Morphology and Structure of Engine-like Soot Particles formed by a Soot/SOF Generator

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Chun-Beom Lee[1] and Kwang-Chul Oh[1]
Heeje Seong[2] and Seungmok Choi[2]

1: KATECH (Korea Automotive Technology Institute)
2: Argonne National Laboratory, USA

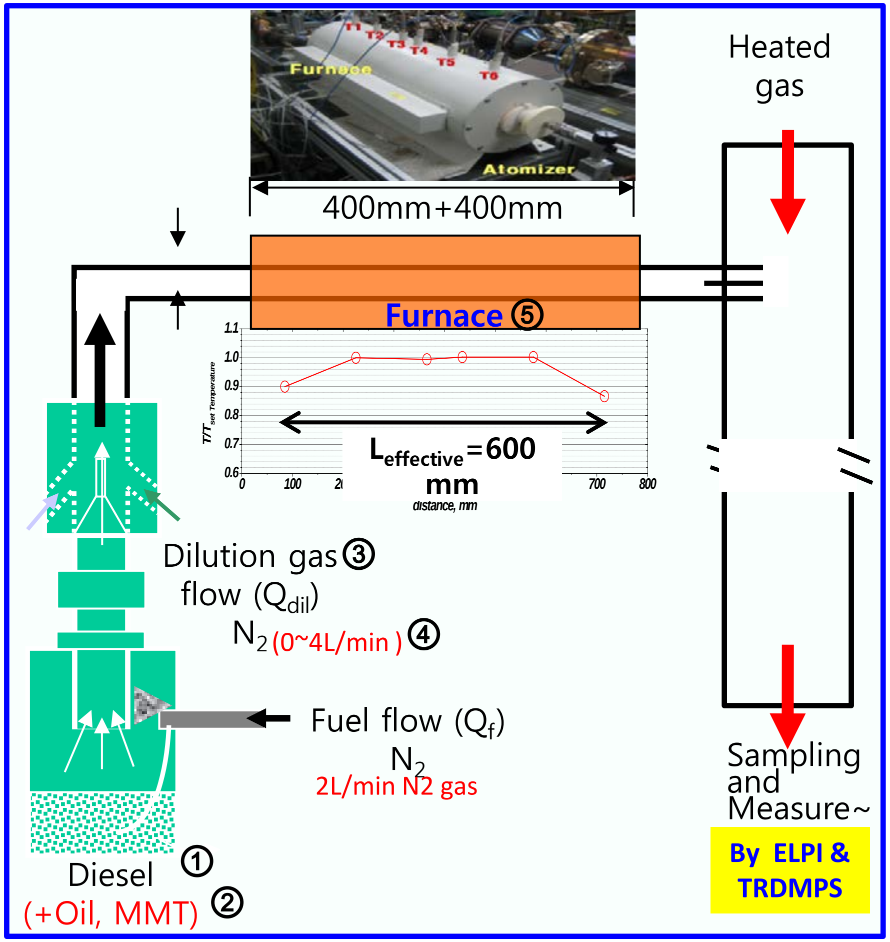
Exhaust Gas Simulator

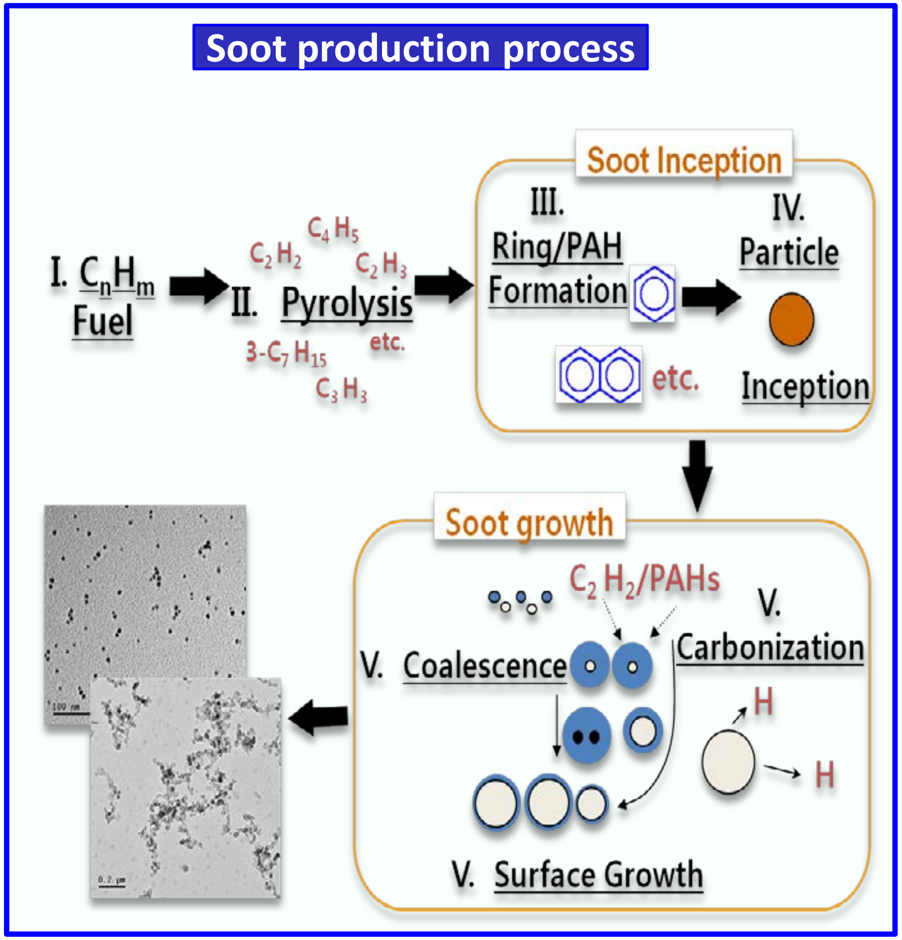

Soot/SOF and solid harmful particle` generator

PM Feeder

Soot and solid harmful particles can be produced and controlled by the 5 CVs of pyrolysis soot generator

✓ 5 CVs(Control Variables) : ①fuel, ②additive, ③dilution gas & ④flowrate, ⑤furnace T.
➔ particle size, number distribution, soot volume and SOF composition





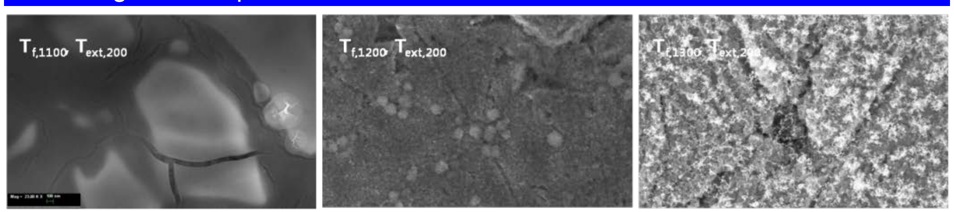
The objective of this study is ~

- Soot and solid harmful particles generated during the engine operation have a great influence on the performance and the life cycle of the after treatment parts ; Fouling or deposit effects of EGR cooler, aging and poisoning effects of sensors(T, O2, PM)

- We designed and produced the soot generator to produce an engine like soot and solid harmful particles like as the materials coming from the real engine

- The morphology, structures and size distribution were compared with the real soot and this soot generator were used to evaluate the deterioration characteristics of after treatment parts according to the soot and solid harmful particles

SEM image of soot particles collected from the diesel fuel dozed with 5% lube oil

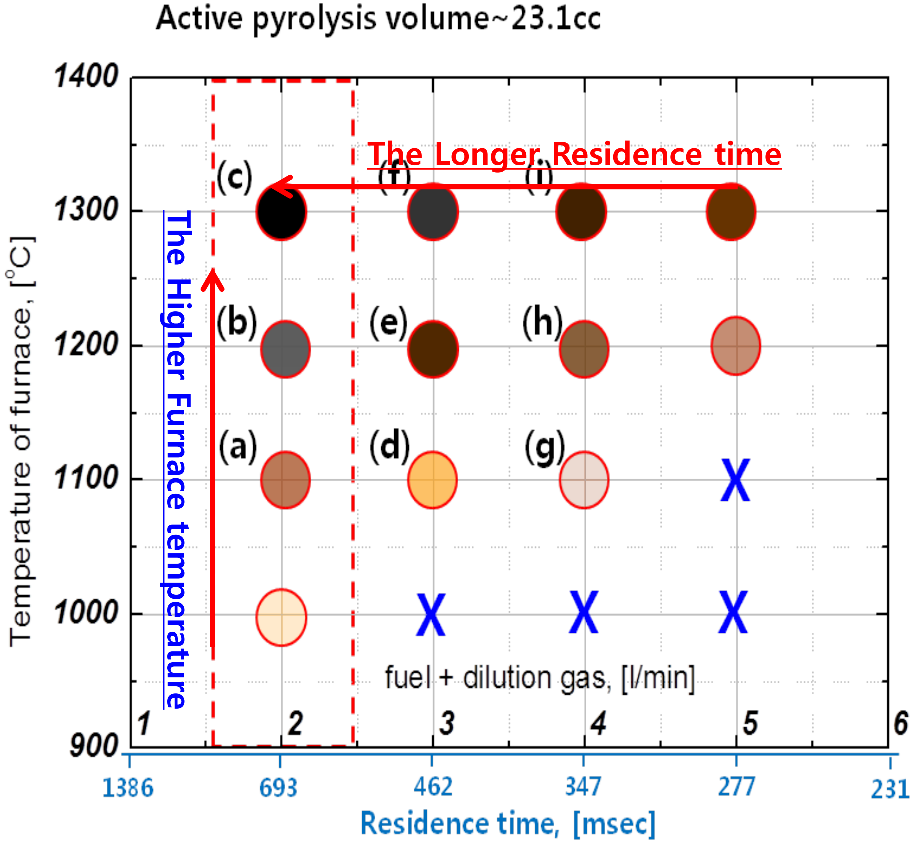


Test example of fouled EGR cooler by particles

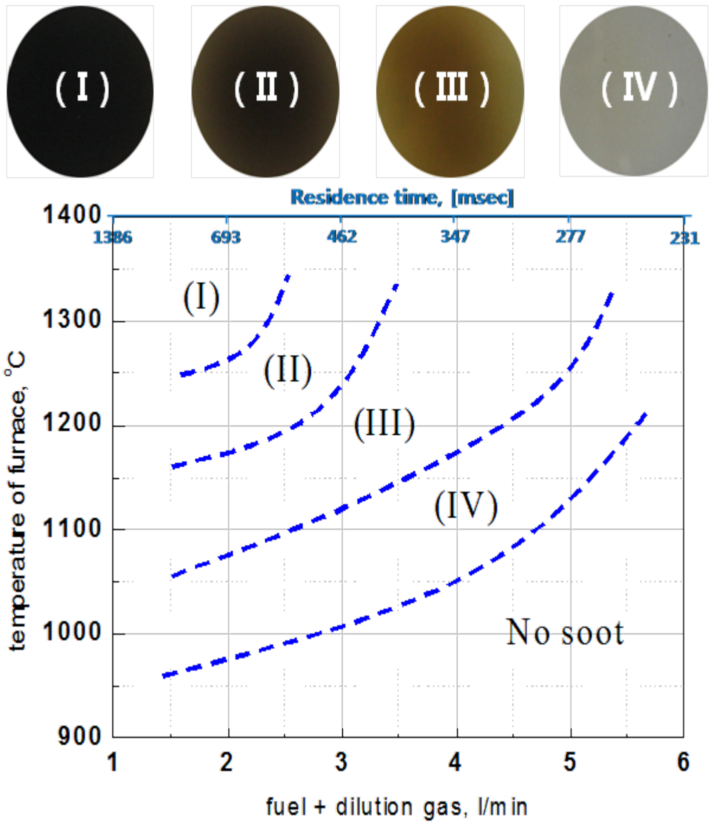
Soot production could be distinguished by 4-regimes according to the temperature and residence time

✓ No soot formation **below 1,100°C** in diesel fuel case

- from **dry soot(regime (I))** to **wet soot** (high SOF & low C/H ratio, regime(III~IV))



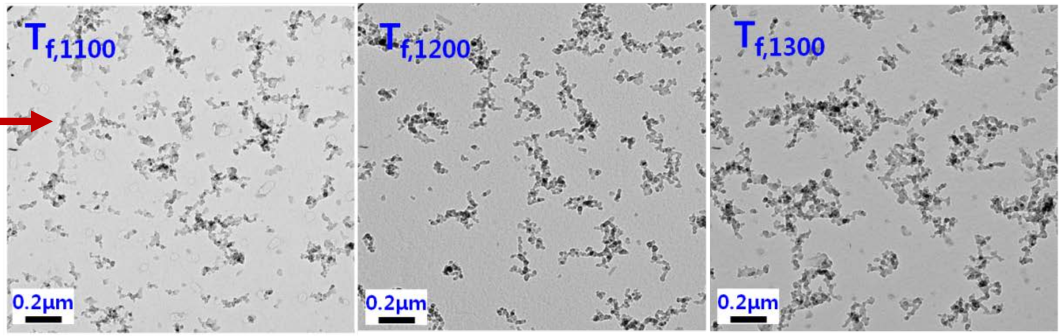
Decrease Particle size & Increase SOF



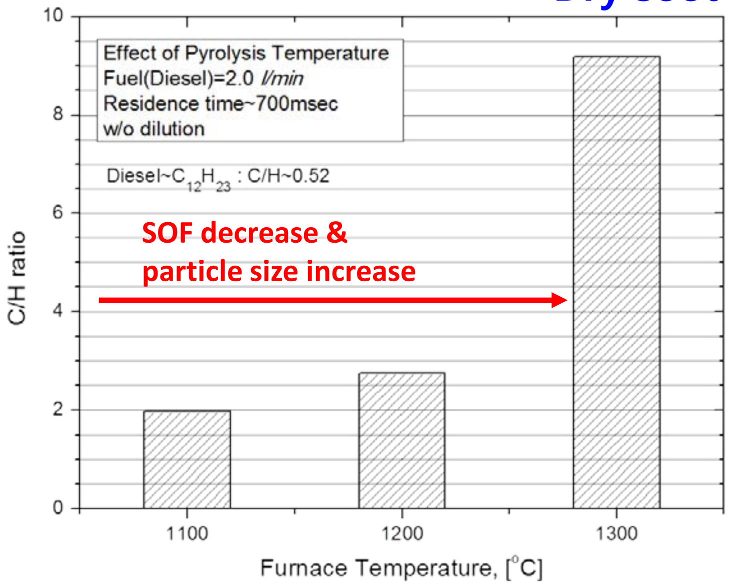
Wetness of soot by SOF & VOF were studied by TGA/DTG techniques

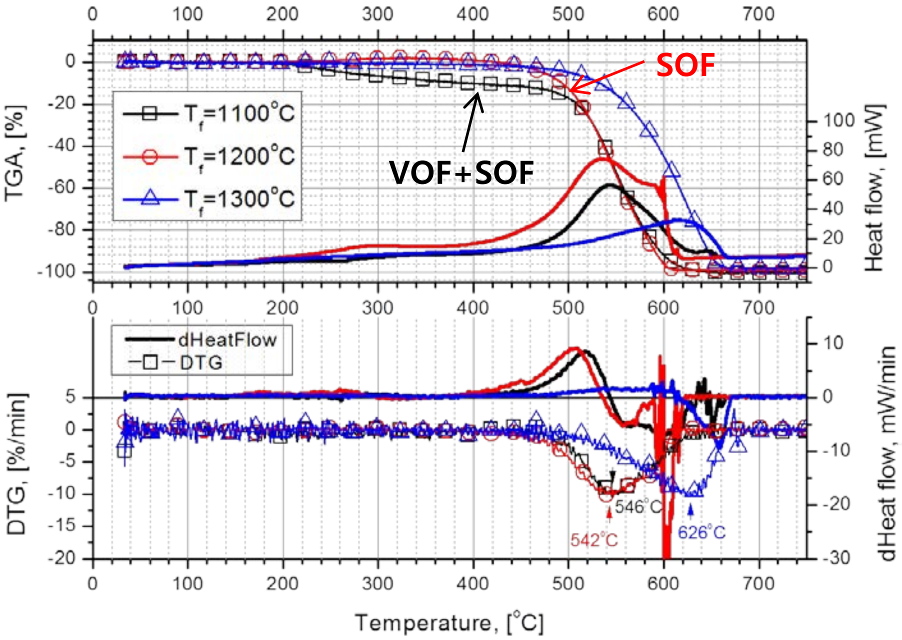
SOF decrease & particle size increase
C/H ratio increase

From the transparent
& liquid like particle

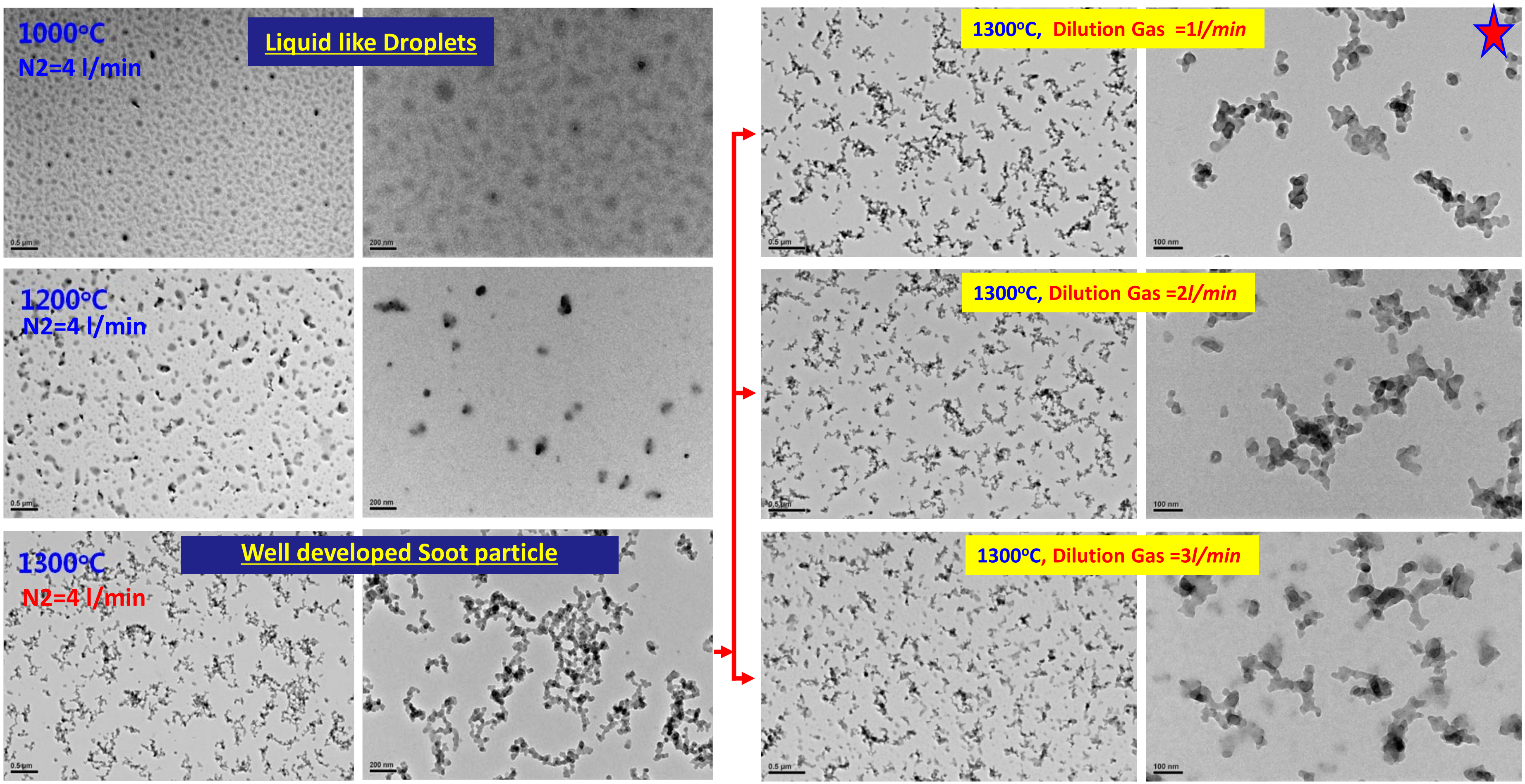


Wet soot ↔ Dry soot



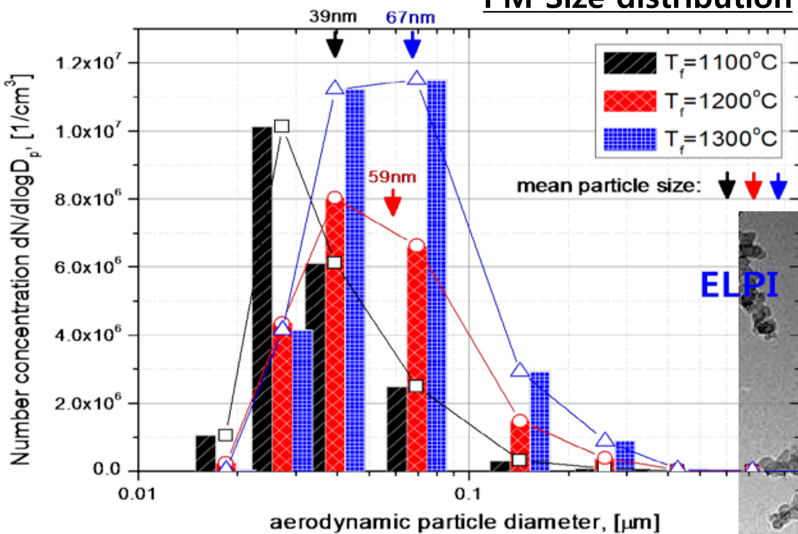


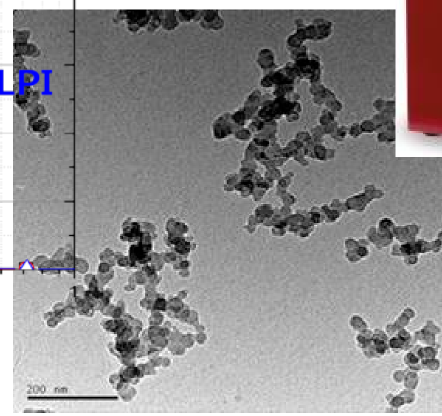
Soot structure and morphology was controlled by the temperature, residence time and dilution gas



- ❑ The higher temperature and the less flow rate, we can get the well developed soot particles like as a real engine soot.

Number Concentration of the generated soot was compared with a real diesel & gasoline particles





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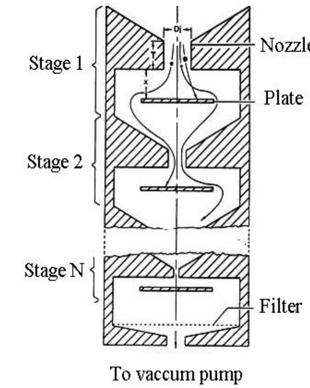
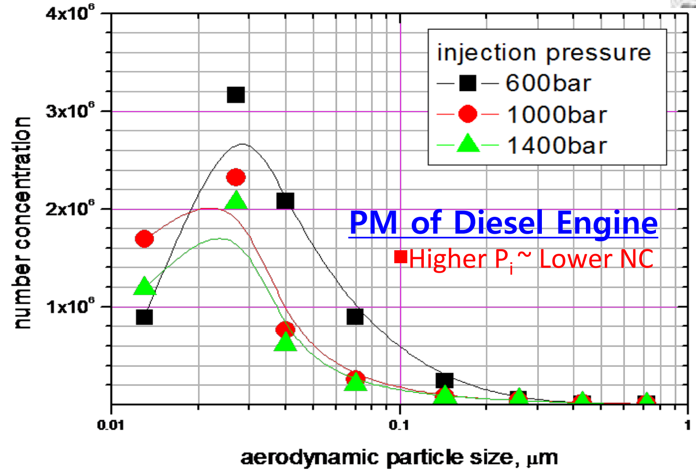
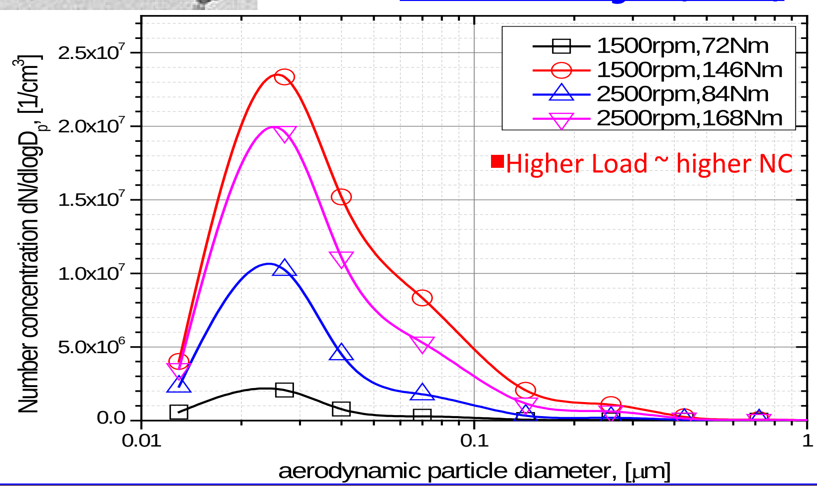
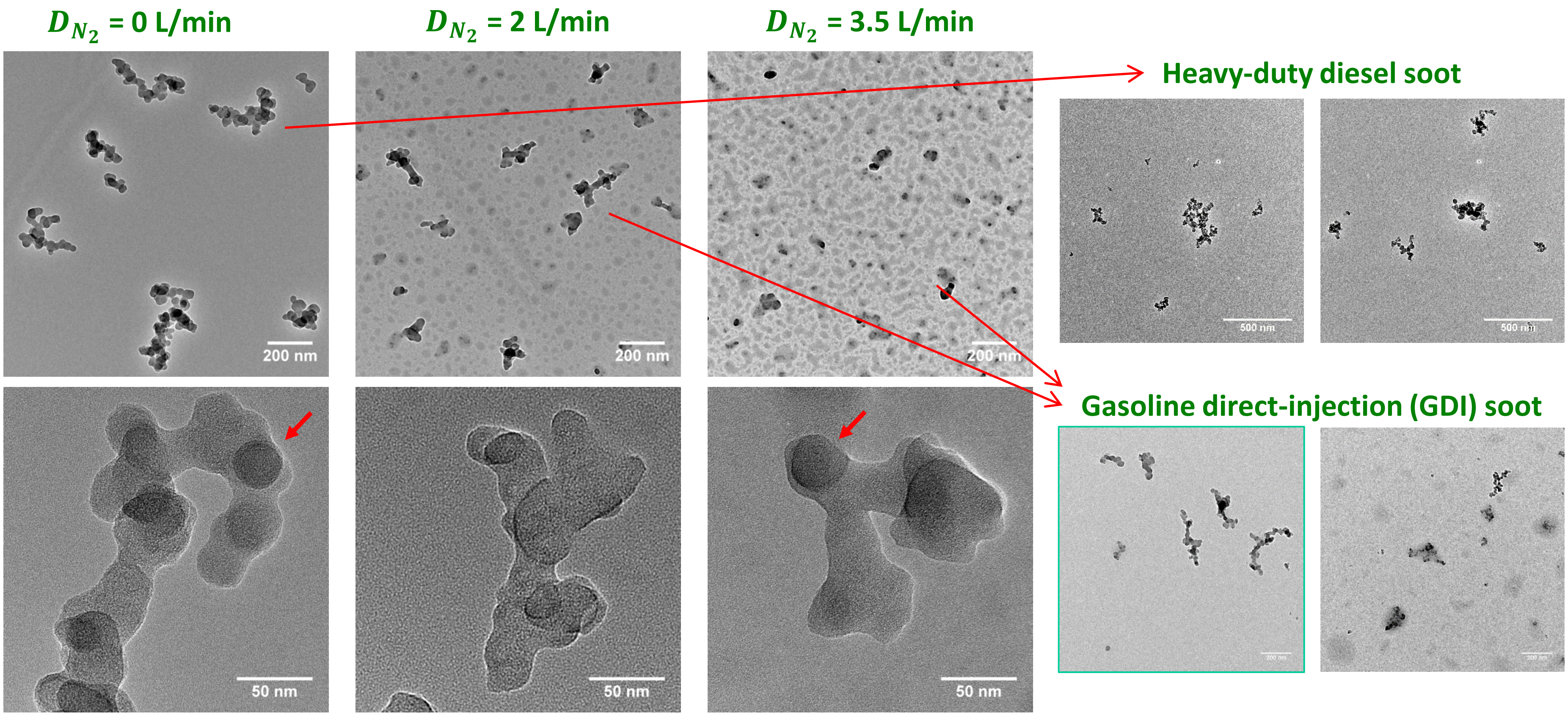






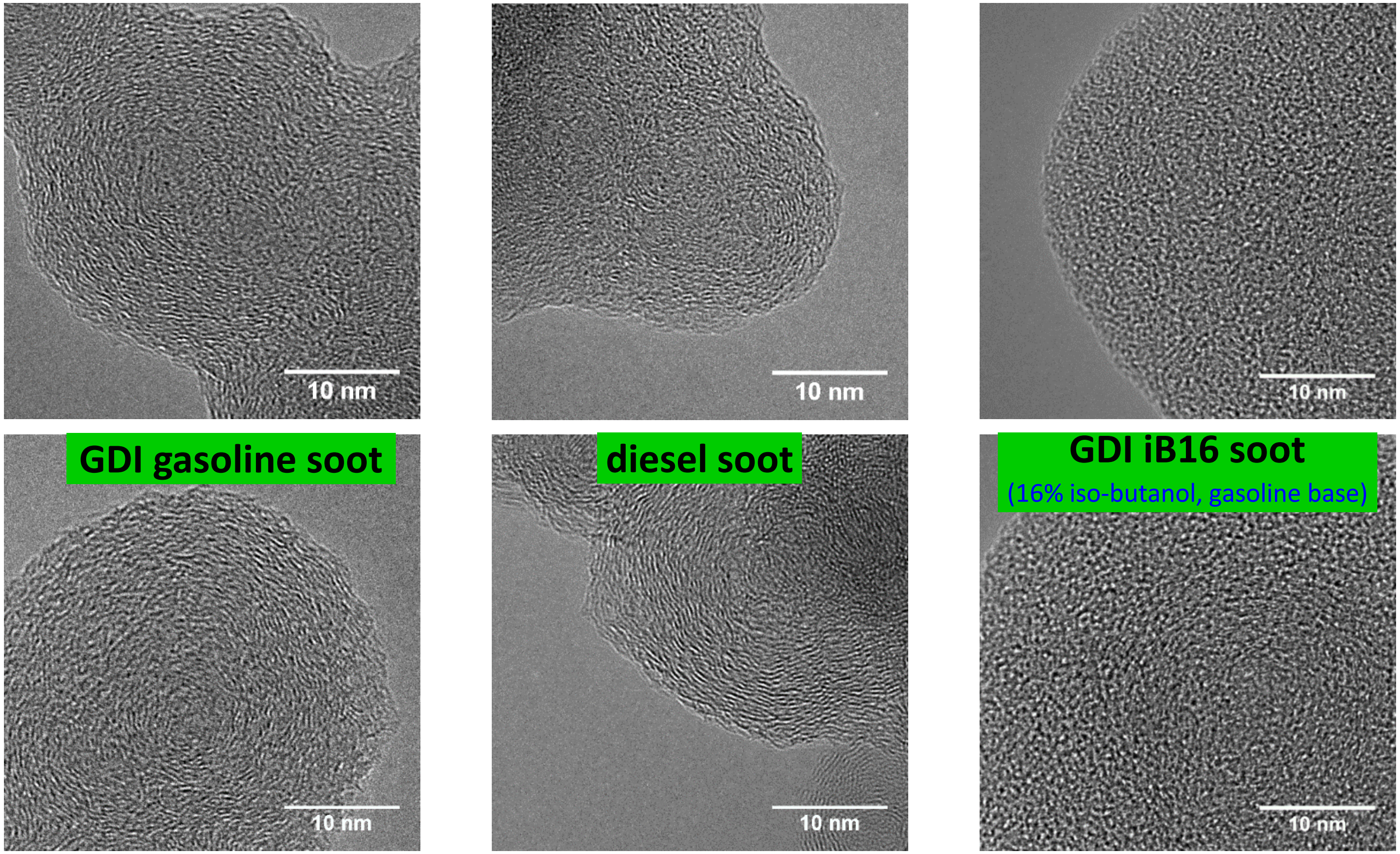
With decreased dilution flow rate, soot aggregates become more chain-like structures



- ❑ With decreased dilution flow rate, soot was found to be matured with clear spherical primary particles.
- ❑ Based on apparent shapes, matured aggregates were more like diesel soot, while relatively less-matured aggregates with nucleated particles were more like GDI soot.

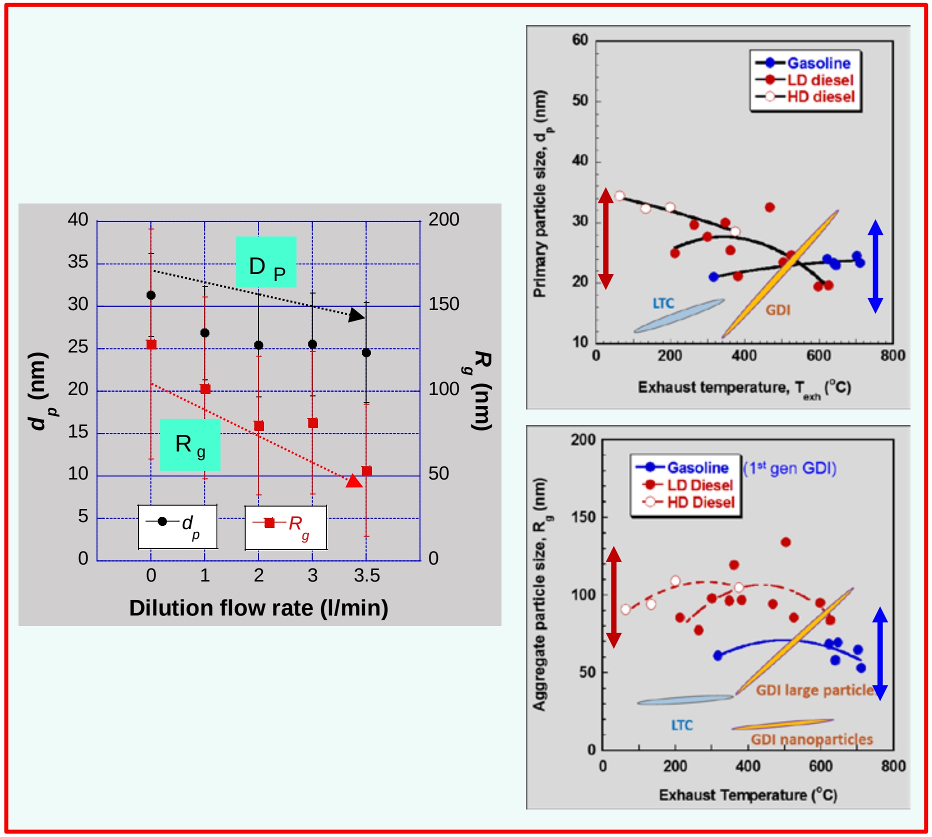
With decreased dilution flow rate, nanostructure shifts from amorphous soot to graphite-like soot

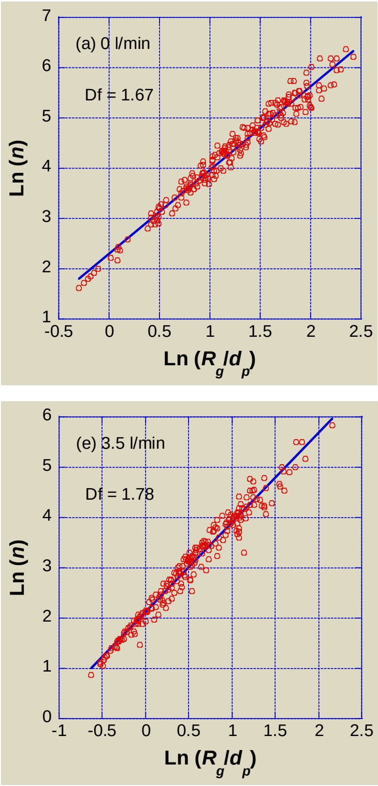
D_{N_2} = 0 L/min | D_{N_2} = 2 L/min | D_{N_2} = 3.5 L/min

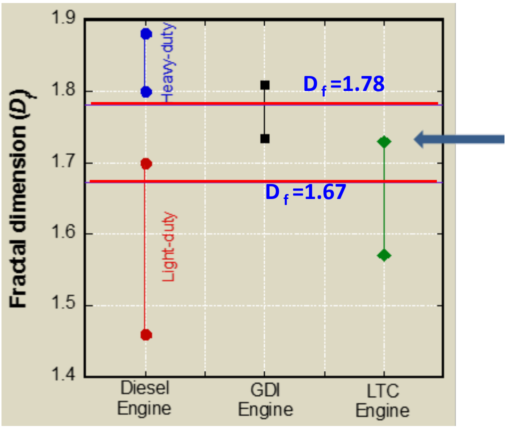


- With decreased dilution flow rate like as 0 or 2L/min, concentric fringe patterns surrounding nucleus were clear, indicating graphite-like soot found in typical GDI and diesel soot.
- Amorphous soot showing no clear fringe patterns like as flow rate 3.5L/min is similar to the soot produced from the gasoline base 16% iso-butanol GDI combustion.

Statistically, primary & aggregate sizes and fractal geometry are in the range of actual engine soot

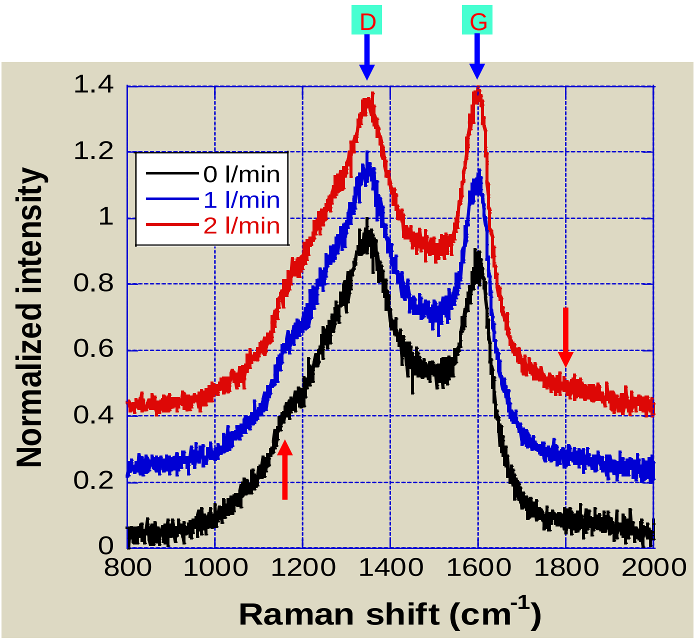


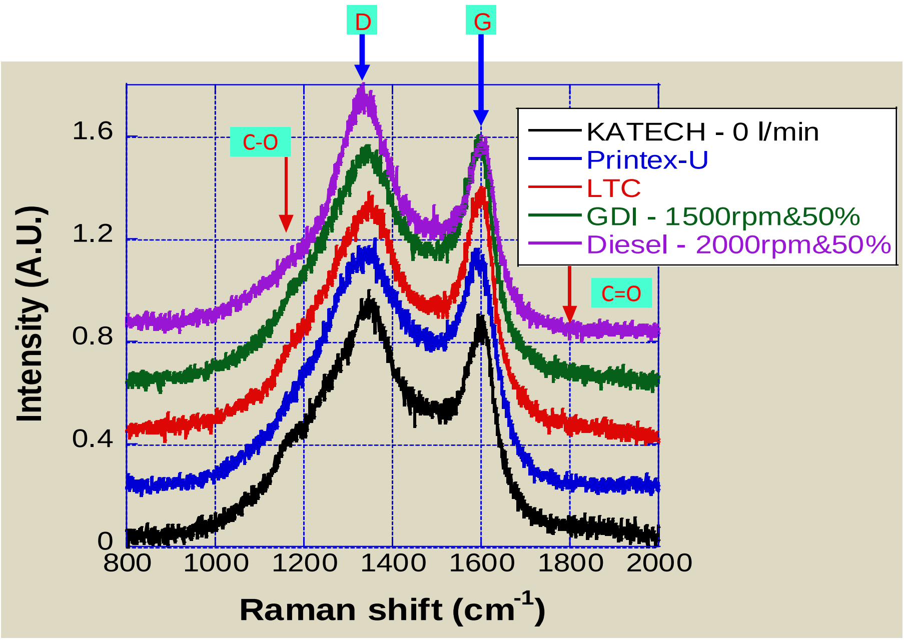




- The average primary and aggregate sizes of our samples are in the range of 24 to 31 nm and 50 to 125 nm, respectively, which are comparable to those of GDI and diesel soot.
- Based on fractal analysis, fractal dimensions were in the range of 1.67 to 1.78, which are comparable to those of GDI and light-duty diesel soot with respect to aggregate geometry.

Crystalline structure of generated soot is quite similar to engine soot, but organic content may be different





- Carbon crystalline structures are quite similar in the flow range of 0 to 2 L/min, although it is evaluated that structure is more ordered with decreased flow rate. Also, organic content seems to decrease with decreased flow rate based on peak patterns at 1,800 and 1,150 cm^{-1}.
- When compared to engine soot, the carbon crystalline order of generated soot seems to be in between LTC and GDI soot, indicating much less ordered than diesel soot at medium load.

The soot produced by the KATECH's soot generator shows the similar characteristics with real engine soot

- The soot and solid harmful particles generated during the engine operation have a great influence on the performance and the life cycle of the after treatment parts ; Fouling or deposit effects of EGR cooler, aging and poisoning effects of sensors(T, O2, PM,)

- KATECH developed a soot generator to use for the development of diesel particulate filters (DPFs), high temperature sensors(T, O2, PM) and the fouling effects of exhaust gas recirculation (EGR) cooler

- The TEM, HR-TEM and Raman spectroscopy showed that average primary particles diameter were observed to be in a range of 24 to 31nm and average aggregate sizes are in the range of 50 to 125 nm which are comparable to those of GDI and diesel soot.

- With increasing dilution flow rate, soot changed from well-defined graphite-like carbon, such as typical diesel and GDI gasoline soot, to amorphous carbon, such as GDI iso-butanol 16% case, resulted from delayed soot formation maybe.

Thank you for your attention

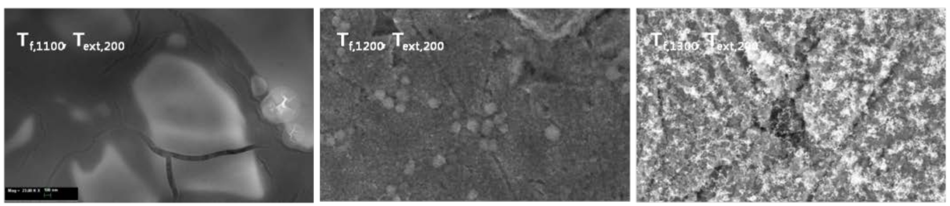
Further Questions on the soot generator

-E-mail: cblee@katech.re.kr

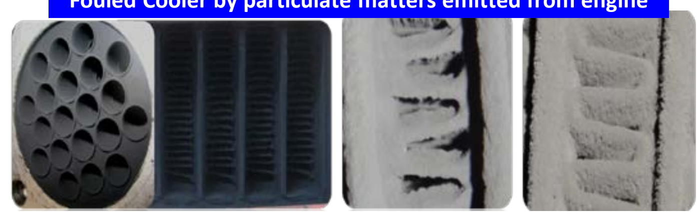
Soot & solid harmful particles ?

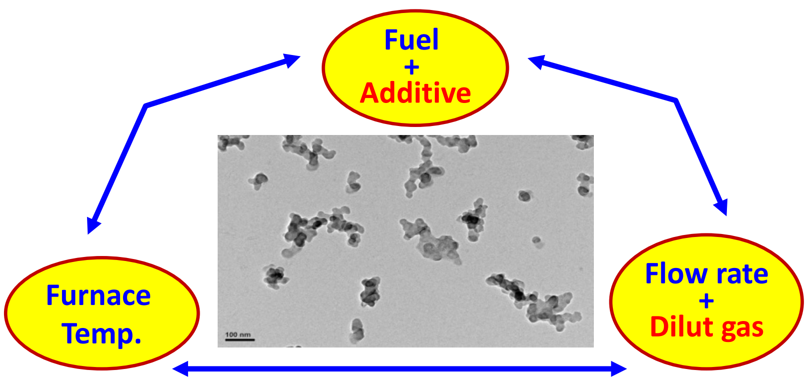
- ➔ Evaluation of fouling effects and particulate matter deposit characteristics on the cooler surface
- ➔ Evaluation of Aging and Poisoning Effects of Sensors

SEM image of soot particles collected from the diesel fuel dozed with 5% lube oil

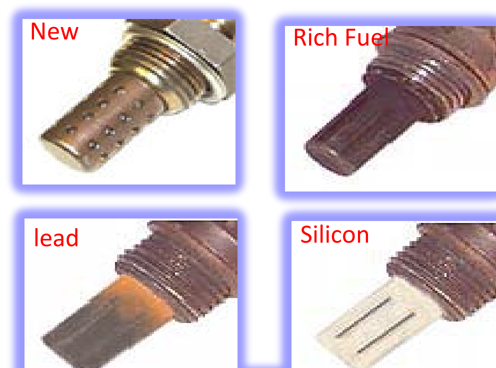


Fouled Cooler by particulate matters emitted from engine





Control variables of Particle generator



Poisoning of O_2 Sensor