Pressure Response during Filtration and Oxidation in Diesel Particulate Filter

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Introduction

- Combustion-generated soot particles from diesel vehicles are known to cause substantial damages to the environment and human health
- A diesel particulate filter (DPF) is needed to trap diesel soot
- Since the filter would be clogged by collected particles with a rise of filter backpressure (pressure drop, ΔP), resulting in worsening of fuel efficiency and a decrease in the engine output
- Filter regeneration is conducted to oxidize deposited particles
- To realize efficient filter regeneration with less fuel usage, precise prediction for amount of particles in DPF is needed by ΔP
- However, it is difficult to investigate **filtration & regeneration** processes correspondingly, because characteristics of real soot depend on fuel, exhaust gas component, and engine conditions

Objectives

Investigation of filtration and regeneration performances of DPF by using carbon particles from particle generator (PALAS soot)

Ex.1: Filtration of carbon particles

Use of carbon particles with different particle size distribution
→ Filtration efficiency and pressure drop in three cases

Ex.2: DPF regeneration

Oxidation of carbon particles used in Ex.1
→ Pressure drop, CO & CO_2 concentrations in three cases

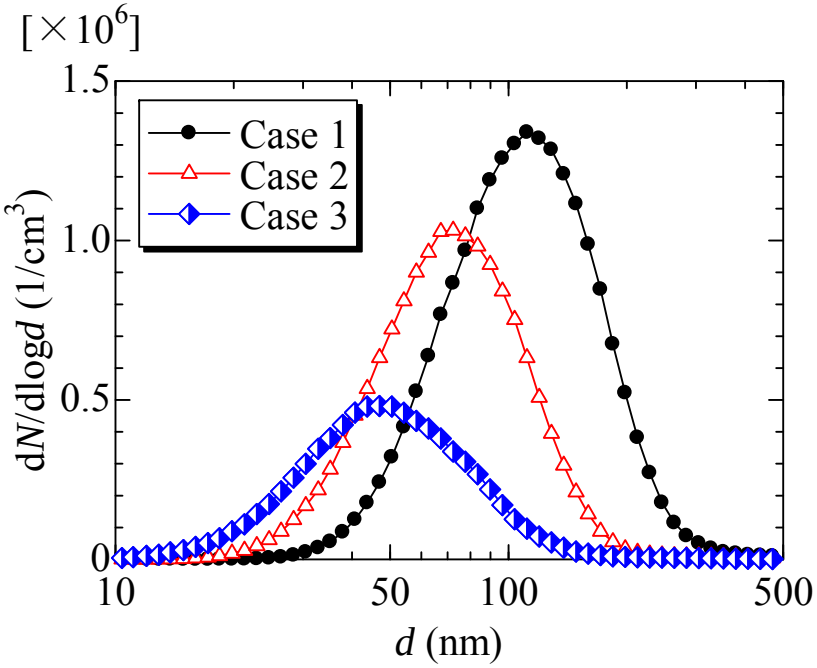
Ex.3: Filtration and regeneration (not continuous regeneration)

Filtration and oxidation of carbon particles at high temperature
→ Variation of pressure drop during filtration and regeneration

Particle Generator

DNP-2000 (PALAS)

Imitation of diesel soot using carbon particles produced by PALAS soot generator

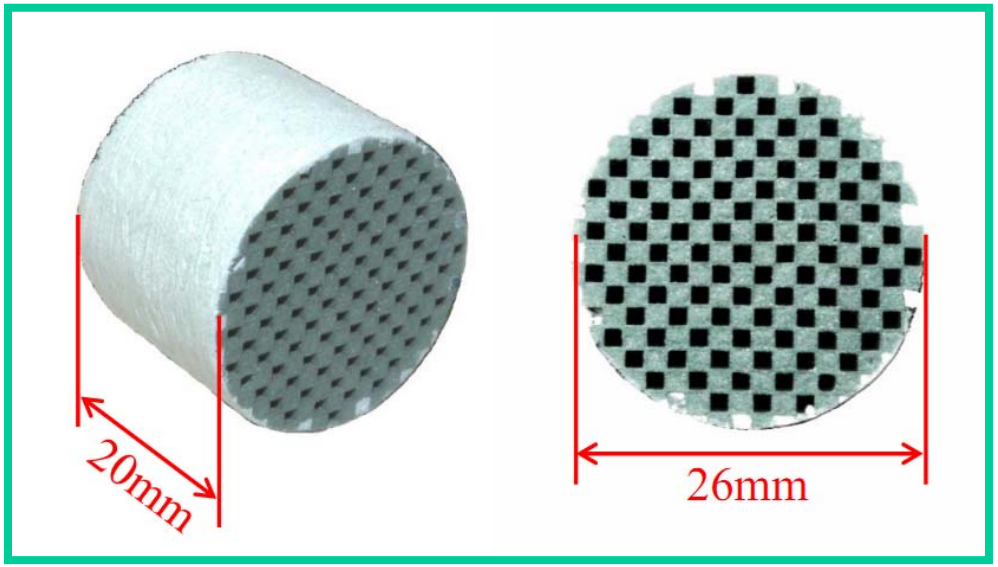


Particle size distribution (Case1 to 3)

Characteristics of carbon particles

	Peak diameter(nm)	Total number concentration(1/cm^3)
Case 1	111	2.06×10^7
Case 2	72	1.55×10^7
Case 3	47	0.81×10^7

SiC-DPF



Picture of SiC-DPF

- Material : SiC
- Porosity : 42 %
- Average pore size : 11 μm
- Wall thickness : 0.25 mm
- Cell density : 300 cpsi

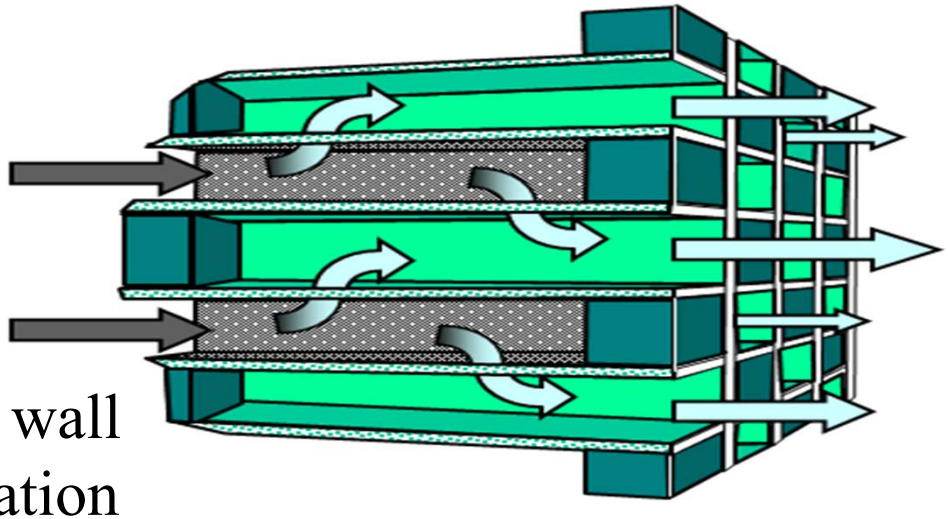
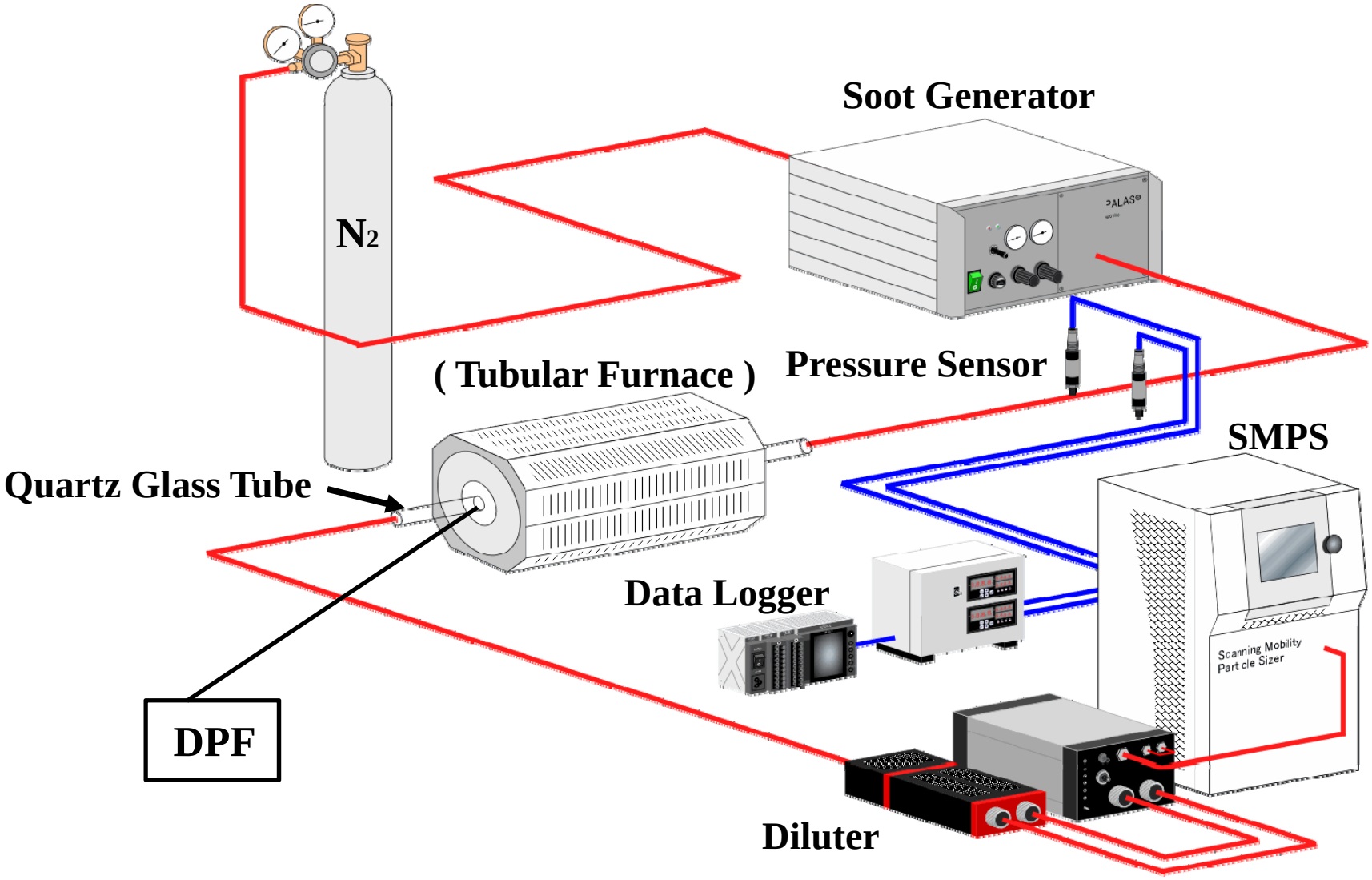


Image of filtration (TYK)

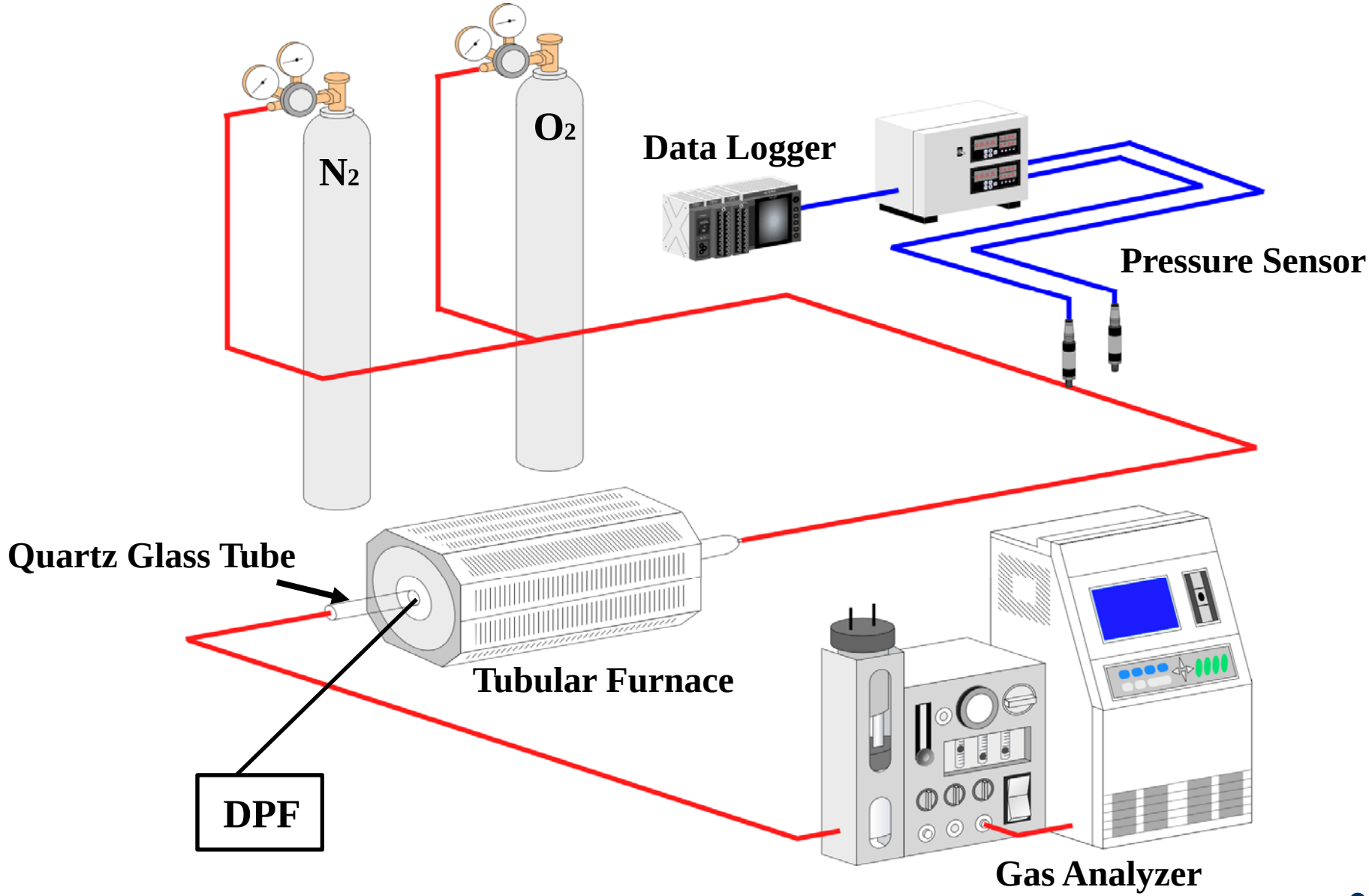
DPF filtration

- Particles are trapped by porous wall
- Depth filtration → surface filtration

Experimental Setup (Filtration)



Experimental Setup (Regeneration)



Experimental Conditions

Ex.1: Filtration of carbon particles

Flow rate: N_2 (with particles) 4L/min, Temperature: 25℃
Experiment time: Case 1→30min, Case 2, 3→ until pressure drop increases up to $\Delta P = 0.308$kPa, which is the final value of pressure drop in case 1

Ex.2: DPF regeneration

Flow rate: N_2 (w/o particles) 3.6L/min + O_2 0.4L/min, Temp.: 550℃
Experiment time: until pressure drop reduces to ΔP_{550} (initial pressure drop at 550℃ without particle deposition)

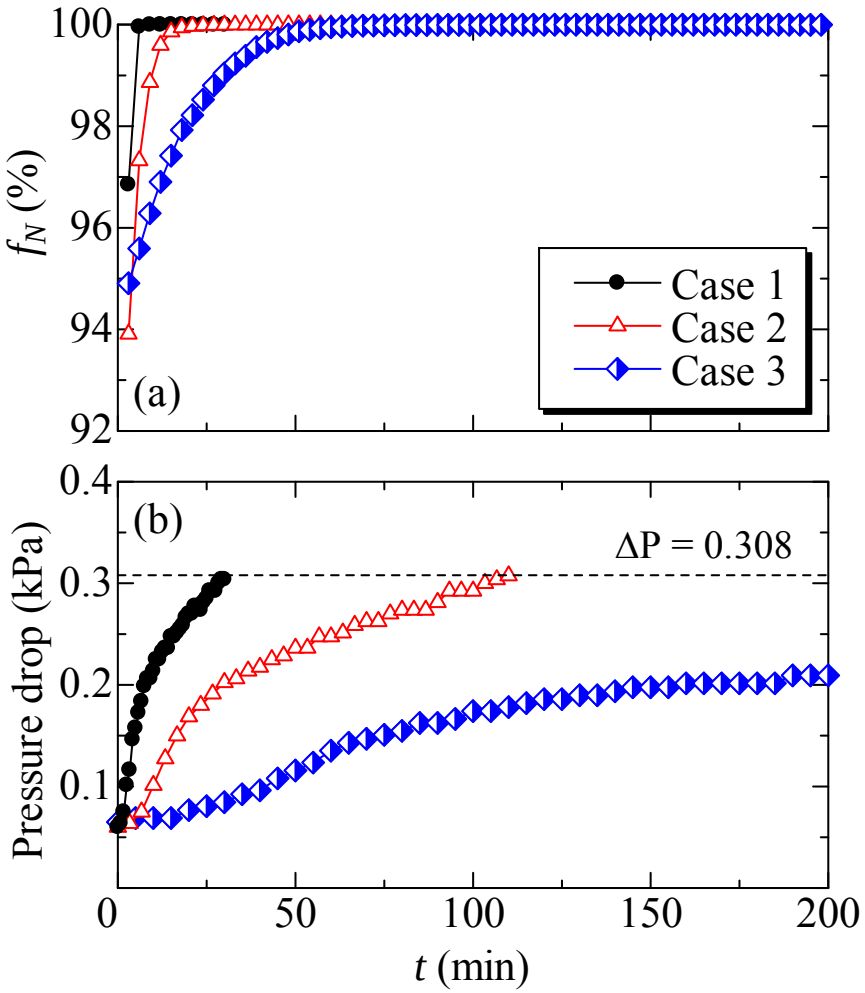
Ex.3: Filtration and regeneration at high temperature

Filtration → Flow rate: N_2 (with soot) 4L/min, Temp.: 550℃
Experiment time: 30min (case 1)

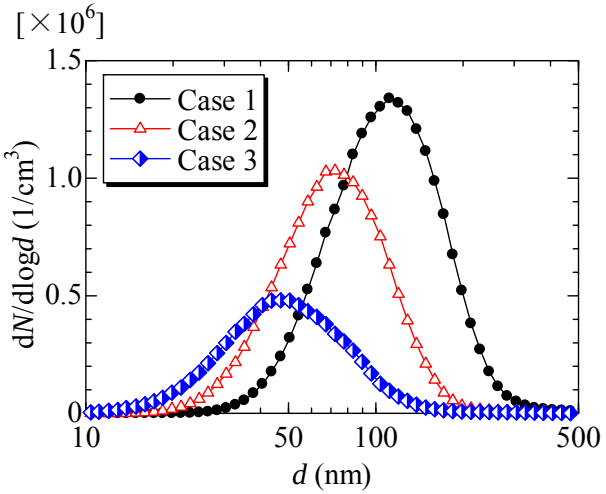
Regeneration → until pressure drop reduces to ΔP_{550}

Results and Discussion

Ex.1: Filtration of Carbon Particles



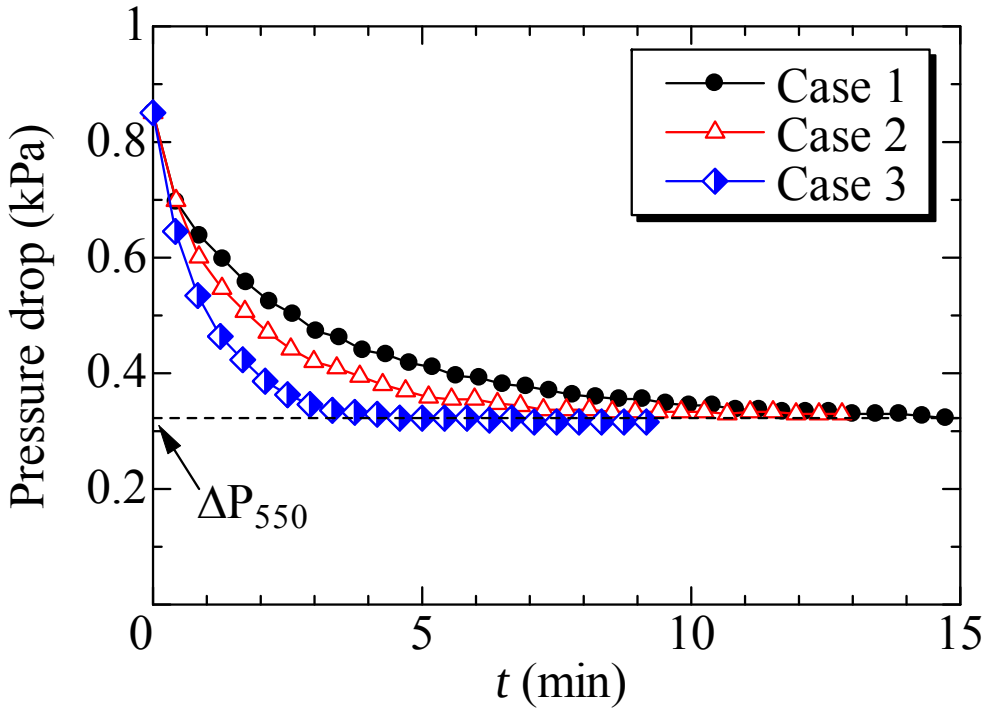
(a) Filtration efficiency and (b) pressure drop



Independent of particle size distribution,

- Filtration efficiency and pressure drop increase with the time
- Based on the variation of filtration efficiency, it is derived that there is a shift from depth filtration to surface filtration during the filtration process

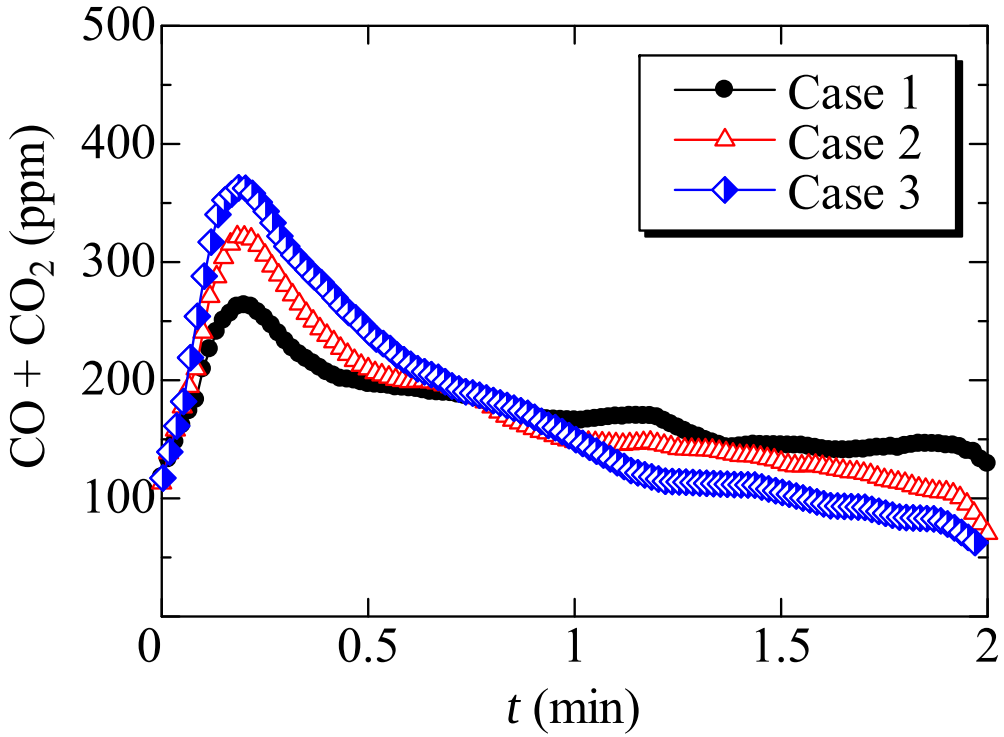
Ex.2: DPF Regeneration



Pressure drop during regeneration process

- **Pressure drop simply decreases with the time**
- **In all cases, the curve of pressure drop is concave**
- **Reduction of pressure drop in case 3 is largest**

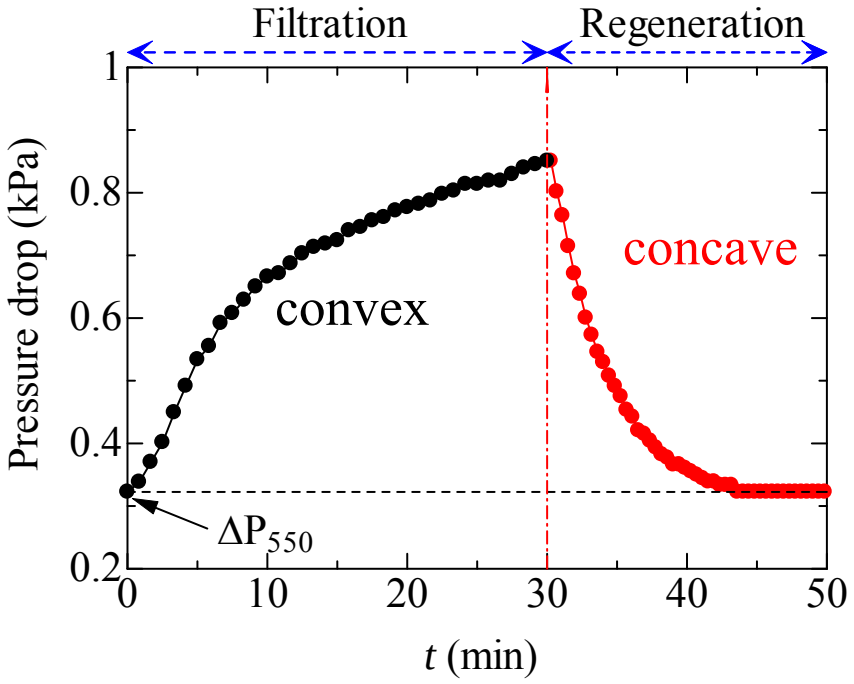
Volume Fraction of Total CO & CO_2

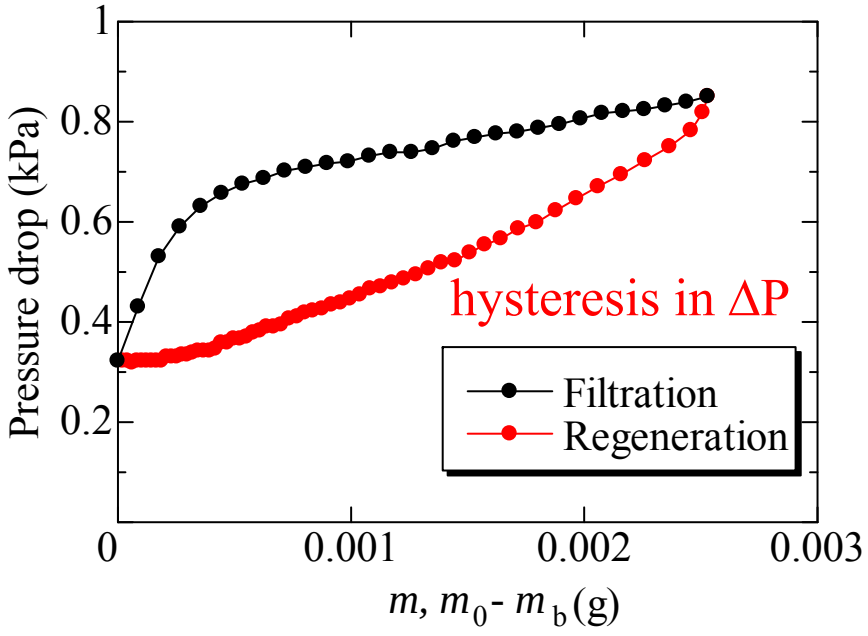


- CO and CO_2 concentrations initially increase with the time, reach the maximum, and then decrease gradually
- In case 3, total concentration of CO and CO_2 decreases very rapidly, suggesting higher oxidation rate of smaller particles

Ex.3: Filtration & Regeneration at High Temp.

- Filtration at high temperature (550℃) was conducted
- ΔP in consecutive test was measured during filtration, regeneration





⇒ **By comparing two curves, different ΔP is observed even when amount of particles is the same during filtration, regeneration**

Summary

In the present study, using carbon particles as model soot, we evaluated filtration and regeneration performances of SiC-DPF. Especially, particles with different size distributions were tested. Following results were obtained.

1. Independent of the particle size, the pressure drop (ΔP) raised by the particle deposition, suggesting that there is always a shift from depth filtration to surface filtration during the filtration process.
2. In the filter regeneration process, CO and CO_2 concentrations initially increased with the time, reached the maximum, and then decreased gradually. By comparing the variation of ΔP during filtration and regeneration, its dependence on the deposited particle mass was quite different, showing the hysteresis in the transition of the pressure drop.