

Emissions from HD Truck with Damaged DPF and its Detection at PTI

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Japanese inspection system for automobile exhaust

- Type approval tests **for Newly developed car**

- Exhaust measurements with chassis / engine dyno
- Checked by NTSEL

- In-use conformity tests **for selected car families**

- Similar method with type approval test
- Checked by NTSEL

- Sampling tests of line off cars **for cars randomly sampled at production lines**

- Similar method with type approval test (Judged by averaged results)
- Checked by car manufacturers

- Periodic technical inspections **for all cars every 2 or 3 (passenger) 1 or 2 (commercial) years**

- Free acceleration Soot HC and CO measurements (Non-harmonized limit with type approval tests)
- Checked by NAVI

NTSEL: National Traffic Safety and Environment Laboratory
NAVI: National Agency of Vehicle Inspection

Requirement for test procedure at PTI

PTI is mostly done by private auto repair shops over 30000.

- Quick: No cold start tests, No preconditioning, and measuring time for 1min
- Cheap: No dyno, no CVS, and no MEXA-one.

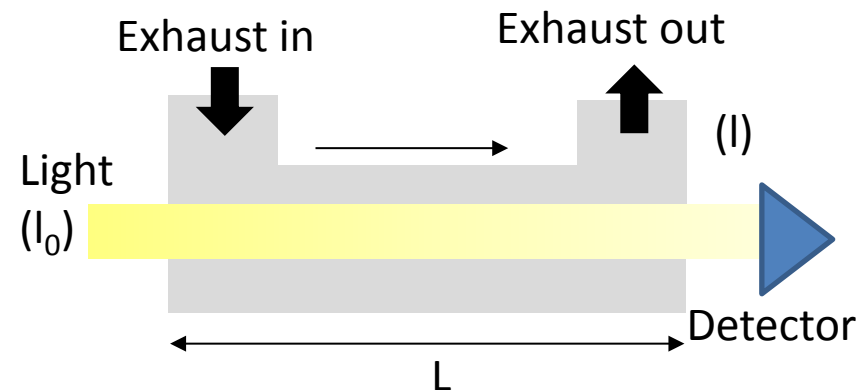
PTI is rough scan.

PM (soot) measurement at PTI

- K value measurement with opacity meter in free acceleration from idle



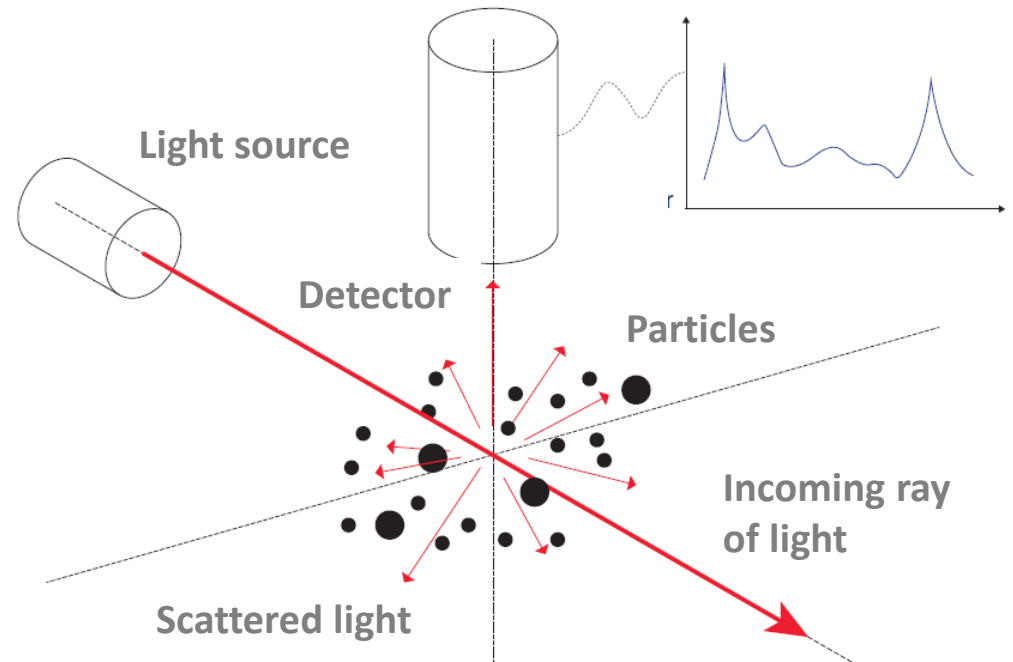
$$I / I_0 = \text{Exp} (-K \cdot L)$$



Recent situations surrounding PTI



EU-TEDDIE Final Report



AVL Ditest Smoke 2000

- EU TEDDIE program evaluated measurement procedure for PTI with DPF cars
 - Opacity meter does not have enough sensitivity for detecting damage with DPF
 - OBD were less sensitive than the opacity meter
 - Laser light scattering photometry (LLSP) have enough sensitivity for damaged DPF

Objective of this study

We decided to perform similar study to EU TEDDIE program, checking performances of LLSP, opacity meter and **particle number counter** at PTI using heavy duty vehicles with damaged DPF.

- Effects of DPF damage on exhaust emissions in type approval tests
- Evaluation of the opacity meter and the LLSP at PTI
- Evaluation of particle number at PTI
- Correlation between PTI limit and type approval test limit

Test vehicles



	Mid-Duty (MD)	Heavy-Duty(HD)
Max. payload	3 ton	10 ton
Displacement	3L	10L
Aftertreatments	DOC+DPF	DOC+DPF+Urea SCR

Evaluated measurement systems

Opacity meters



GSM-200(Sokken)



Dismoke 4000(AVL)

Number counters



EEPS3090 (TSI)

LLSPs



LEX-635(Sokken)



GSM-600(Sokken)



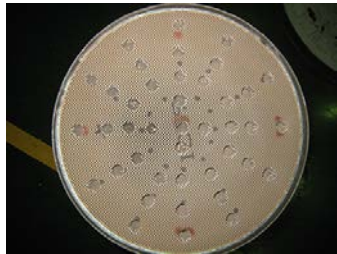
Smoke 2000 (AVL)

Tested DPF conditions

HD DPF conditions



0 hole (0%)

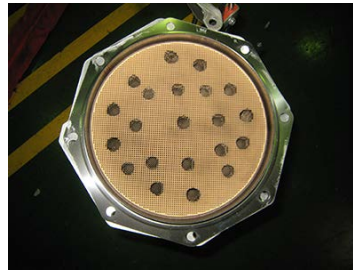


41holes (16.4%)

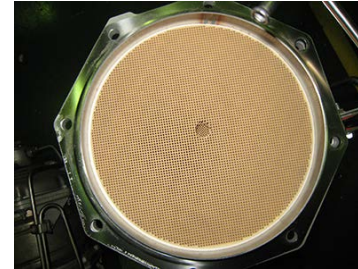
MD DPF conditions

No image

0 hole (0%)



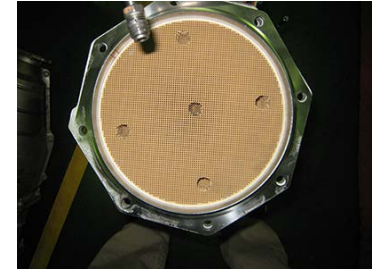
17 holes (9.3%)



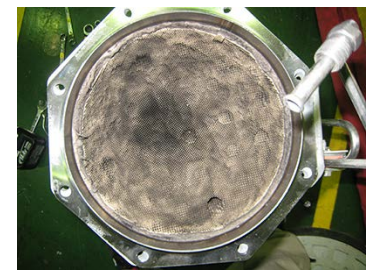
1hole (0.5%)



41 holes(22.5%)

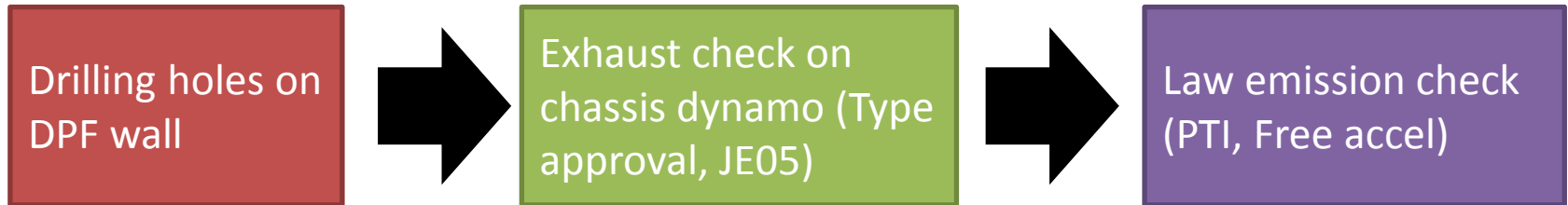


5 holes (2.7%)



Completely (100%)

Test flow



Effects of DPF damage on exhaust emissions in type approval tests

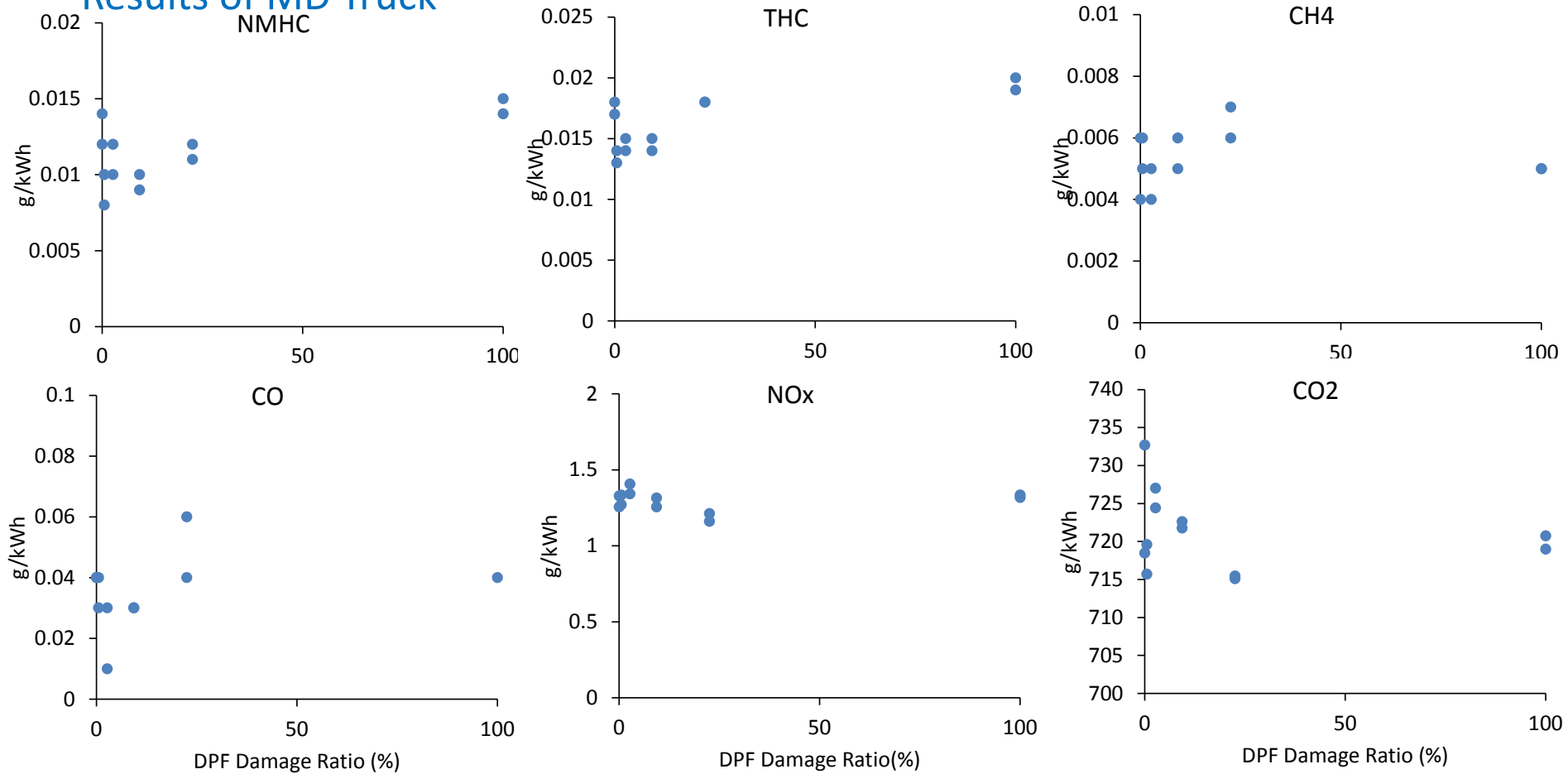
Evaluation of opacity meter and LLSP at PTI

Evaluation of particle number at PTI

Correlation between PTI limit and type approval test limit

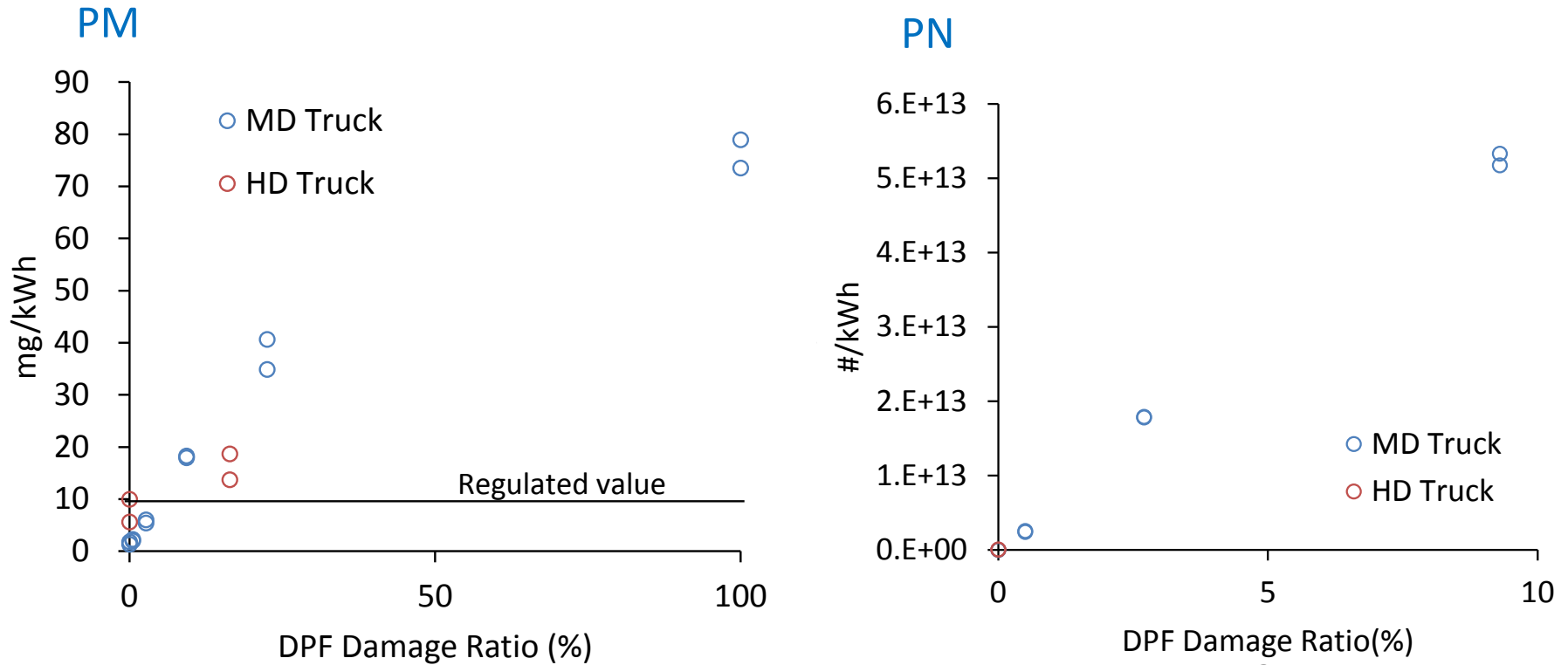
Effect of DPF damage on gaseous emissions

Results of MD Truck



No clear relations were observed. Damage of DPF did not affect on these emissions

Effect of DPF damage on PM and PN



- Emission of PM and PN increased linearly with DPF Damage ratio
- PN emission exceeded regulation limit by only 0.5 % damage, whereas PM exceeded by 9.3 % damage (PN limit is more tight than PM)
- Increased PM emission with fully damaged DPF was 80 times higher than normal condition whereas PN was 40000 times higher

PN is more sensitive than PM for DPF damage

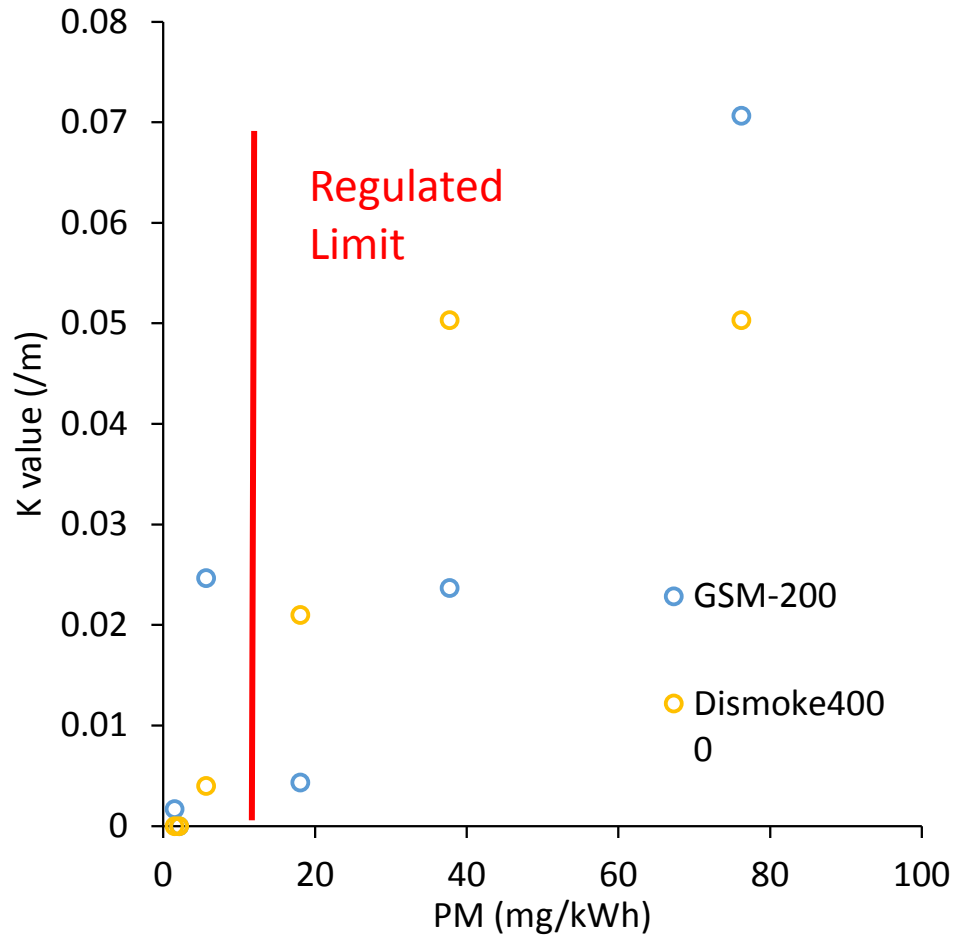
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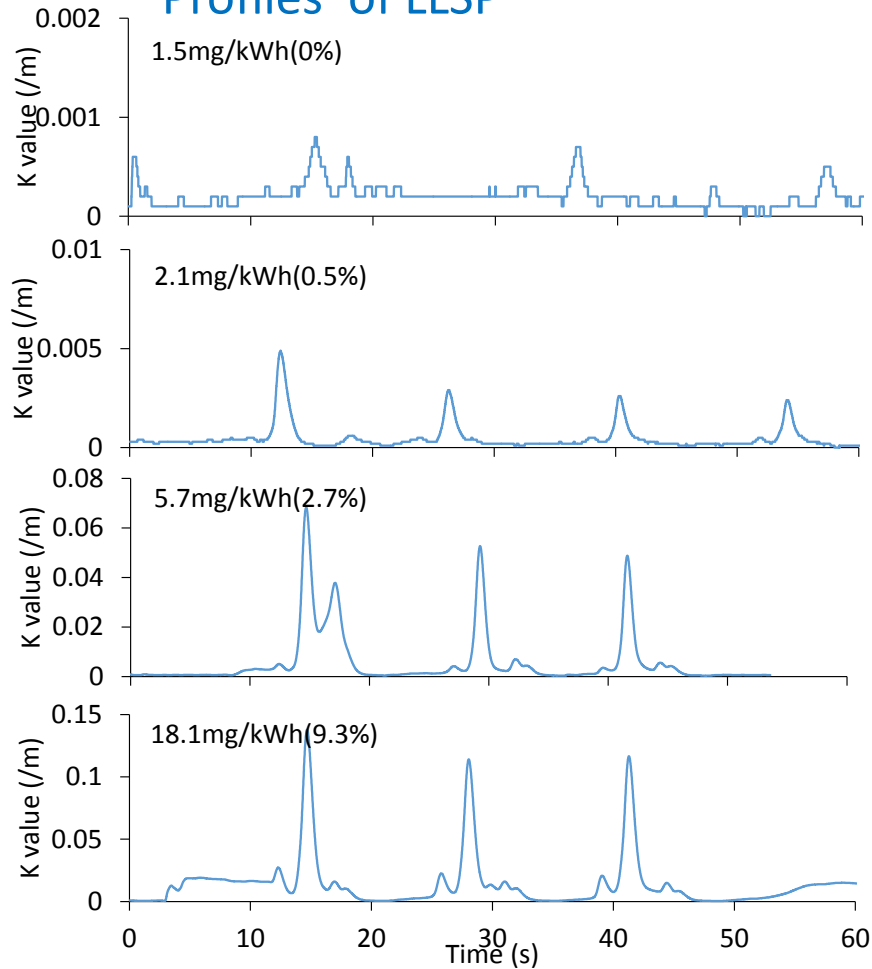
Opacity meter result in PTI condition



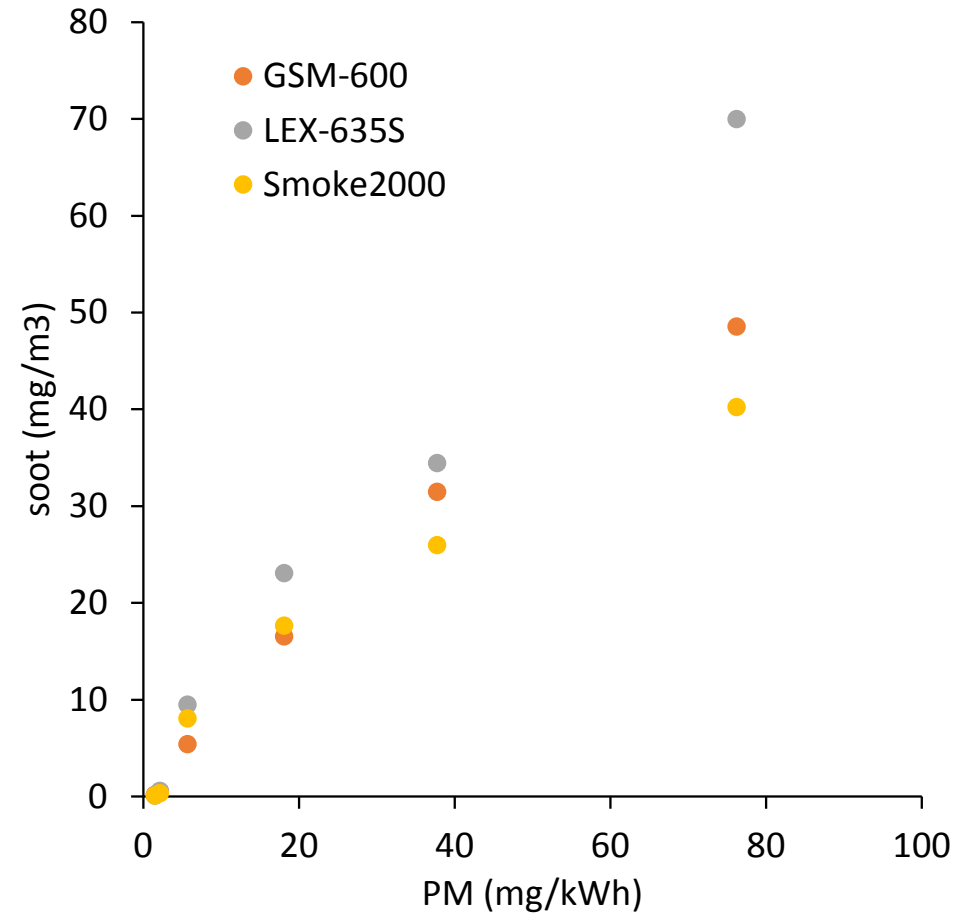
➤ Opacity meter is difficult to detect PM around regulation limit

Comparison of LLSP systems

Profiles of LLSP



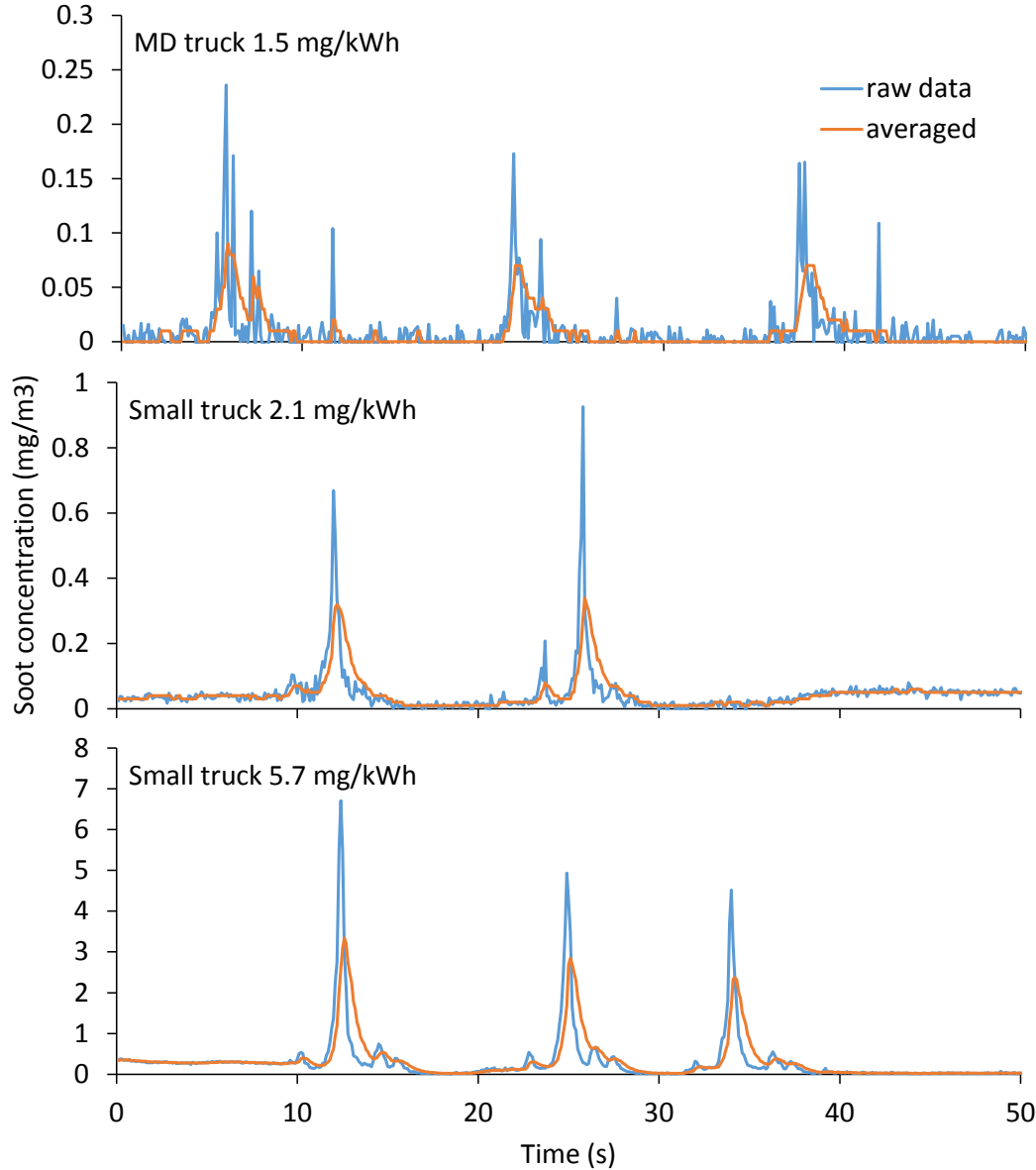
Peak values of LLSP



- LLSPs have enough sensitivities to detect emissions even from no damaged DPF
- Output values varied almost twice among devices

Effect of realtime data treatment

Profiles of GSM600



- Peaks of raw data were too narrow and highly fluctuated
- Data treatments were differed among devices
- Measurement procedure at PTI is peak value reading of transient event
- Not only data treatments but also system designs might have some effect on the results

Effects of DPF damage on exhaust emissions in type approval tests

Evaluation of opacity meter and LLSP at PTI

Evaluation of particle number at PTI

Correlation between PTI limit and type approval test limit

Evaluation of Free Acceleration by Number

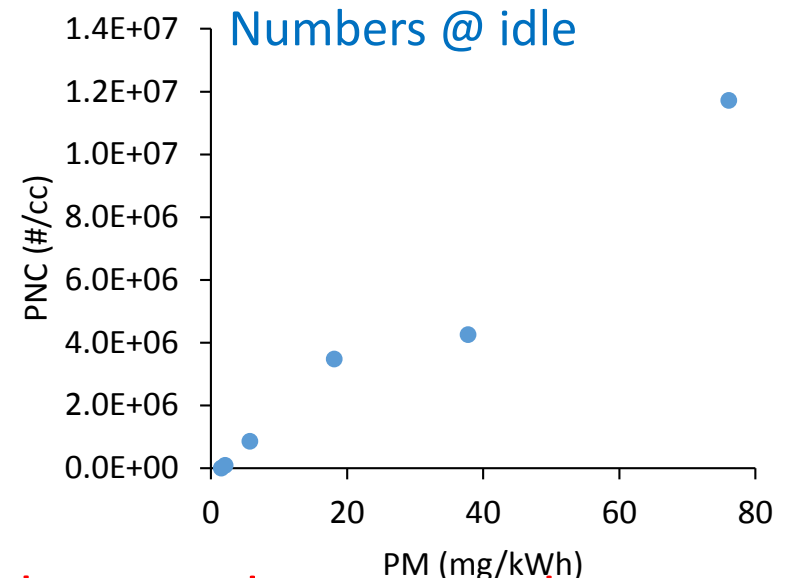
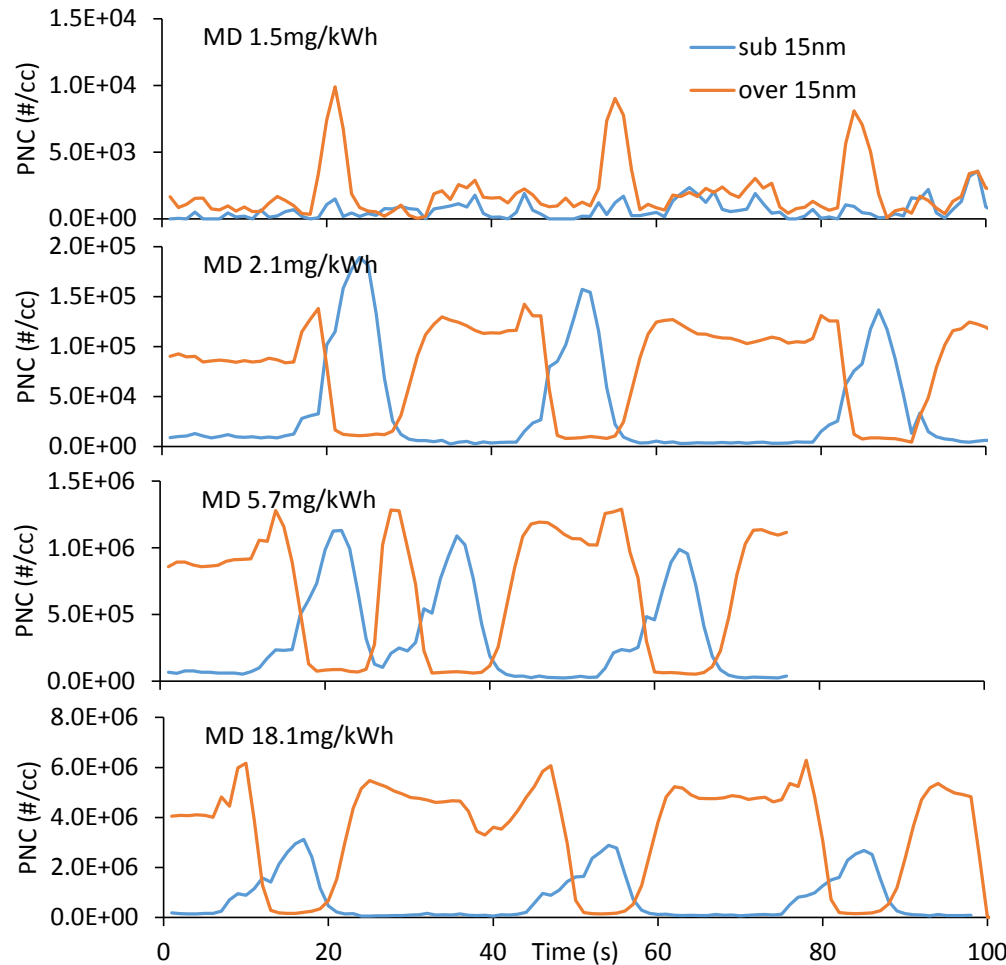
Profiles differed over and below 15 nm

Sub 15nm

➤ Large peaks during deceleration (Nuclei?)

Over 15nm

➤ Small peaks during acceleration
➤ High constant emissions



Measurement over 15 nm particle number can detect DPF damage at idle

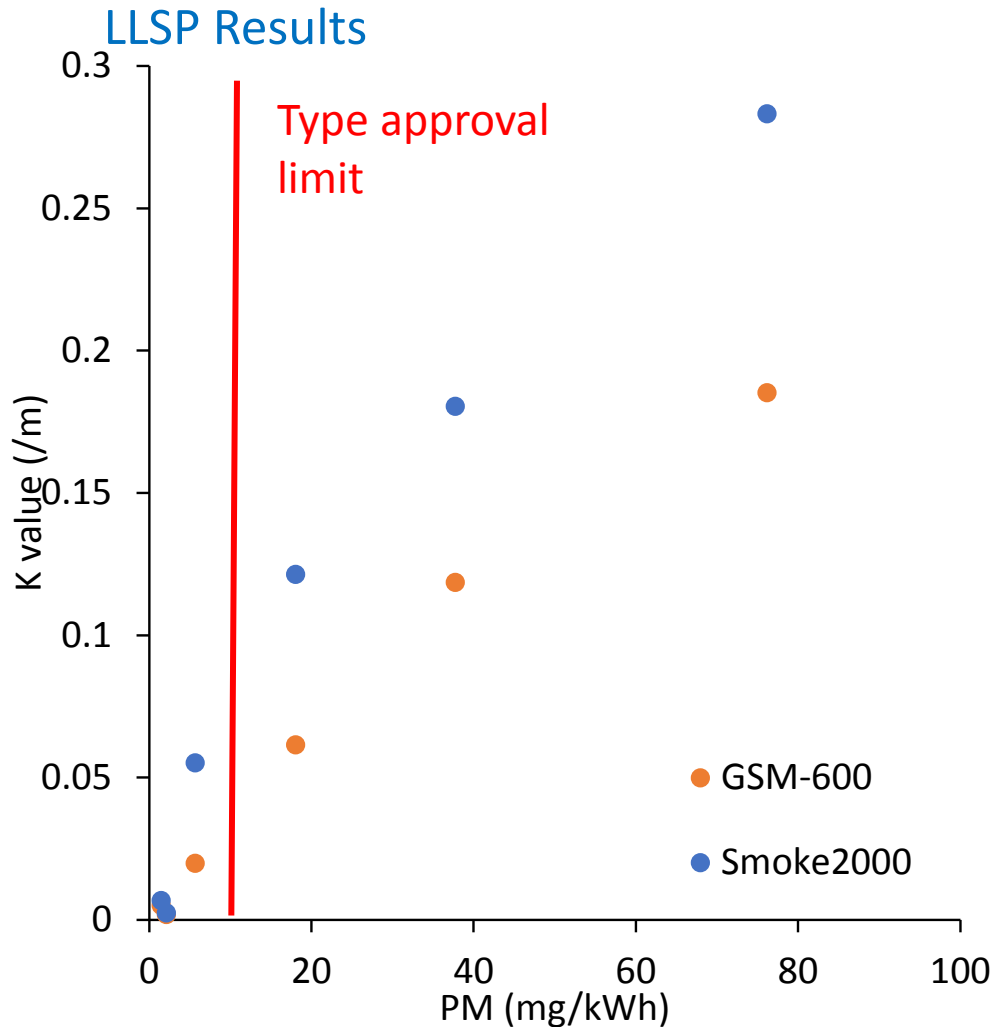
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PTI limit vs. Type approval limit



PTI K value limit (0.5) was too high compared with type approval limit (10 mg/kWh)

100 % damaged DPF can pass PTI limit

Conclusion

Exhaust particles were measured in type approval mode (JE05) and free acceleration tests using damaged DPF

PM and PN emissions in JE05 mode

- PM and PN emissions increased linearly with DPF damage ratio
- PN is more sensitive to DPF damage than PM

Free acceleration Tests

- Opacity meter which is used in PTI did not have enough sensitivity to detect the emissions around type approval limit
- LLSP have a sensitivity to detect the emission from normal DPF
- Profiles of particle number were quite different from those of LLSP
- The results of LLSP differed almost twice by different systems because the test condition (free acceleration) was transient test
- Over 15 nm particle number measurement in idle can detect the DPF damage

PTI limit vs. type approval limit

- Current PTI limit was too loose compared with type approval test

Acknowledge

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Thank you