



Proposal Family Building

PMP Webconference

23rd Nov 2022, 12:00-15:00 CET

Version 23.11.2022



Description of Family Building

1.) A brake family is defined by a brake system considering of caliper, disc or drum, pad and vehicle parameters

Component	Item	KO criteria (new test required)	Remark
Caliper/BP	Type caliper	Any change (floating vs. fixed caliper) Number of pistons Size of pistons Mean effective friction radius (position of pistons) Retraction element (springs, air gap)	Only the same caliper allowed for family building
Disc/drum	Disc/drum type	Total disc/drum mass Any material/design change, including surface coatings Geometric change of friction surface, including surface finishing Type of drum brake (e.g. simplex, duplex)	Disc/drum size is considered in the mentioned parameters on the left side
Pad	Size / shape	Changes on the friction surface geometry	
	Material	Any change to friction material / production process (e.g. scorching, ...)	Backing plate, friction ingredients, process
Pad	Secondary measures	With influence to the residual torque behaviour	
Vehicle	Vehicle mass	Is the parameter on the x-axis as parameter for brake energy	Can different WL/DM Temperatur levels be combined in one brake family?
Tire	Dynamic rolling radius	significant change	small changes acceptable, tbd
Other characteristics	Others	That have a non-neglectable influence on brake emissions	Other characteristics allow opening of new families on request of vehicle manufacturers



Description of Family Building

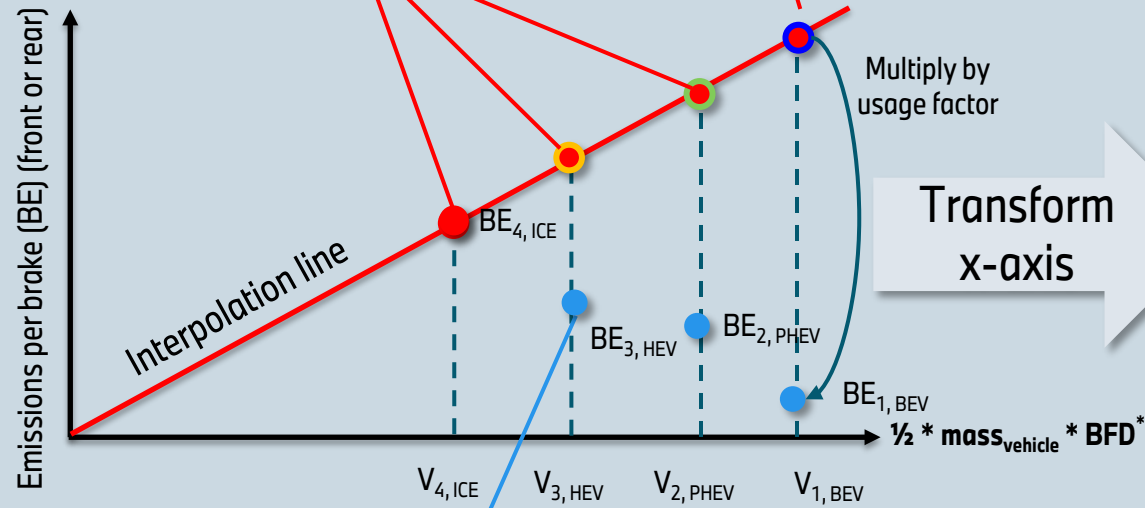
- 2.) For vehicles using this brake family the application with the highest wheel load ($WL = \frac{1}{2} \times \text{vehicle mass} \times \text{Brake Force Distribution (BFD)}$) is identified
- 3.) The brake is tested according to the JRC method with highest WL and emission per brake measured (BE) is measured
- 4.) For this vehicle application (for example V1 PHEV), the BE is multiplied by the friction energy share defined by the GTR
- 5.) For a lighter vehicle application using this brake family (for example V2 HEV), the BE is multiplied by the ratio of $WL(V2) / WL(V1)$
- 6.) The interpolated BE of V2 is multiplied by the friction energy share defined by the GTR
- 7.) The vehicle emission value is the sum of 2x front brakes and 2x rear brakes



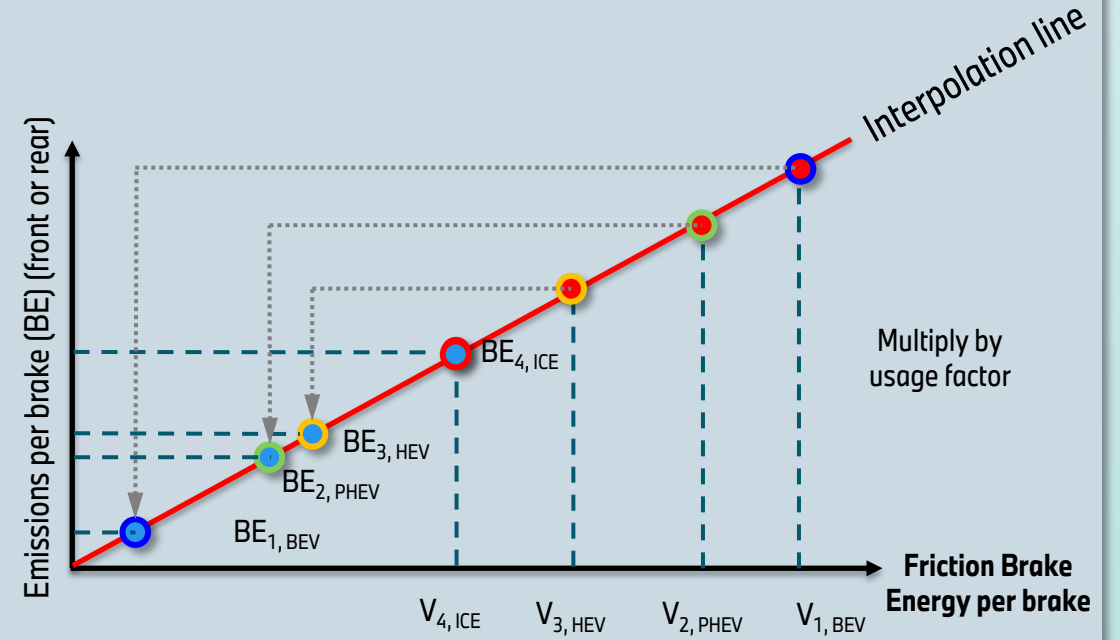
Schematic of Family Building

Vehicle with highest brake load per axle, measured at test stand (@ FFB) = **head** of brake emission family

Brake emissions possible to measure @ test stand but not necessary due to **family building** (interpolation!)



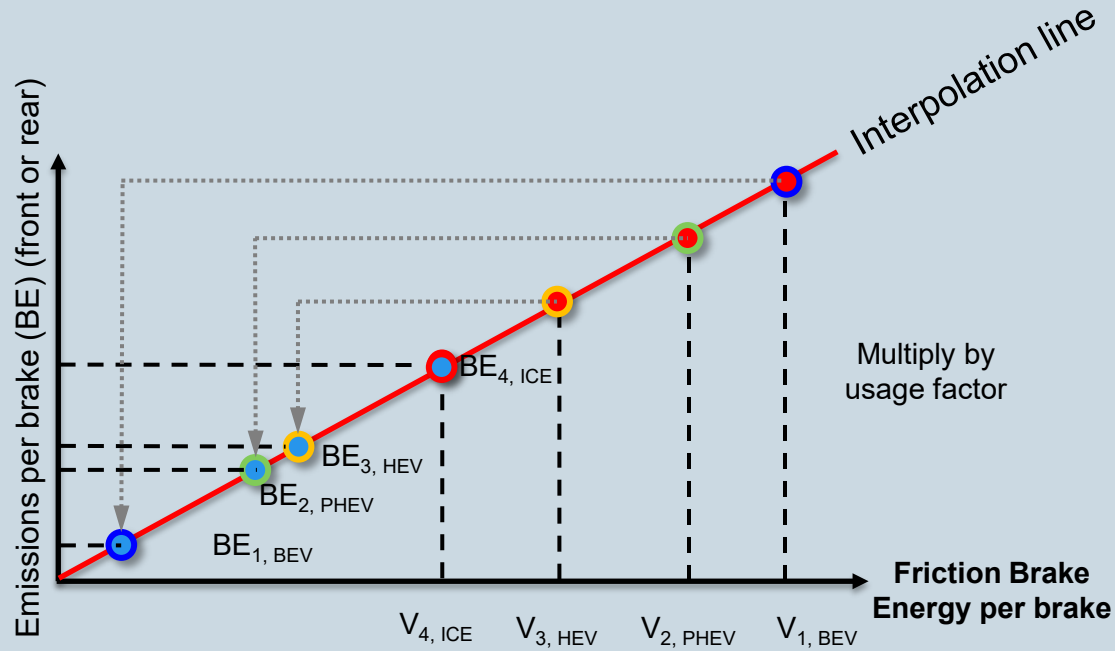
"real" vehicle brake emission behaviour per brake
Interpolated emission value, **not** measured!



*BFD := Brake Force Distribution



Brake Emission Families, Transformation of x-Axis



- Graph shows different vehicles with different electrification grades
- Having exactly the same brake system on one axle (e.g. front axle) = different members of one brake emission family
- Vehicle V1 has the highest mass of all relevant vehicles => V1 is head of brake emission family
- Brake system is measured on component test stand with wheel load of V1 resulting in e.g. a reference result of 10 mg/km/brake
- Reference result is multiplied by the vehicle category coefficient to get the final brake emission factor:

V1 is a BEV: $BE_{1, BEV} = 10 \text{ mg/km/brake} \times 0.02^*) = 0.2 \text{ mg/km/brake}$

V2 is a PHEV: $BE_{2, PHEV} = 10 \text{ mg/km/brake} \times \text{mass}_{PHEV} / \text{mass}_{BEV} \times 0.09^*)$ (e.g.: $\text{mass}_{PHEV} / \text{mass}_{BEV} = 85\%$, BFD = const.)

$BE_{2, PHEV} = 10 \text{ mg/km/brake} \times 0.85 \times 0.09 = 0.77 \text{ mg/km/brake}$

^{*)}OICA observed Coefficients

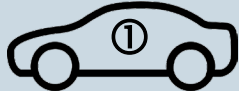

✓ A common fixed coefficient is proposed for each vehicle category. Different vehicles categories will have different fixed coefficients (4 coefficients to be defined: PEV, OVC-HEV, NOVC-HEV, Mild-Hybrid)

$$\text{FINAL BRAKE EMISSION FACTOR} = \text{FULL-FRICTION EMISSION FACTOR} * \text{FIXED COEFFICIENT}$$

Vehicle Category	Observed Energy / Coefficient WLTP Brake median (range)	JRC's initial Coefficients
PEV	0.02 (0.0 - 0.03)	0.17 - 0.19
OVC-HEV	0.09 (0.05 - 0.18)	0.30 - 0.32
NOVC-HEV		
NOVC-HEV („Mild-Hybrid“)	(0.23 - 0.62)	0.60 - 0.65



Example calculation: Brake Emissions for different vehicles (within one brake family)

	Vehicle No	Axle	Electrification type	Wheel load	PM10 emission full friction braking per brake	Coefficient Electrification	PM10 Emissions final per brake	PM10 Emissions final per vehicle
	1	FA	BEV	1000	10 mg/km	0,02 (OICA)	0,2 mg/km	0,6 mg/km
	1	RA	BEV	500	5 mg/km	0,02 (OICA)	0,1 mg/km	
	1	FA	BEV	1000	10 mg/km	0,19 (JRC)	1,9 mg/km	5,7 mg/km
	1	RA	BEV	500	5 mg/km	0,19 (JRC)	0,95 mg/km	
	2	FA	PHEV	850	$10 \text{ mg/km} \cdot 850 / 1000 = 8,5 \text{ mg/km}$	0,09 (OICA)	0,77 mg/km	2,26 mg/km
	2	RA	PHEV	400	$5 \text{ mg/km} \cdot 400 / 500 = 4 \text{ mg/km}$	0,09 (OICA)	0,36 mg/km	
	2	FA	PHEV	850	$10 \text{ mg/km} \cdot 850 / 1000 = 8,5 \text{ mg/km}$	0,32 (JRC)	2,72 mg/km	8 mg/km
	2	RA	PHEV	400	$5 \text{ mg/km} \cdot 400 / 500 = 4 \text{ mg/km}$	0,32 (JRC)	1,28 mg/km	

- Family concept:
 - is a practical approach
 - Needs to consider different values for front and rear axle
- JRC / OICA coefficients have a substantial impact on vehicle result