

10th ETH-Conference on Combustion Generated Nanoparticles
at ETH Zentrum, Zurich, Switzerland
August 21-23, 2006

Effect of Biodiesel on PM Emission Characteristics of Modern Diesel Engine

Daisuke Kawano Hajime Ishii Yuichi Goto Akira Noda



National Traffic Safety and Environment Laboratory

Tokyo, JAPAN

- Background
- Test Engine and Fuels
- PM Measurement Instruments
- PM Measurement Results
 - Engine-out
 - Aftertreatment-out
- Conclusions

✓ Background

➤ Test Engine and Fuels

➤ PM Measurement Instruments

➤ PM Measurement Results

- Engine-out
- Aftertreatment-out

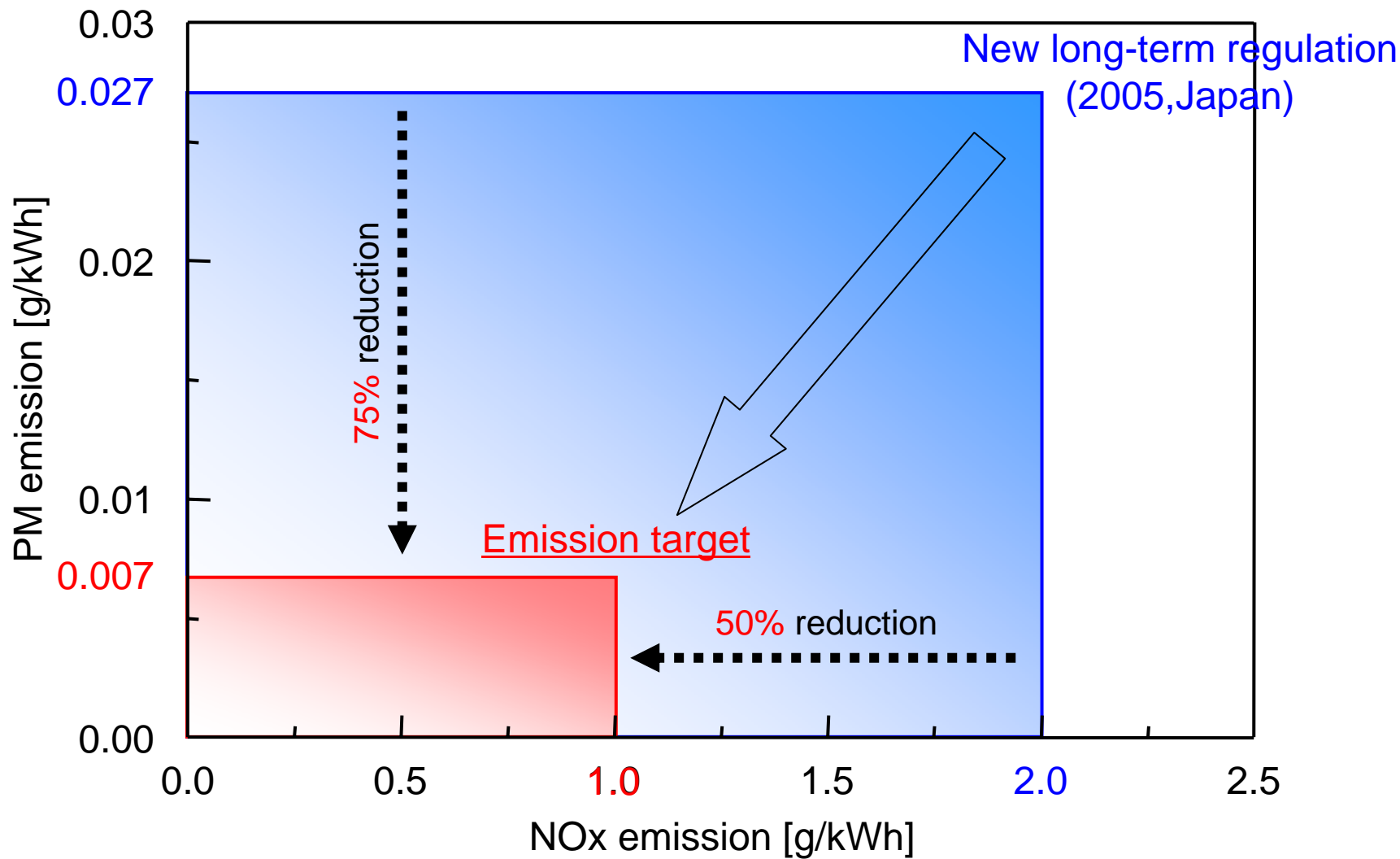
➤ Conclusions

Overview of Biodiesel Project

- Utilization of 100 % biodiesel fuel (neat)
- Modification of engine system for biodiesel
- Clarification of technologies for biodiesel

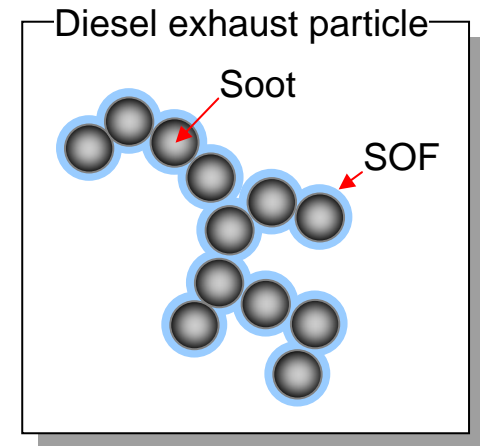


Emission Target



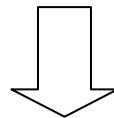
➤ Biodiesel Fuel (BDF)

- Oxygenated fuel \implies Soot emission \searrow
 - Low volatility \implies SOF emission \nearrow
- ➔** Total PM emission ?



➤ Conventional Studies on Biodiesel

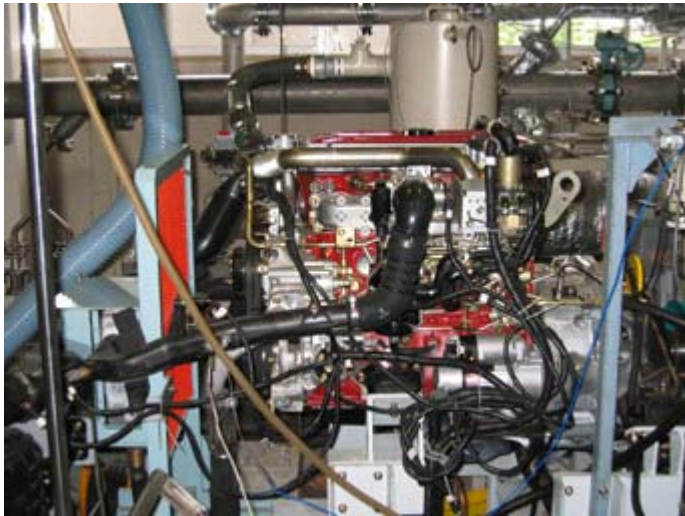
- Application of biodiesel to **old diesel engines**
- **No modification** for biodiesel



PM emission characteristics of **modern diesel engine** fuelled with **biodiesel** ?

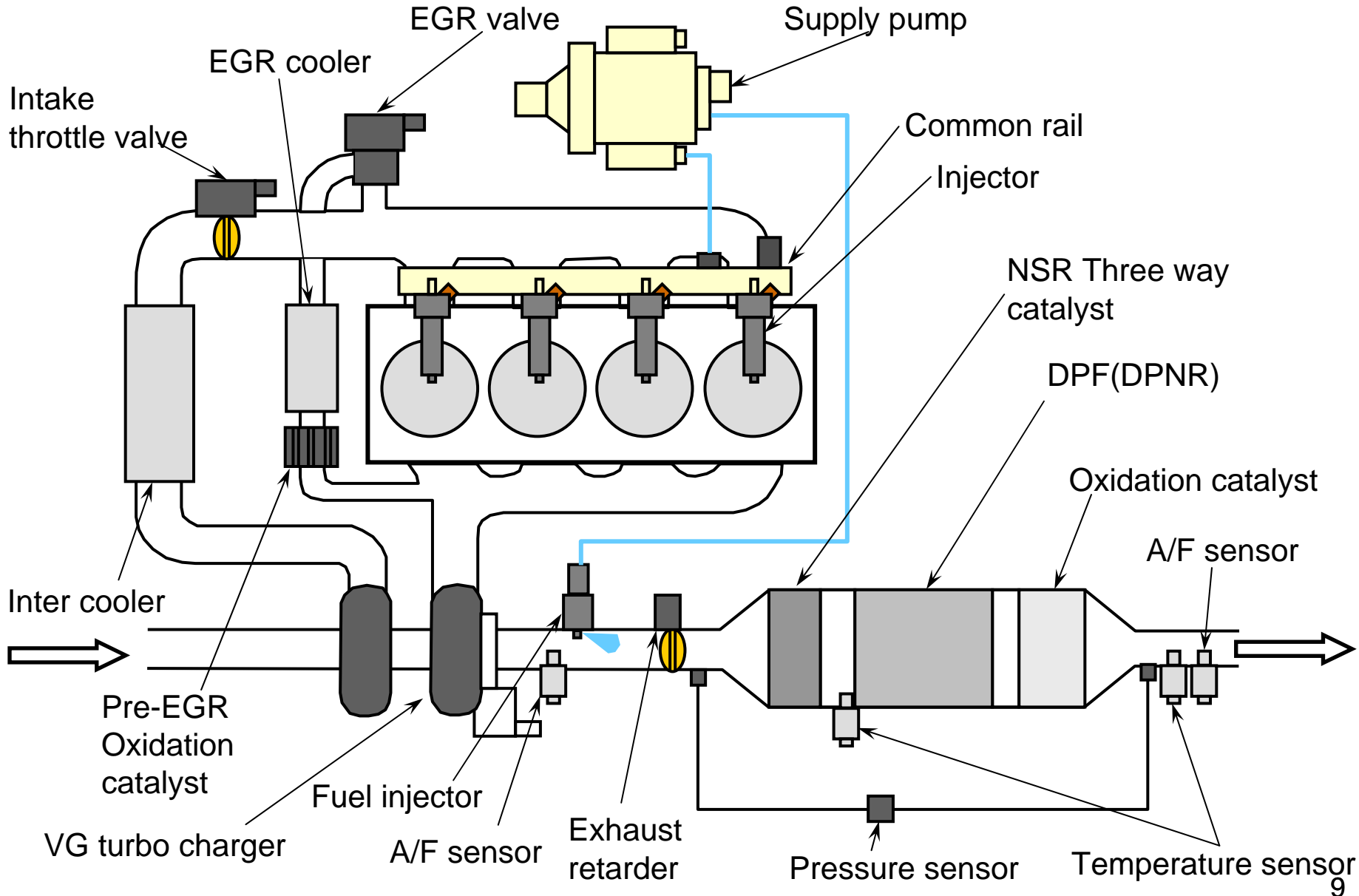
- Background
- ✓ Test Engine and Fuels
- PM Measurement Instruments
- PM Measurement Results
 - Engine-out
 - Aftertreatment-out
- Conclusions

Engine Specifications



Model	Hino N04C-TA
Type	4-cylinder Intercooler-turbo diesel engine
Fuel	Low S (S<10ppm)
Injection system	Common-rail
Devices for low emission	Cooled EGR, VGT DPF + NSR Catalyst
Bore×stroke (mm)	104×118
Displacement (L)	4,009
Compression ratio	18.0
Max. power	110kW (150PS) / 3,000rpm
Max. torque	392N·m (40.0kg·m) / 1,600rpm

Engine System



Fuel Properties



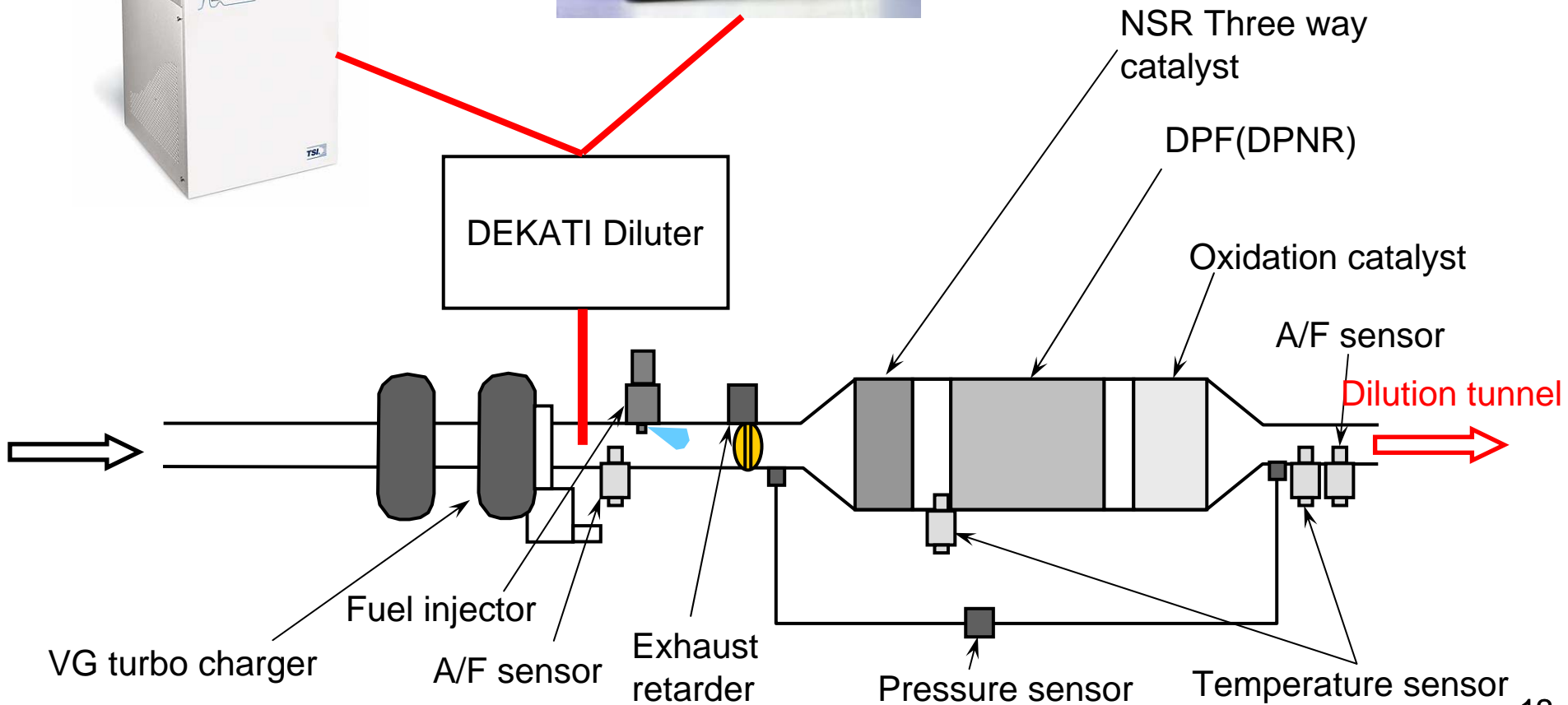
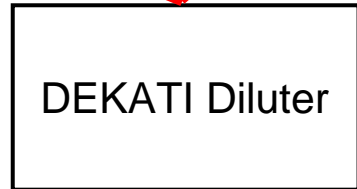
Properties		Diesel fuel	RME
Density (15 °C) [g/cm ³]		0.8217	0.8835
Viscosity [mm ² /s]		3.355 (30 °C)	4.310 (40 °C)
Flash point [°C]		64.0	174.0
Cetane number [-]		58.3	52.8
Distillation point	[°C]	IBP	336.5
		10%	339.5
		50%	341.5
		90%	345.0
		EP	408.0
CHO	[wt.%]	C	77.0
		H	12.0
		O	10.2
Heating value [kJ/kg]		43,092	36,980
Pour point [°C]		-27.5	-10.0
Cloud point [°C]		-5.0	-5.0
CFPP [°C]		-9.0	-5.0
Sulfur content [ppm]		3.0	2.0

- Background
- Test Engine and Fuels
- ✓ **PM Measurement Instruments**
- PM Measurement Results
 - Engine-out
 - Aftertreatment-out
- Conclusions

PM Measurement Instruments

AVL 483 Micro Soot Sensor

TSI EEPS Model 3090

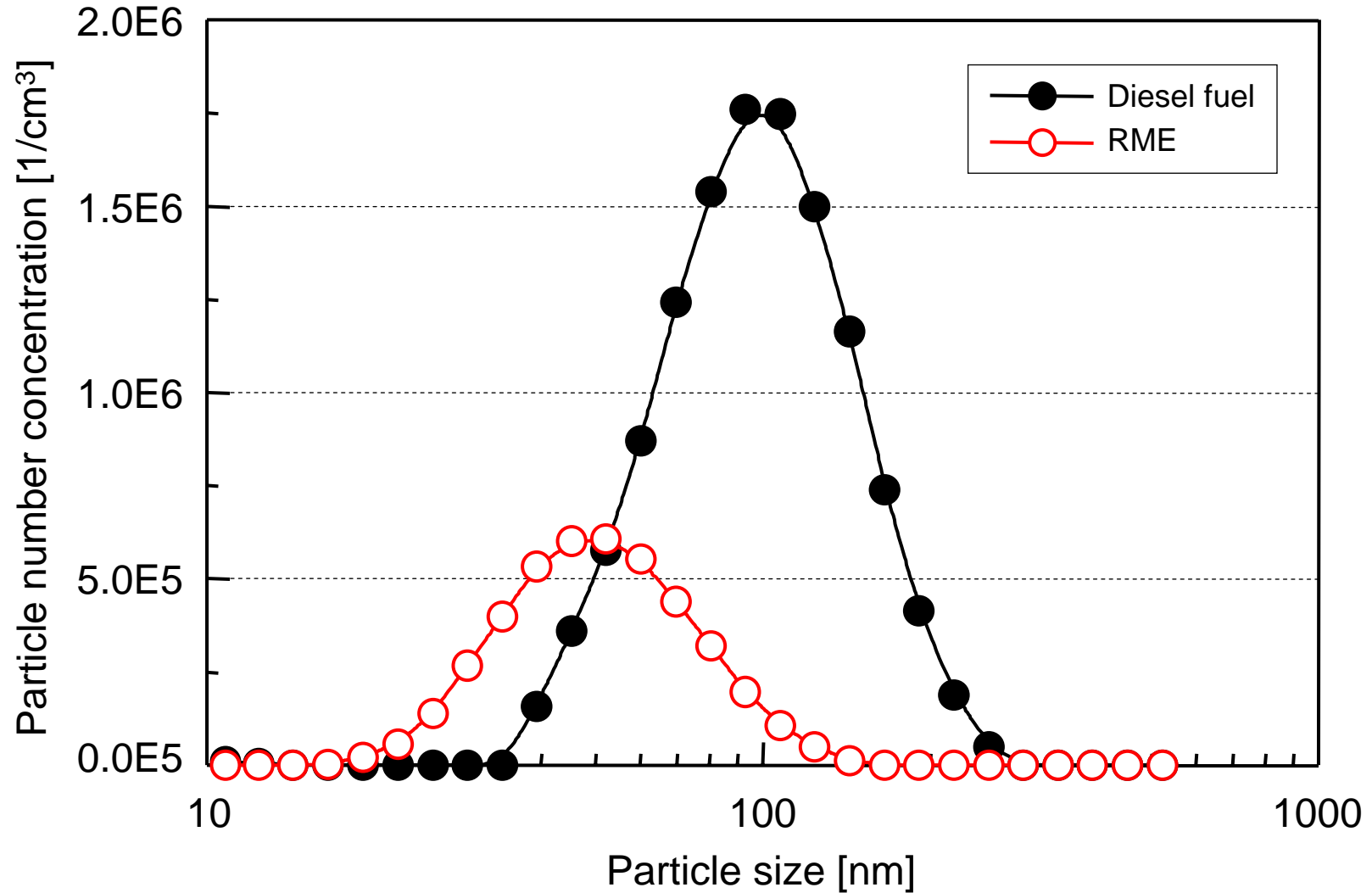


- Background
- Test Engine and Fuels
- PM Measurement Instruments
- ✓ PM Measurement Results
 - ✓ Engine-out
 - Aftertreatment-out
- Conclusions

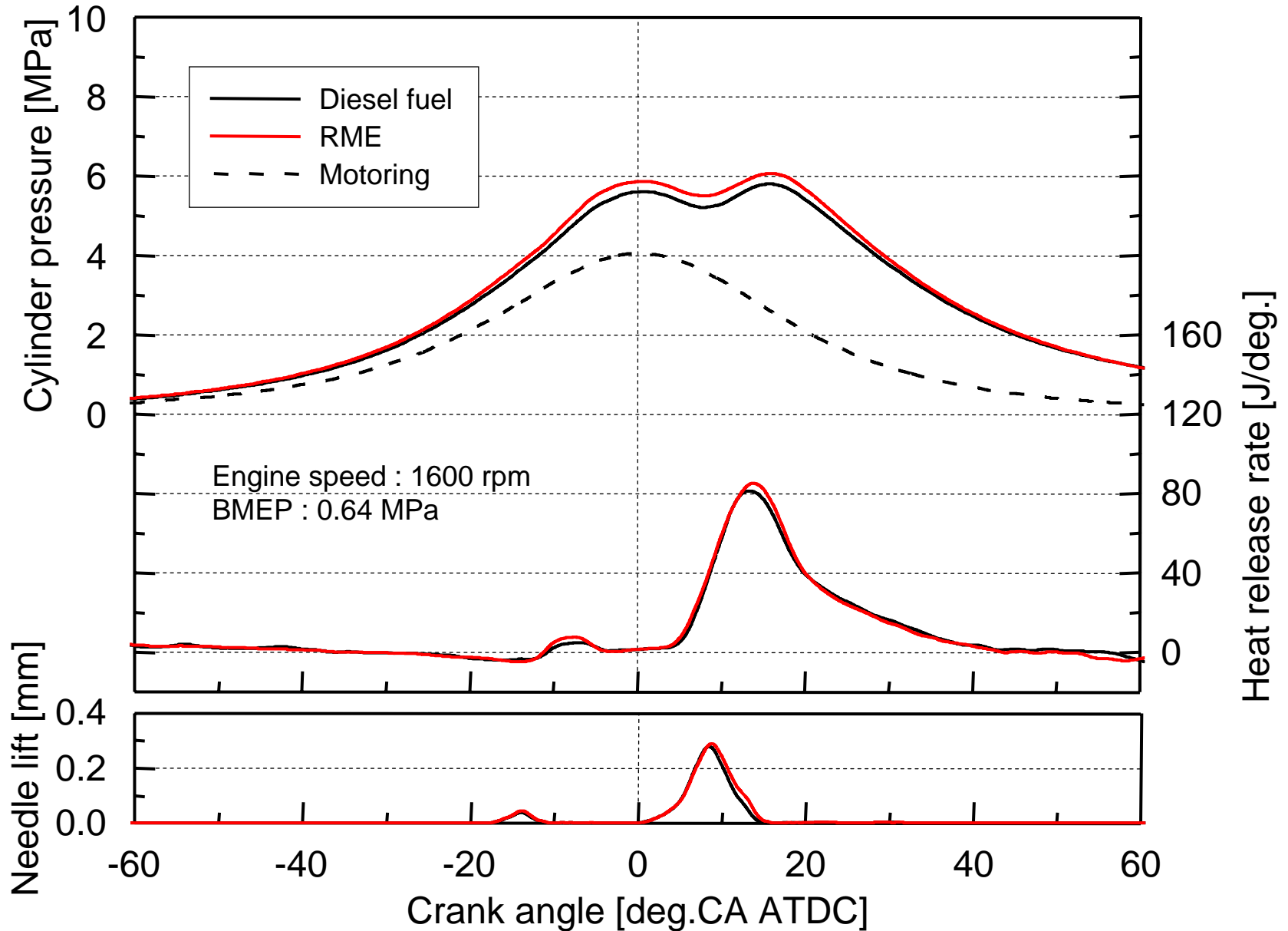
Particle Size Distribution (medium load)



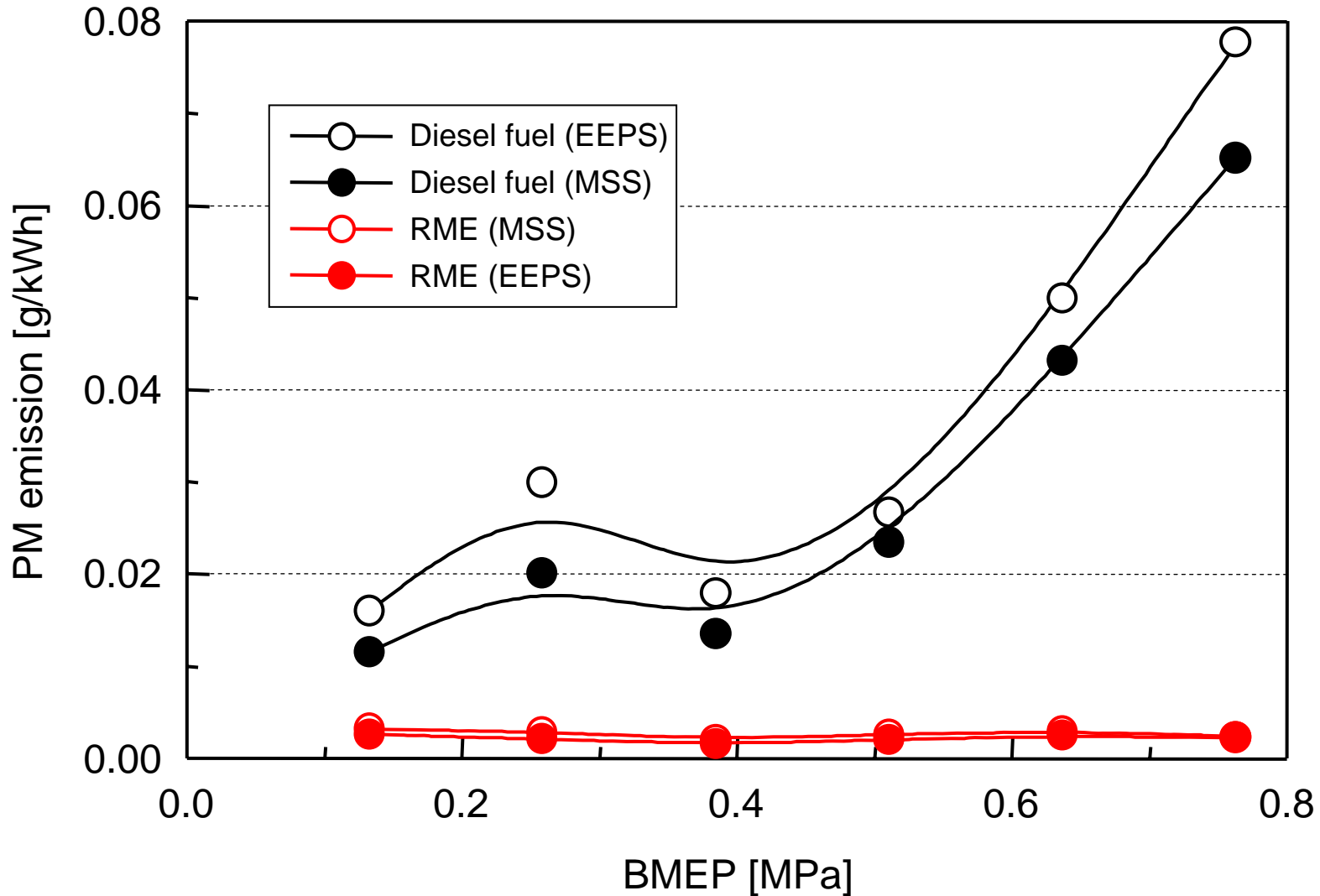
Engine speed : 1600 rpm
BMEP : 0.64 MPa



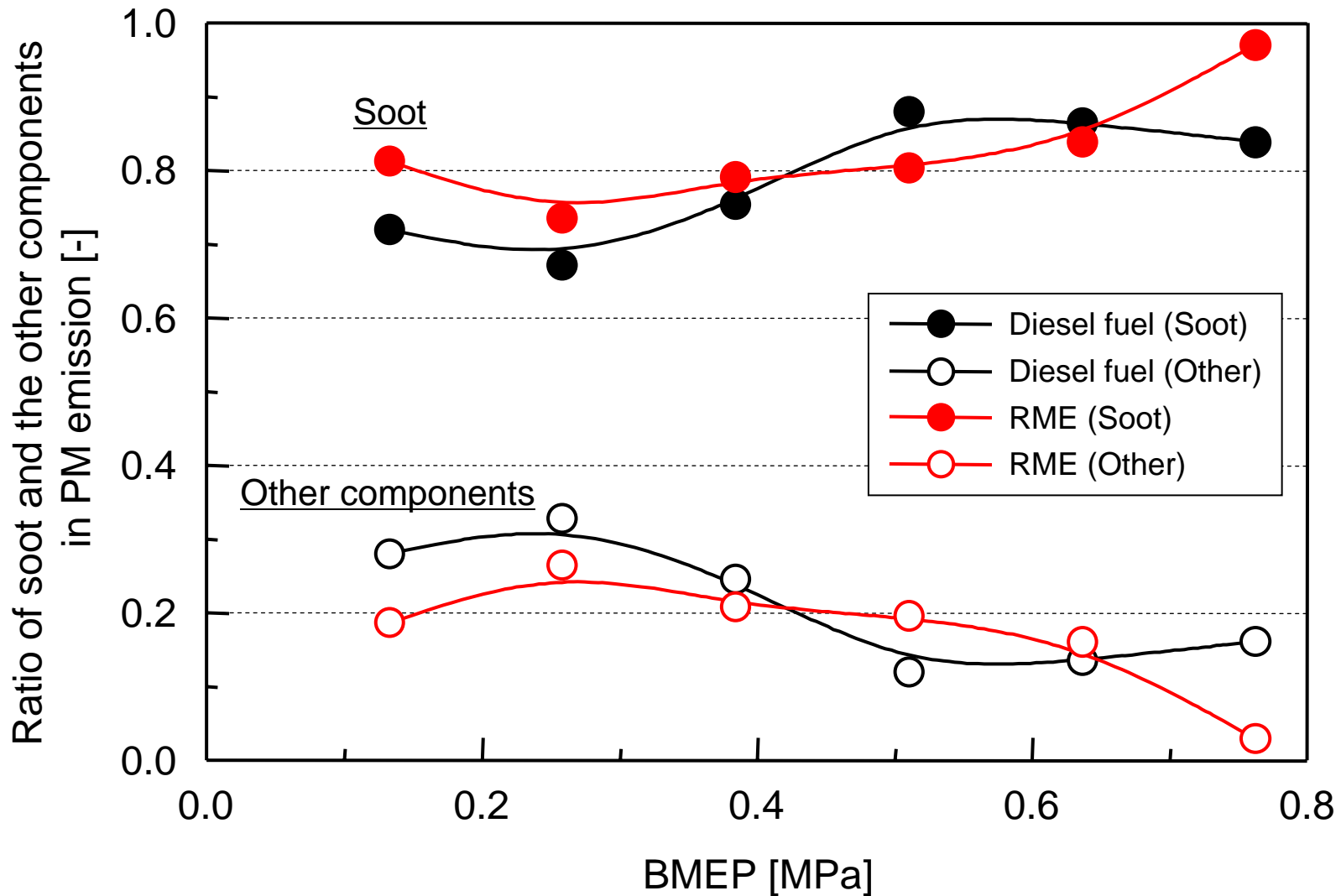
Combustion Characteristics (medium load)



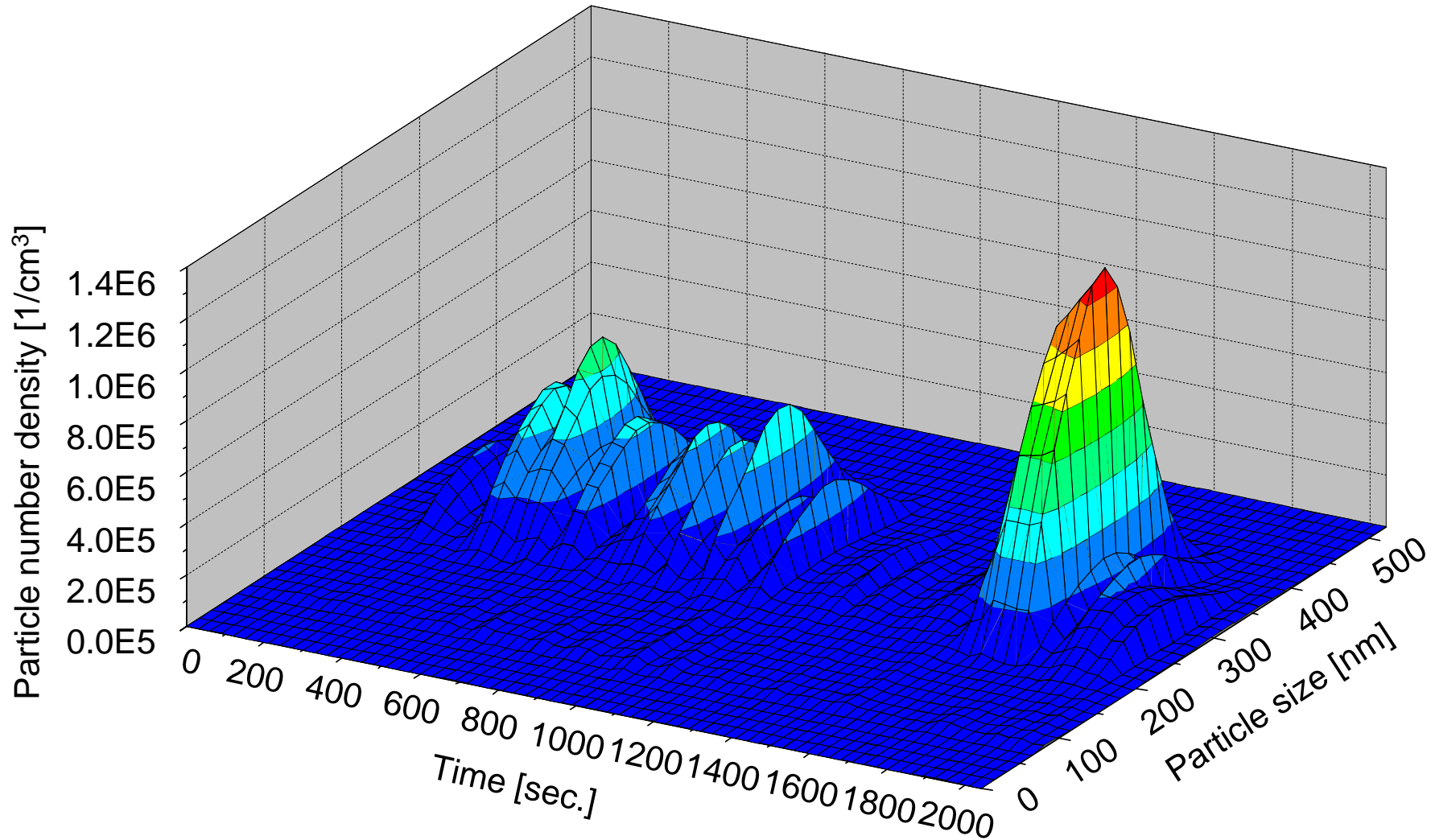
Engine-out PM Emission



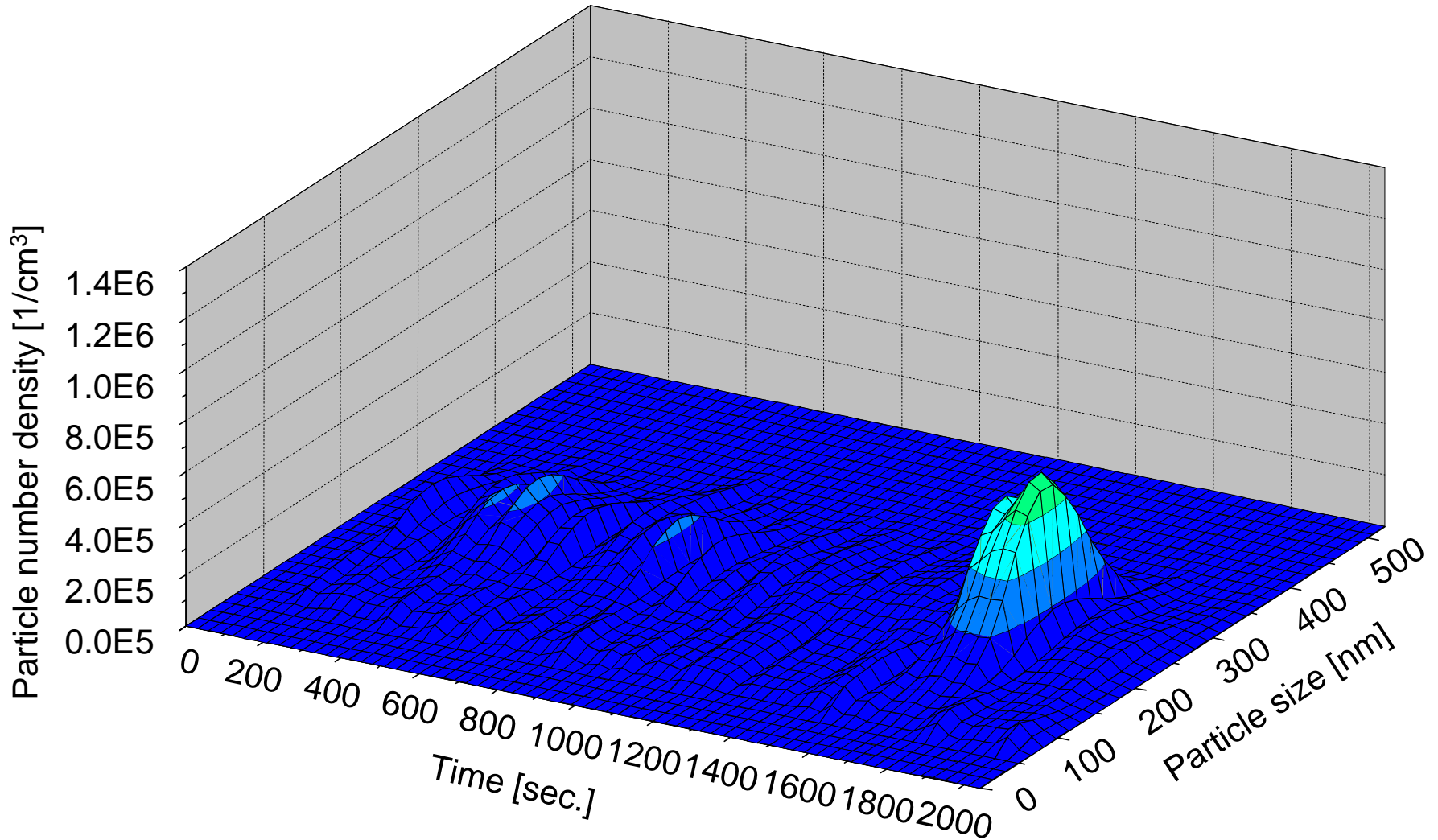
Soot Ratio in PM Emission



PM Emission in JE05 Mode (Diesel Fuel)



PM Emission in JE05 Mode (RME)

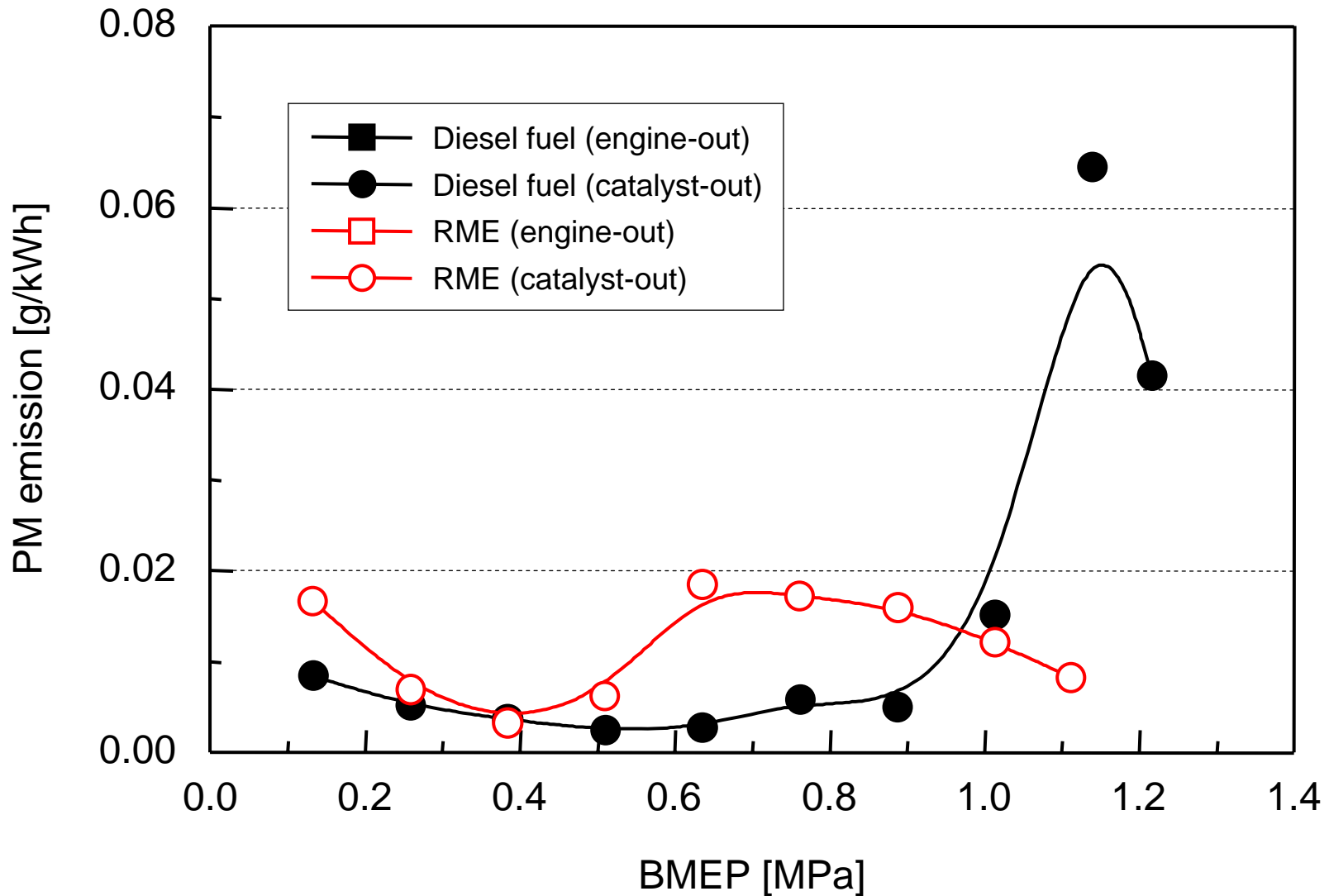


- Background
- Test Engine and Fuels
- PM Measurement Instruments
- ✓ PM Measurement Results
 - Engine-out
 - ✓ Aftertreatment-out
- Conclusions

Aftertreatment-out PM Emission

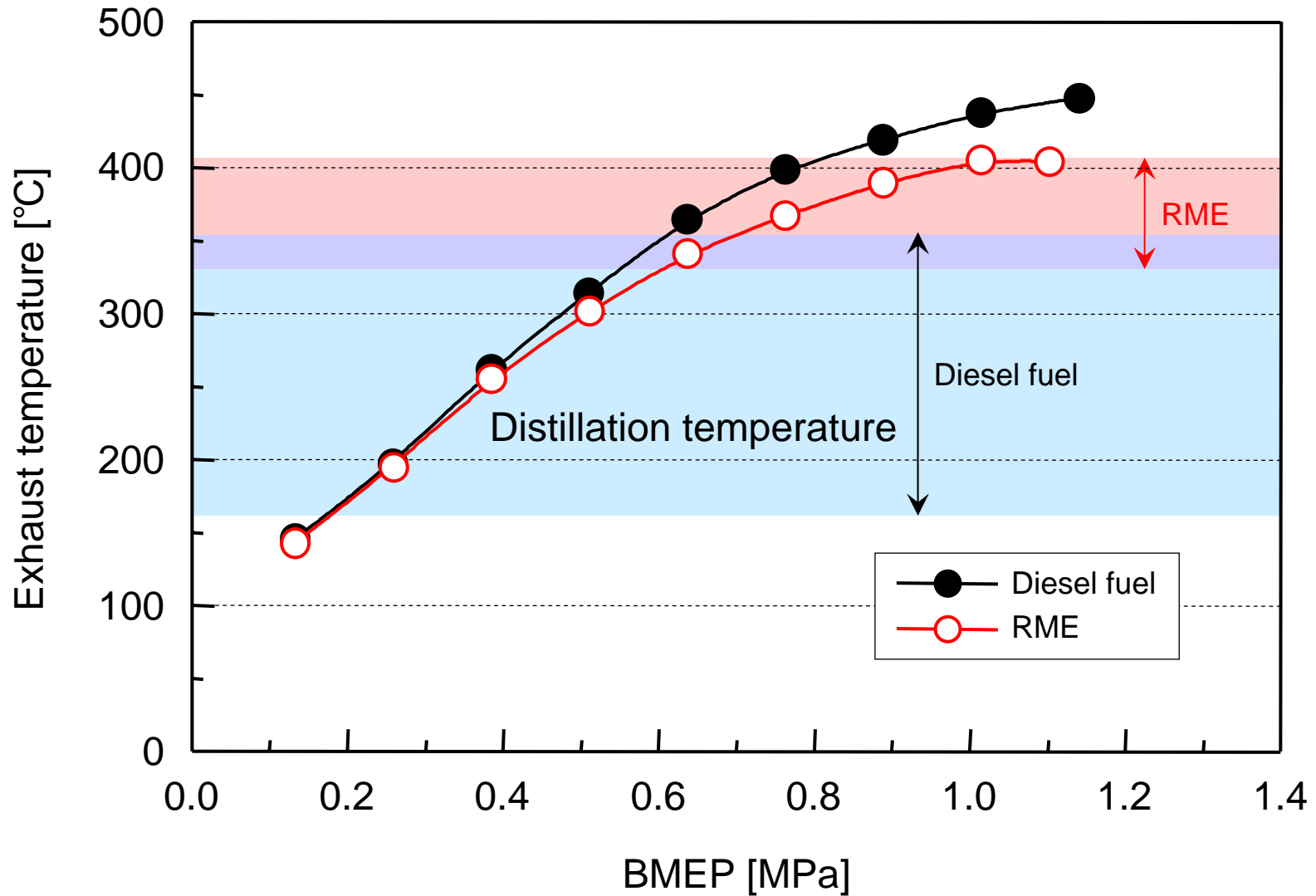


Engine speed : 1600 rpm



Exhaust Temperature

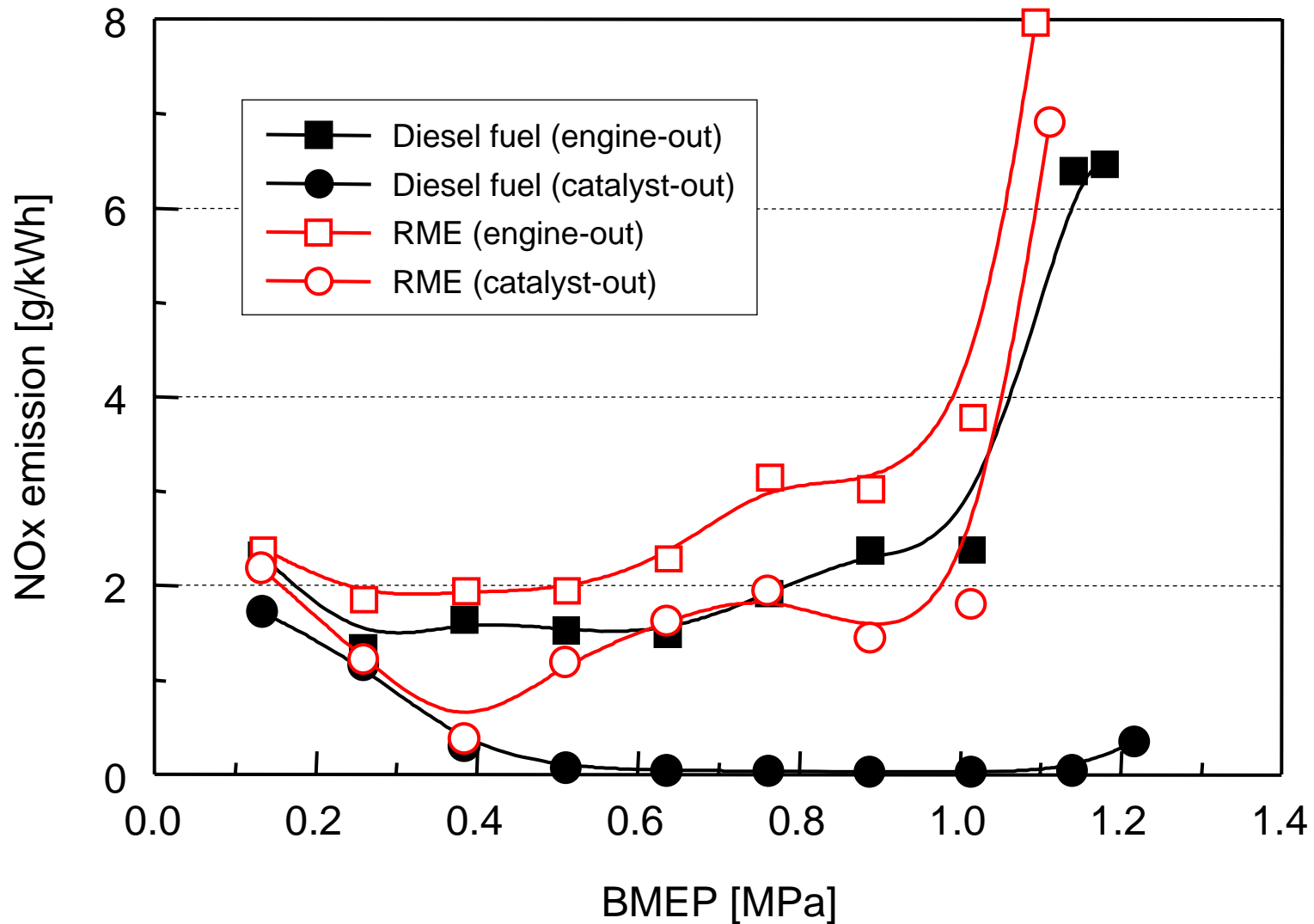
Engine speed : 1600 rpm



NOx Emission



Engine speed : 1600 rpm



- Background
- Test Engine and Fuels
- PM Measurement Instruments
- PM Measurement Results
 - Engine-out
 - Aftertreatment-out
- ✓ Conclusions

➤ Engine-out PM emission

- Biodiesel causes smaller primary soot particle size and lower particle number density due to the effect of oxygenated fuel.
- If biodiesel is applied to modern diesel engine, low volatility of biodiesel does not increase SOF emission due to the fine combustion tuning.

➤ Aftertreatment-out PM emission

- Aftertreatment-out PM emission is higher than that of diesel fuel due to SOF emission derived from biodiesel injected as a rich spike.

Thank you for your kind attention !



National Traffic Safety and Environment Laboratory

Tokyo, JAPAN

<http://www.ntsels.go.jp/>

Engine Exhaust Particle Sizer (EEPS)



TSI Model 3090

- Fast size distributions for submicron aerosol
 - 10 Hz time resolution
- High size resolution
 - 16 size channels per decade (32 channels total)
 - From 5.6 to 560 nm

Micro Soot Sensor (MSS)



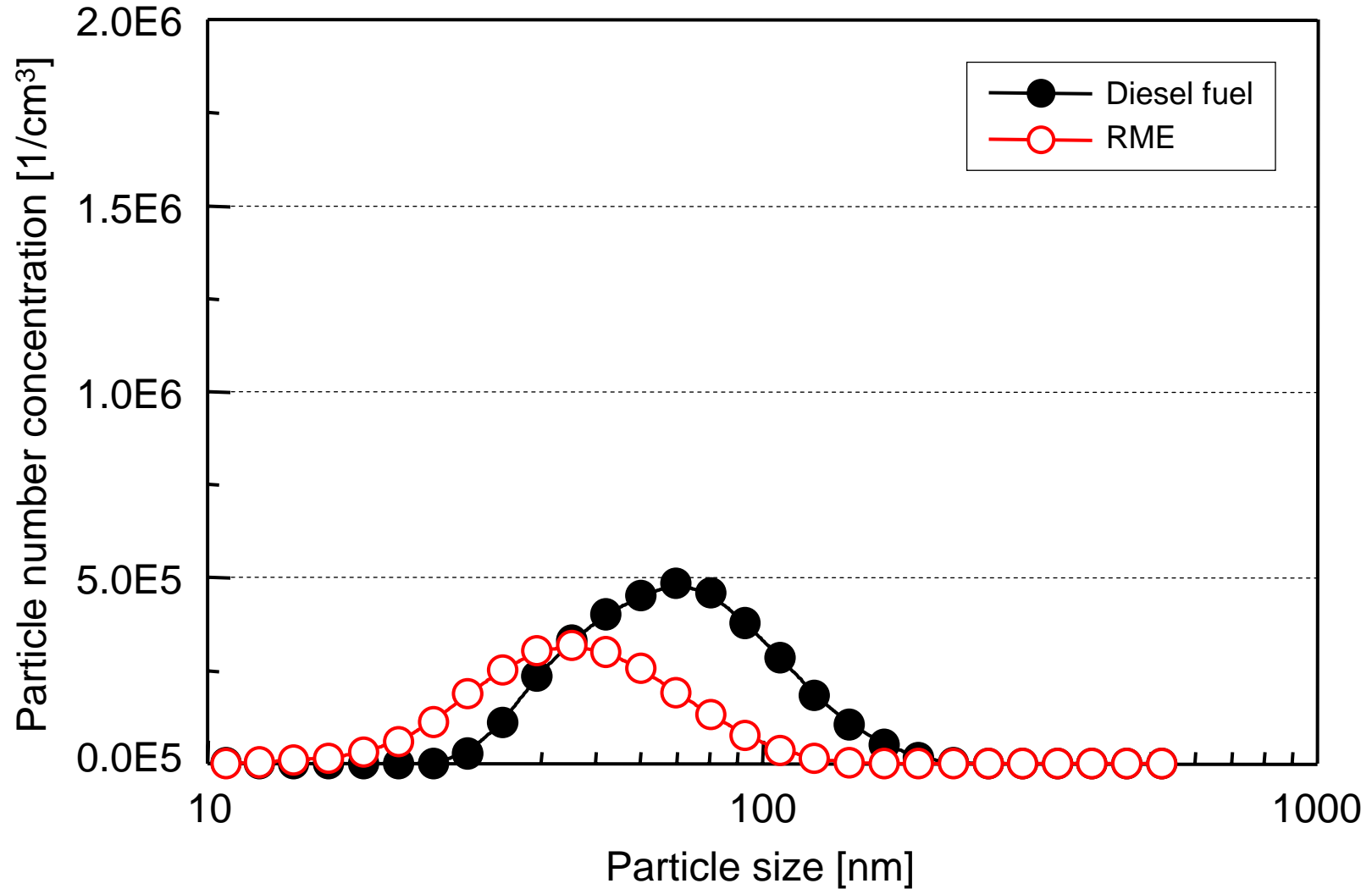
AVL 483 Micro Soot Sensor

- Transient measurement of soot concentration [mg/m^3]
 - 10 Hz time resolution
- Sensitive to soot
 - No interference to other components
- High measuring range
 - From 0 to $50 \text{ mg}/\text{m}^3$

Particle Size Distribution (low load)



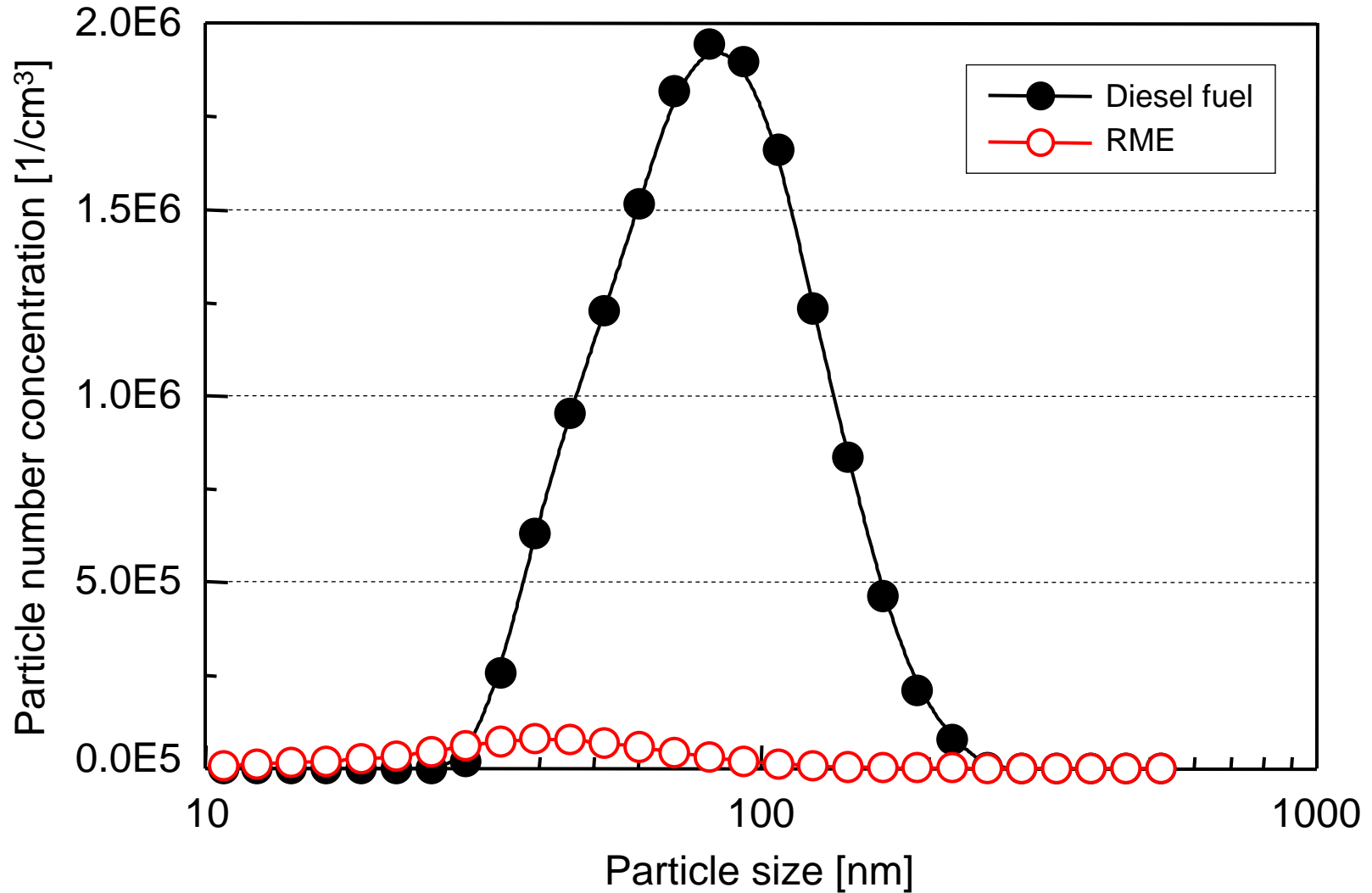
Engine speed : 1600 rpm
BMEP : 0.13 MPa



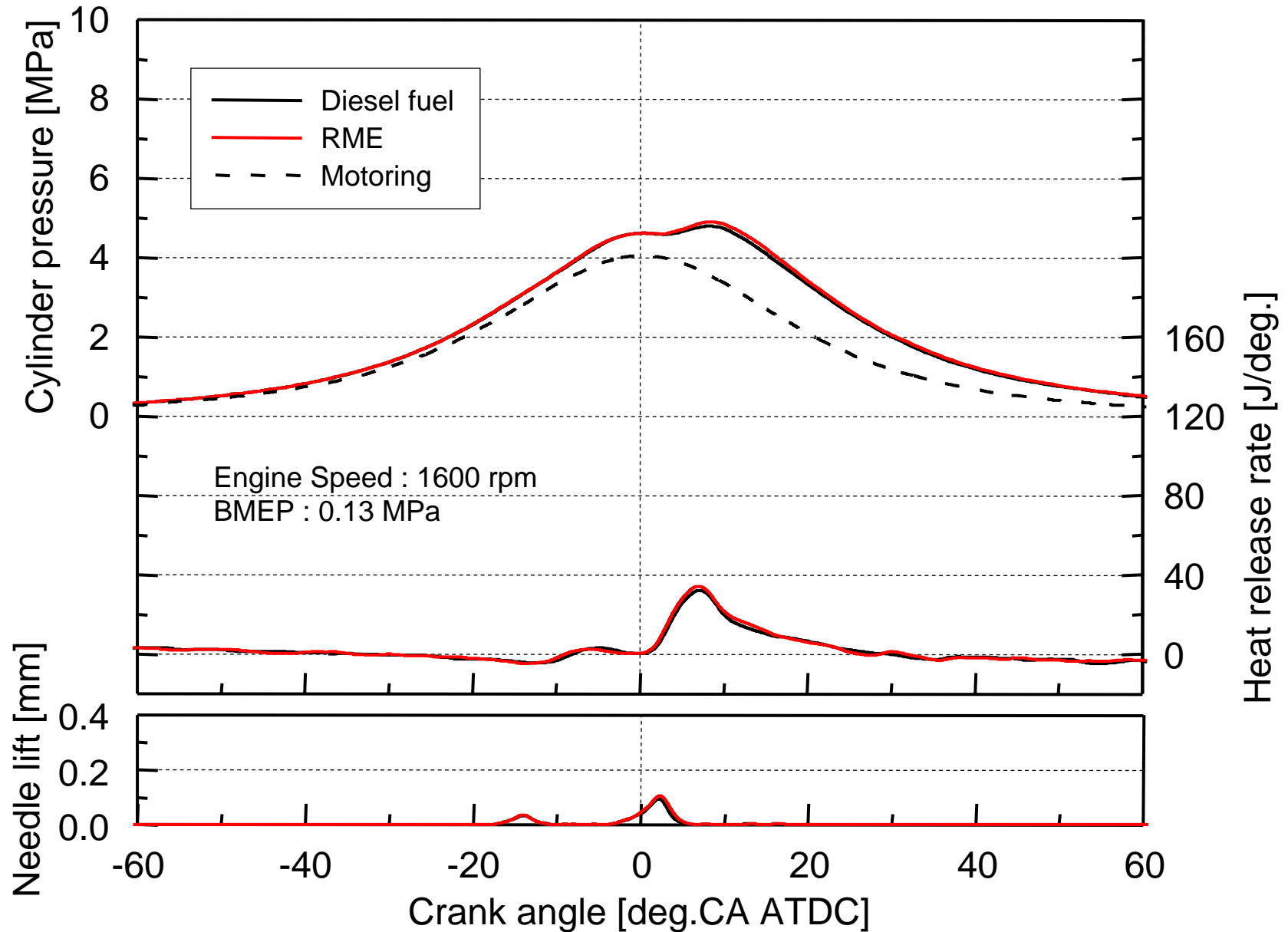
Particle Size Distribution (high load)



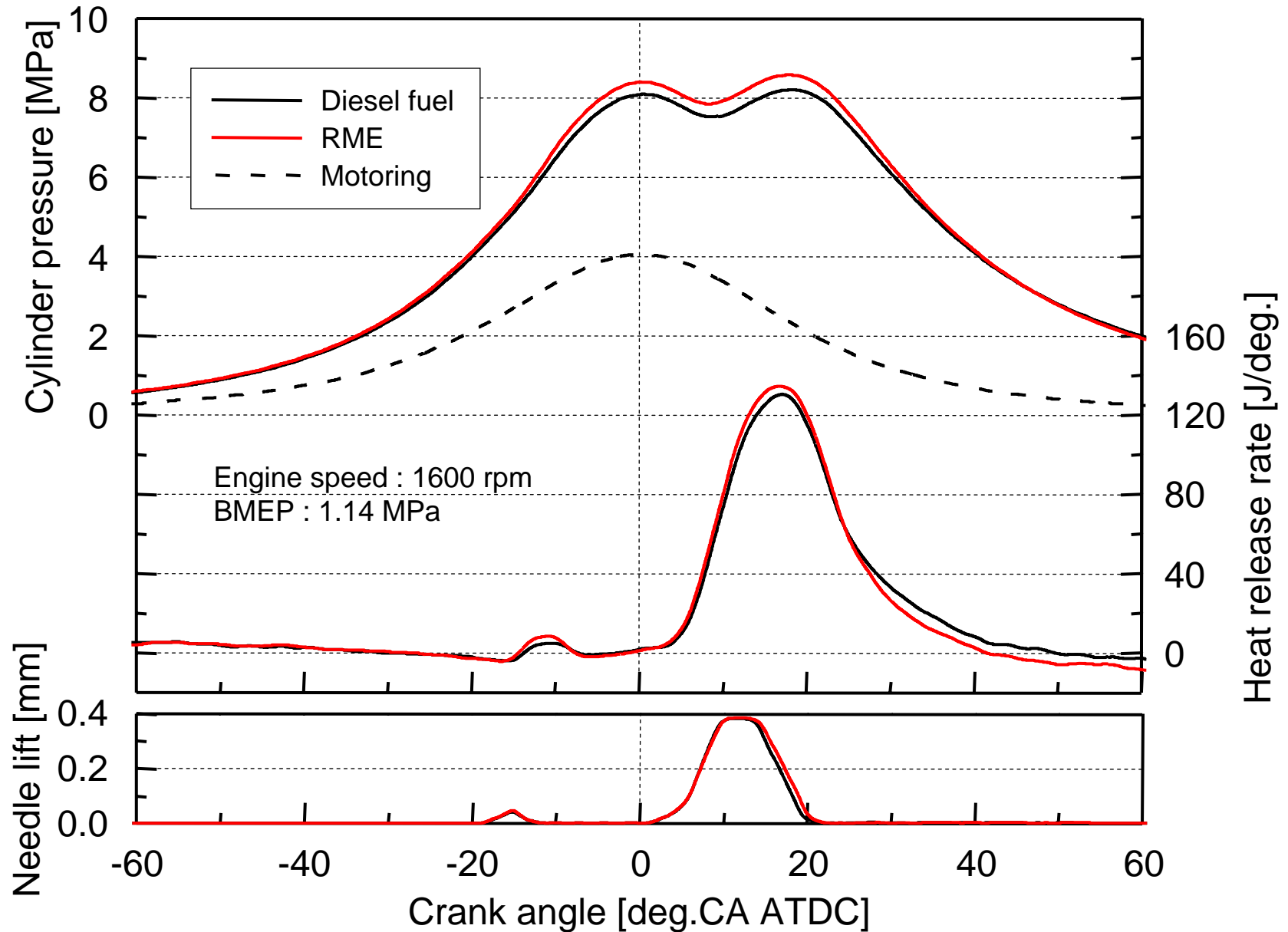
Engine speed : 1600 rpm
BMEP : 1.14 MPa



Combustion Characteristics (low load)

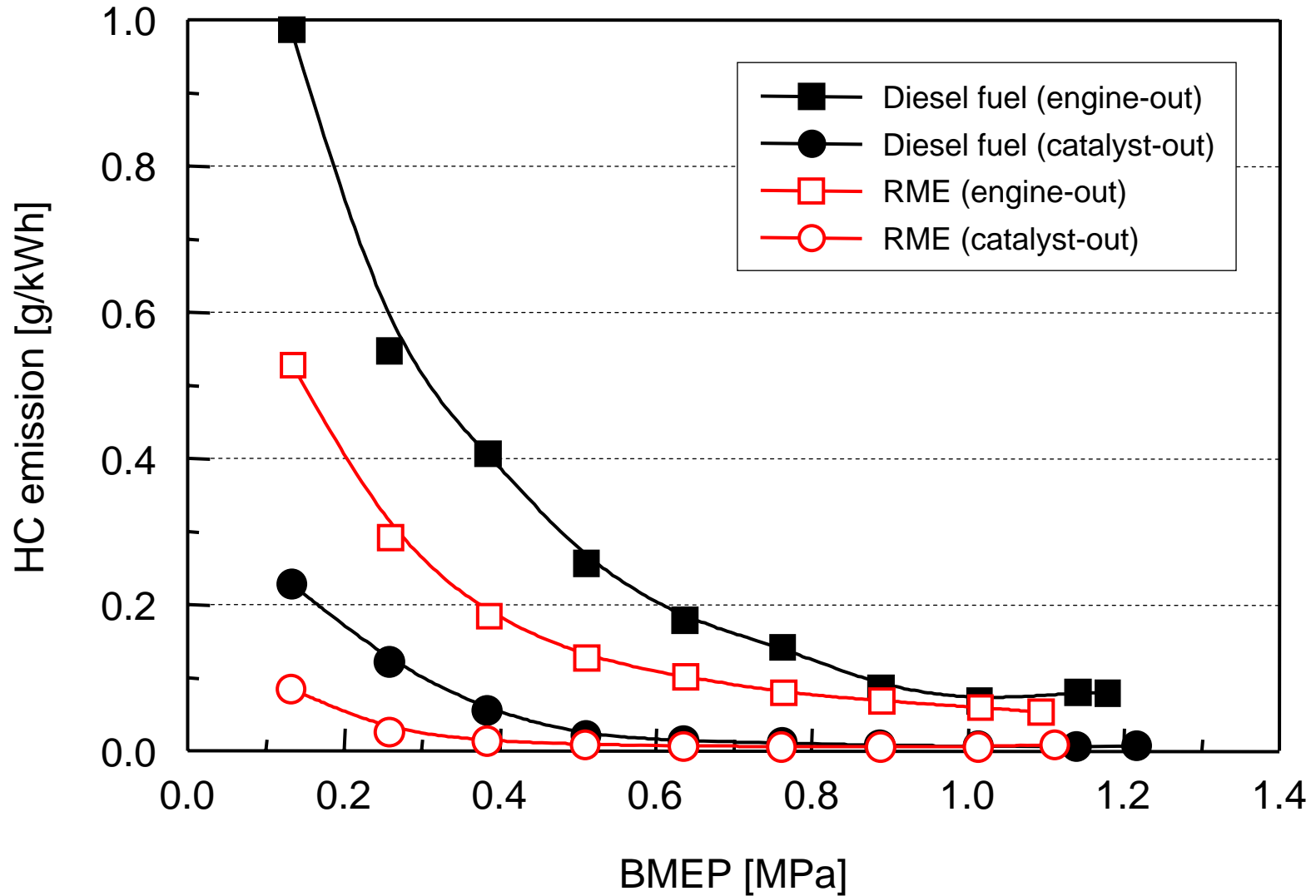


Combustion Characteristics (high load)



HC Emission

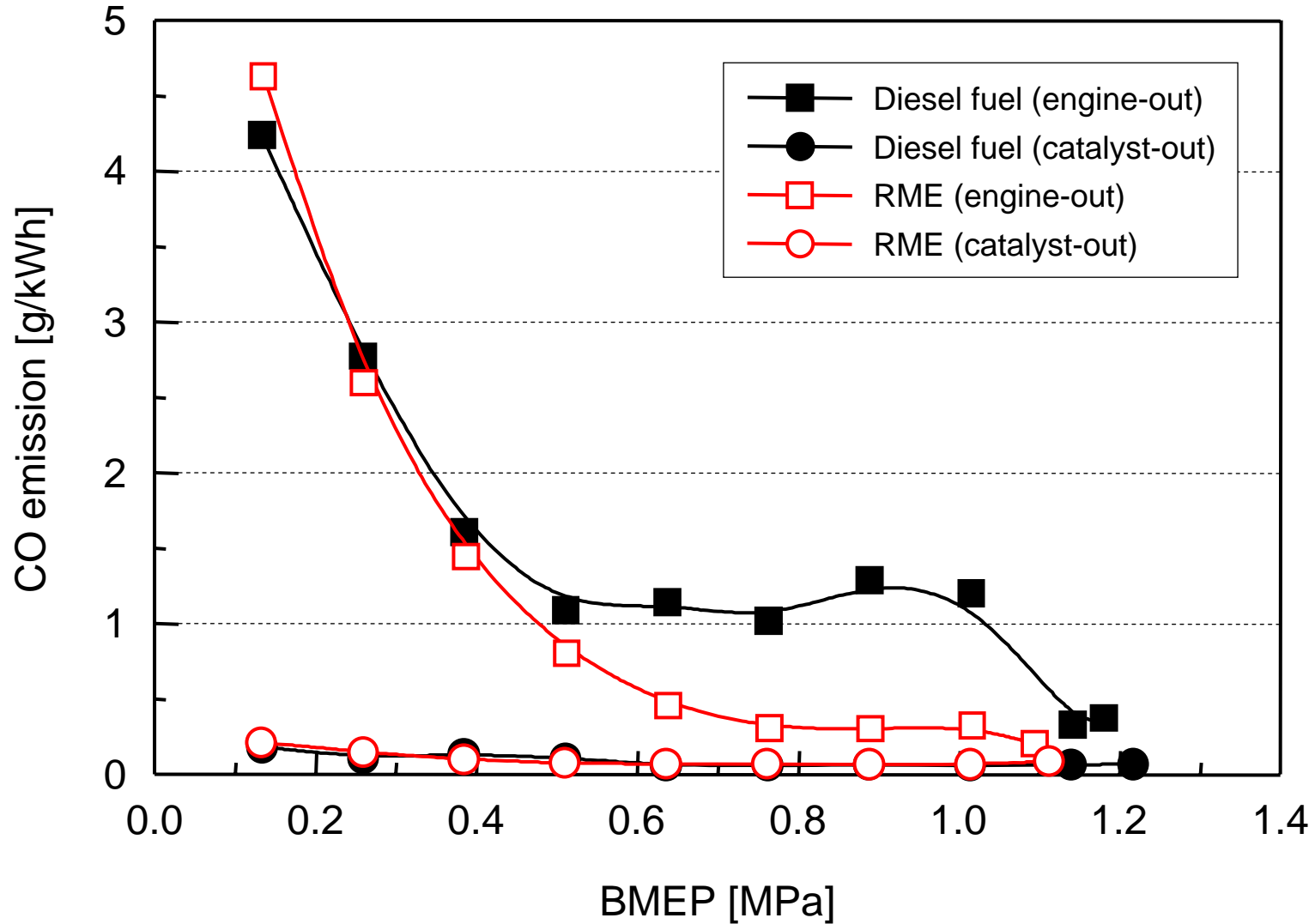
Engine speed : 1600 rpm



CO Emission

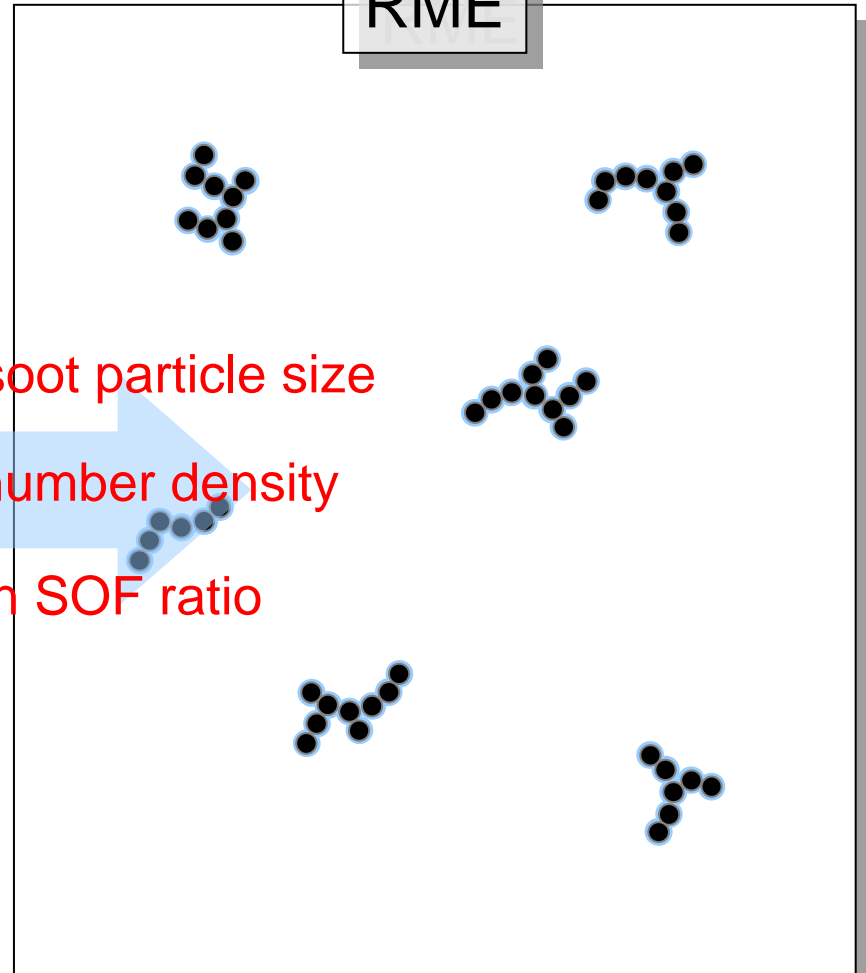
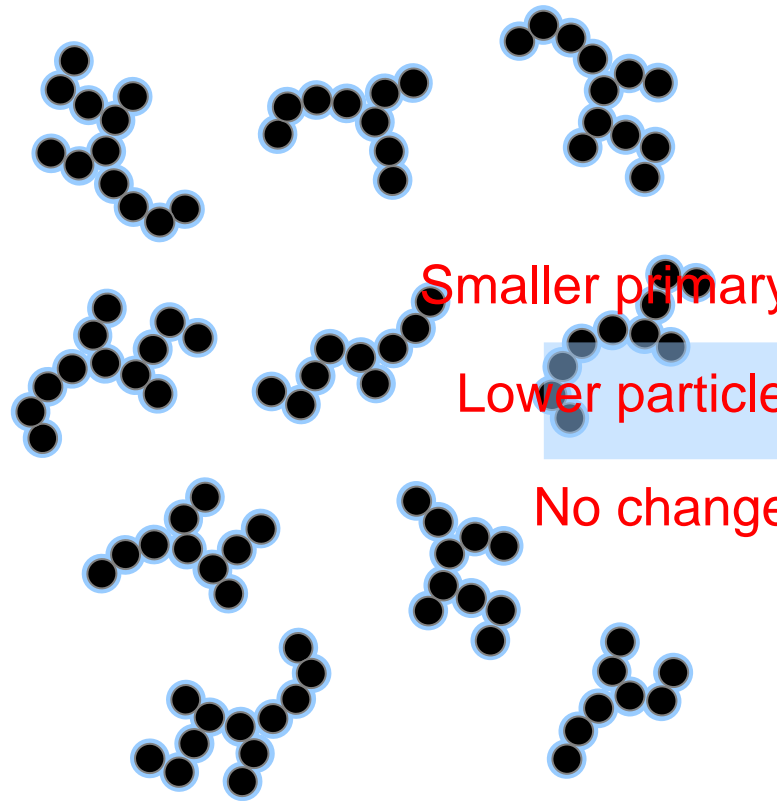


Engine speed : 1600 rpm



Diesel Fuel

RME



Smaller primary soot particle size

Lower particle number density

No change in SOF ratio