48th PMP Meeting
8th November 2018
Joint Research Centre, Ispra

Recent Activity for Brake Wear Particle Emission Measurement using JARI System

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Contents

What we want to Measure and How ?

- ◆ PMP : Propose Common Methodologies (Technologies) for PN and PM
- ◆ JSAE / JARI :

Most Common Methodology → Wear Mass Measurement

Important : Most Comparable Methodology → Wear Mass vs ???

Air Quality Improvements

Control and Contribution

Brake Emission (PN, PM)

Most Important

Comparability (Correlation)

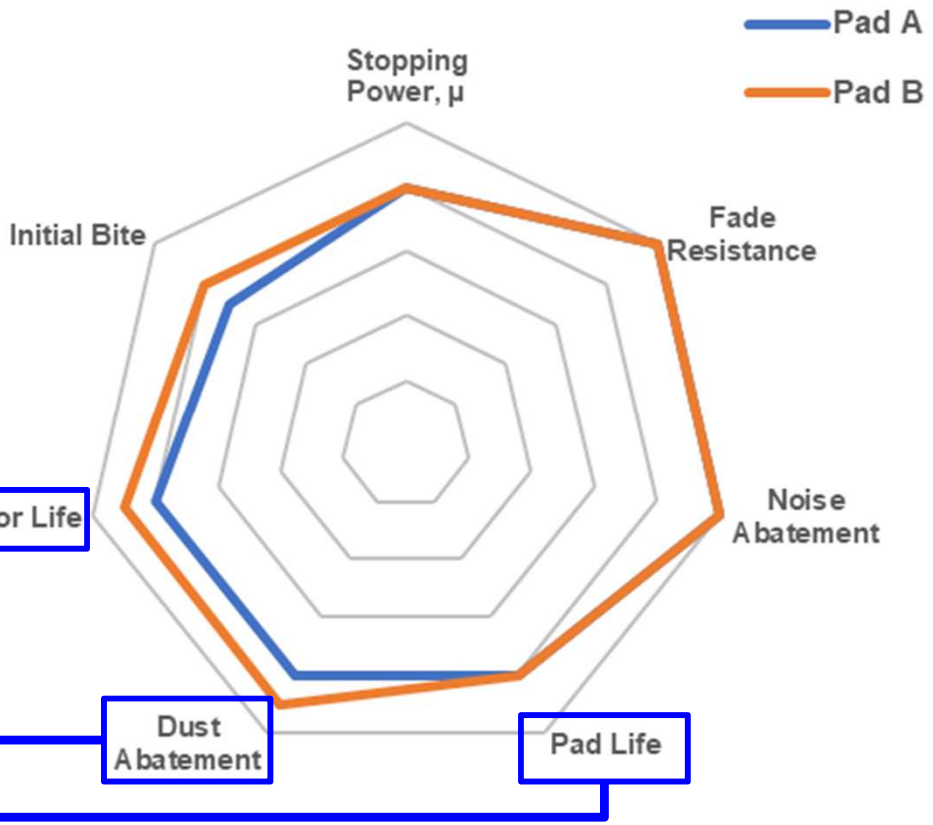
Most Common Methodology

Wear Mass (Wear Pad + Wear Rotor)

Control and Development

Development Brake Design
System, Rotor Aggression, Pad Wear, Friction Mechanisms
(Loose granular, Dens sheet, Oxidation, Gas cushion, Liquid lubrication…)

Ex.) Brake Design



Current Status JARI Measurement System

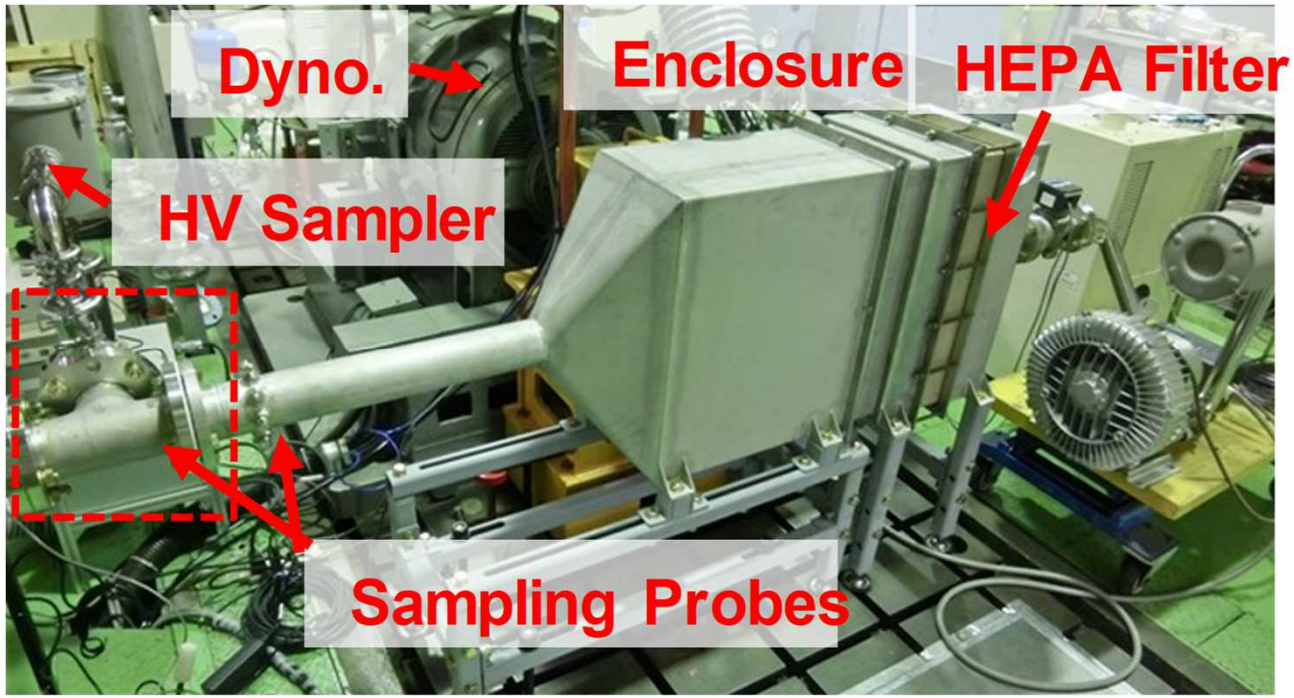
- Sampling System : Storable in Pre-Exiting Dyno. and Bench (JSAE 4 labs.)
  Visited to JSAE member labs. and Measured the Sizes.
- Compromise Necessary for Sampling Efficiency
- Incapable of Compromise for Comparability of Emissions vs Wear

JARI Measurement System

PM Measurement
Filter Sampling with Impactor (PM_{10}, $PM_{2.5}$)
Filter: PTFE 47φ
Sampling: 20L/min

PN Measurement
Fine Particles:
CPC without pre-treatment
Coarse Particles:
APS without pre-treatment

Pull ⇦ Particle Sampling ⇦ *Push* Particle Free Air 25±5℃, RH50±10%



Challenges for Common Technology

- **Common Challenges : Comparability with Emission and Wear (Dust, Pad & Rotor life)**
- **Common Technology : Constant Flow Sampling and Validations, so How ?**

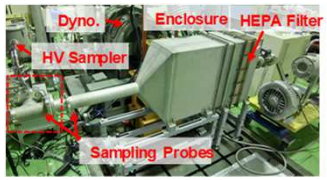
Sampling Efficiency

Particle Depositions on Brake Systems

Caliper in-side *Brake Pad Surface*

Compromise Necessary !!

Uniformed Design JARI / JSAE



Quality Assurance (QA)

Sampling Efficiency Testing
focused on Chamber & Tunnel
using PSL (0.002~10 um)

Next Step

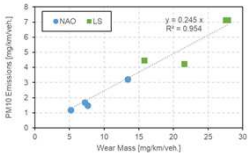
Air Flow

This Presentation

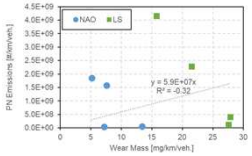
PM & PN survey in JARI

Review on Test Results under Low Air Flow Rate during JC08, WLTC, NEDC, PMP

Ex.)



PM vs Wear Mass

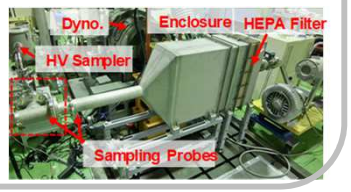


PN vs Wear Mass

Modified System JARI / JSAE

Next Step

Effective-Cooling / Wall-Loss-Less Modification

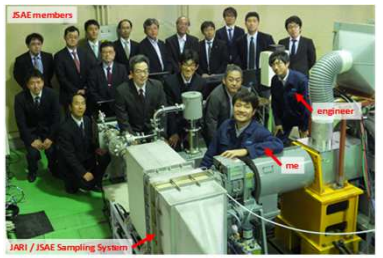


System Validations

This Presentation

only PM survey in JARI / JSAE

Interlaboratory Testing with Same Brake Systems, Same Sampling Systems, Preexisting Dyno.



Modified System

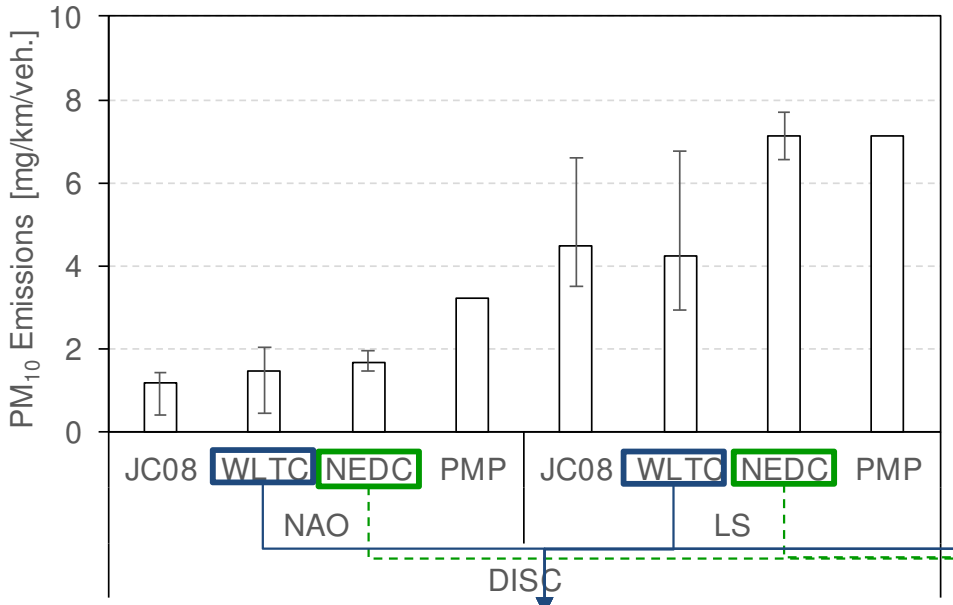
JASO Standardization for PM with comparable PN measurements

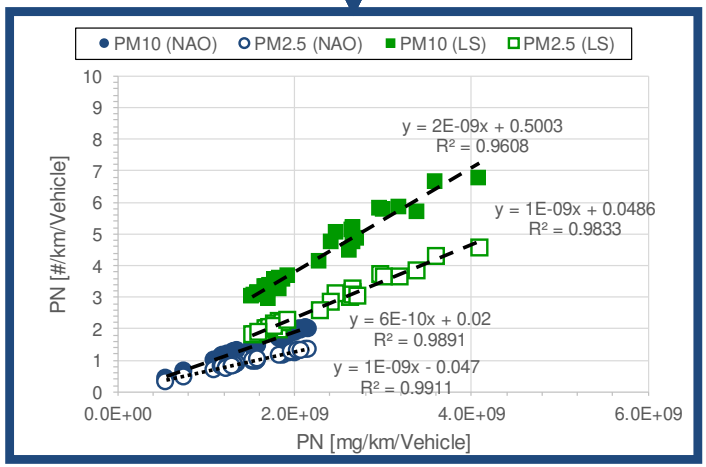
Contents

Emission Levels vary in Different Driving Cycles

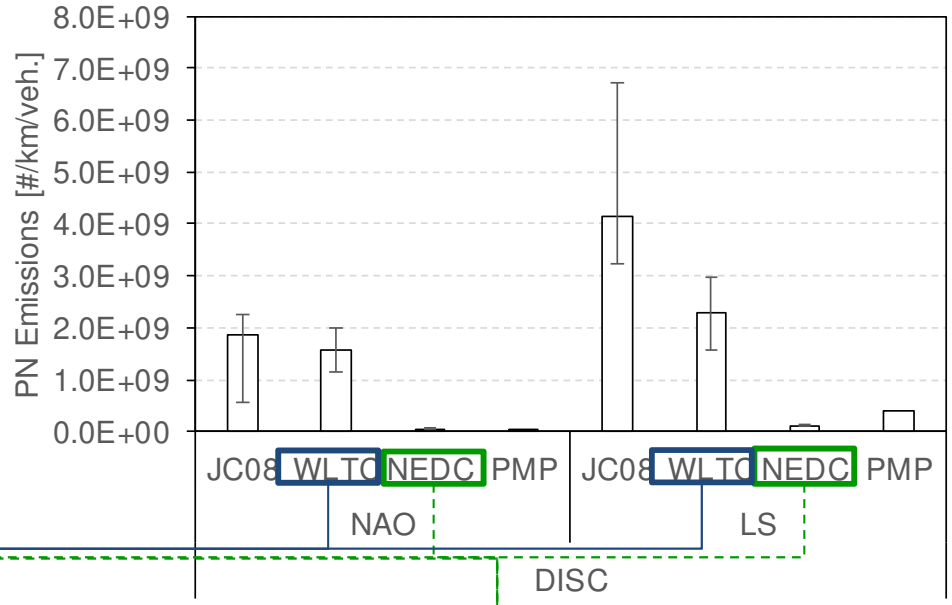
- ◆ Good Correlation with PN and PM emission during Same Driving Cycle
- ◆ but Slope (PN/PM Factor) might be changed by Particle Size and Brake Pad

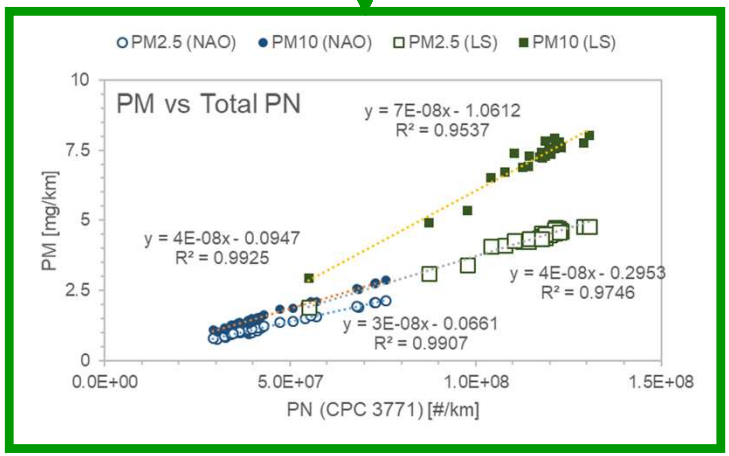
PM_{10} Emission Levels





PN Emission Levels (only CPC meas.)

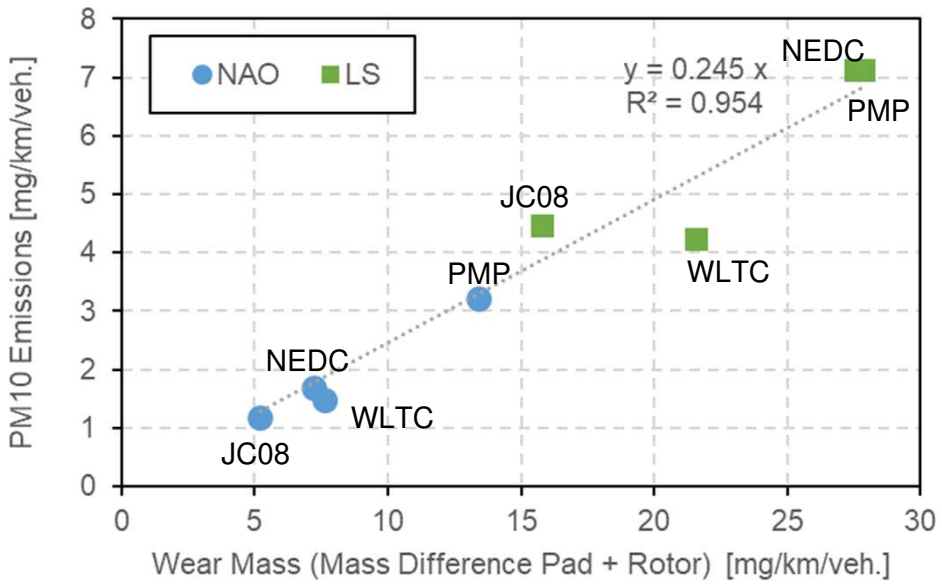




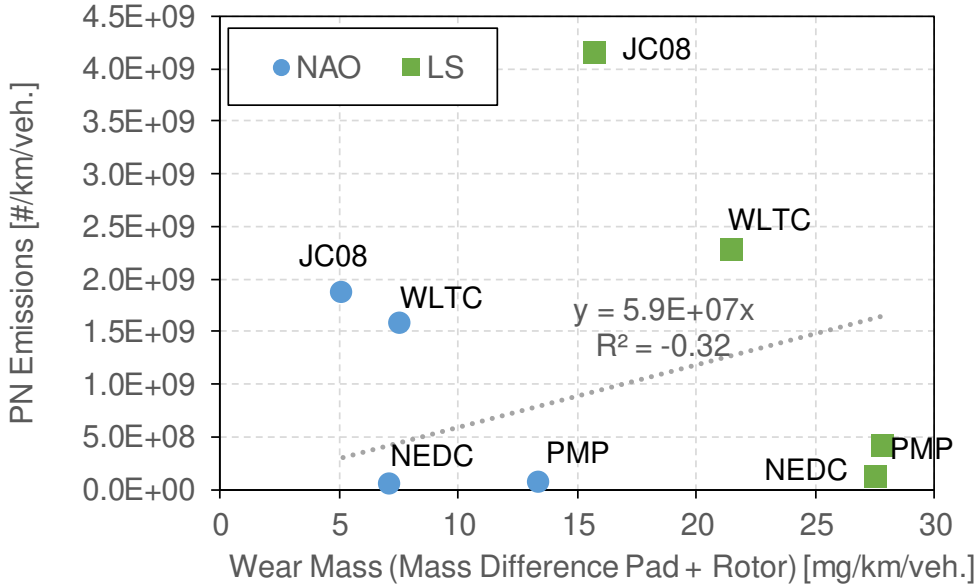
Need Comparability PM, PN, and Wear Mass

- Good Correlation with PM and Wear Mass emission under Different Driving Cycles with Same NAO/LS Brake
- Nature of Particle Emission might be quite different between PN and PM

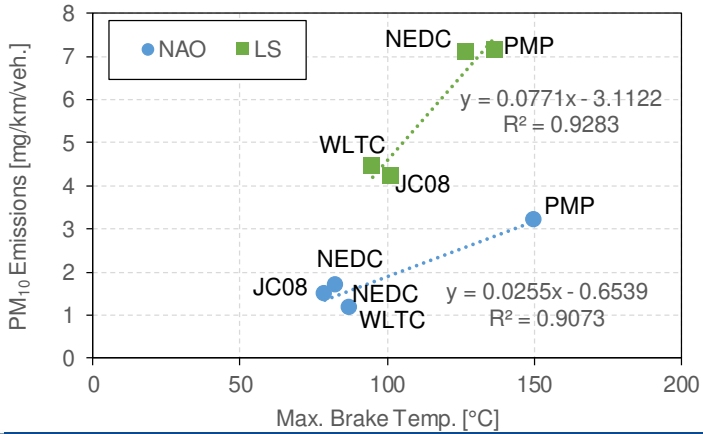
PM_{10} vs. Wear Mass (Pad + Rotor)



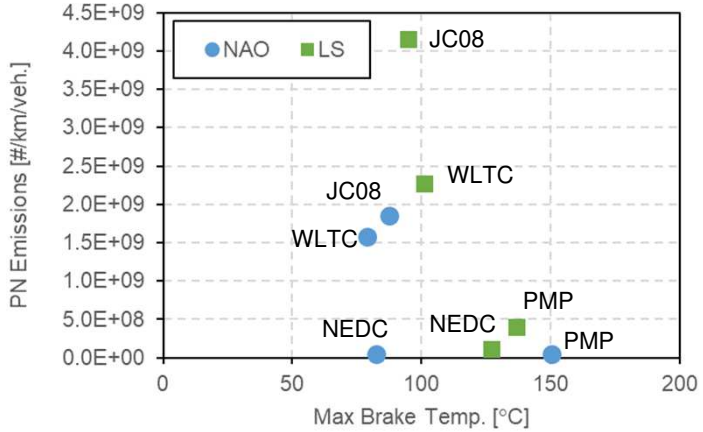
PN vs. Wear Mass (Pad + Rotor)



PM_{10} vs. Brake Temp. (∝ Brake Energy)

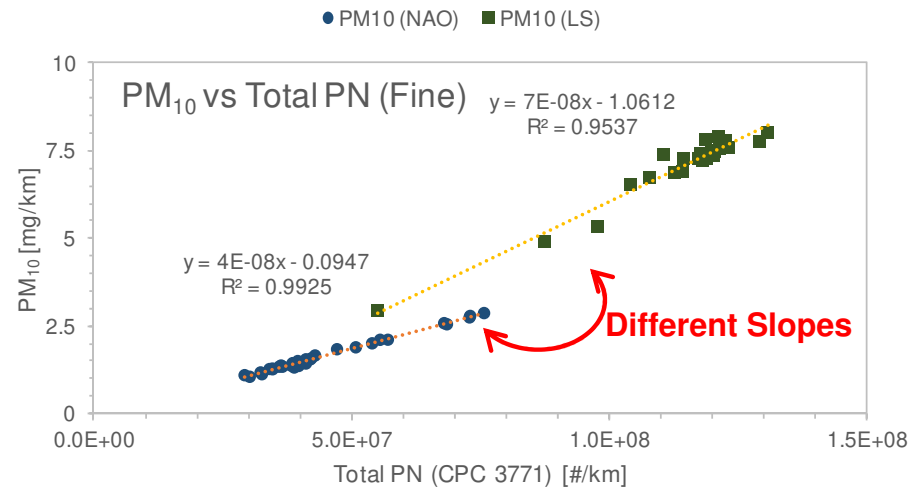


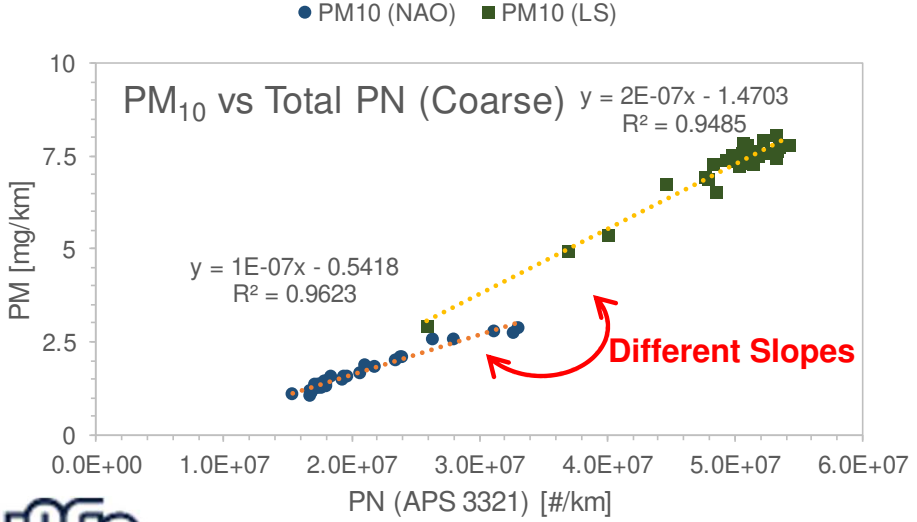
PN vs. Brake Temp. (∝ Brake Energy)

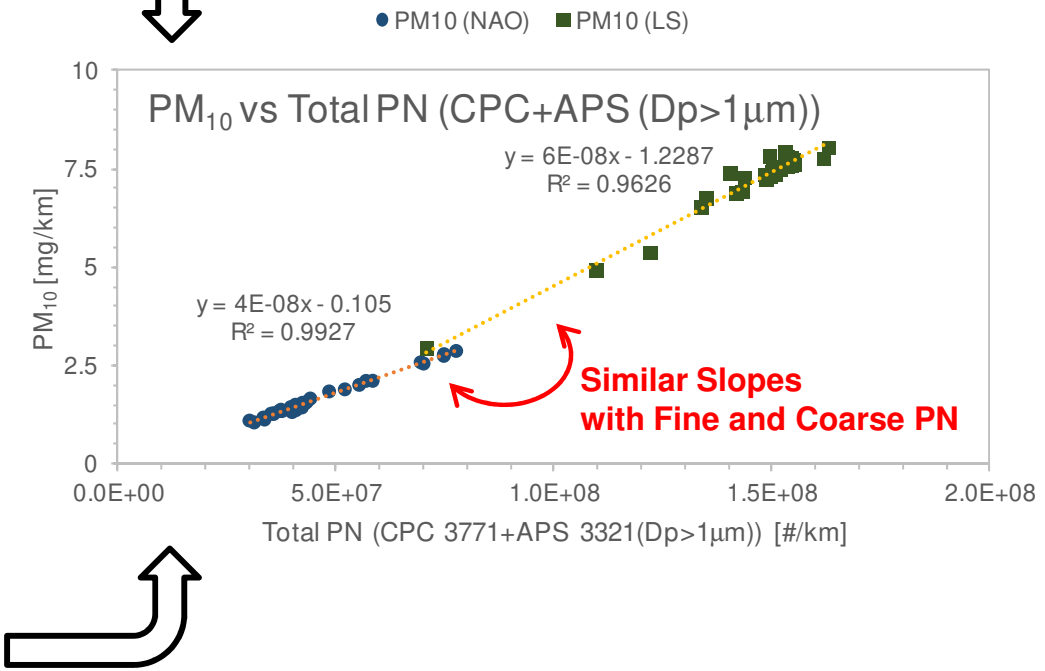


Comparability PM and PN

- **Brake Wear Particle Emissions during NEDC cycle**
- **Good correlation between PM10 and total PN (e.g. CPC and APS),**
- **Due to PM and PN Compatibility, PN (10nm-10μm) measurement is highly recommended**



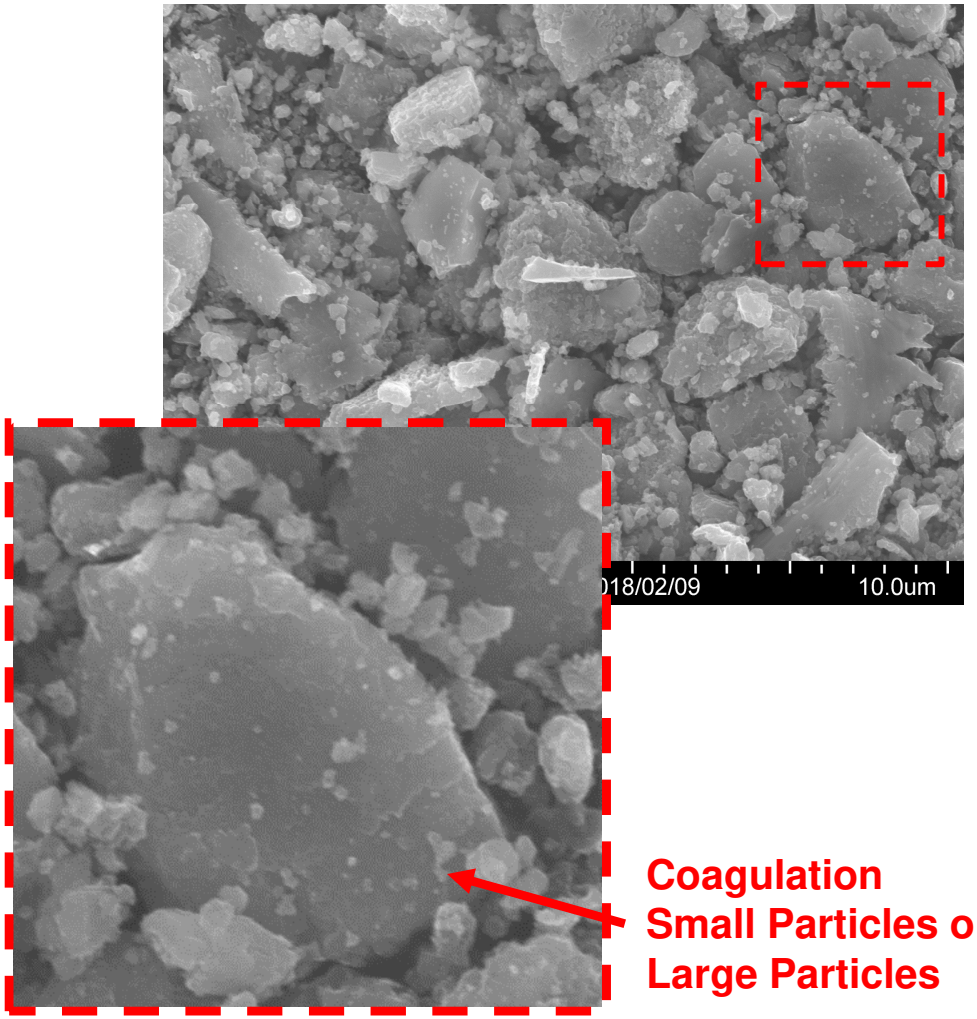


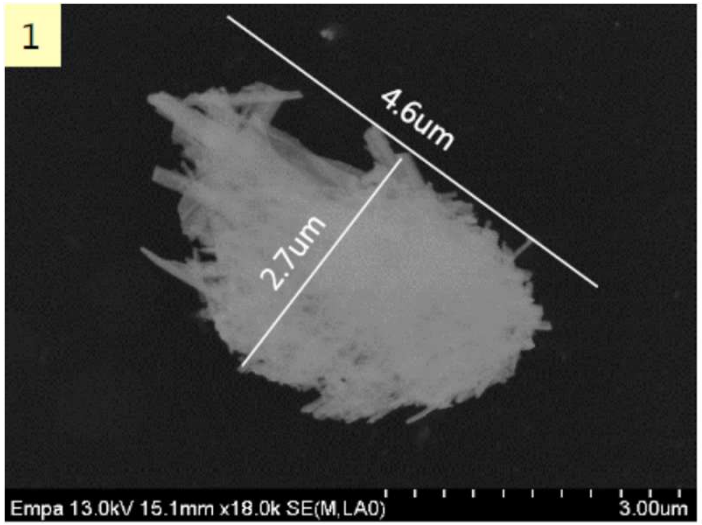


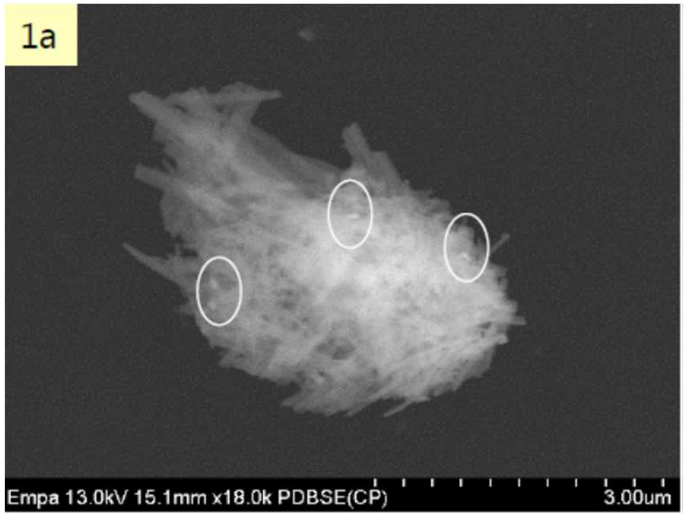
Ref.: Hagino et al., in preparation

Brake Wear Particle Morphology

- Coagulation Small Particles (Adhesion on Particle) allowed
- Is it enough to measure coarse PN for obtaining good correlation with PM?
- Coarse (Large) PN measurement needs to manage
  Fibrous particles (Materials) tends to be detected in the Larger Size







Ref.: Hagino et al., in EuroBrake2018

Ref.: Eggenschwiler and Schreiber in PMP session 47

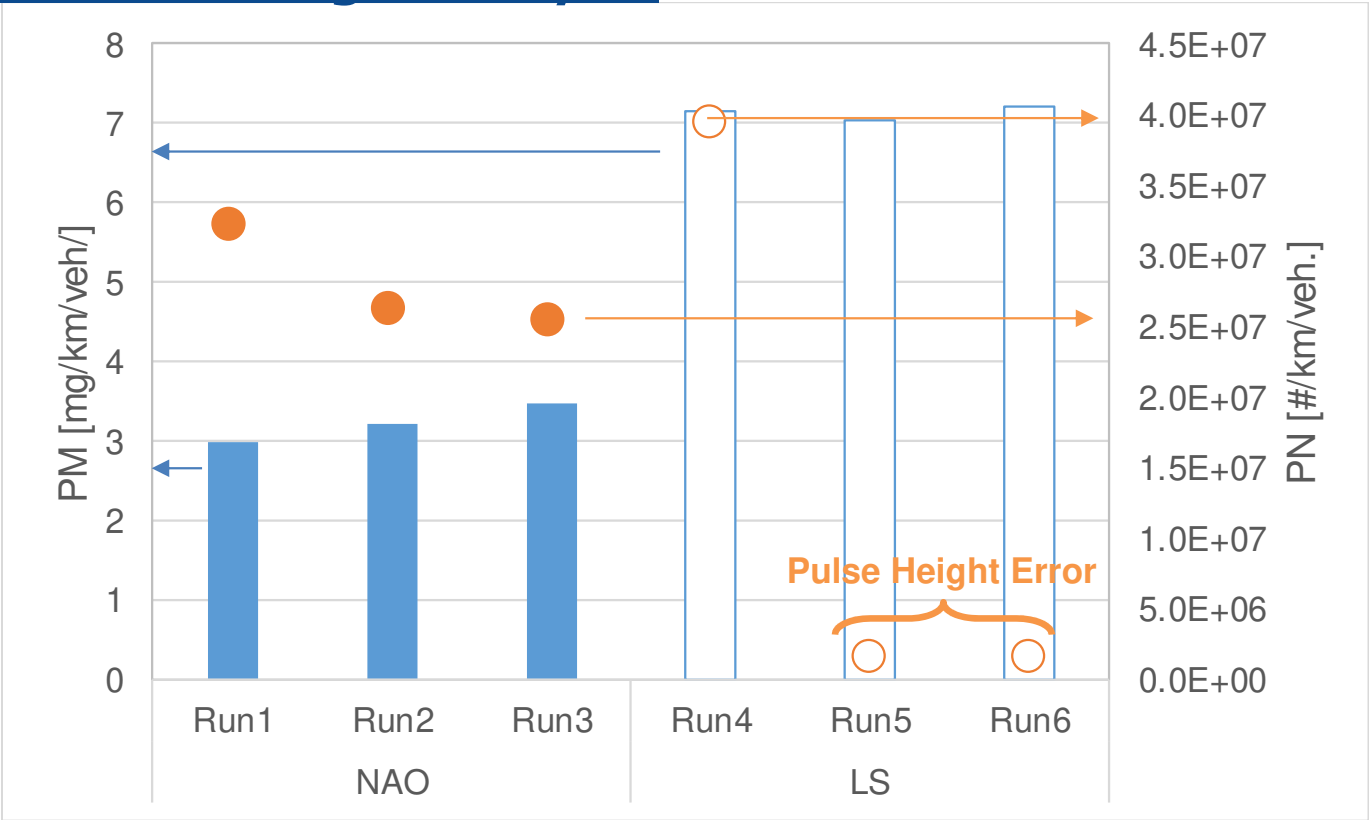
Contents

Why we need modify Air Flow for PN ?

- PM measurement: Robust System under Low Air Flow
- PN measurement: High Sensitive System for High Air Flow
- JARI system Observed …
  Over concentration (> 10^5 #/cm^3 for typical CPC (CPC3750 (>7nm)))
  Nozzle Warm (Clogging of Orifice by Large Size Particles)
  Pulse Height Error (Butanol Back Current by Clogging of Orifice)

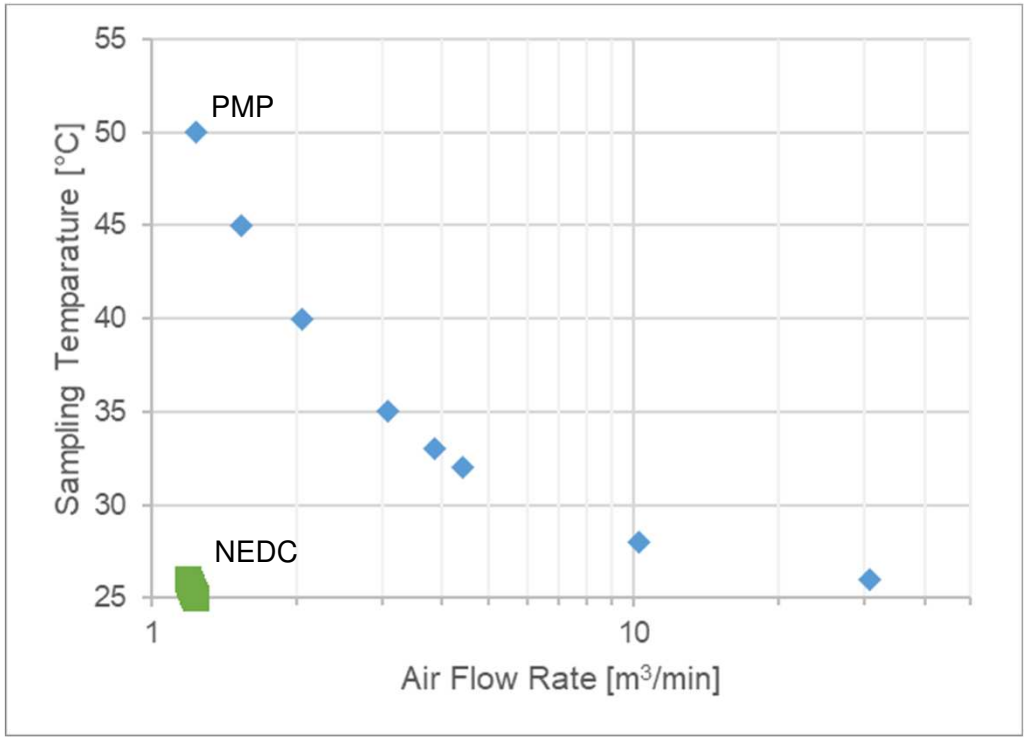
Necessary of more Air Flow to Obtain Robust Optimization
Needed for using Cyclone (Removing for Large Particles) for CPC Measurement

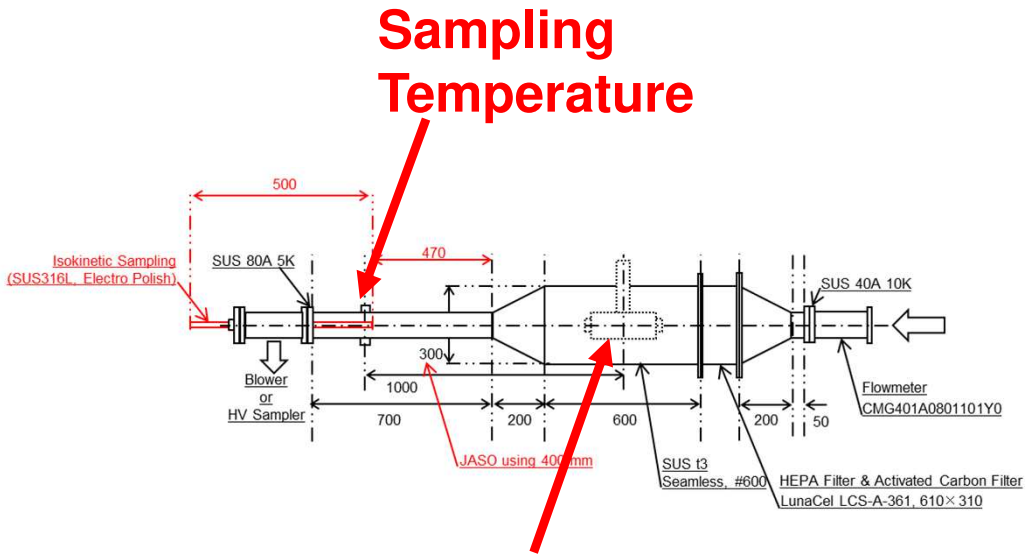
Ex.) Repeat Test using PMP cycle



Modification of Air Flow for PN

- PMP cycle is Much Higher Sampling Temperature than NEDC
- Sampling Temperature might have to be set for conventional CPC (< 35 °C)





$$Q = \frac{60 \times q}{\rho \times Cp \times \Delta T}$$

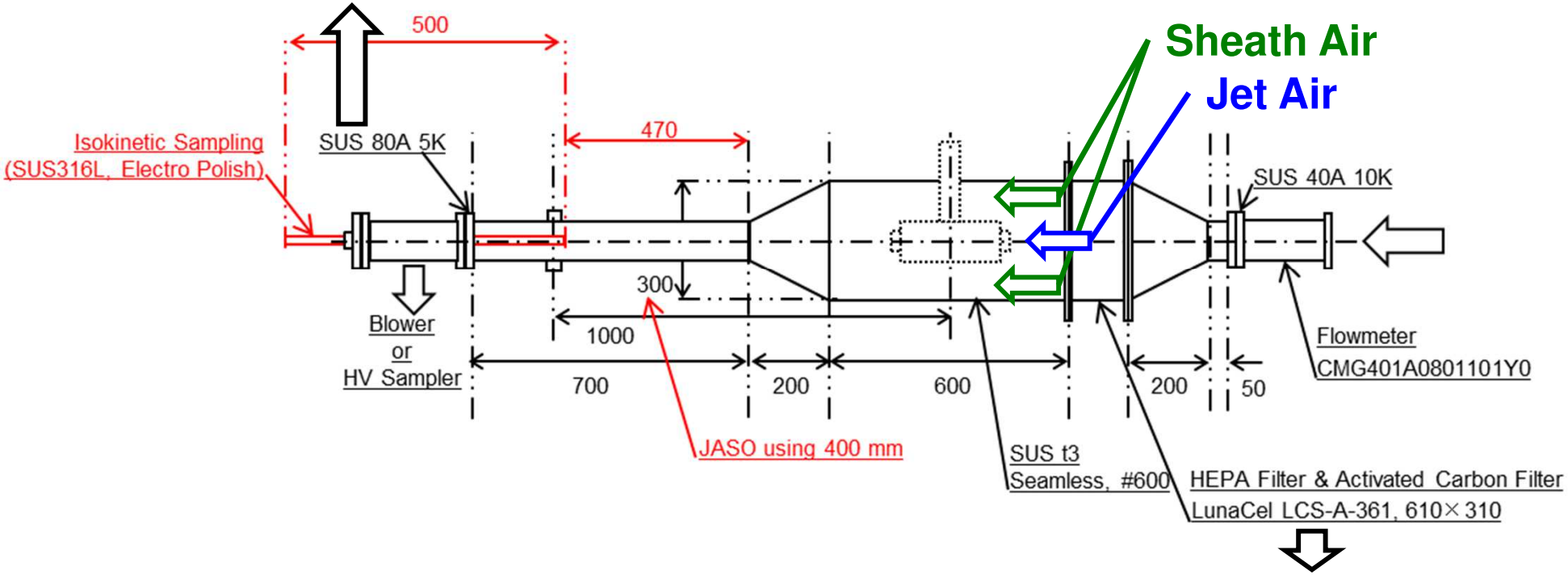
q : Calorific value [W]
ΔT : Difference temp. (In/Sampling) [K]
ρ : Air Density, 1.20 [kg/m^3]
Cp : Isobaric Specific Heat, 1007 [J/(kg/K)]
Q : Air Flow [m^3/min]

Modification of Air Flow for PN

◆ Change Air Supply for Higher Air-Velocity and Lower Chamber Wall-Loss

4 m³/min : 150A with Same Isokinetic Sampling Probe (SUS 316L Electro Polish)

1 m³/min : 80A

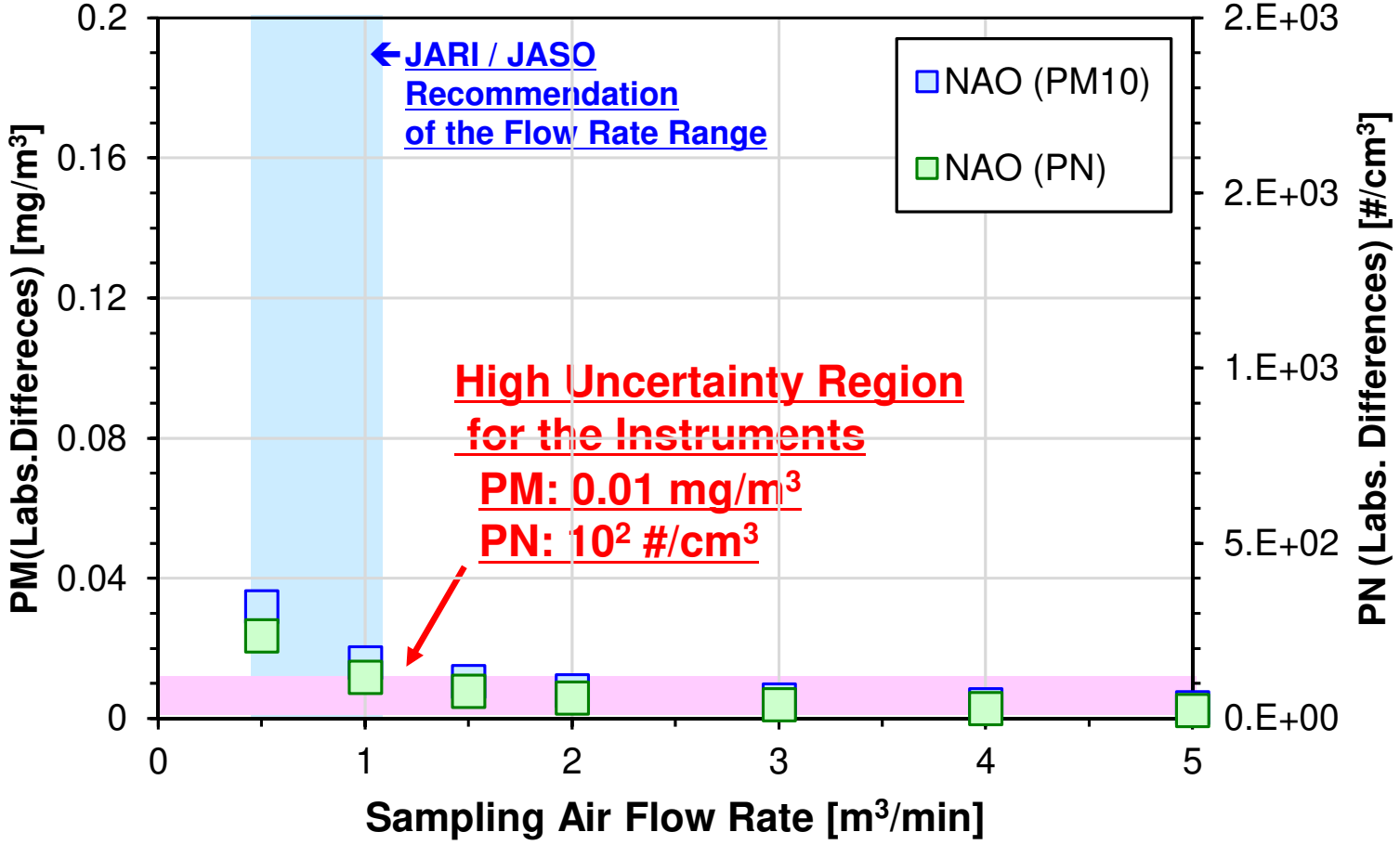


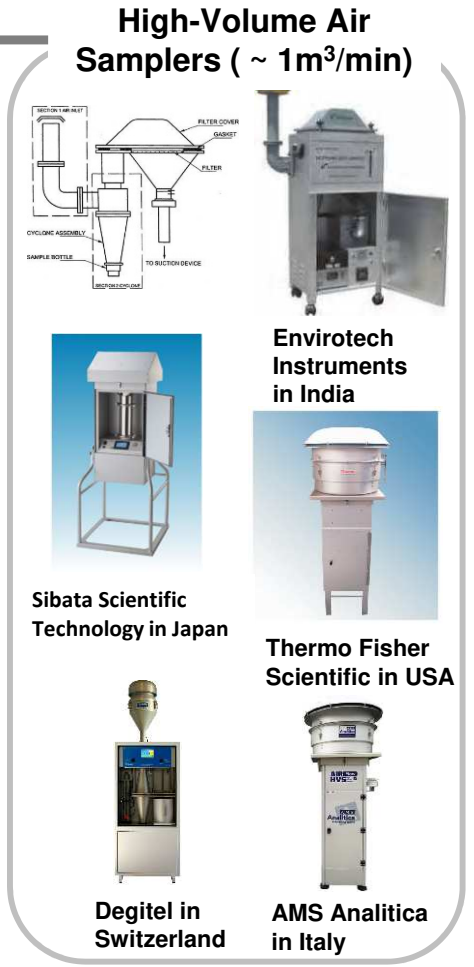
Attachment of Apparatus for Higher Air-Velocity and Lower Chamber Wall-Loss

Labs. Difference vs. Air Flow Rate

Looking Back

- Air Flow Rate may be contribute for High Uncertainties of Instruments
- High Volume Filter Sampling (1 m^3/min) is using worldwide
- JARI system was applied the compatibility Sampling, but adjustable by 5 m^3/min





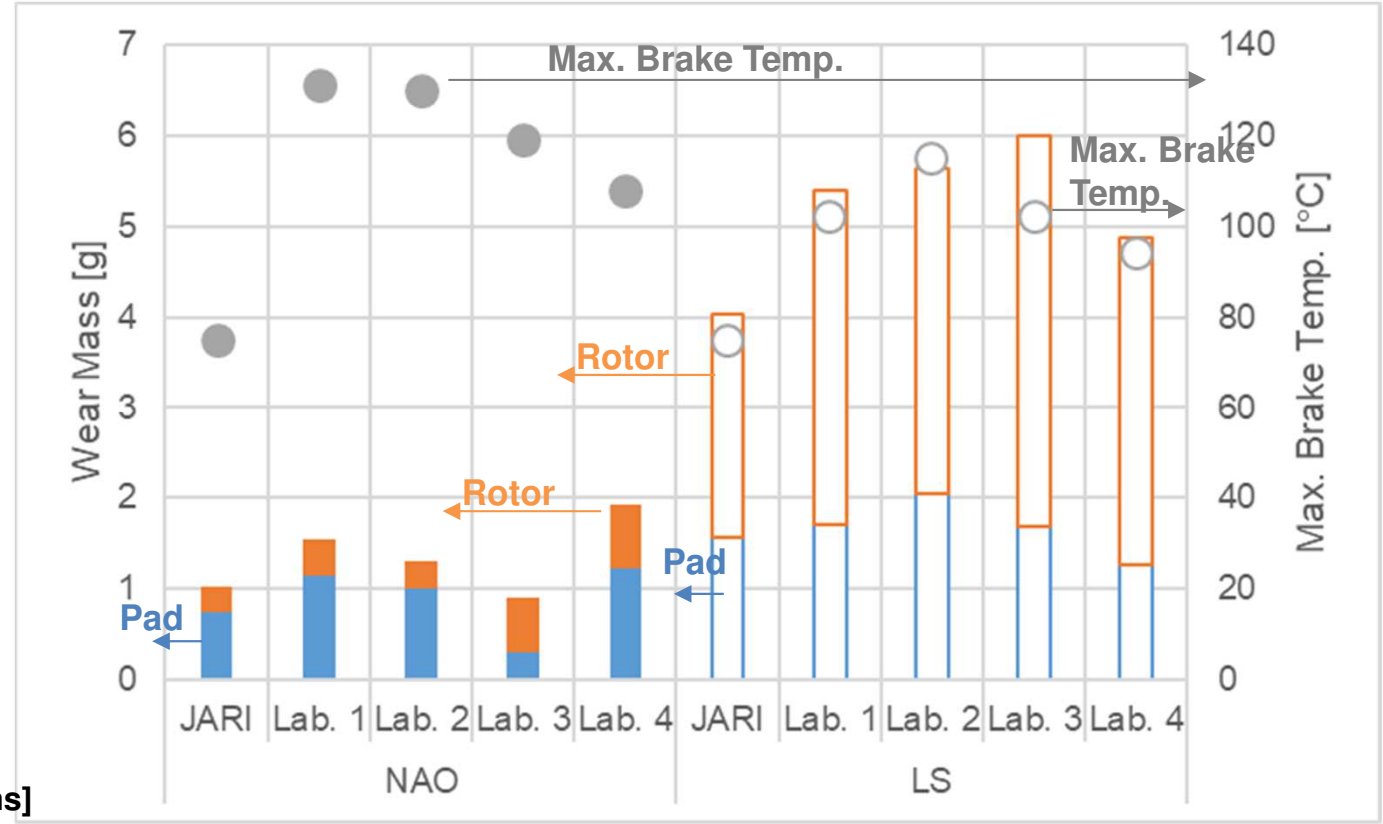
Cycle: simulated-WLTC, 30 Repeated, PM data: DustTrak II 8530 corrected by gravimetric measurement, PN data: TSI CPC 3775 (D_{50} = 4 nm) without pretreatment

Ref : Hagino et al., *EuroBrake2018 in Presentation, revised.*

Contents

Comparison of Brake Wear Testing

- ◆ On-going project: Comparison of PM Emission (NEDC and PMP cycles) Existing Dynamometers
- ◆ Wear Mass : for More High Reproductivity,
  Actual Brake Torque might be need to Control
- ◆ Rotor/Brake Wear Mass and Temp. did not affected by Lower Flow Rate Condition



[Testing Conditions]
Pre-conditioning : Initial Speed 65km/h, Deceleration 3.5m/s^2, 200 times (or more for NAO discs) repeated,
Vehicle: Weight 1,130kg, Ratio 8:2, Eff. Tire Rad. 0.298m,
Brake Systems: NAO Disc (Front) / LS Disc (Front),
Test Cycle: NEDC (JARI Emission Testing), 30 times Repeated

Ref : Hagino et al., *Wear & EuroBrake2018 in Preparation*

Conclusions & Next Steps

Conclusions:

- **Good Correlation with PM and Wear Mass emission**
- **Nature of Particle Emission might be quite different between PN and PM**
- **Due to PM and PN Compatibility, PN (10nm-10μm) measurement is highly recommended**
- **PN measurement needs further investigation**
- **Inter-lab. Testing of Wear Mass**
  Needing of Actual Brake Torque Control

Next Steps:

- **Modification of Air Flow for PN measurement using JARI/JSAE system (On-going)**
- **Reproducibility of PM Emissions with Uniformed Sampling Design with JSAE Four Labs. (On-going)**