UNIVERSITY OF BIRMINGHAM

Investigation on PM Emissions of a Light Duty Diesel Engine with 10% RME and GTL Blends

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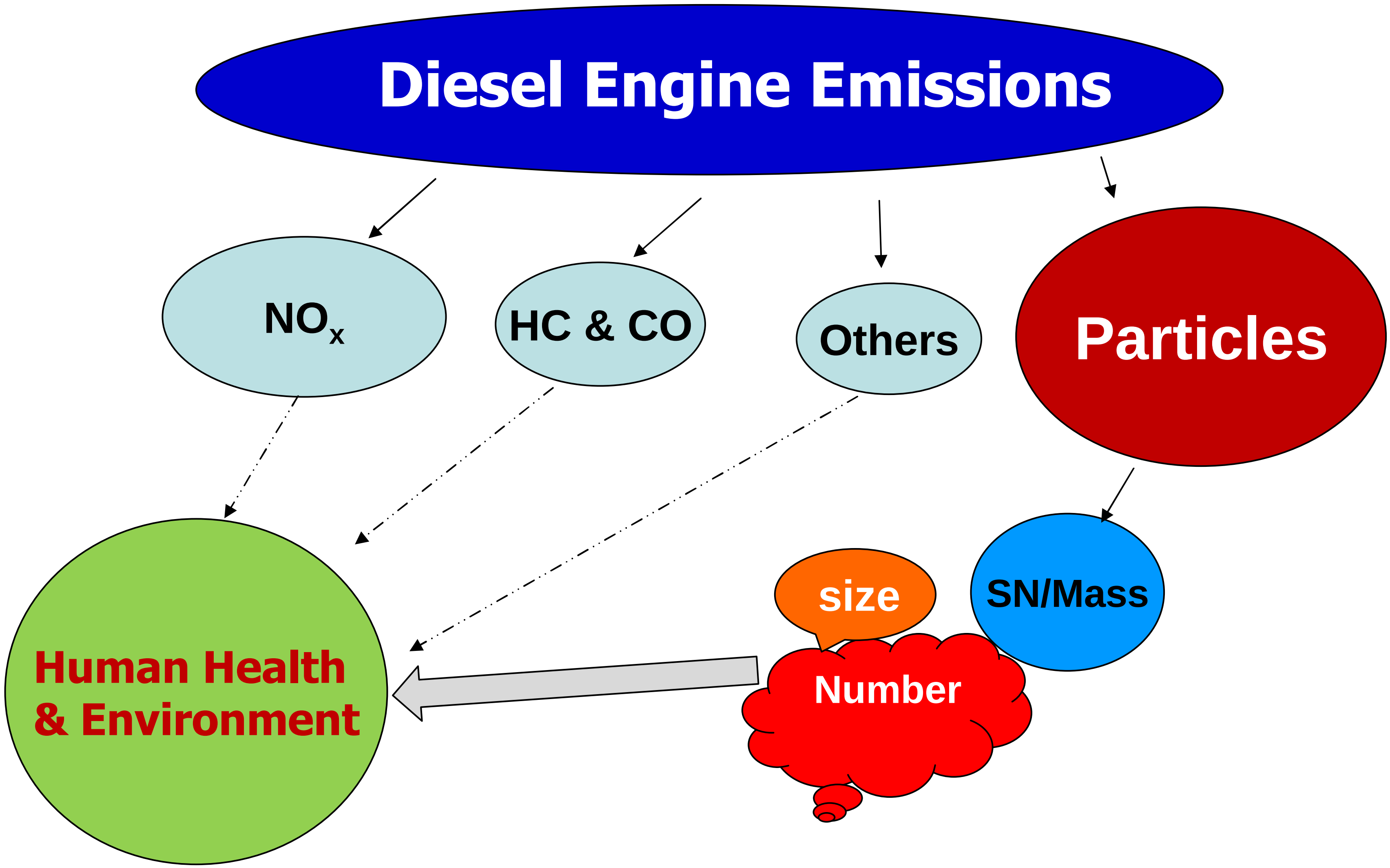
Presentation Outline

1. Introduction
2. Experimental System
3. Results and Discussion
    - Effect of 10% RME and GTL blends
    - Effect of Injection strategy
4. Conclusions

1. Introduction

Background



Diesel Engine Emissions
NO$_x$
HC & CO
Others
Particles
SN/Mass
size
Number
Human Health
& Environment

Development of legislations g/km *#/km

Tier	Date	CO	NO_x	$HC+NO_x$	PM	PN*
Euro 4	Jan 2005	0.50	0.25	0.30	0.025	-
Euro 5	Sept 2009	0.50	0.18	0.23	0.005	6.0×10^{11}
Euro 6	Jan 2014	0.50	0.08	0.17	0.0045	6.0×10^{11}

Regulations (EC) No 715/2007 of the European Parliament and the Council, "Emissions-Light Duty Vehicles", Jul, 2009.

- Compared with Euro 4, Euro 5 confines the emissions further for carbon monoxide (CO), hydrocarbons (HC), oxides of nitrogen (NOx) and Particulates Matter (PM) and the latter two had a 28% and 80% reduction respectively.
- Particle number

Objective of the present study

Emission Reduction

B

NOx control

Injection Strategy

A

Alternative Fuels
(Biodiesel, GTL Diesel, and etc)

Pilot Injection

2020 target

10% Fuel Blends with Diesel

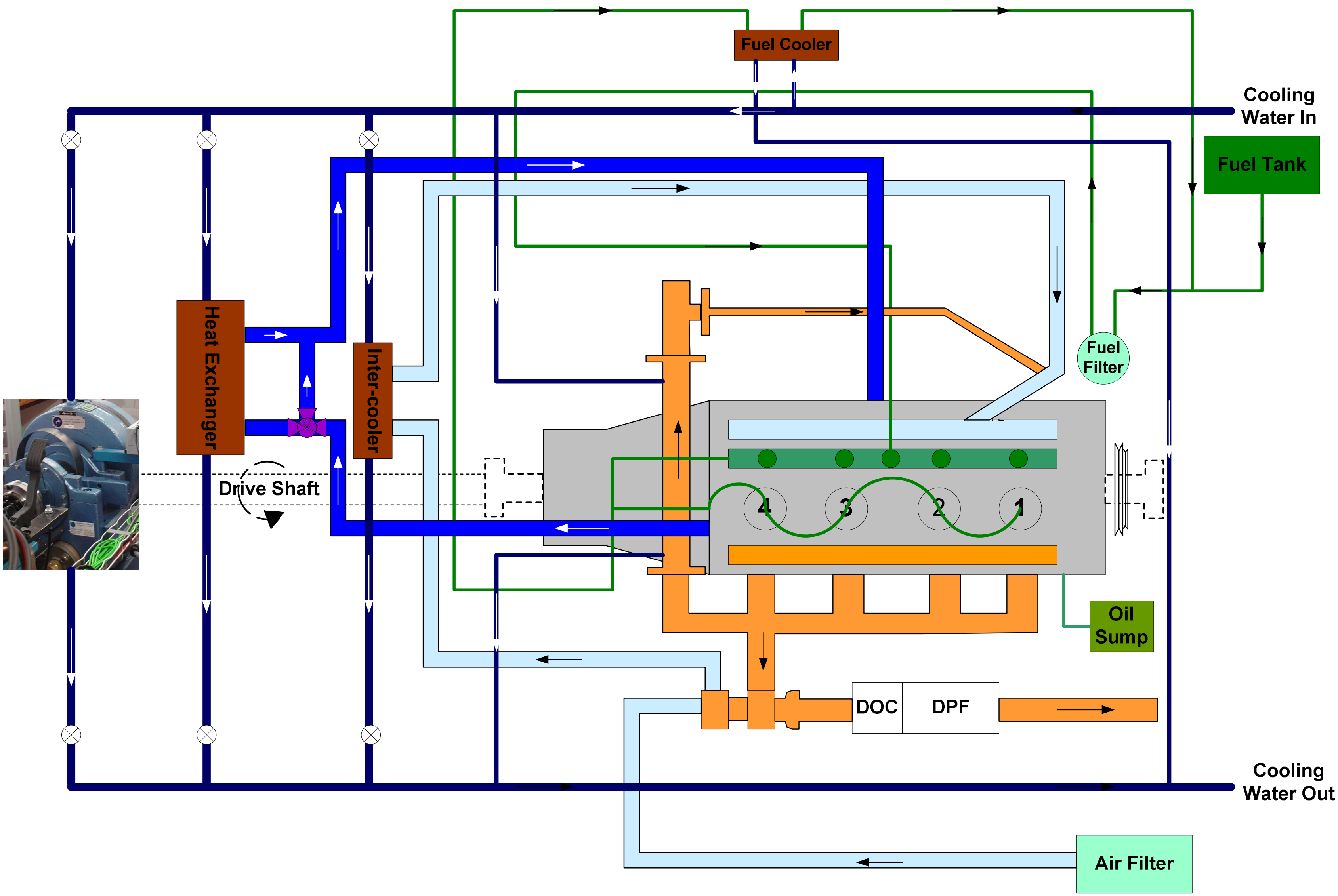
Particle characteristics

2. Experimental System

Test cell and the Ford Puma engine

Bore	86mm, 4 cylinders
Stroke	94.6mm
Compression Ratio	16.6
Engine Capacity	2198cc
Max Power	96KW (±5%)@3500rpm
Max Torque	310.0NM(±5%)@1600-2500rpm
Injector type	Common Rail, Direct Injection

Engine test rig layout



Exhaust Measurement

Horiba MEXA 7100 DEGR

TSI SMPS 3936

AVL Smoke meter 415SG002

Fuel properties

PROPERTY	UNIT	Diesel	RME	GTL Diesel
Ester content	% (m/m)	/	99.44	/
Density @ 15°C	kg/m^3	834.9	883.3	781
Viscosity @ 40°C	mm2/s	2.87	4.441	3.1
Flash point	°C	68.5	171.5	91
Sulphur content	mg/kg	8.6	<3.0	<3.0
Carbon residue	% (m/m)	0.13	<0.1	<0.3
Cetane number		51.1	51	77
Total contamination (particulate)	mg/kg	6.0	1.6	1.6
Lubricity	μm	402	/	612
Distillation (Initial Boiling Point)	°C	181.3	/	204
Aromatics	%,m	/	/	<0.1

Engine Test Modes (A)

Mode	Engine Speed (rpm)	Torque (Nm)	Load (%)	EGR Valve Opening (%)
1	800	2.1	0.68	0
2	1800	30	9.68	**30.91**
3	1800	30	9.68	15.45
4	1800	30	9.68	0
5	1800	134	**43.23**	0
6	3100	35	11.29	**18.18**
7	3100	138	44.52	0
8	3100	230	**74.19**	0

Engine Test Modes (B)

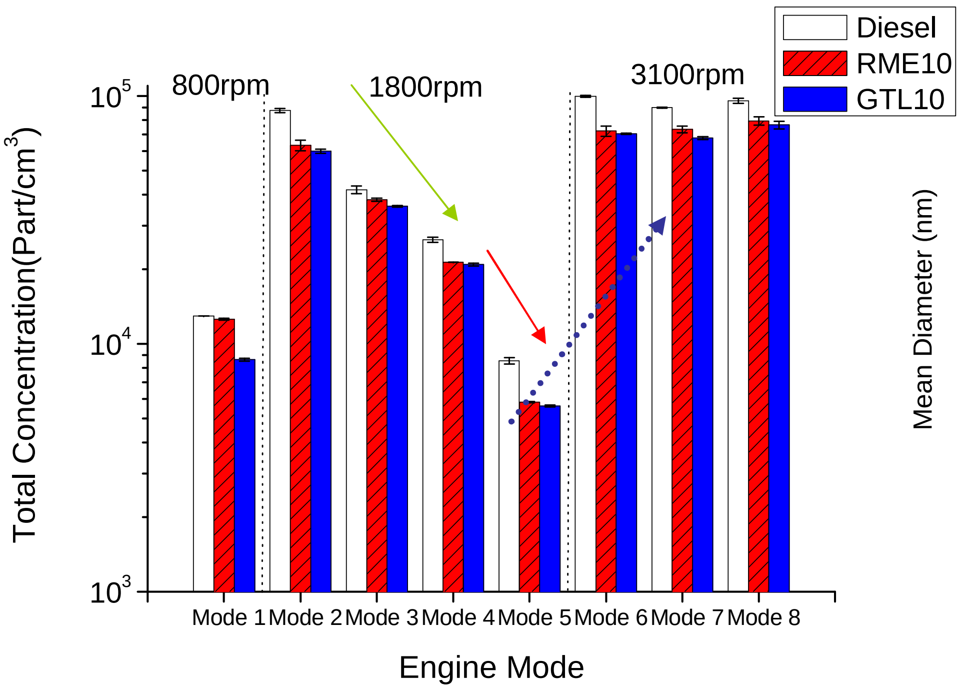
Mode	Engine Speed (rpm)	Main SOI (BTDC)	BMEP (bar)	EGR
Idle	800	-1	0.68	NO
Middle Speed/Load	1800	-2.69	5.2	YES
High Speed/Load	2500	-2.69	7.0	NO

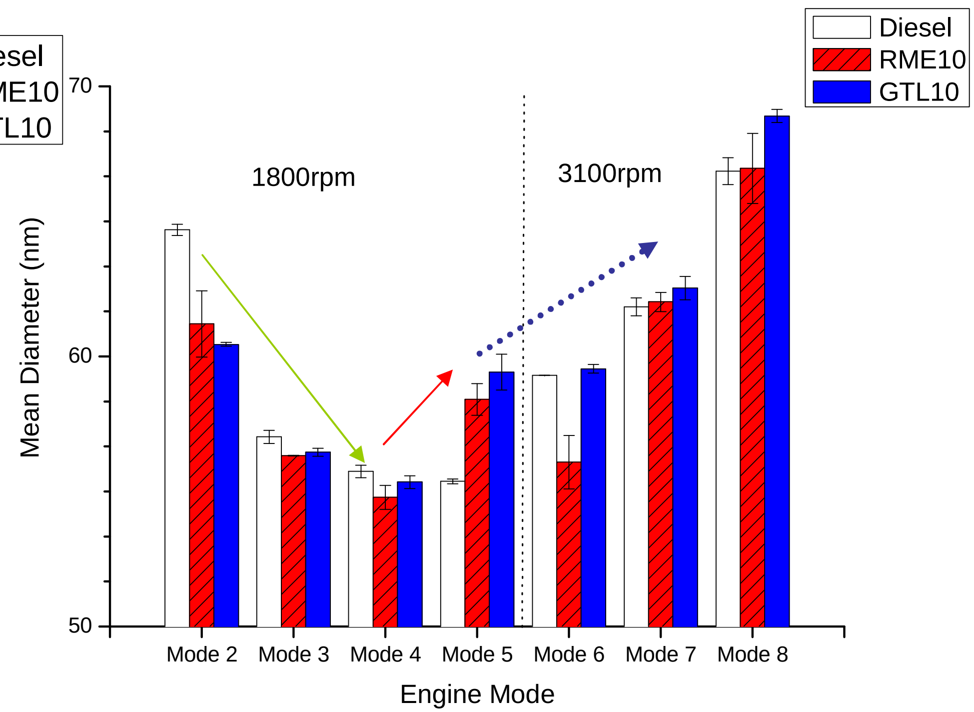
Pilot Injection	0 (mm^3/stroke)	1.5mm (mm^3/stroke)	3(mm^3/stroke)
+5º CA	(a)	(b)	(e)
Base		(c)	(f)
-5º CA		(d)	(g)

3. Test Results

A. With 10% RME and GTL blends

Particulate number and mean diameter





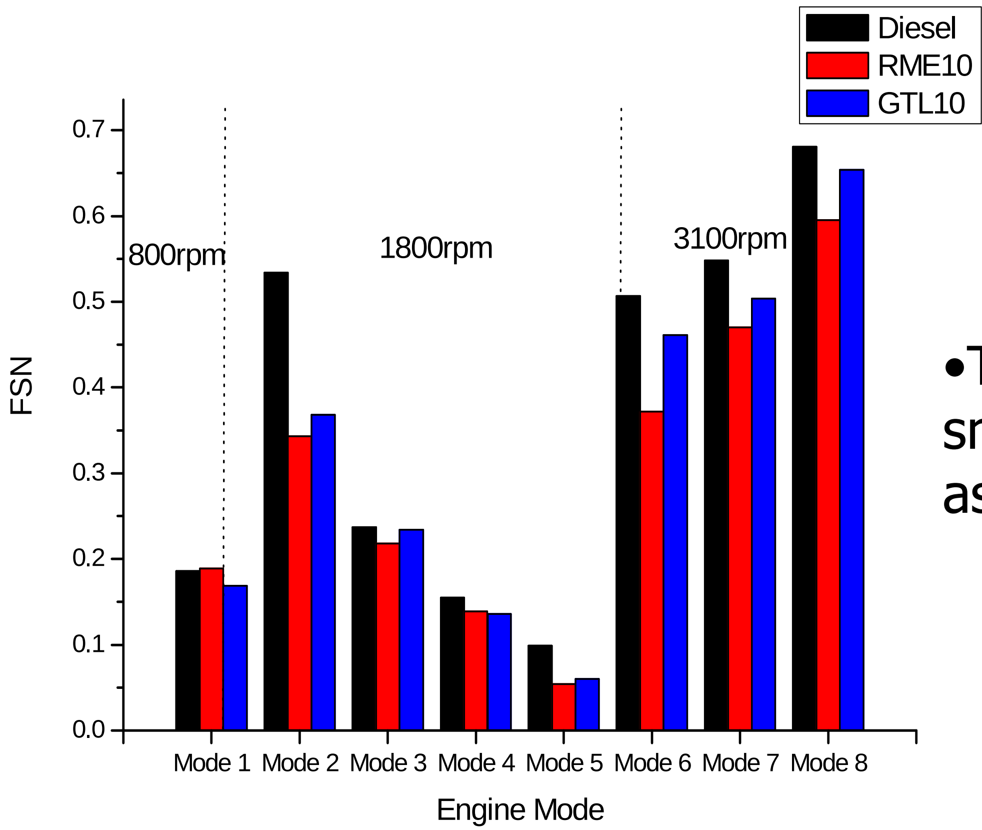
RME10/ GTL10 → Fewer particles

Increase of engine load — Fewer particles, larger size

Increase of speed — More particles, larger size

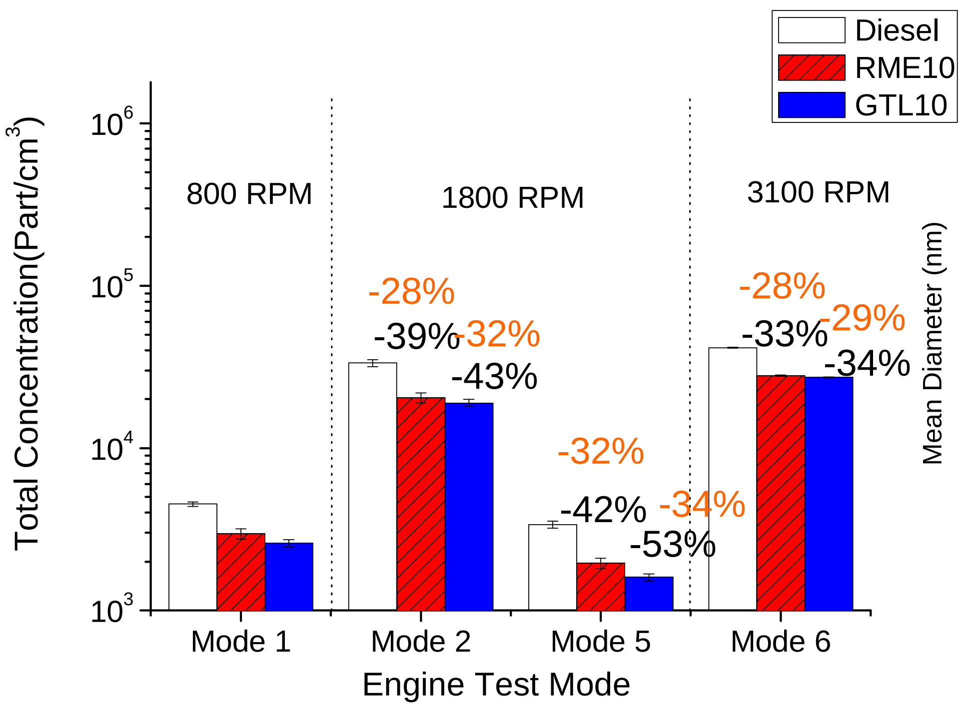
Less EGR — Fewer particles, smaller size

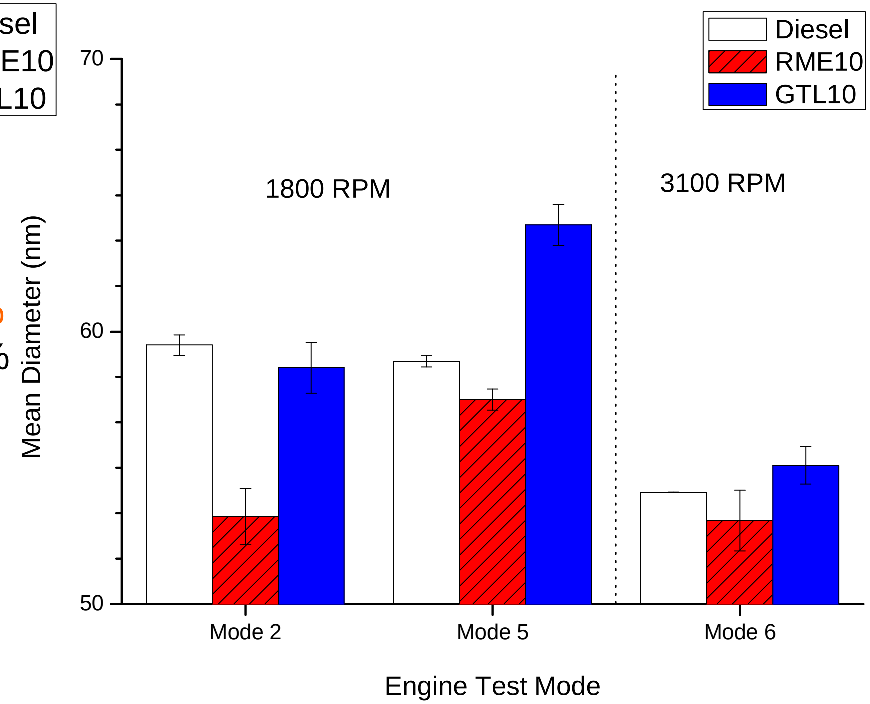
Smoke



- The trend of variation of smoke is not quite the same as the particle numbers

Non-volatile particles

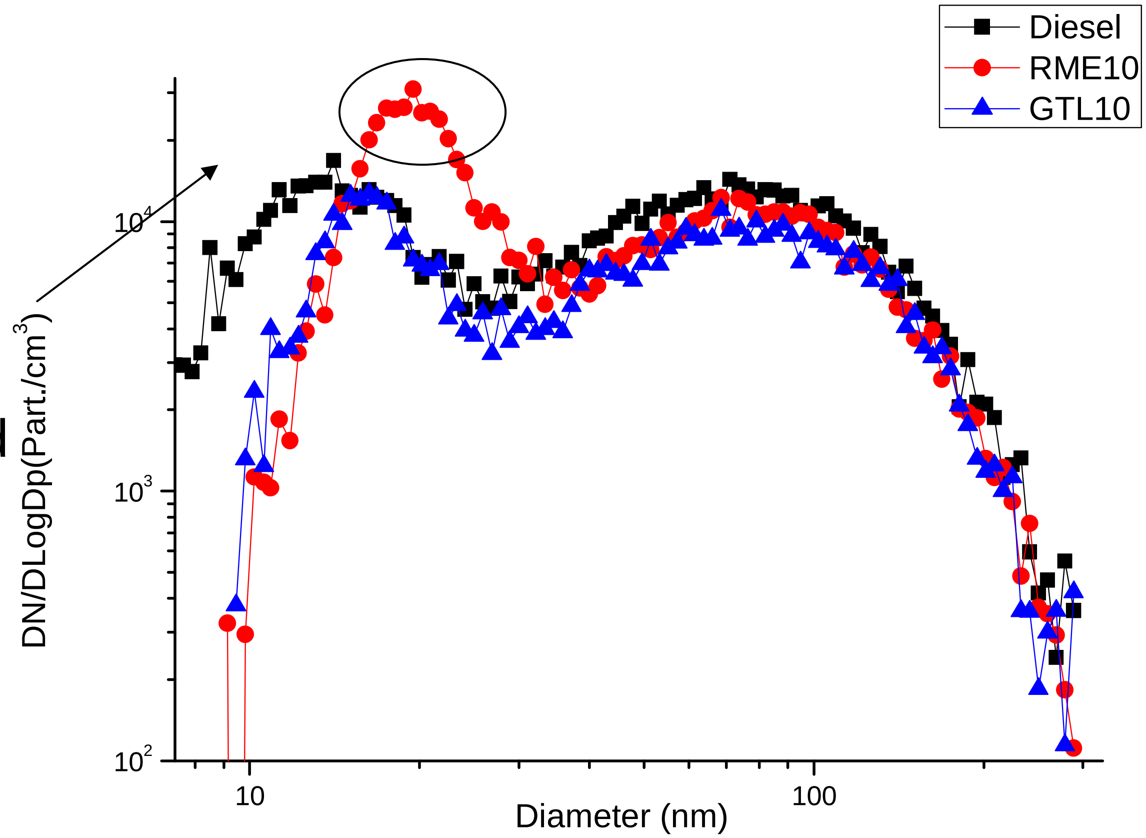




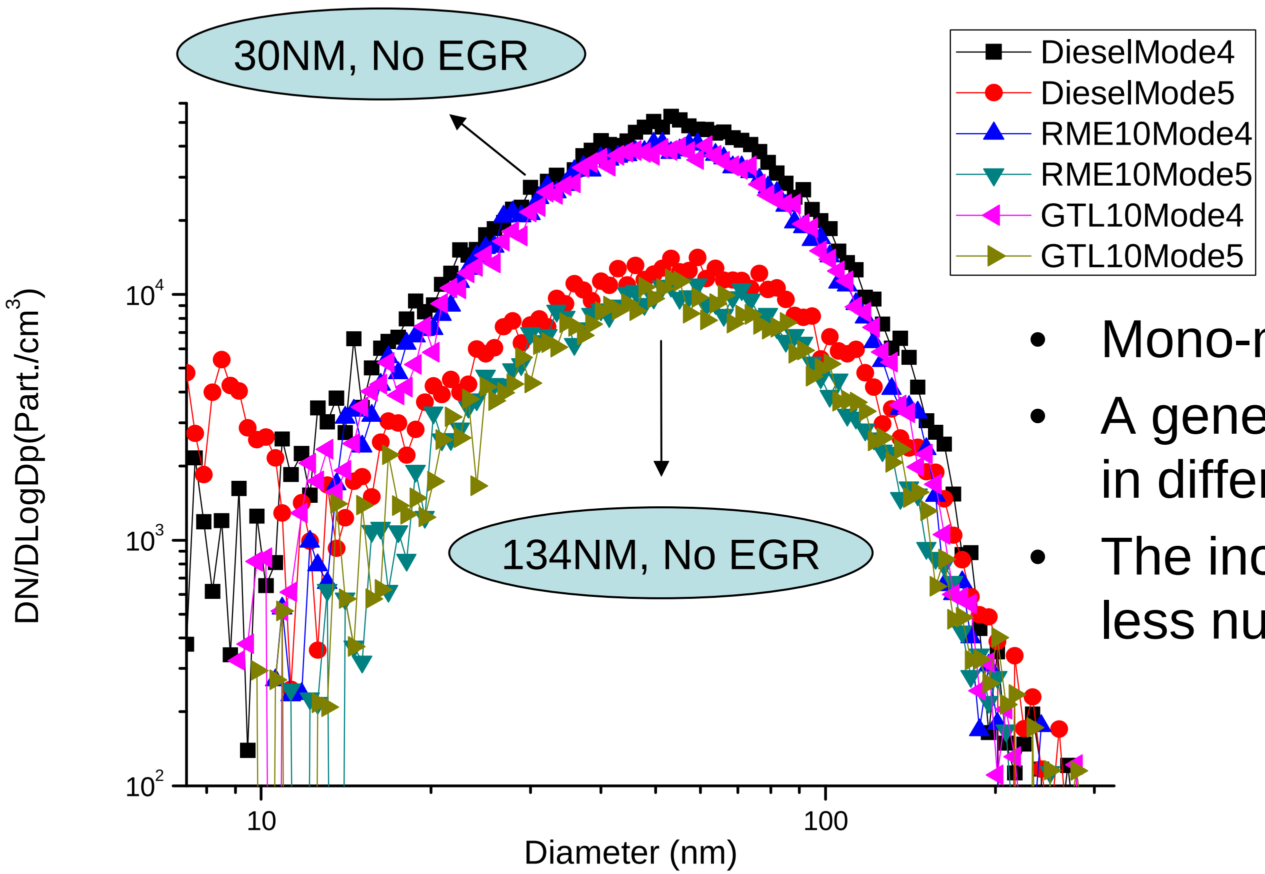
- The non-volatiles number reduction by the alternative fuel blends were all higher than the rates when thermo-dilution was not used

Particulate Size Distribution at 800 rpm, Idle

- Bimodal mode
- A general reduction of particles in different sizes
- Small peak at 20nm when RME10 was used

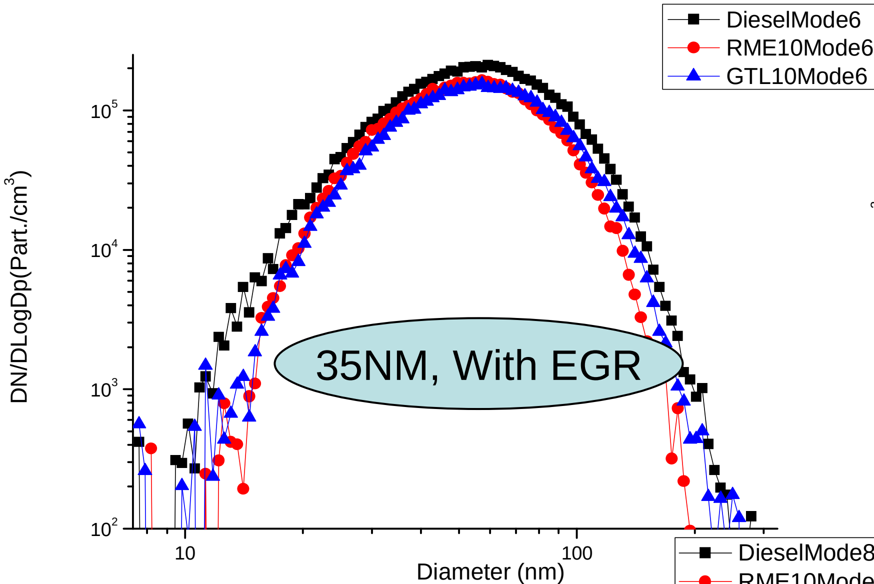


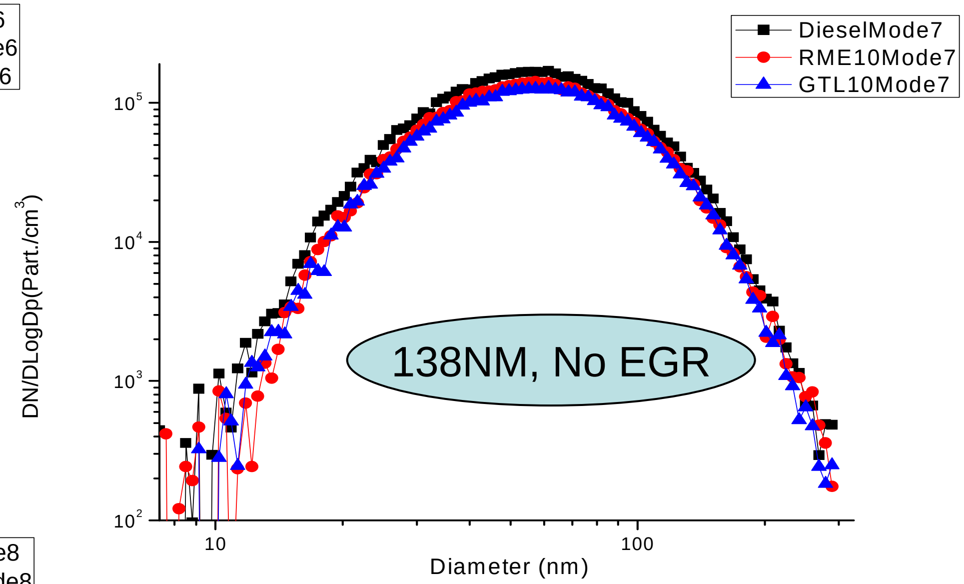
Particulate Size Distribution at 1800 rpm

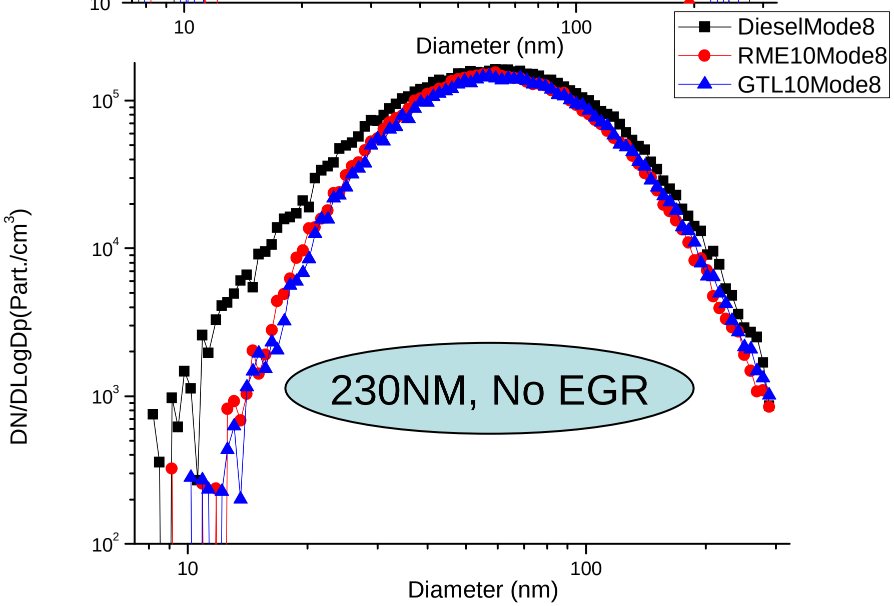


- Mono-modal feature
- A general reduction of particles in different sizes
- The increase of load leads to less nucleation mode particles

Particulate Size Distribution at 3100rpm

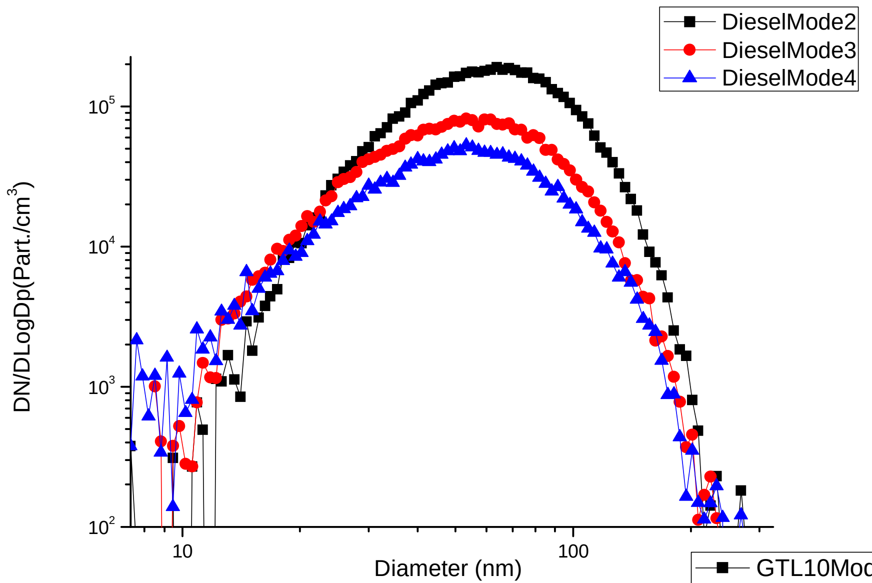


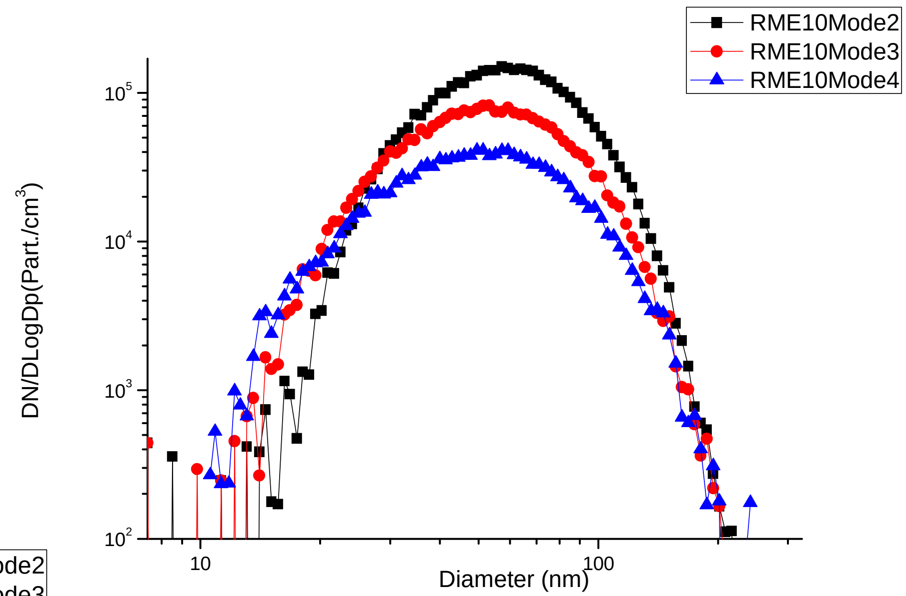


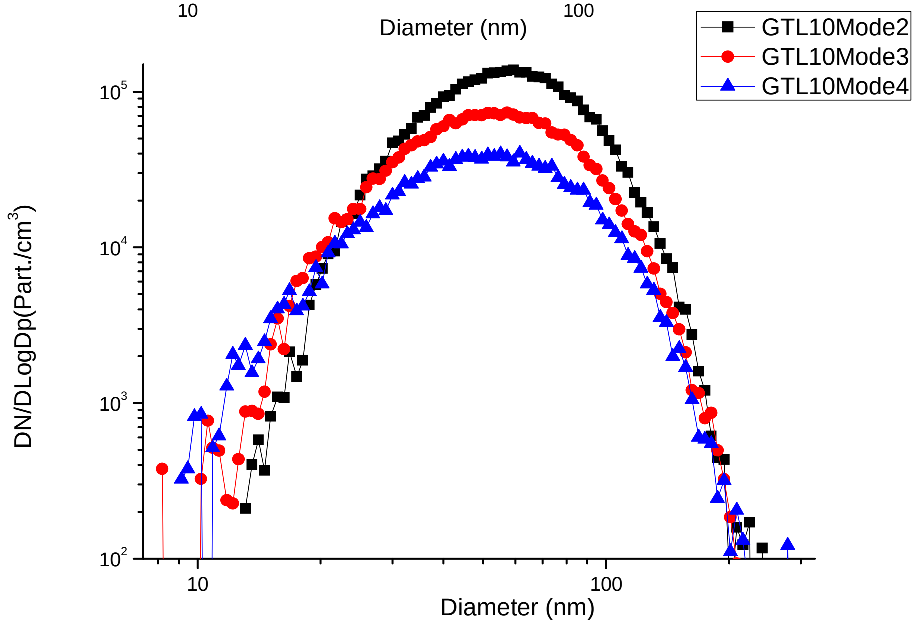


- Particles numbers reduced by RME10 or GTL10
- Larger particles with the increase of the load

Particulate Size Distribution with different EGR



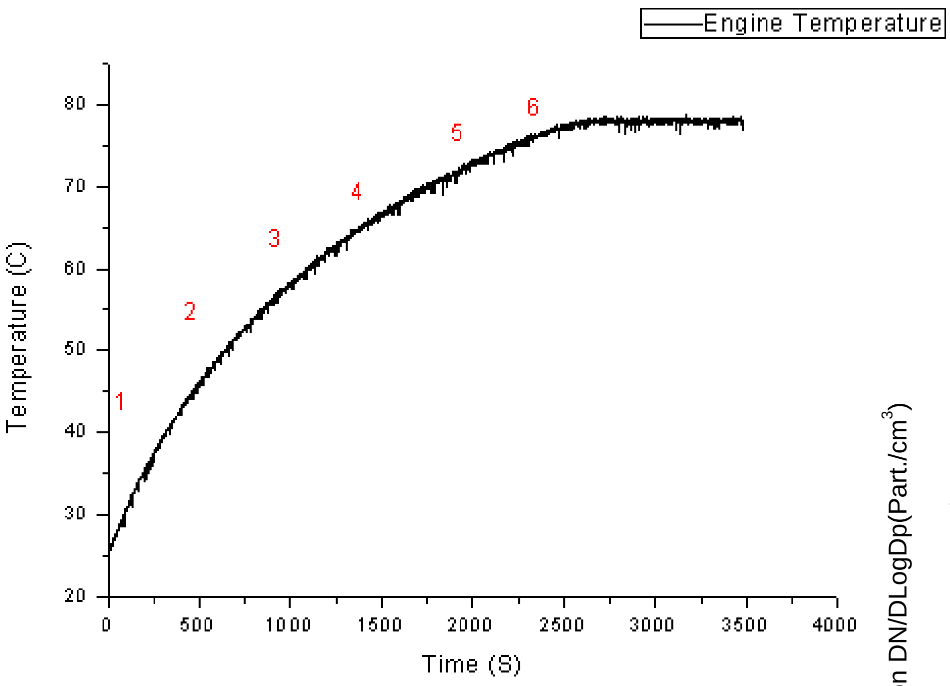




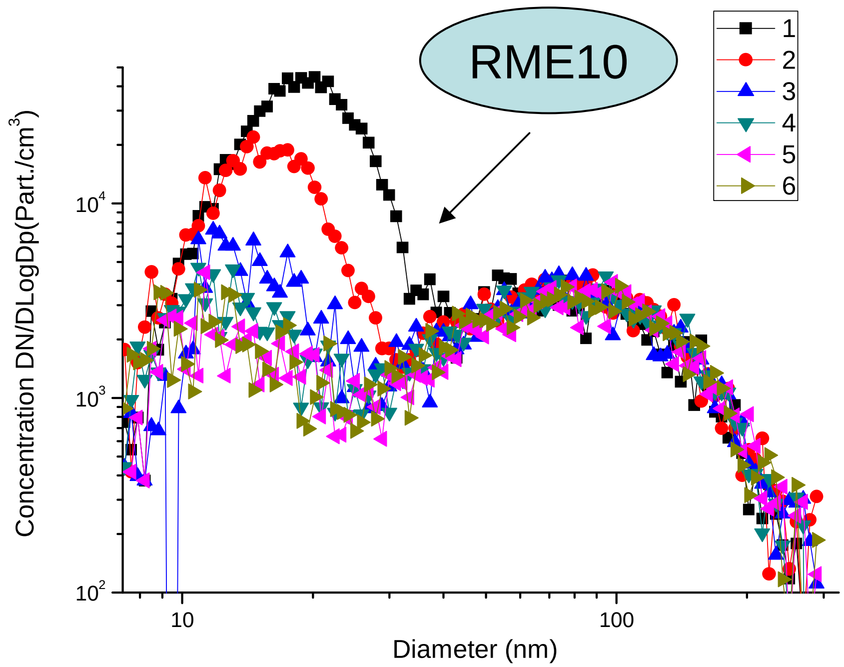
1800 RPM

- More EGR, more nucleation particles
- some nucleation particles around 10 nm might be reduced

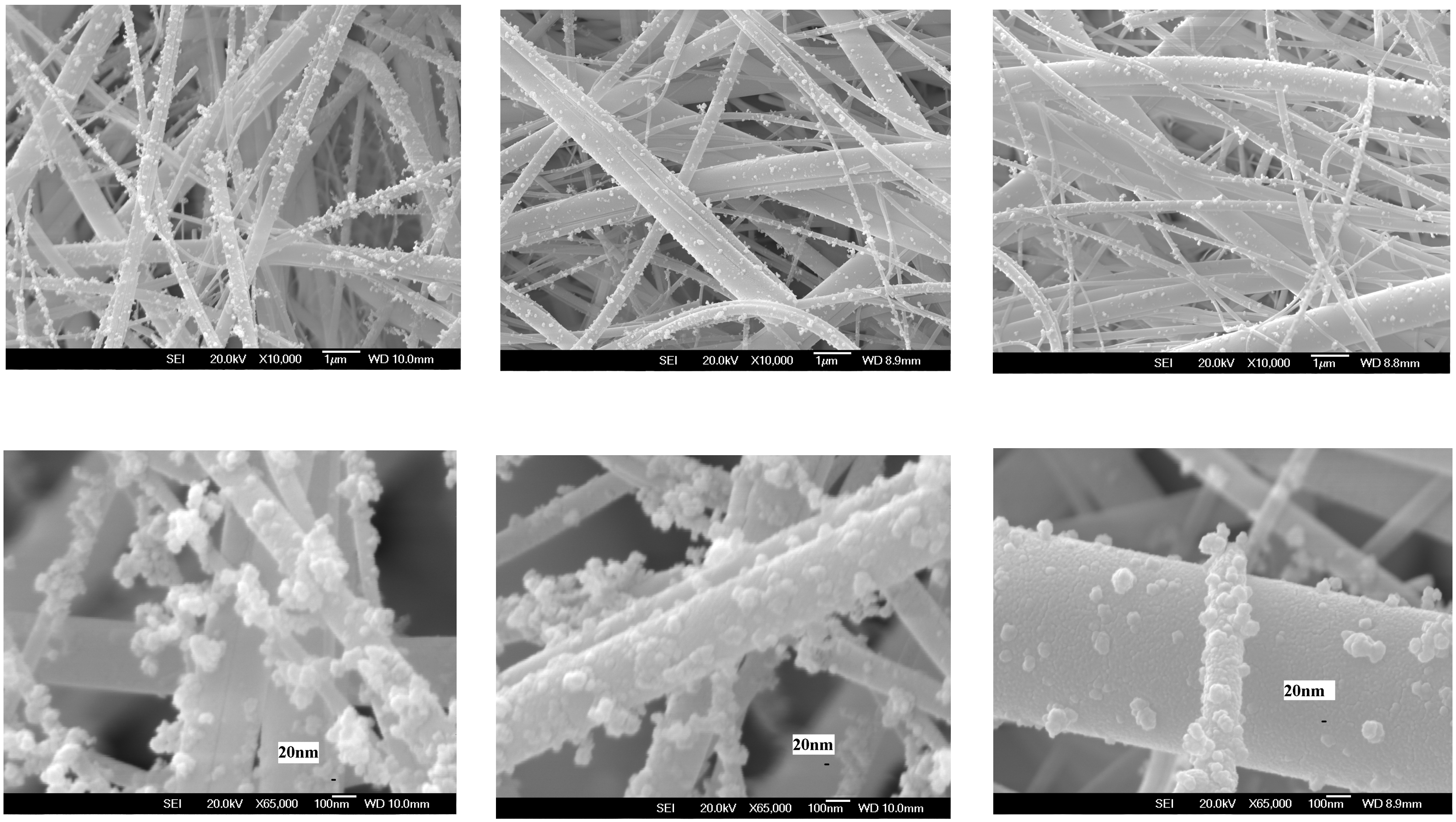
Non-volatiles during Warming-up



(1) large amount of soot from incomplete combustion.
(2) The mutated hydrocarbons during the combustion were likely to quench.



Particle morphology (1800rpm, 30Nm)



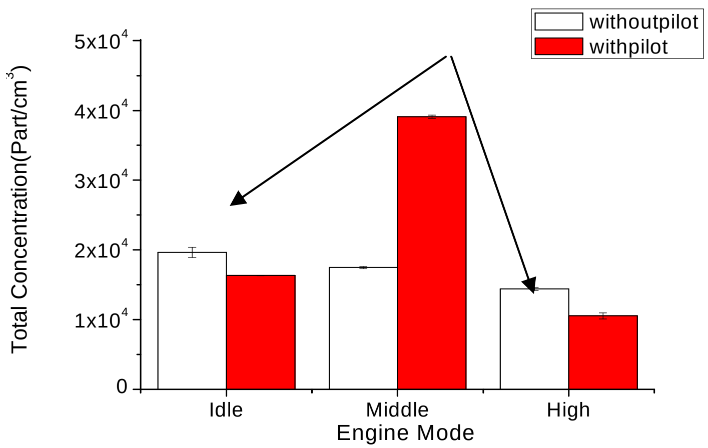
(a) Diesel magnification of 10000(b) Diesel magnification of 65000 (c) RME 10 magnification of 10000
(d) RME magnification of 65000 (e) GTL10 magnification of 10000 (f) GTL10 magnification of 65000

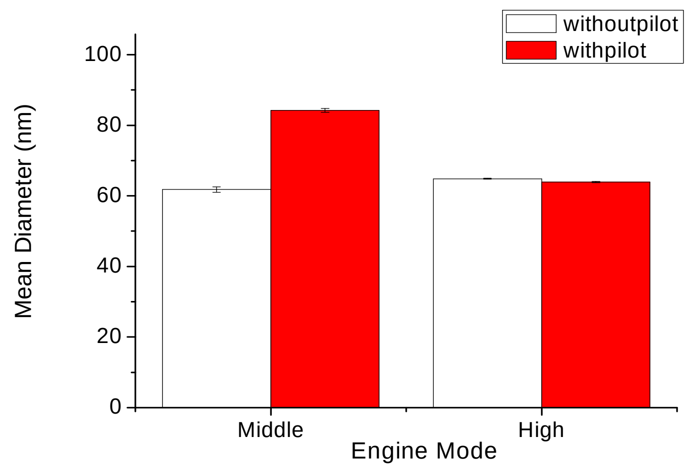
Summary and conclusions (A)

- RME10 and GTL10 can lead to a similar reduction in total particle numbers under various engine conditions but their influences to the particle mean diameters are not clear
- RME10 and GTL10 reduce the accumulation mode particles and some nucleation particles in the larger size range (>30nm); however, RME 10 could also increase those in the small size range under certain cases (<20nm).
- Particles from diesel combustion have more clusters than those from the RME10 or GTL10 and the primary particle size of all the three fuels is around 20-50 nm.
- At 1800rpm, the increase of engine load results in an increase of particle mean diameter and the reduction of particle numbers (differently at 3000rpm); the increase of either engine speed or EGR increases the particle numbers as well as the mean diameters
- Cold starts could result in much higher non-volatile particles in the nucleation mode.

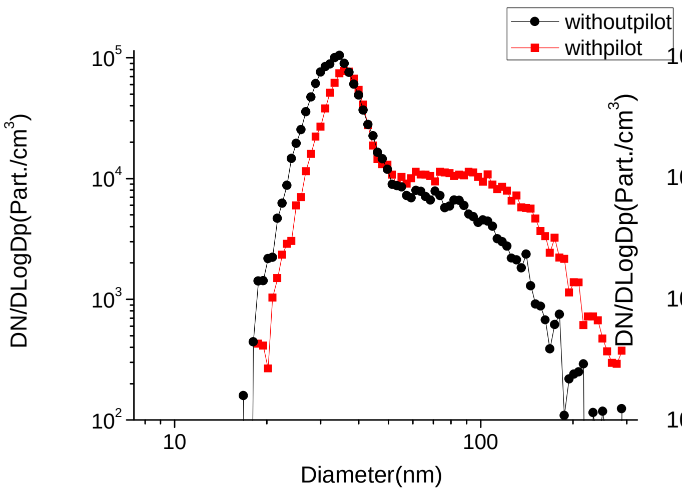
B. Particles influenced by pilot injection

Effect of pilot injection

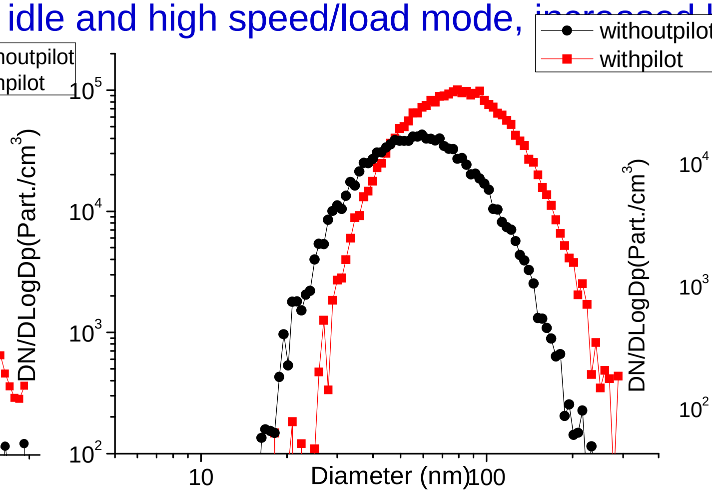




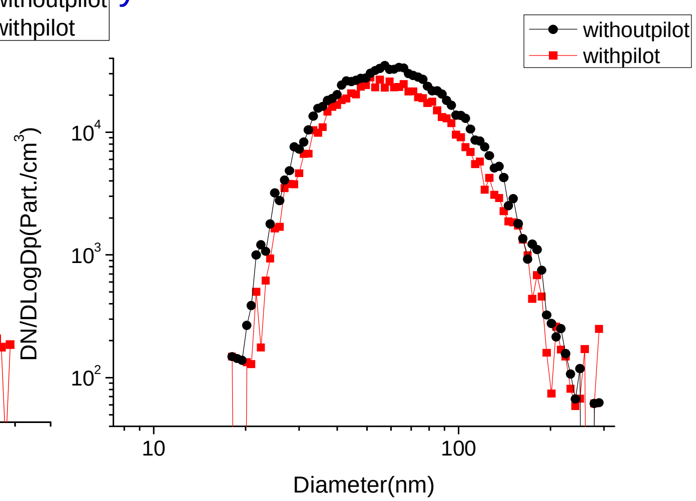
Particle number reduction at idle and high speed/load mode, increased by EGR at medium load



Idle mode



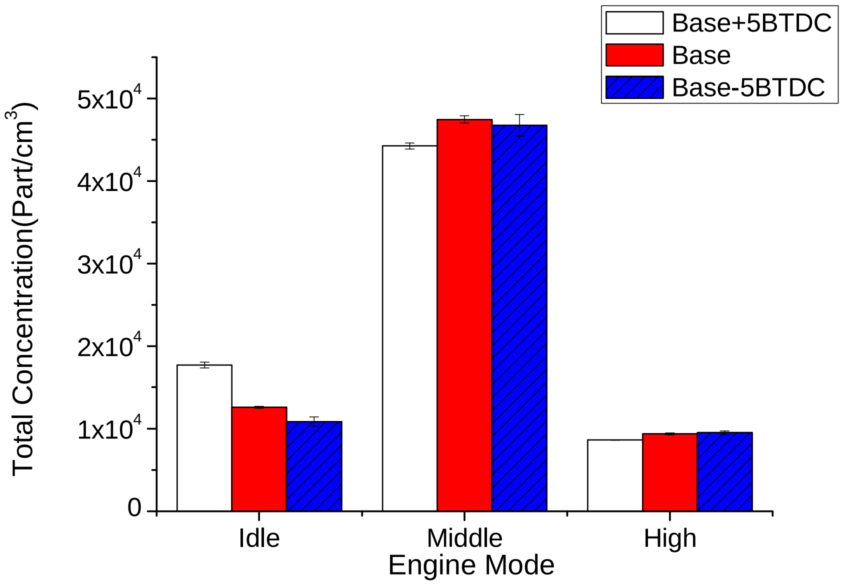
Middle mode

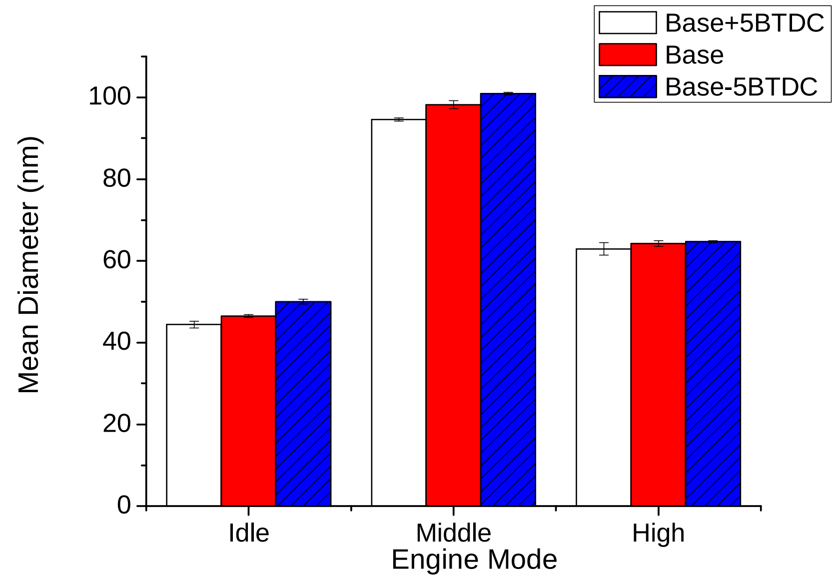


High mode

Larger particles using pilot injection in idle/middle mode

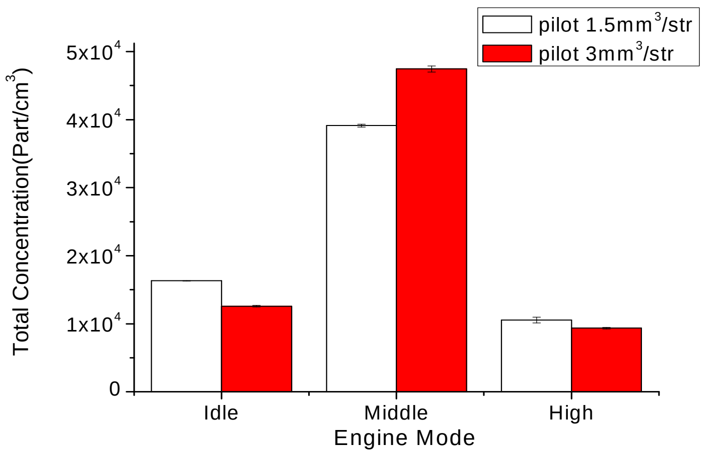
Effects of pilot injection timing

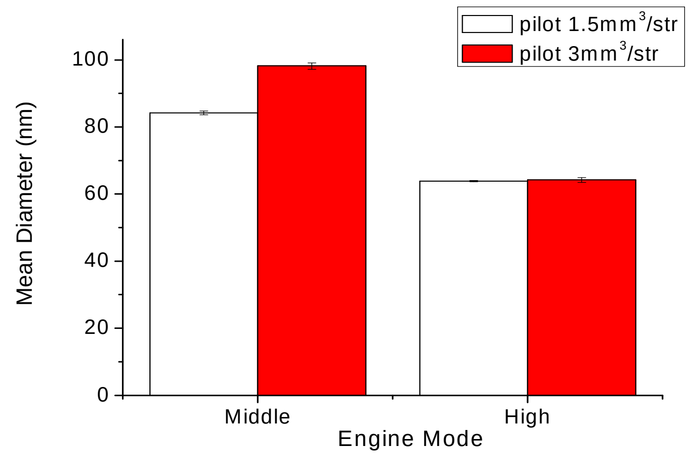


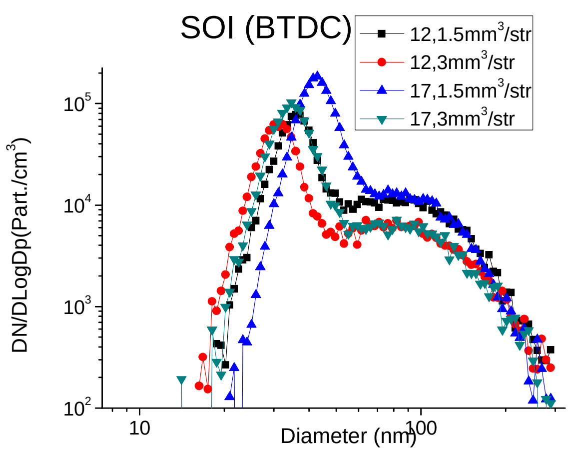


- The advance of the pilot injection leads to a reduction of the particle numbers and mean diameters

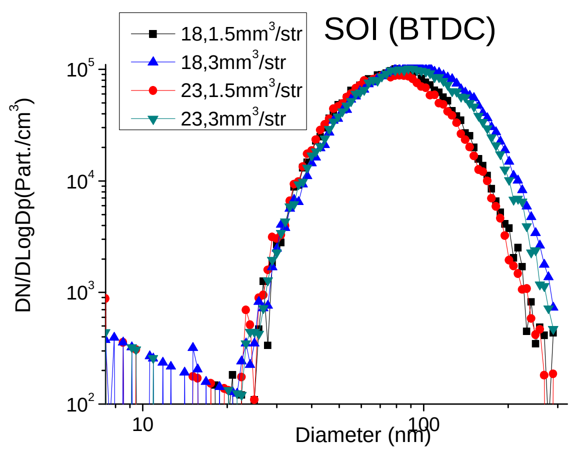
Effect of pilot injection quantity



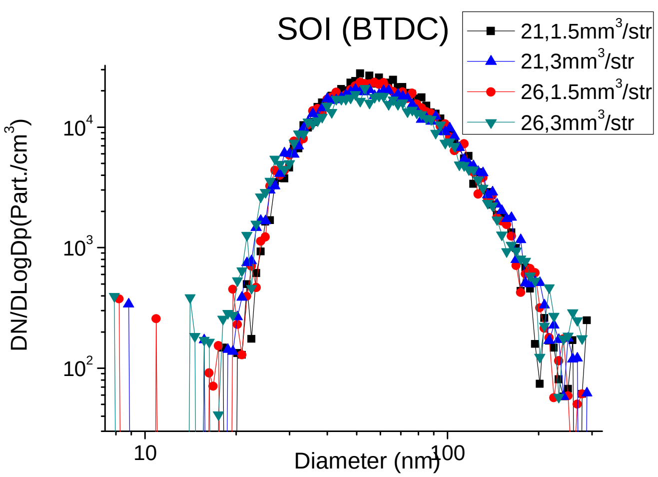




Idle mode



middle mode



high mode

Summary and conclusions (B)

- In the absence of EGR, pilot injection seems to help reduce particle numbers, as in the idle and high speeds. When EGR is applied, as in medium speed/load, the introduction and increase of pilot injection quantities increases both the particle number and mean diameter.

- The advanced timing of a higher radio of pilot injection tends to reduce the number and diameter of particles.

- The strategy of pilot injection influences the PM emissions from the pilot combustion and at the same time the main combustion through ignition delay. This effect is less significant with the increase of the engine load and with the advance of the pilot injection timing.

- It is expected that when the strategy of pilot injection is used for NOx and NVH reduction as for biodiesel, attention will be required to minimise its impact on PM emissions.

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Thank you!