

43rd PMP IWP meeting on 16 March 2017

Measurement of Brake Wear Particle Emissions using a Dynamometer System under Urban City Driving Cycles

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Reference

Hagino et al., *Wear*, 334-335, pp.44-48 (2015) doi:10.1016/j.wear.2015.04.012

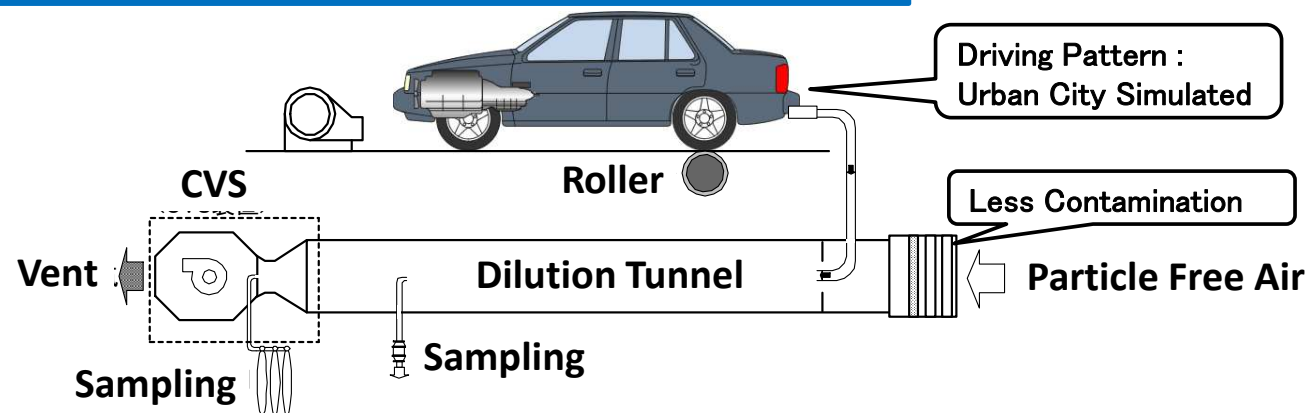
Hagino et al., *Atmos. Environ.* 131, pp.269-278 (2016)doi:10.1016/j.atmosenv.2016.02.014

Hagino et al., WLTC cycle data, *In preparation*

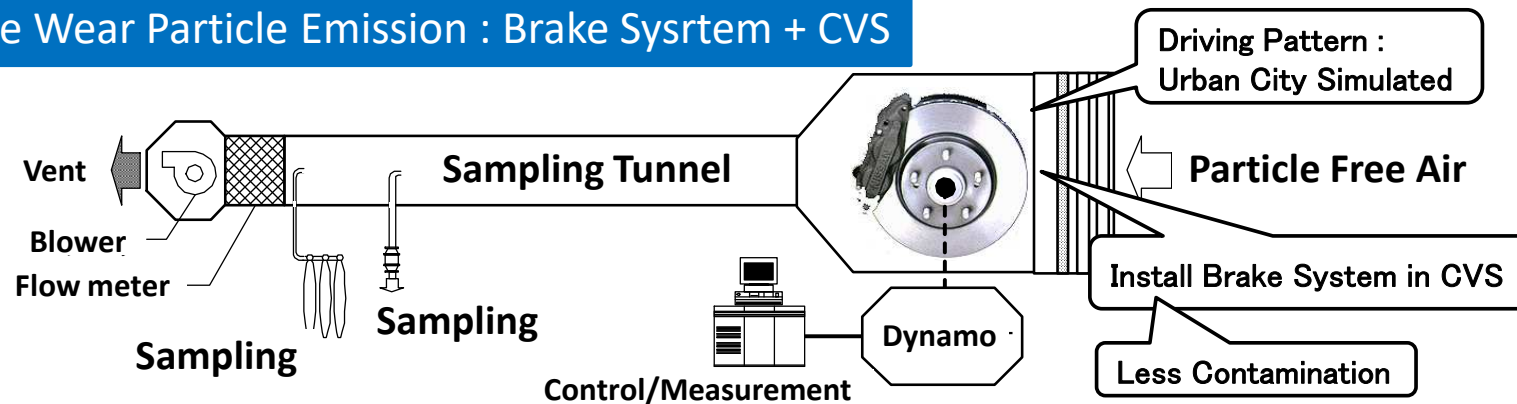
Thinking of Emission Measurement

- Tail-Pipe Emission : Well Controlled System, Simulated Driving Cycles, Many Data
- Non Tail-Pipe Emission : Comparable Data to Tail-Pipe Emission for the First Step

Tail-Pipe Emission Test : Constant Volume Sampler (CVS)

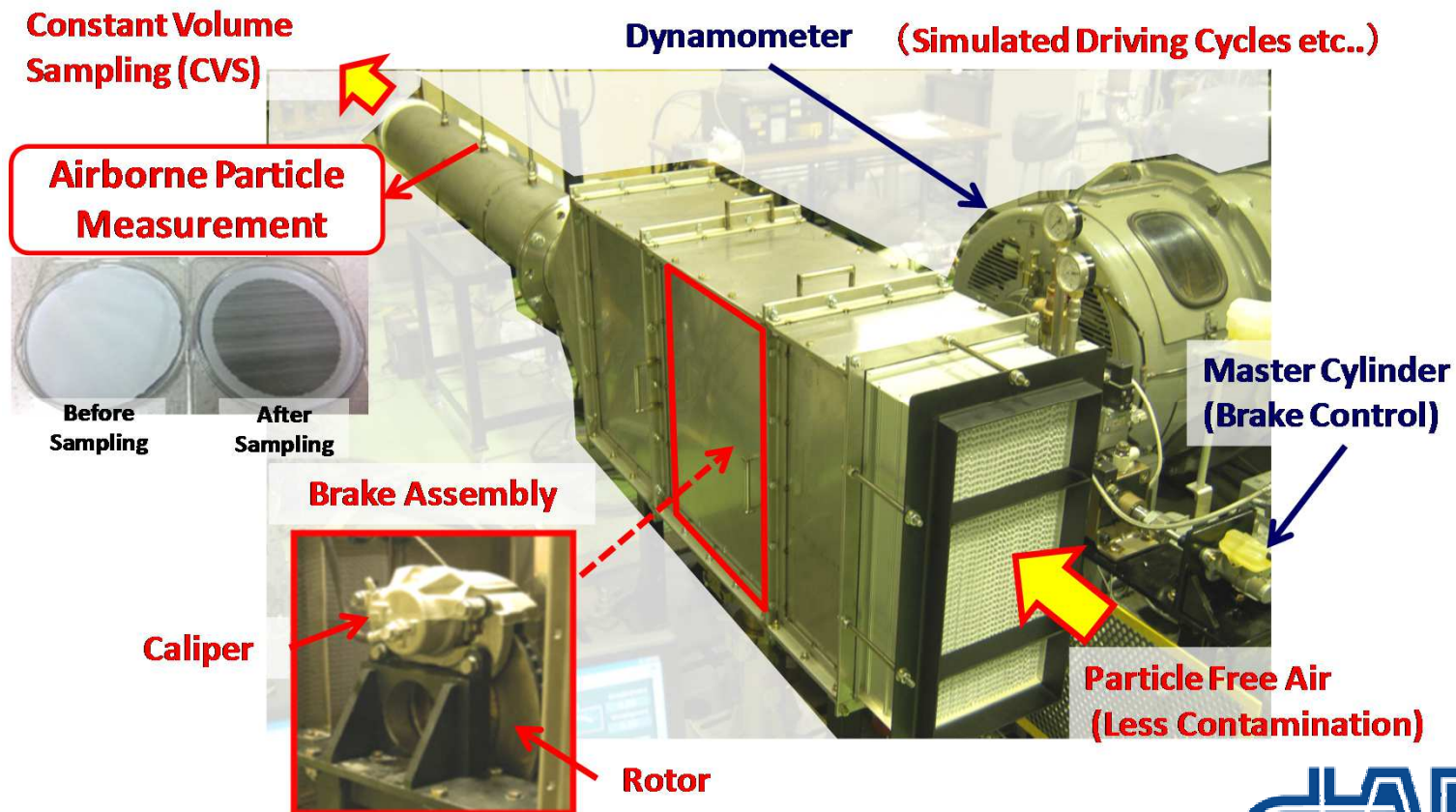


Brake Wear Particle Emission : Brake System + CVS



Brake Dynamometer for Measurement of Emission

- Driving Operation → Simulated Driving Cycles (Transient) or Constant
- Quantitative Sampling → Constant Volume Sampling (CVS)

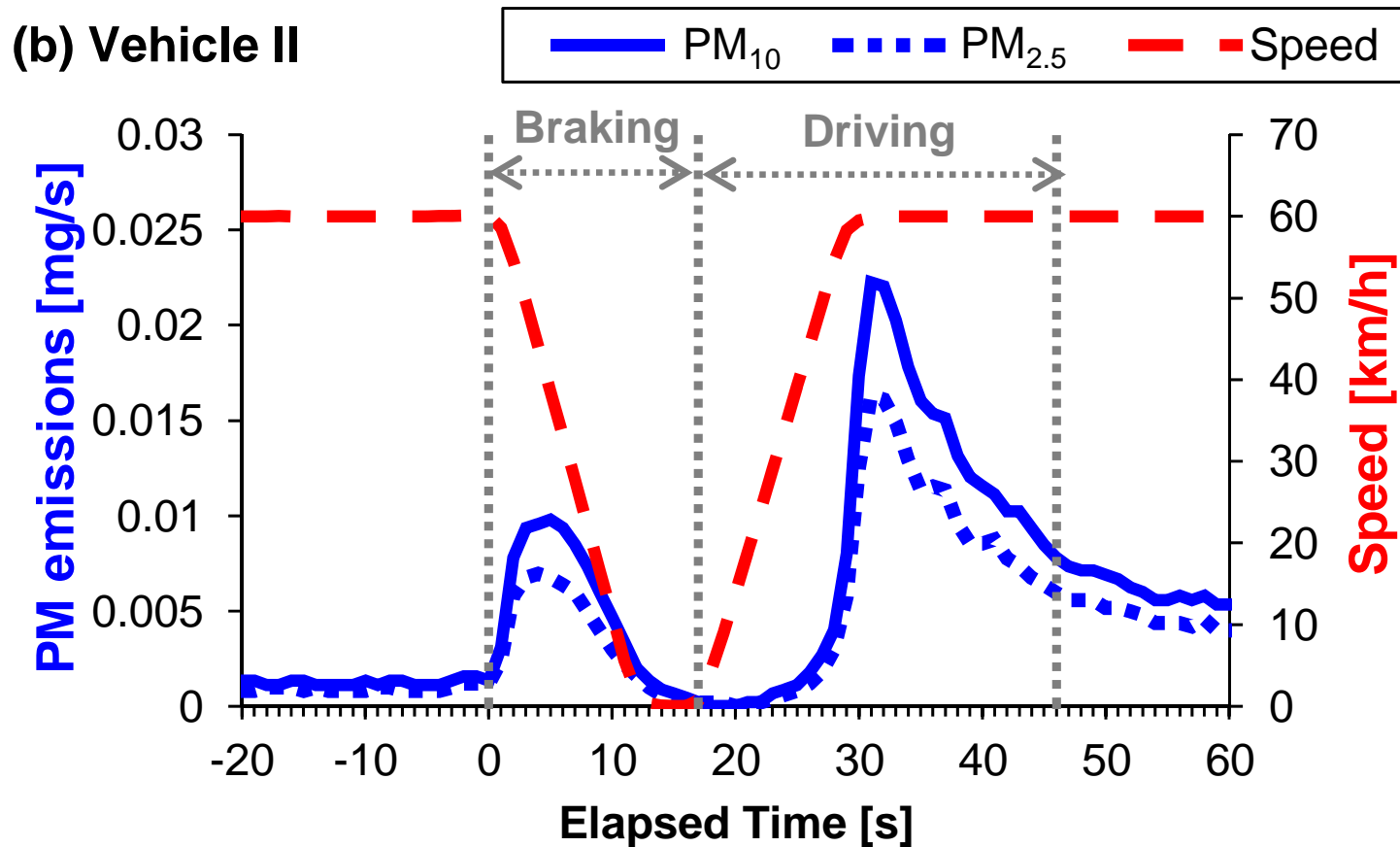


Ref & Rev: Hagino et al., *Wear* 334-335, pp.44–48 (2015)



Constant Operation

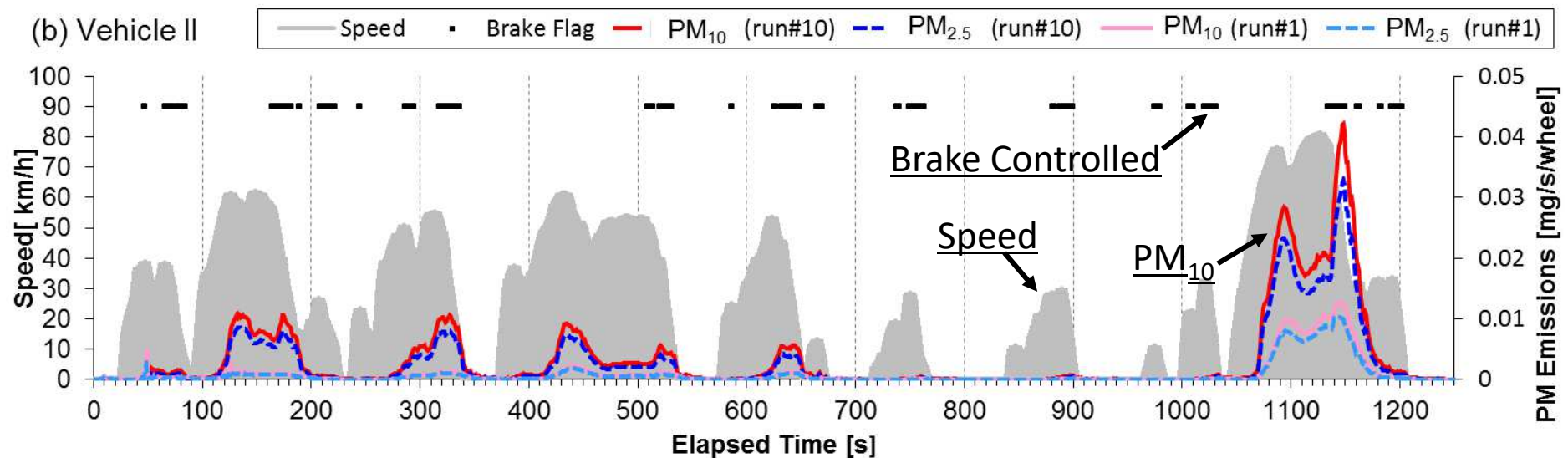
- Importance of Resuspended Particles and/or Dragging
- Brake Emission should be including Braking and Driving, both



Ref: Hagino et al., *Wear* 334-335, pp.44–48 (2015)

Simulated Urban City Driving Cycle Tests

- Tail-Pipe Emission : Authorized Procedures, Simulated Driving Cycles
- Non Tail-Pipe Emission : **Comparable Data to Tail-Pipe Emission for the First Step**
→ e.g. JC08 test cycle in this study



Emission per Vehicle

$$E_{vehicle} = E_{wheel} \times \text{Number}_{front} + E_{wheel} \times \text{Force Distribution} \times \text{Number}_{rear}$$

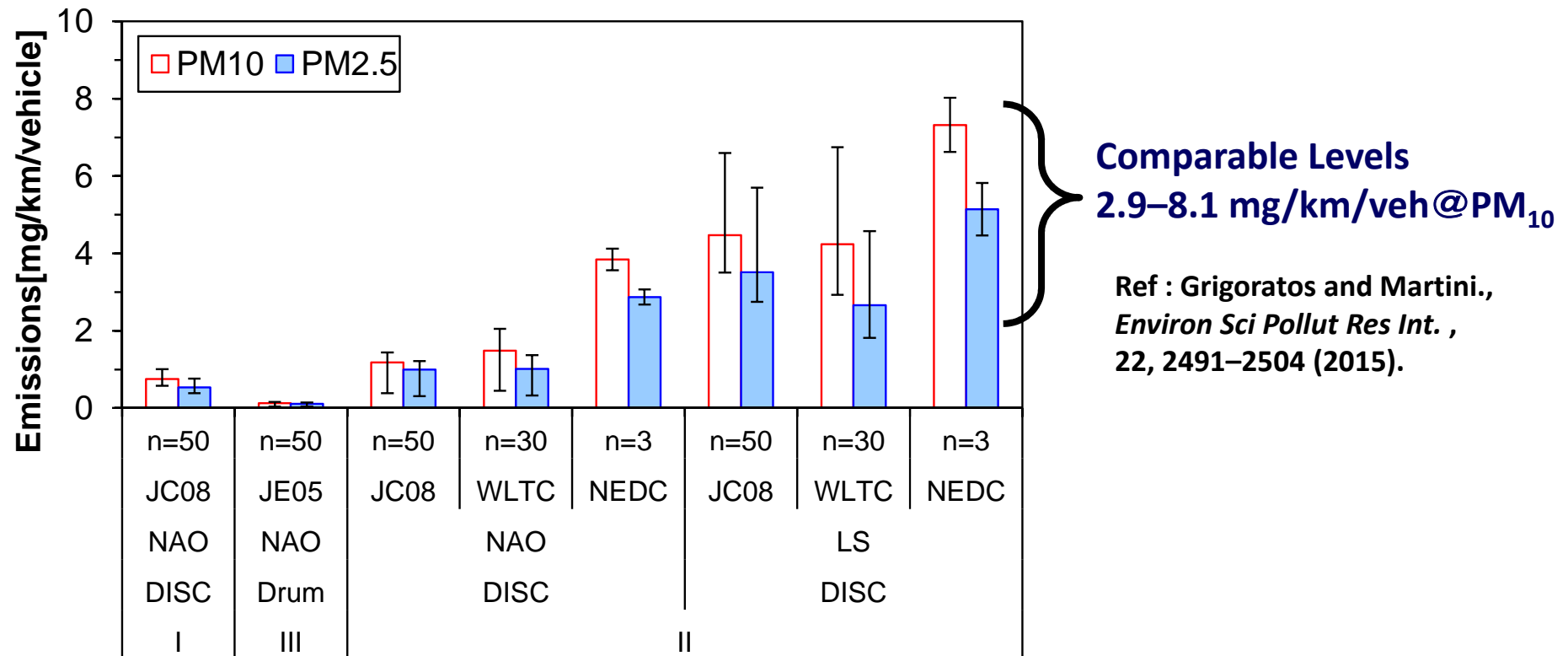
Emission per Wheel

$$E_{wheel} = \text{PM}_{tunnel} \times \text{Flow Rate}_{tunnel} \times \text{Time}_{test} / \text{Distance}_{JC08 \text{ or } JE05}$$

Ref: Hagino et al., *Atmos. Environ.* 131, pp.269-278 (2016)

Emission Levels in mg/km (PM)

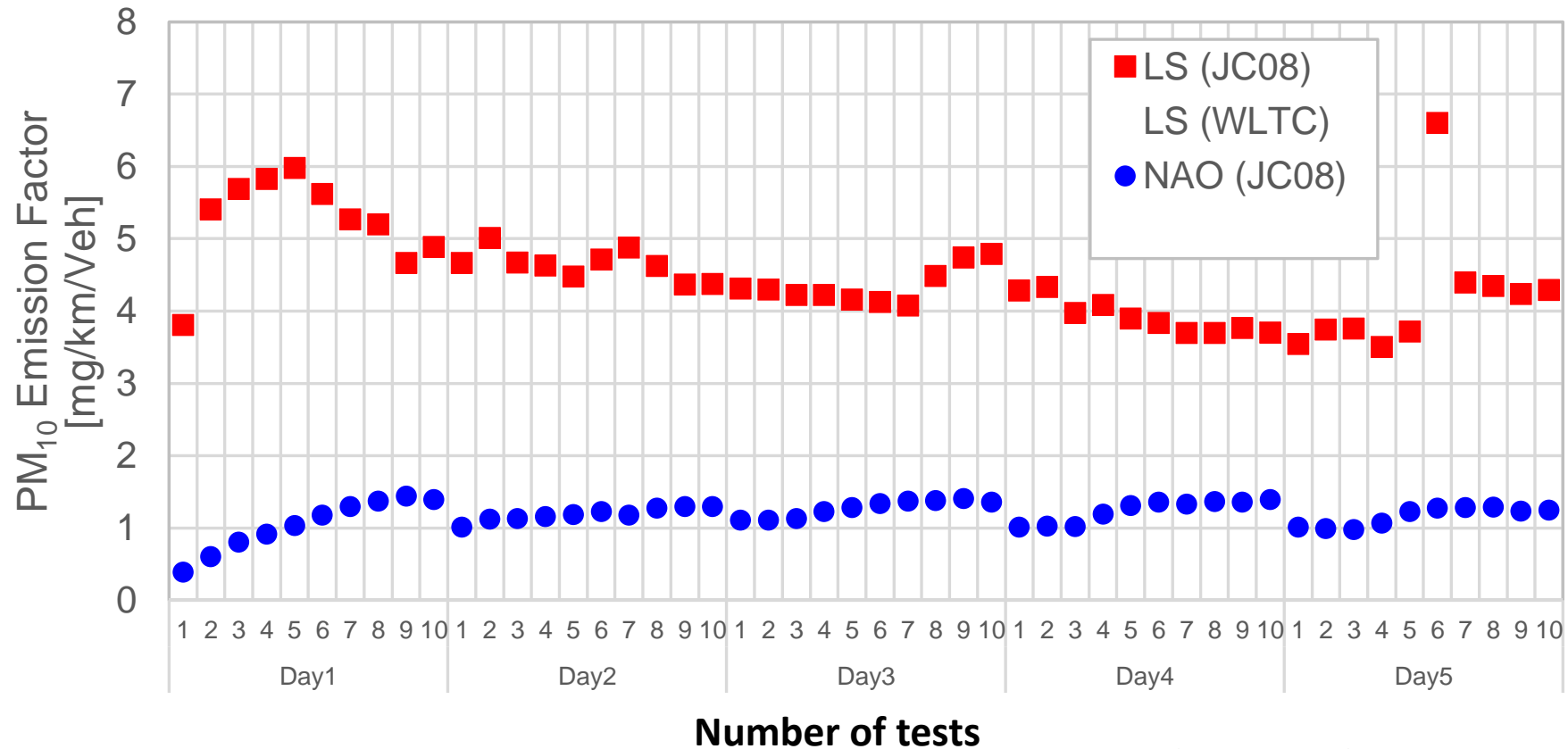
- Tail-Pipe Emission : Recent Emission Levels in mg/km, sub mg/km Challenging
- Non Tail-Pipe Emission : **Comparable Levels in Literature**
Strongly Depending on Materials (Cycles, and Assembly)



Ref : Hagino et al., *in Preparation*

Emission Levels in mg/km (PM)

- Non Tail-Pipe Emission **with Low Repeatability**
50 test (10 test × 5 days) JC08 Test Cycle



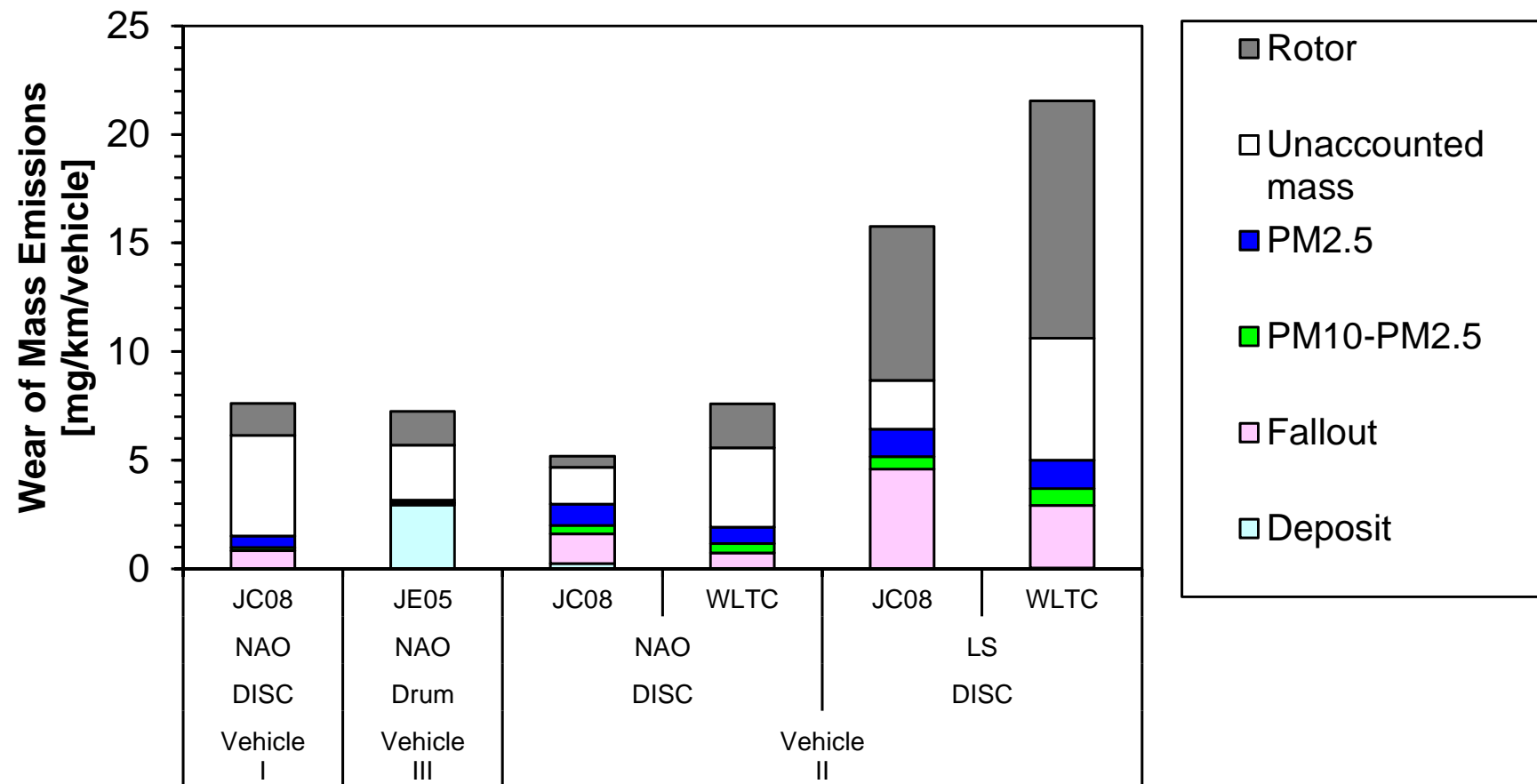
Ref: Hagino et al., *Atmos. Environ.* 131, pp.269-278 (2016)

PM10 data: DustTrak II 8530
corrected by gravimetric measurement

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Wear Mass Balance

- Rotor → Unignorable Emission
- Unaccounted mass → **Gasification ?** Particle Loss?

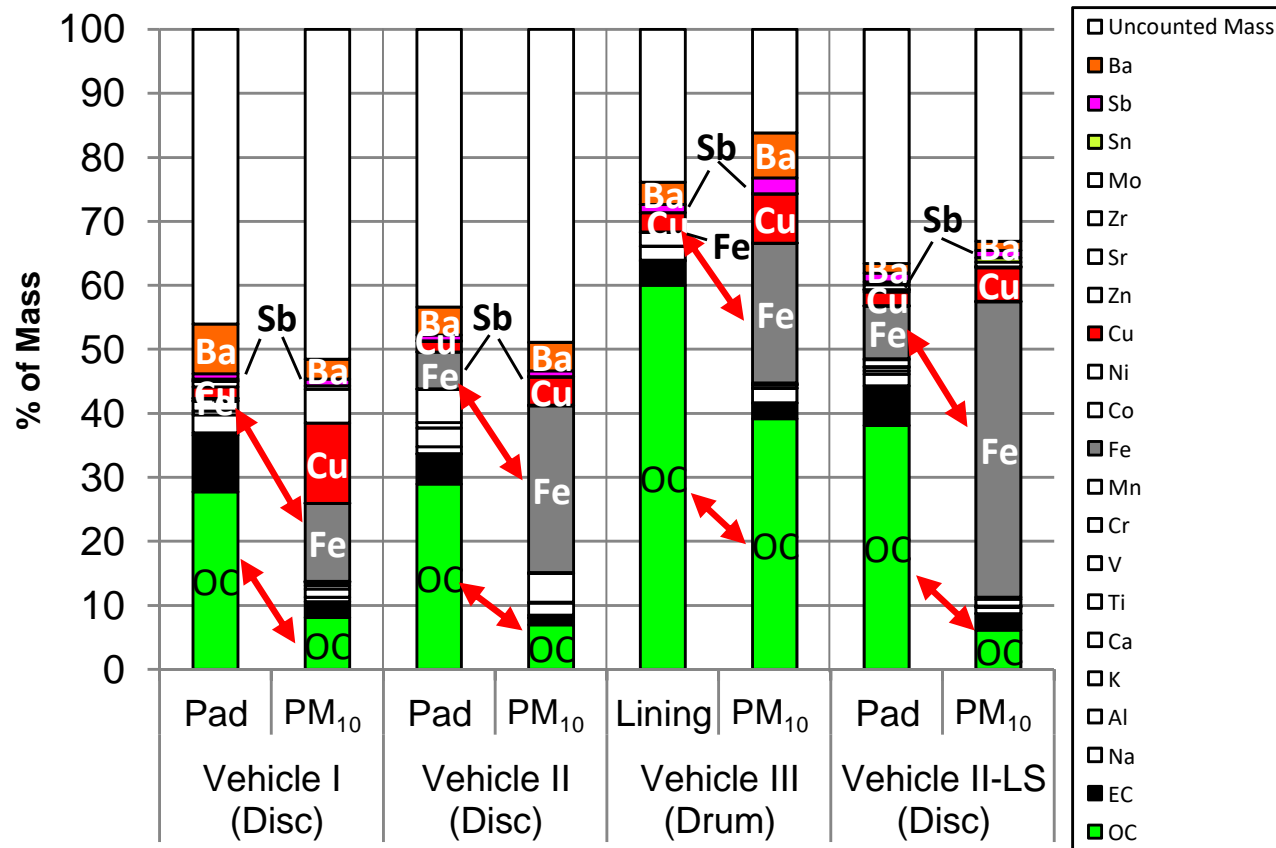


Ref : Hagino et al., *in Preparation*

✘ One data per 50 or 30 cycles repeated

Compositions

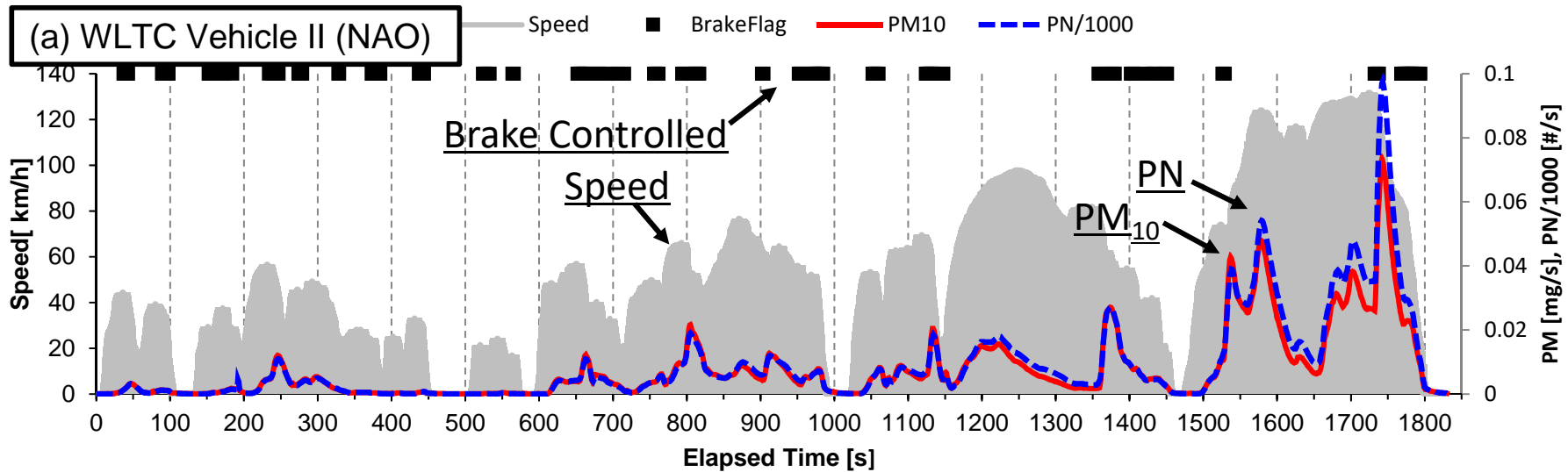
- OC (**Organic Carbon**) **Decreases** : Gasification by Mechanochemical Reaction ?
- Key tracers (Cu, Ba, and Sb) **in atmosphere** were detected
e.g. Comparable **Sb** : Road Tunnel 4-17 $\mu\text{g}/\text{km}$, This Study 3-12 $\mu\text{g}/\text{km}$



Ref : Hagino et al., *in Preparation*

Simulated Urban City Driving Cycle Tests

- Tail-Pipe Emission : Well Controlled System, Simulated Driving Cycles, Many Data
- Non Tail-Pipe Emission : **Comparable Data to Tail-Pipe Emission for the First Step**
 → e.g. WLTC test cycle



Ref : Hagino et al., *in Preparation* (2017)

Emission per Vehicle

$$E_{vehicle} = E_{wheel} \times \text{Number}_{front} + E_{wheel} \times \text{Force Distribution} \times \text{Number}_{rear}$$

Emission per Wheel

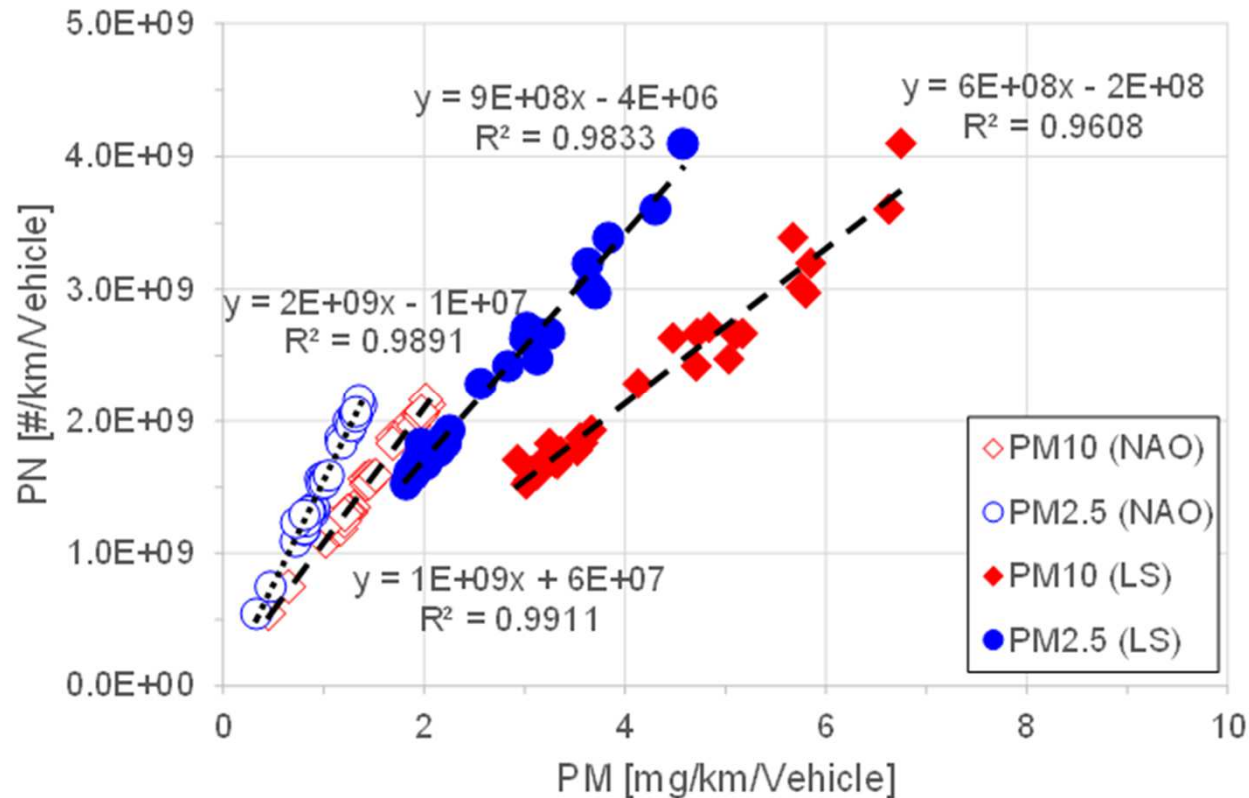
$$E_{wheel} = \text{PM}_{tunnel} \times \text{Flow Rate}_{tunnel} \times \text{Time}_{test} / \text{Distance}_{JC08 \text{ or } JE05}$$

Ref : Hagino et al., *in Preparation*

Emission Levels in #/km (PN)

- Tail-Pipe Emission : Recent Emission Levels in 10^{11} #/km
- Non Tail-Pipe Emission : Good Correlation PM mg/km vs PN #/km

Detection Levels in 10^9 #/km, but very low



Ref : Hagino et al., *in Preparation*

PM data: DustTrak II 8530 corrected by gravimetric measurement
 PN data: TSI CPC 3775 ($D_{50} = 4$ nm)

Conclusion

- Importance of Brake Assembly for the Emission Test
- Emission levels in Transient Driving Cycles:
sub-mg/km/vehicle.
- Wear Mass Balance :
e.g. Rotor, Unaccounted Mass (Gasification or Loss)
- Next Steps:

Schedule for the Next Experiment → Nov of 2017

Pad (NAO, Low Steel, Others)

Driving Cycles (JC08, WLTP, **PMP** , Others)

Emissions (PM, PN)

Particle Characterizations

(Composition, Size , Shape, Density)

Mass Balance (Wear Mass, Gas Analysis)

Share the cycle pattern
with us