Sub-10 nm Particles Observation Using PMP Methodology

-Down from Ten-

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Background

Number counting method for Particle regulation proposed by PMP (PMP methodology) has been introduced into automobile type approval tests in Europe. Japanese ministry of environment officially stated that they will start the discussion to introduce PMP methodology in end of May, 2017.

The next issue of PMP is lowering D50 detection limit from 23 to 10 nm. There are some project which discuss the possibility of counting particles from 10 to 23 nm in Europe and Joint Research Center of European Commission have published a report that indicates reduction to 10 nm is possible. According to these discussion, Round Robin Exercise which confirm the possibility will start in the middle of 2017.

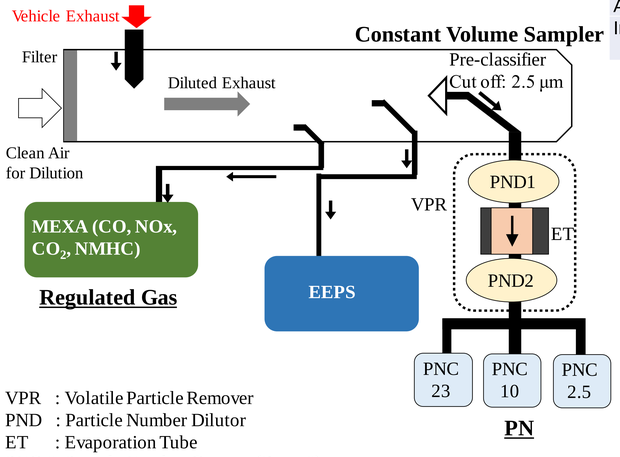
Objectives

Discussion of downing the D50 to 10 nm have been made widely. On the other hand, there are little information about applying PMP methodology to smaller particles from 10 nm.

- Challenge to measuring particles below 10 nm from DPF diesel and Gasoline Direct Injection (DI) passenger cars with PMP methodology will be performed.
- Effect of condition of Volatile Particle Remover (VPR; temperature and dilution factor) will be discussed.
- Discussion that observed particles are true tailpipe emission or artifact in the counting system will be made by comparing data with those without VPR.

Experimental

We set three CPC which D50 were 23 nm (ordinal PMP), 10 nm (3772, TSI) and 2.5 nm (3776, TSI) downstream of VPR. As for PMP system we used APC (AVL) which does not have a catalytic stripper. We also measure the particles using EEPS (TSI) which is directly connected to CVS to evaluate the effect of volatile particles. Tested cars are two gasoline DI and two DPF diesel passenger cars for Japanese market. We monitor the particle emissions by changing PCRF and VPR temperature.



VPR : Volatile Particle Remover
PND : Particle Number Dilutor
ET : Evaporation Tube
PNC #: Particle Number Counter (D_{50} = #)

AVL Particle Counter
D50=23nm

TSI CPC3776
D50=2.5nm

TSI CPC3772
D50=10nm

Test mode : WLTC LMH (Cold Start)

	Gasoline DI-1	Gasoline DI-2	DPF Diesel-1	DPF Diesel-2
Vehicle name	Levorg	Voxy	Demio	Land Cruiser Prado
Manufacturer	Subaru	Toyota	Mazda	Toyota
Identification no.	DBA-VM4	DBA-AZR60G	LDA-DJ5FS	LDA-GDJ150W
Vehicle Weight in kg	1530	1500	1130	2270
Displacement in cm³	1599	1998	1489	2754
Engine family	Stoichiometric DI	Stoichiometric DI	DPF Diesel	DPF Diesel
After treatment	3 way cat.	3 way cat.	DPF	SCR + DPF
Intake management	Intercooler Turbo	N. A.	Intercooler Turbo	Intercooler Turbo

Gasoline DI

Gasoline DI-1

Gasoline DI-2

DPF Diesel

DPF Diesel-1

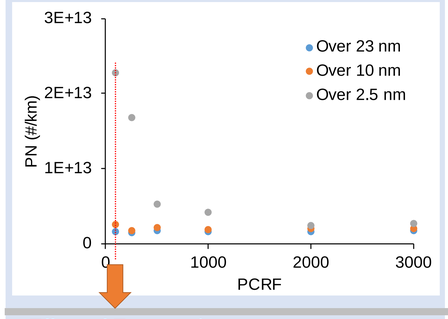
DPF Diesel-2

Results

Gasoline DI

Gasoline DI-1
Evaporation Tube (ET) temp. = 350°C

Effect of PCRF



Effect of Evaporation Tube Temp.

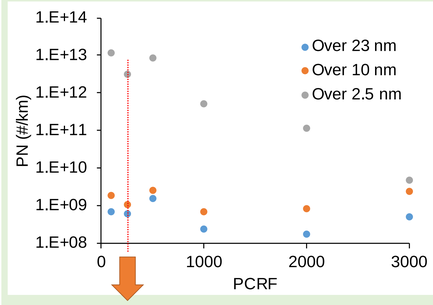
Gasoline DI-2
PCRF = 100

Comparison with EEPS

Gasoline DI-2
PCRF = 100
ET temp = 350 °C

DPF Diesel

DPF Diesel-1
ET temp. = 350°C



DPF Diesel-2
PCRF = 250

DPF Diesel-2
PCRF = 100
ET temp = 350 °C

PNs over 10 and over 23 nm were not affected by PCRF in PCRF > 100 which is required by PMP in both Gasoline DI and DPF Diesel. PN over 10 and 23 nm from diesel engine have some fluctuation due to quite low emissions.
PNs over 2.5 nm increased as decreasing PCRF in both cars. Possibility of this type of particles appearance is due to re-nucleation of semi-volatile particles. The feature of increased PNs over 2.5 nm in DPF Diesel was greater than Gasoline DI.

By decreasing ET temp., PN of all range increased. This may be due to decreasing removal efficiency of volatile particles.
Increased PNs over 2.5 nm observed in low PCRF disappeared by decreasing temperature of ET below 300 °C.
It is difficult to explain this reduction by simple evaporation and re-nucleation process.

Particles without ET obtained by EEPS were well agree with PNs over 10 nm.
Sometime, PNs over 2.5 nm exceed the particles without ET. These data suggested that there are particles formed in ET at over 300 °C.
Formation profiles of ET formed particles differed between Gasoline DI and DPF Diesel. In the case of Gasoline DI, ET formed particles appeared only in cold start process. But in DPF Diesel case, the particle appeared various places.

Conclusion

We performed PN measurement down to 2.5 nm using PMP methodology.
Particles produced in ET in low PCRF and temperature > 300 °C were observed.
These particle emission profiles differed between Gasoline DI and DPF Diesel.

What are they?

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