be implemented in GTR or EU7

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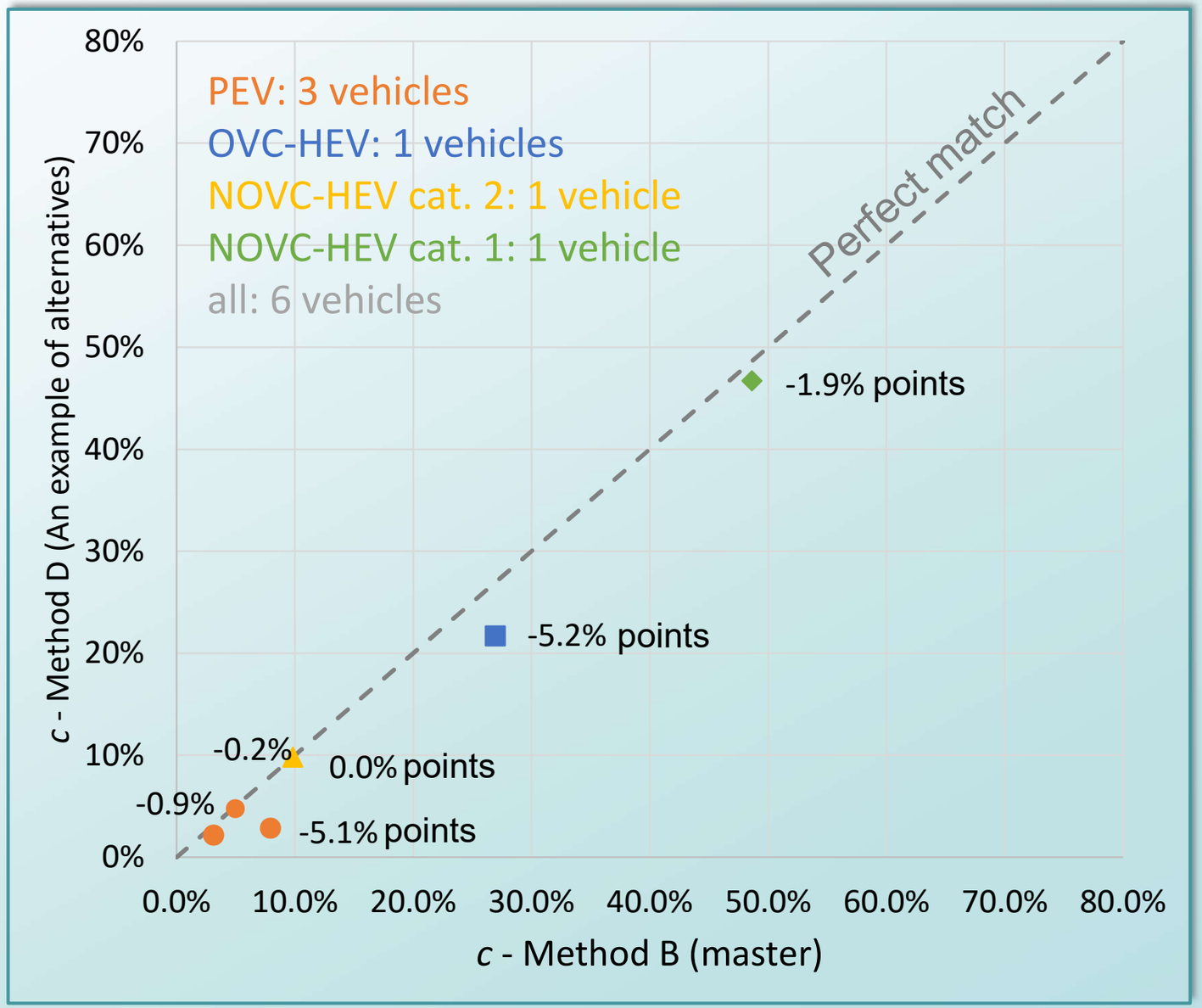
Alternative Method(s)

- An alternative method shall be tested in comparison to the Master Method (B) and demonstrated to the Technical Service
- Drive cycle shall be WLTP Brake
- Alternative method is valid if c(Alternative) = c(Method B) ±[x]% points
- TF-4 work shows tests for each electrification concept (PEV, NOVC-HEV I II, OVC-HEV)



Timing Plan

- Data evaluated (NOVC-HEV I, NOVC-HEV II, PEV, OVC-HEV) on WLTP-Brake (incl. Trip 10), WLTP –Exhaust. – 21.04.2023
- Further testing / data (data complete 05.05.)
- Present method to TF 4 26.4, present to PMP 27.4
- Receive comments and agree in TF-4 – before Mid May
- Writing of method, inclusion in GTR. TF-4 Meeting ca 15/16 May (tbc.)
- PMP meeting 24/25 May (tbc) – finalize details if necessary
- Present informal document at GRPE 01.06.2023
- Work towards working document (Oct 2023)
- Present working document and technical report to UNECE (Jan 2024)

- Status 26.04.2023 -