Dilution process of fine particles by means of thermodilution

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Abstract

The influence of dilution by means of a thermodiluter, which removes particles of nuclei mode, was clarified to stabilize the measurement results by using a standard particle generator. The effect of oxidation catalyst in CRT on nuclei mode particles was showed by real-time measurement of particle size distribution under transient driving condition.

Introduction

A new PM measurement method is discussing at present in GRPE/PMP, such as particle measurement equipments, samplings and so on. Particles emitted from diesel engines, especially the particles that are called 'Nuclei Mode Particles' are very unstable and easily influenced by the engine operating conditions and the measurement conditions. Most of nuclei mode particles are said to consist of volatile organic particles with mainly high carbon number. These particles may be able to be reduced by an oxidation catalyst in DPF. The purpose of this study is to verify thermodiluters and to investigate the behavior of nuclei mode particles in DPF (CRT) that will become popular. This paper consists of 'Dilution process by thermodiluter' and 'Effect of oxidation catalyst in CRT on nano particles'.

Dilution process by thermodiluter

A standard particles generator (CAST) was used to keep the stability of original particle size distribution. The same transfer tube was used for both without disk diluter and with disk diluter to avoid the effect of transfer tube contamination. Disk diluter was used as a thermodiluter and size distribution was measured by SMPS. Slide 6 shows specifications of a standard particle generator (CAST) and a thermodiluter (Disk Diluter). Slide 7 shows influence of dilution ratio and temperature on monomodal distribution. Red line shows an original distribution of CAST. There is no remarkable difference between the distributions of each dilution ratio except for dilution temperature 25℃ that means no heating. There are some differences between original distributions and dilution distributions. However it may be possible to compensate the difference between original distributions and dilution distributions by calculations, because the original distribution and dilution distribution forms are almost the same except for both very small size particle region and very large size particle region. Basically the tendency of influence distribution ratio and temperature on bimodal distribution is the same as the previous monomodal case.

Effect of oxidation catalyst in CRT on nano particles

Slide 10 shows the specifications of test engine and test DPF (CRT). The used fuel is low sulfur fuel. Sulfur content is less than 35 ppm. Slide 12 shows Fast Particle Sizer Specification. This instrument was used to measure transient behaviors of particle size distribution. Test conditions are two conditions One is a steady state engine condition. High exhaust gas temperature was achieved by initial running the engine at middle load for a certain period of time. Just after achieving the required high exhaust gas temperature, the engine was suddenly switched from middle speed and load to idling. The exhaust gas temperature was decreasing slowly because the temperature of exhaust system was still high. During this time, the measurement of size distribution was carried out by DMS500. Another is a transient engine condition. The real-time measurement of size distribution was carried out in the condition of FTP mode by DMS500.

Slide 14 shows experimental apparatus for oxidation catalyst in DPF (CRT). The measurements were carried out at three points, before DPF, after oxidation catalyst in DPF and after DPF. Slide 16 shows typical behavior of fine particles in DPF due to exhaust gas temperature change during idling. Just after the change from middle speed and load to idling, nuclei mode particles did not appear in each three measuring points. After 200 seconds, exhaust gas temperature went down under 200℃. So nuclei mode particles appeared before DPF and after oxidation catalyst also. In less than 200℃, the oxidation catalyst was not active enough to oxidize nuclei mode particles.

Slide 18 shows typical behavior of fine particles under DPF in the FTP transient driving condition. At 50 seconds after FTP mode started, the temperature of exhaust system was not still high enough. Nuclei mode particles appeared in each measuring point. After 90 seconds, under the same engine speed and load pattern condition, the temperature of exhaust system increased more than 200℃. Nuclei mode particle disappeared after oxidation catalyst, because nuclei mode particles were oxidized. After DPF, the particle number decreased to 1/100 of before DPF. However, in this case the particle number concentration was still higher than background particle number concentration.

Conclusions

Particle size distributions measured by SMPS under dilution conditions by thermodiluter showed good repeatability. The particle size distributions with dilution by thermodiluter kept almost the same form as those without dilution by thermodiluter. The particle loss by dilution may be able to be compensated by calculation. The transient real-time particle size distribution behaviors were measured by DMS500. An oxidation catalyst in CRT reduced nuclei mode particles in the condition of more than 200℃ exhaust gas temperature but did not reduce them in less than 200℃. The particle number concentrations reduced to about 1/100 by DPF.

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2. Dilution Process by Thermodiluter
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1. Introduction

● Background

GRPE/PMP Activities (Sampling)

Reduction Effect for Nano Particles by DPF (CRT)

● Objectives

• Verification for Thermodiluter

• Influence of Oxidation Catalyst in CRT on Nano Particles

2.
Dilution Process by Thermodiluter

Experiment Setup for Dilution Process by Thermodiluter (Disk Diluter)

(a)

(b)

Specifications of Measurement Equipments

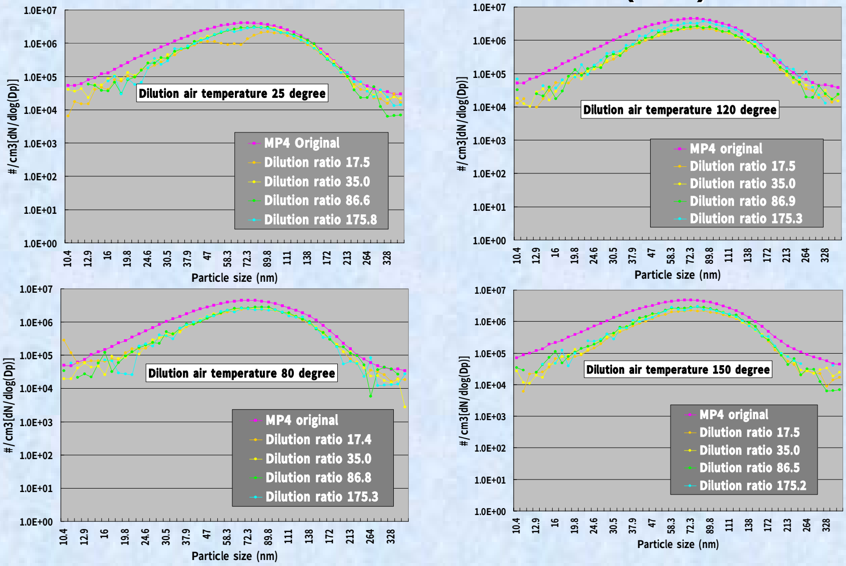
CAST

Aerosol	Soot particles generated in C_3H_8-diffusion flame (propane)
Elemental carbon (EC) fraction	Particles diameter 30 nm: 75 or 97%, 100 nm: 97%, 200 nm: 99%
EC concentration In prediluted test	Particles diameter 30 nm: appr. 4mg/m^3
Aerosol from burner	Particles diameter 100 nm: appr. 60mg/m^3
	Particles diameter 200 nm: appr. 350mg/m^3
Size distribution	monomodal, bimodal
Mean diameter	sevsral mean mobility diameters from 30 to 200 nm on choice
Concentration from adjust. diluter	up to 10^7 part./cm^3 on test aerosol output
Accuracy	10% for number concentration from adjustable diluter
	5% for number concentration for ptediluted test aerosol
	5% of selected mean size +/- 3nm
Reproducibility	±5 %
Aerosol flow from diluter	0,2 … 4l/min = flow sucked by sensor(s) under test
Dilution air	0 … 30l/min for additional external dilution
Gas-specifications	C_3H_8(propane), purity 99.95%; N2, purity 99.999%
	dry compressed air, oil-and particle filter inside CAST

Disk Diluter

Nominal dilution ranges	1:15 … 1:300 (10 cavities on disk, Fd=0.5 … 1.5 l/min)
	1:150 … 1:3000 (2 cavities on disk, Fd=0.5 … 1.5 l/min)
	Fd > 1.5 l/min, see Fig.1
Input gas flow Fu	appr. 1 l/min
Admissible output gas flow	0.5 … 5 l/min
Accuracy	±10%
Resolution	Output number concentration < 1 part./cm3 at dilution setting 0 %
Application	dilution of aerosols and gases
particle size range	10 … 1000 nm
temperature	0 … 200 ℃
differential pressure	+150/-100 mbar between measurement channel and ambient air
Heating	Adjustments temperature of dilution block and dilution air on
	rotating switch between
	OFF / 80 / 120 / 150 ℃

Influence of Dilution Ratio and Temperature on Monomodal Distribution(MP4)



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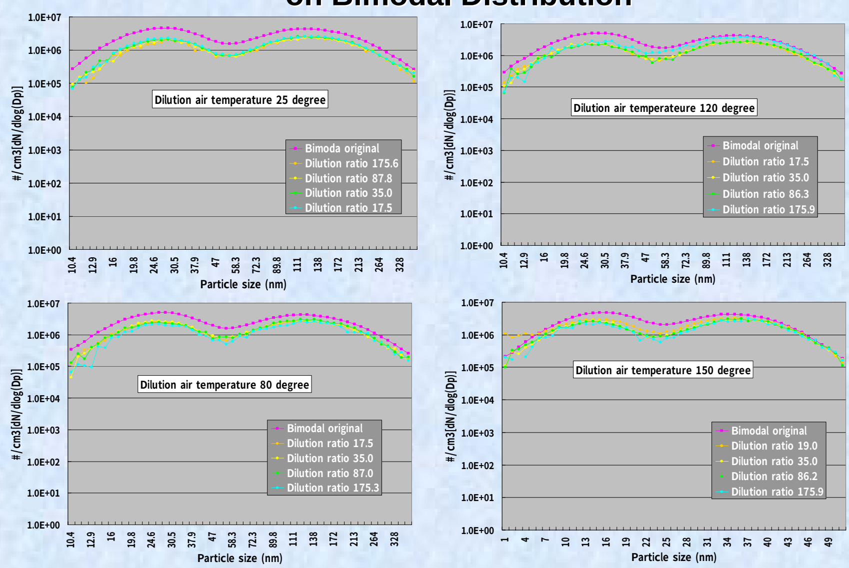
Influence of Dilution Ratio and Temperature on Bimodal Distribution



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3.

Effect of Oxidation Catalyst in CRT on Nano Particles

Specification of Test Engine

Emission Regulation	1998 Japan Domestic
Combustion System	Direct Injection
Engine Type	Intercooler-turbo
Bore / Stroke (mm)	114 / 130
Rated Power (kW/rpm)	191 / 2700
Max. Torque (Nm/rpm)	745 / 1600
Displacement (cm^3)	7,961

Test DPF(CRT) Specification

Filter Type	Honeycomb
Regeneration System	Continuously Regenerating Trap

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Properties of Test Fuel

Density (5℃ g/cm³)		0.8267
Kinematic Viscosity (mm²/s @30℃)		3.041
Flash Point PM (℃)		71
Distillation Profile(℃)	T_{10}	193.5
	T_{50}	260.0
	T_{90}	314.0
	FBP	357.5
Cetane Index		53.1
Sulfur Content (ppm)		35
Pour Point (℃)		-45
Residual Carbon (mass% of residue 10%)		0.01
C.F.P.P. (℃)		-46
Total Heating Value (J/g)		45,890

Fast Particle Sizer (DMS500) Specifications

Measurement principle	Aerosol electrometry
Size classification	Electrical mobility classification
Charging	Unipolar Diffusion
Sample channels	1
Time response	10-90% < 400ms
Instrument size (mm)	h=940, w=350, d=520 + pump
Electrical Supply	100-115/220-240V AC
Particle size range	5nm to 1000nm
Output spectrum elements	16 / decade
Size resolution	0.15 to 0.25 decade
Max data logging rate	10 samples / s
Analogue outputs	4(software configurable) 0-10V 47Ω
Auxiliary analogue inputs (logged with DMS500 data)	4; -10 to +10V

Test Conditions

1. Steady State Condition

1620rpm, 460Nm(Middle)→Idling

2. Transient Condition

FTP Mode

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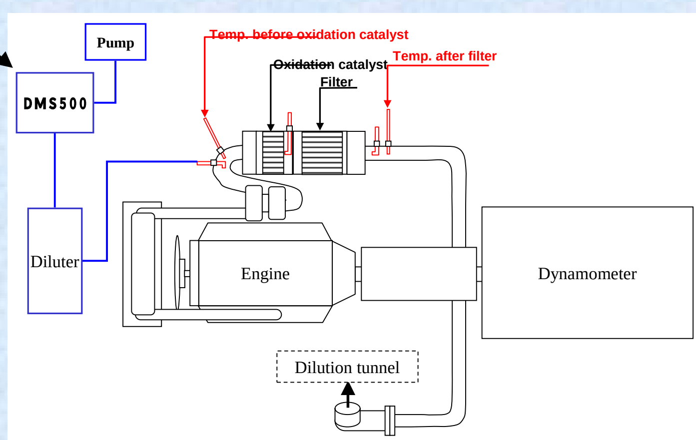
Experimental Apparatus for Oxidation Catalyst in DPF(CRT)

View direction

CRT



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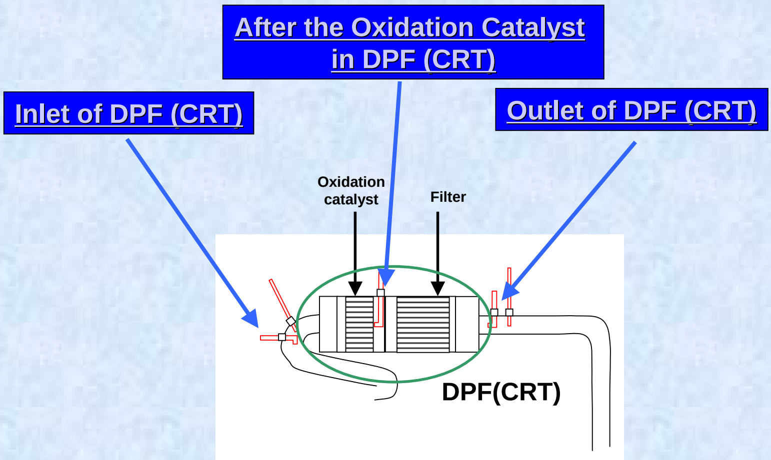
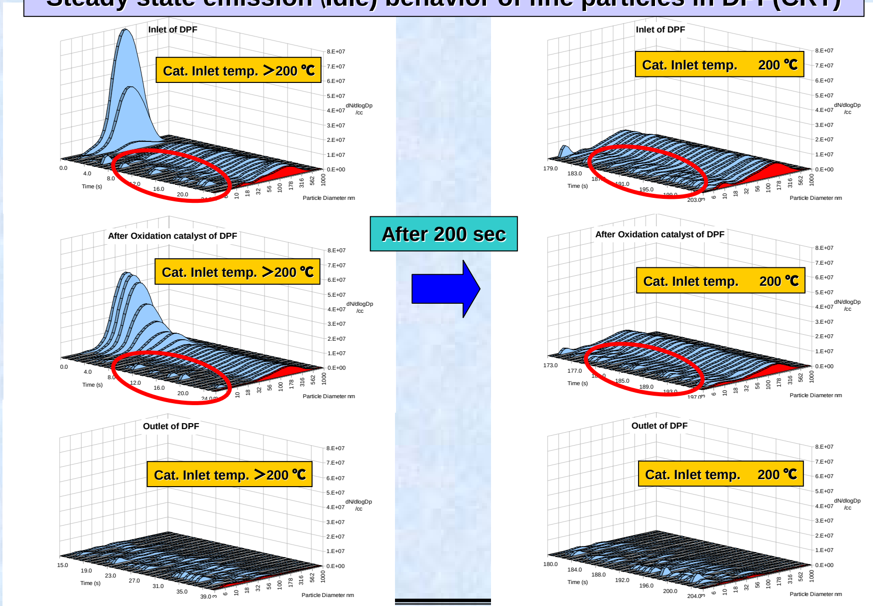
Behavior of fine particles in DPF(CRT) due to exhaust gas temperature change during steady state condition (idling)



Steady state emission (Idle) behavior of fine particles in DPF(CRT)



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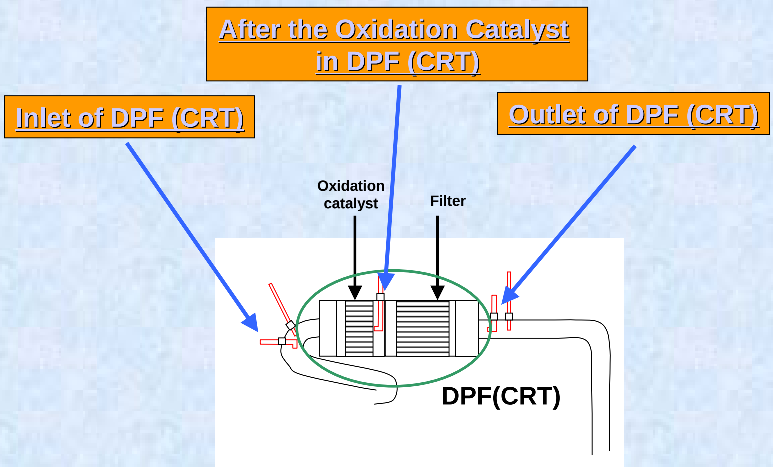
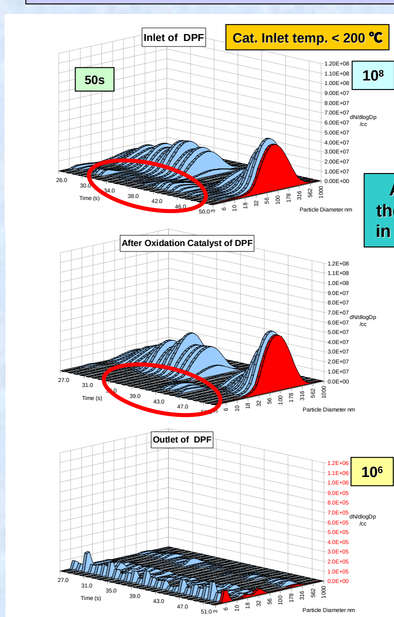
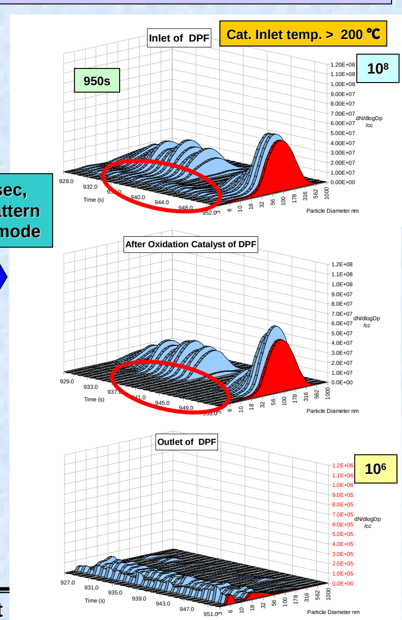
Transient emission behavior of fine particles in DPF(CRT)



Transient emission (FTP) behavior of fine particles in DPF(CRT)



After 900 sec,
the same pattern
in one FTP mode



4. Conclusions

(1)Dilution by Thermodiluter (Disk diluter)

- Good Repeatability
- Conservation of Size Distribution pattern
- Possibility of Particle Loss compensation

(2)Influence of Oxidation Catalyst in CRT on Nano Particles (Number base)

- Reduction of Nuclei Mode Particles by OC (>200℃)
- No Reduction of Nuclei Mode Particles by OC (<200℃)
- 1/100 Reduction of Particle number concentration by DPF