

Experimental investigation of ethanol-gasoline dual-fuel on particle emissions at the exhaust of a small displacement engine

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18th ETH

Conference on Combustion Generated Nanoparticles

Main concerns on transportation



1. Smog & Toxins



2. Greenhouse Gas
Global Warming



3. Energy Security
Diminishing Resources

Introduction

Carbon footprint



Fuel economy



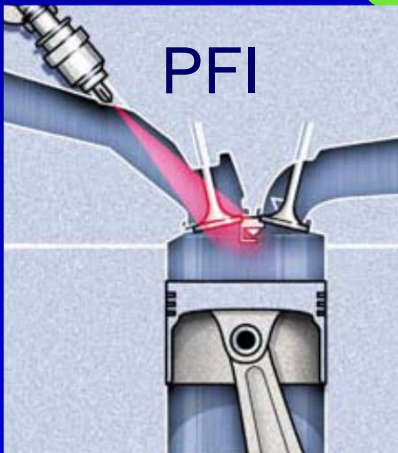
Lowest pollutant emissions



Engine performance



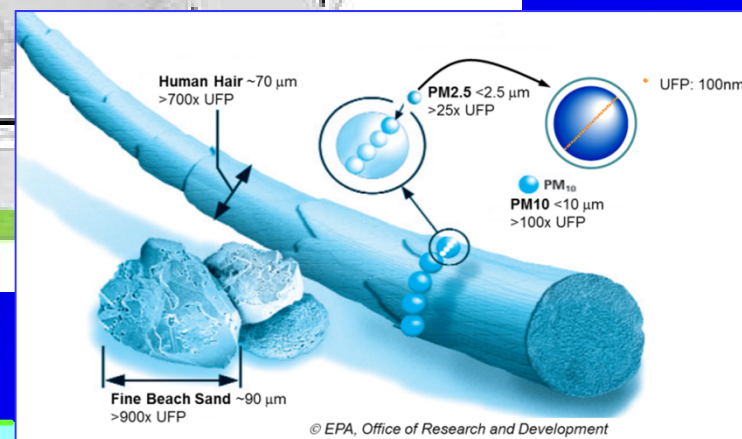
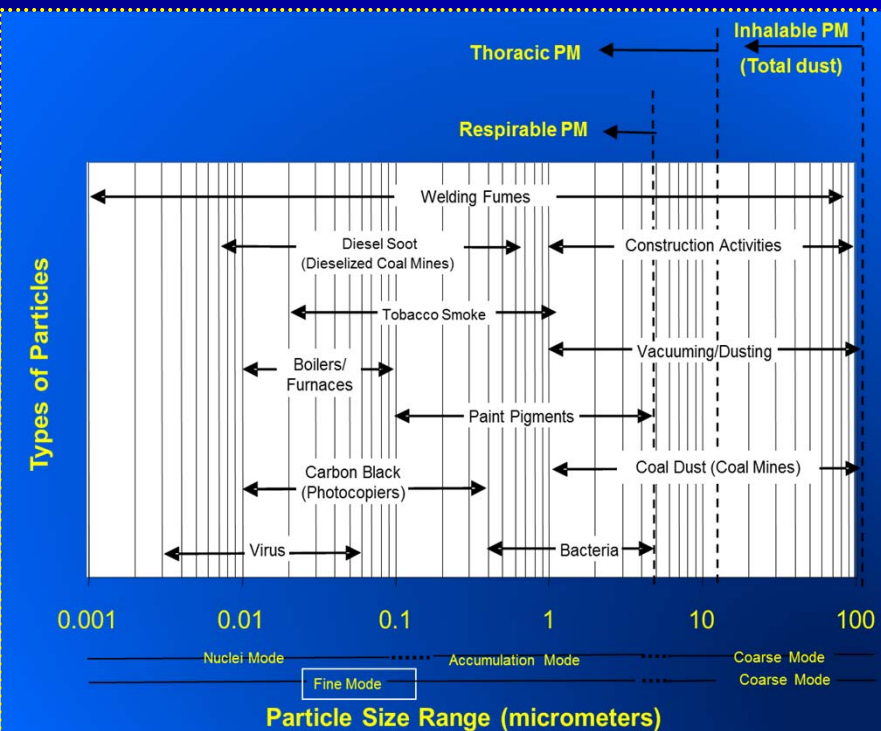
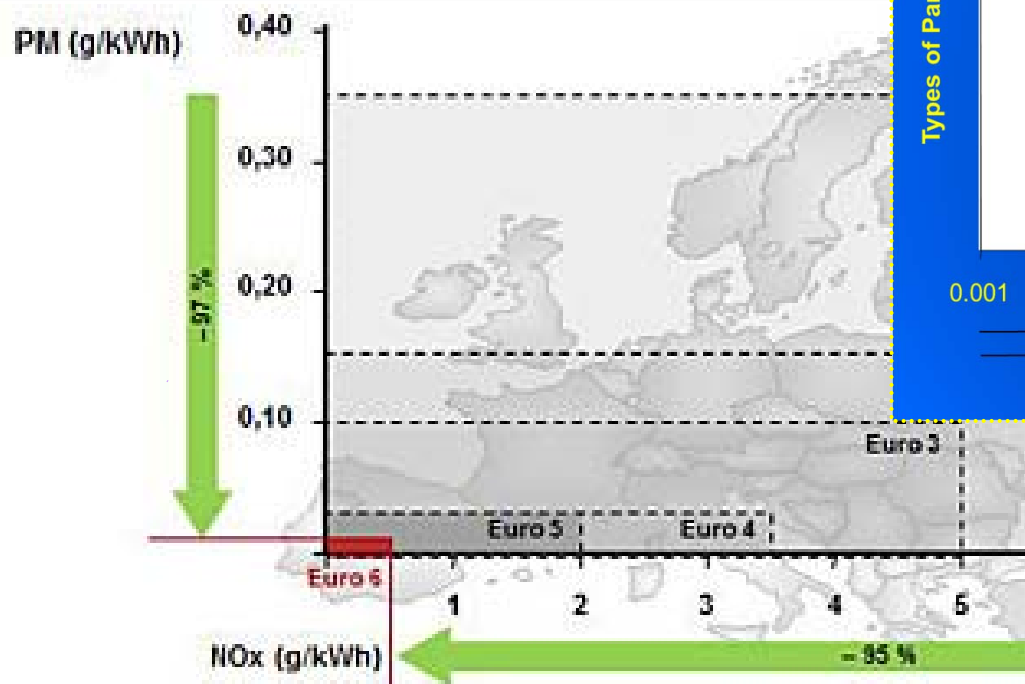
**Increase of
PM
emissions**



*Time for mixture preparation:
charge heterogeneity
Time for fuel evaporation
fuel droplets
Wall impingement
Fuel film*



Emission regulation Euro 6



PN regulation

6.0×10^{12} 1/km of particles smaller than 23 nm

Introduction

Fuel
economy



Engine
performance



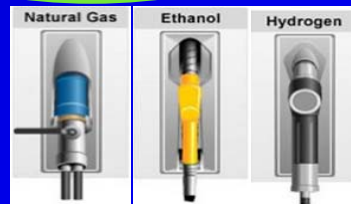
Carbon
footprint



Lowest
pollutant
emissions



Octane enhancer
Oxygenated fuel

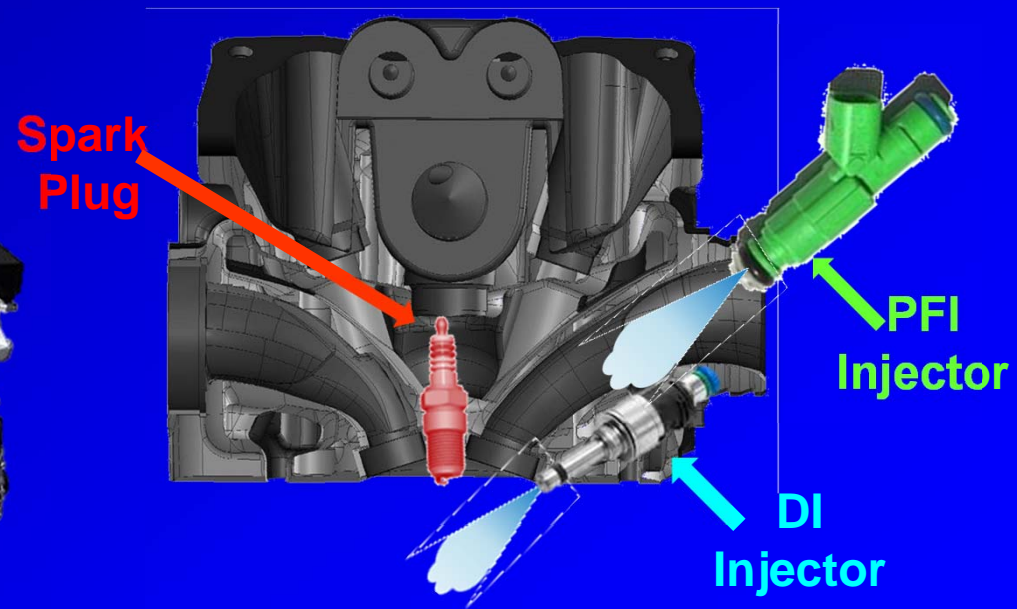


Objective

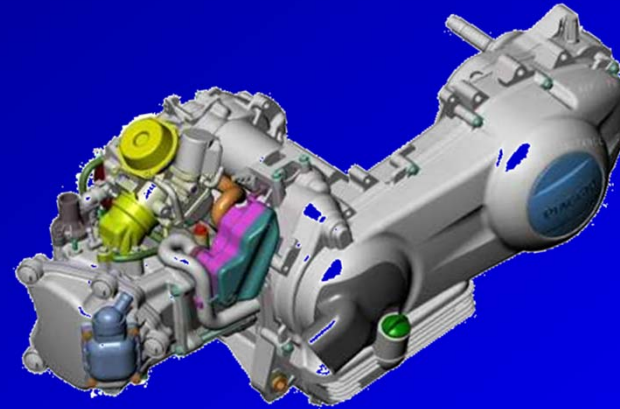
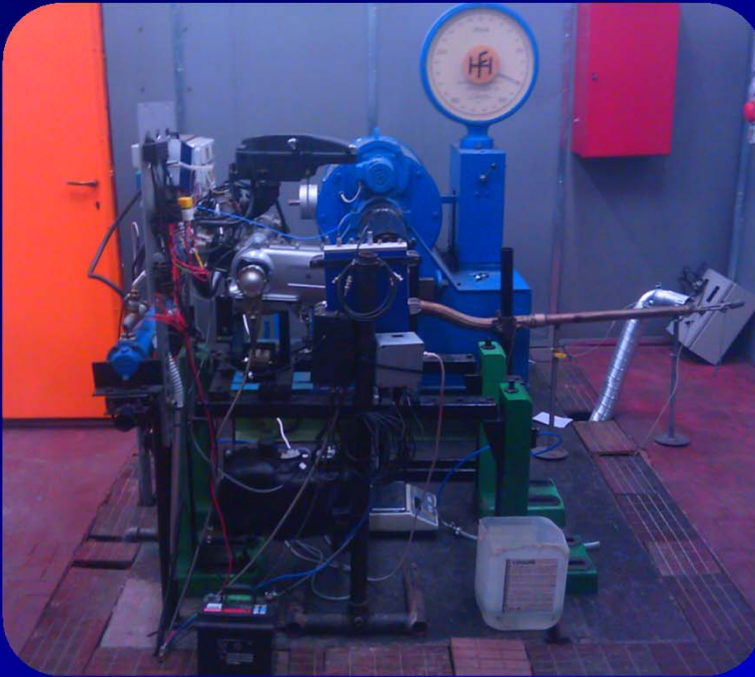
Characterization of particle emissions from ethanol/gasoline dual fueling engine



*Gasoline: Port Fuel Injection
Ethanol: Direct Injection*

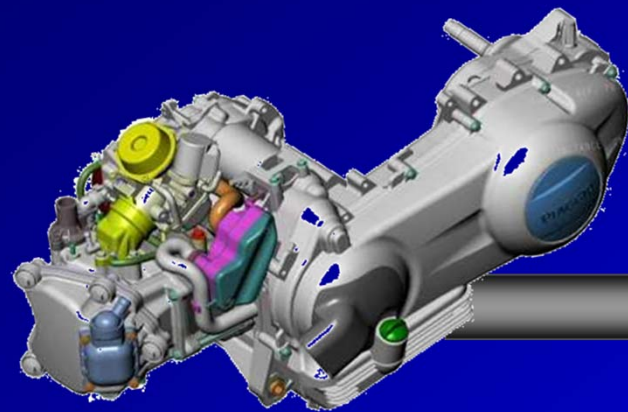


SI Engine



Engine type	4-stroke single cylinder	
Displacement (cm ³)	250	
Bore (mm)	72	
Stroke (mm)	60	
Engine size (cm ³)	522.1	
Bowl Volume (cm ³)	19.7	
Maximum Torque [Nm]	20 Nm @ 5500 rpm	
Maximum Power [kW]	16 kW @ 8000 rpm	
Compression ratio	10.5:1	
Injector Type	PFI	DI
	Commercial	Prototypal
Number of Nozzle Holes	3	6

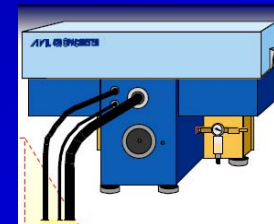
Experimental Layout



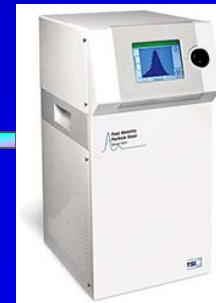
Smoke meter



Opacimeter



DEED



EEPS

DR= 1:100
 $T_1=150^{\circ}\text{C}$
 $T_2=T_{\text{amb}}$
 $T_{\text{EC}}=300^{\circ}\text{C}$



Gas analyzer

Engine operating conditions

Gasoline Gasoline Ethanol
G-PFI G-DI E-DI

DF ratio

$$[\text{Gasoline}] / ([\text{Ethanol}] + [\text{Gasoline}]) * 100$$

DF80

DF50

*Urban
driving conditions*

3000 rpm WOT
4000 rpm WOT
5000 rpm WOT

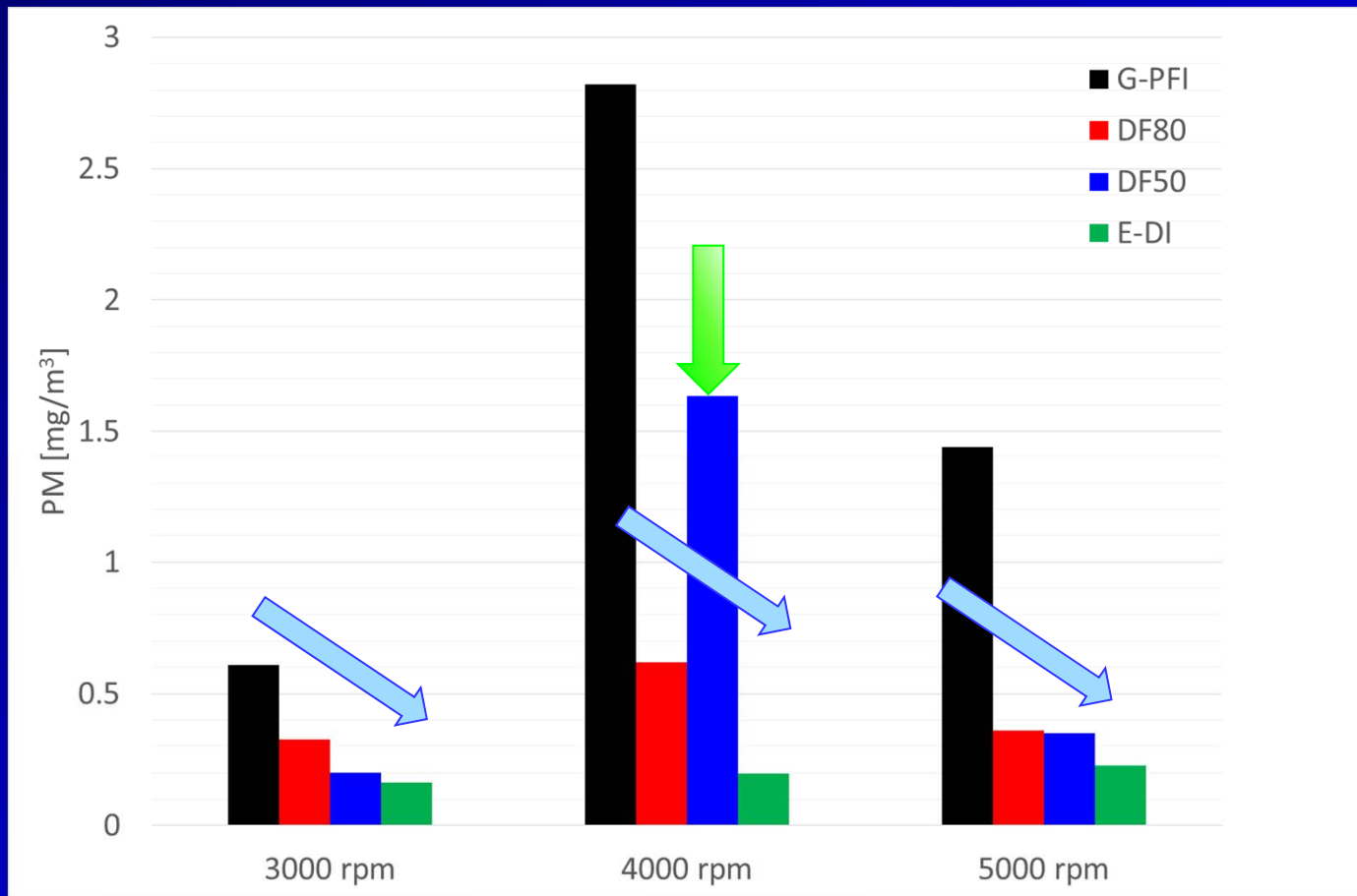
λ 1.0

SOS 22 BTDC @ 3000 rpm
24 BTDC @ 4000 rpm
24 BTDC @ 5000 rpm

SOI 230 PFI

315 DI

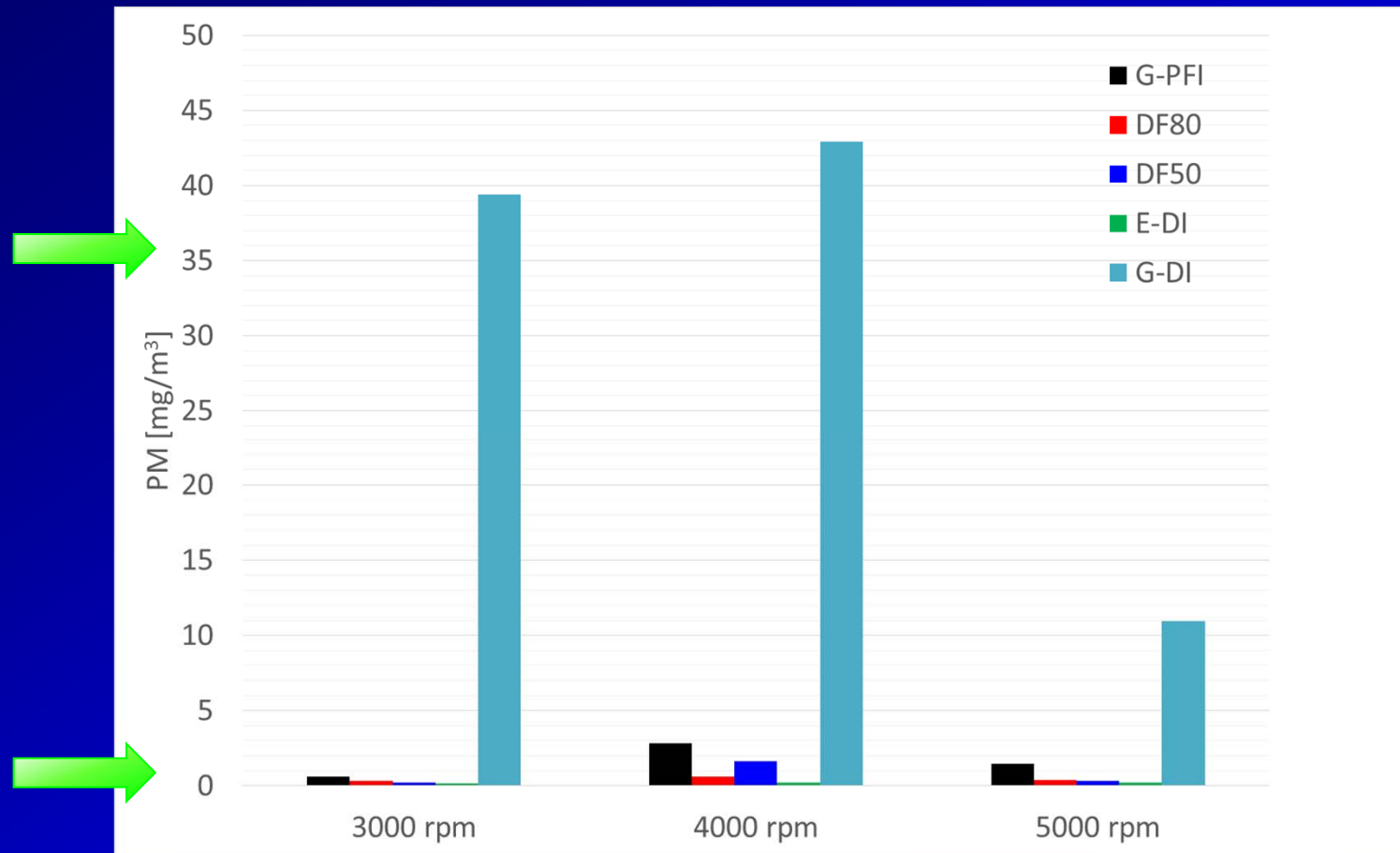
Particle Mass Concentration



DF80: 80% gasoline (PFI) 20% ethanol (DI)

DF50: 50% gasoline (PFI) 50% ethanol (DI)

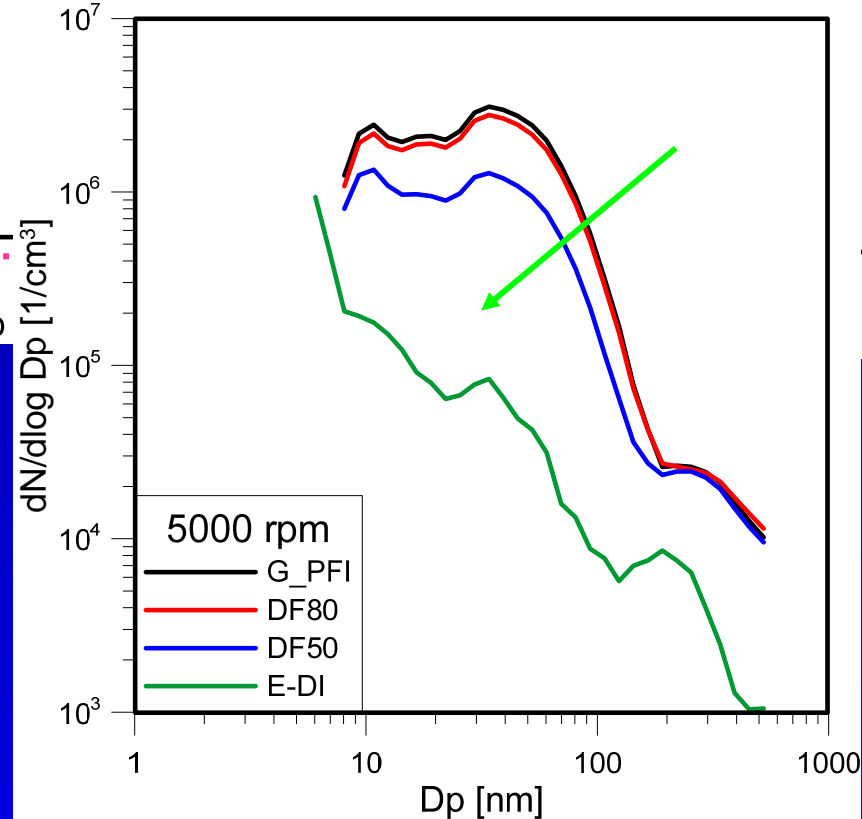
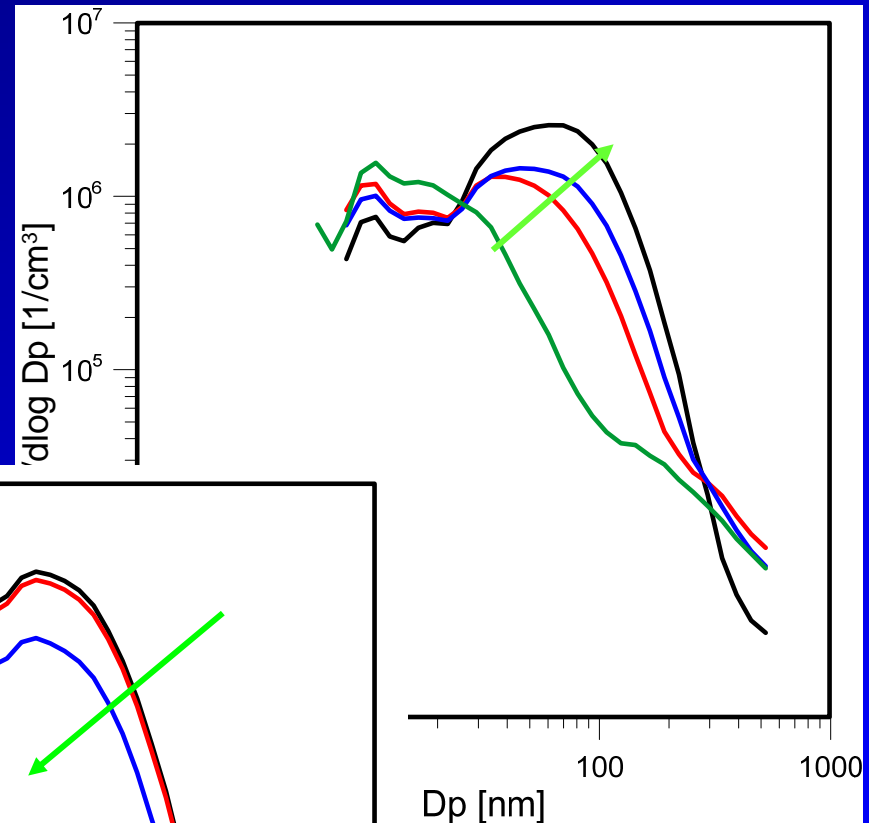
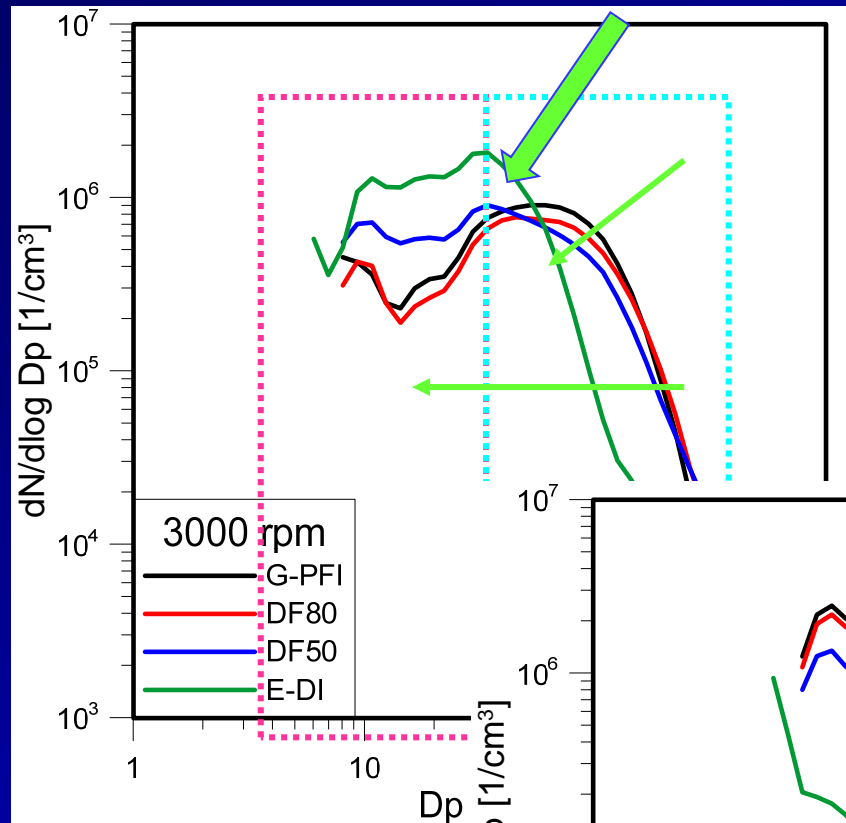
Particle Mass Concentration



DF80: 80% gasoline (PFI) 20% ethanol (DI)

DF50: 50% gasoline (PFI) 50% ethanol (DI)

Particle Size Distribution



Particle Size Distribution

Oxygen content



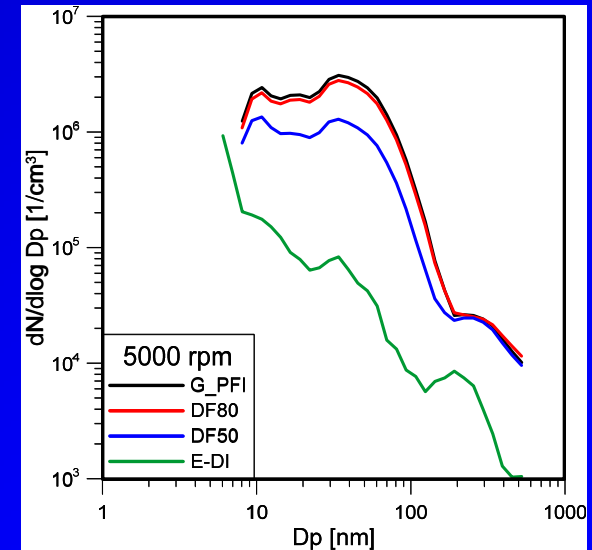
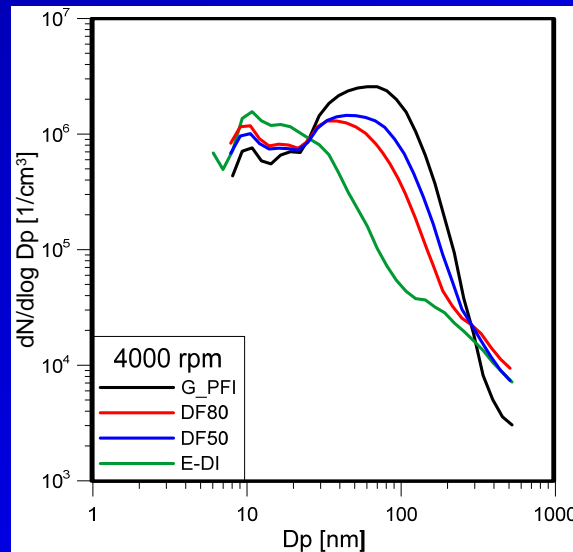
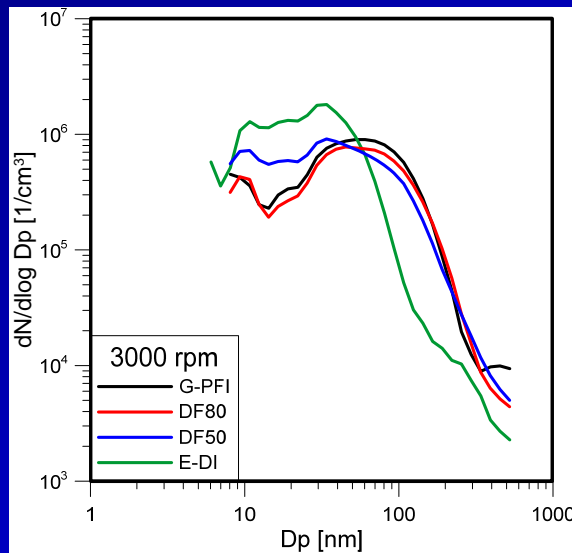
Reduced soot precursor formation
Enhanced soot oxidation

Volatility properties

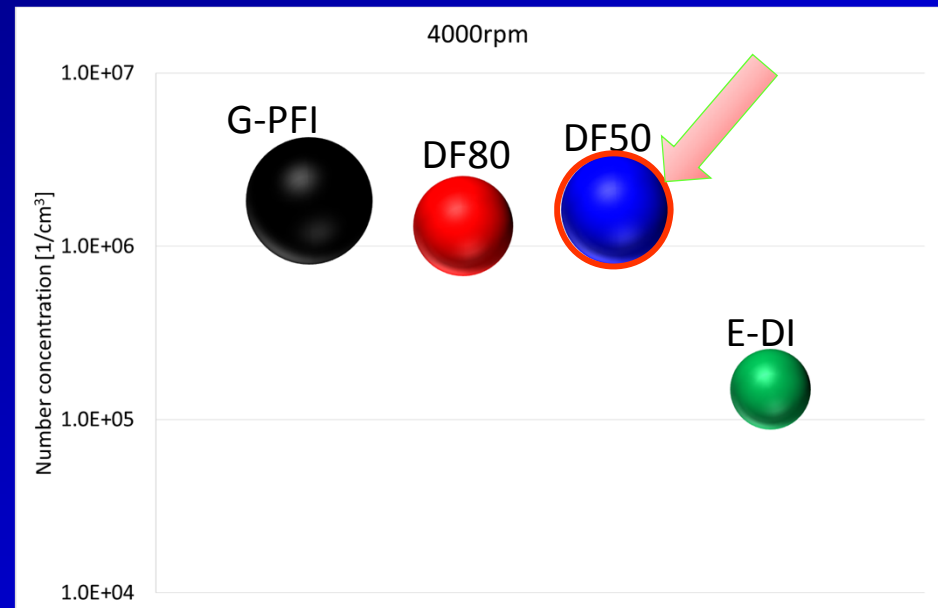
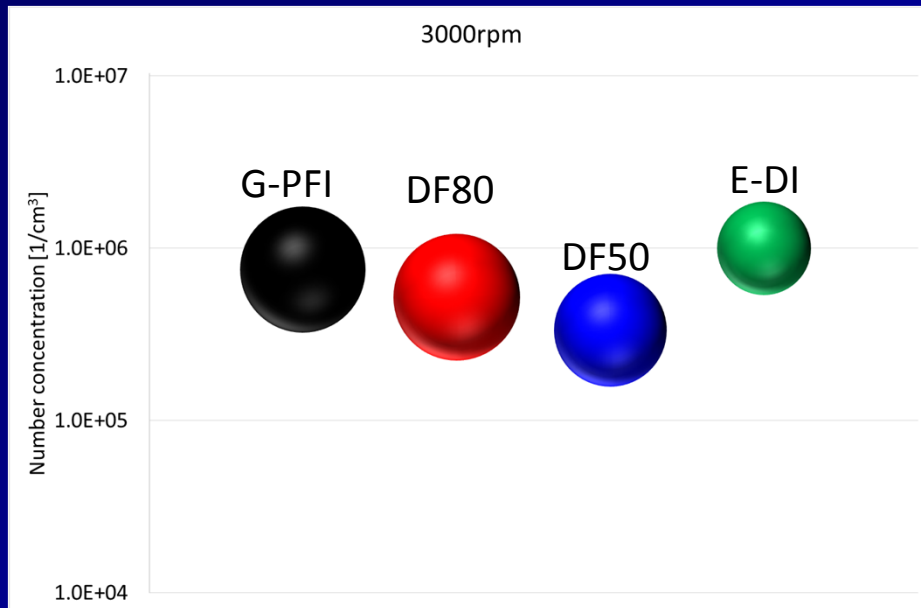
Evaporation
conditions



Enhanced evaporation of lighter
compounds of gasoline: residual fuel will
mainly contain heavier and highly sooting
hydrocarbons



Particle Size and Number

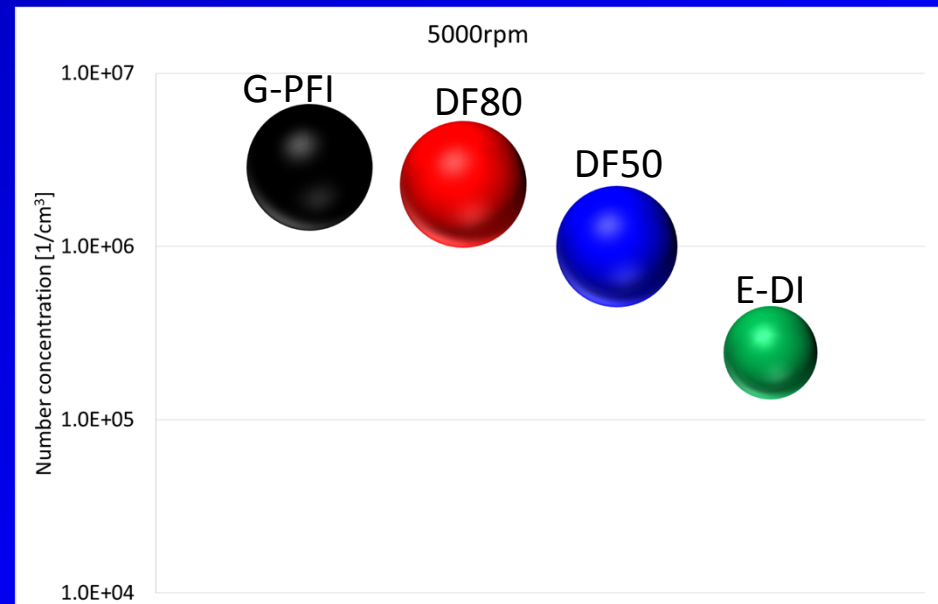


Particle Number

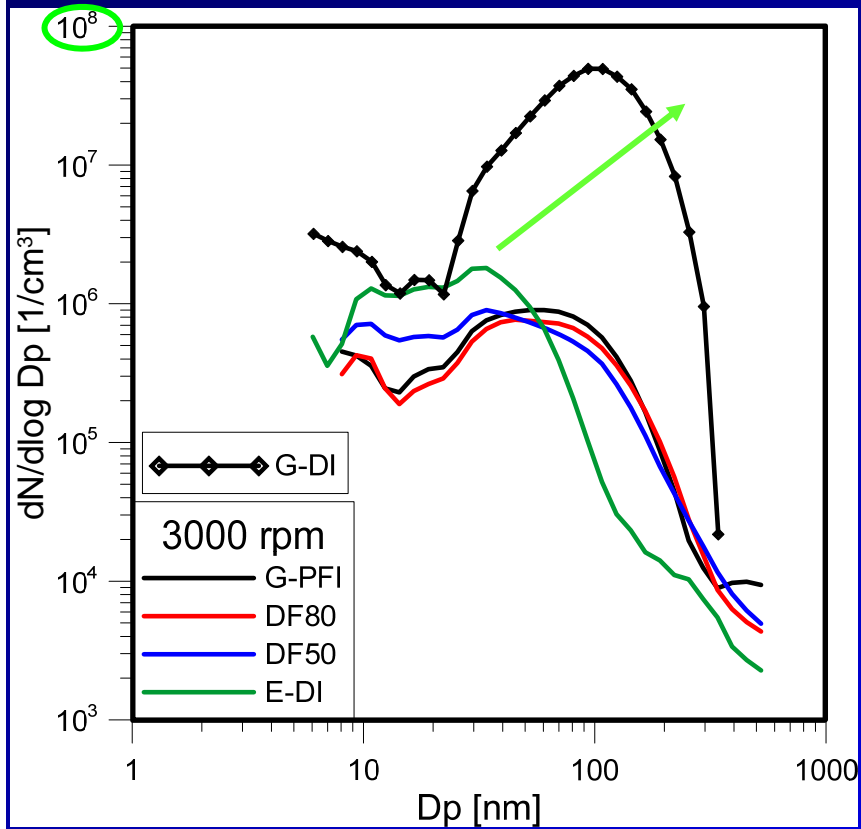
$$N_i = \frac{dN_i / d \log D_p}{16}$$

Mean Particle Diameter

$$D_m = \frac{\sum_{i=1}^n D_{p,i} \cdot N_i}{\sum_{i=1}^n N_i}$$



Particle Emissions: DF vs GDI

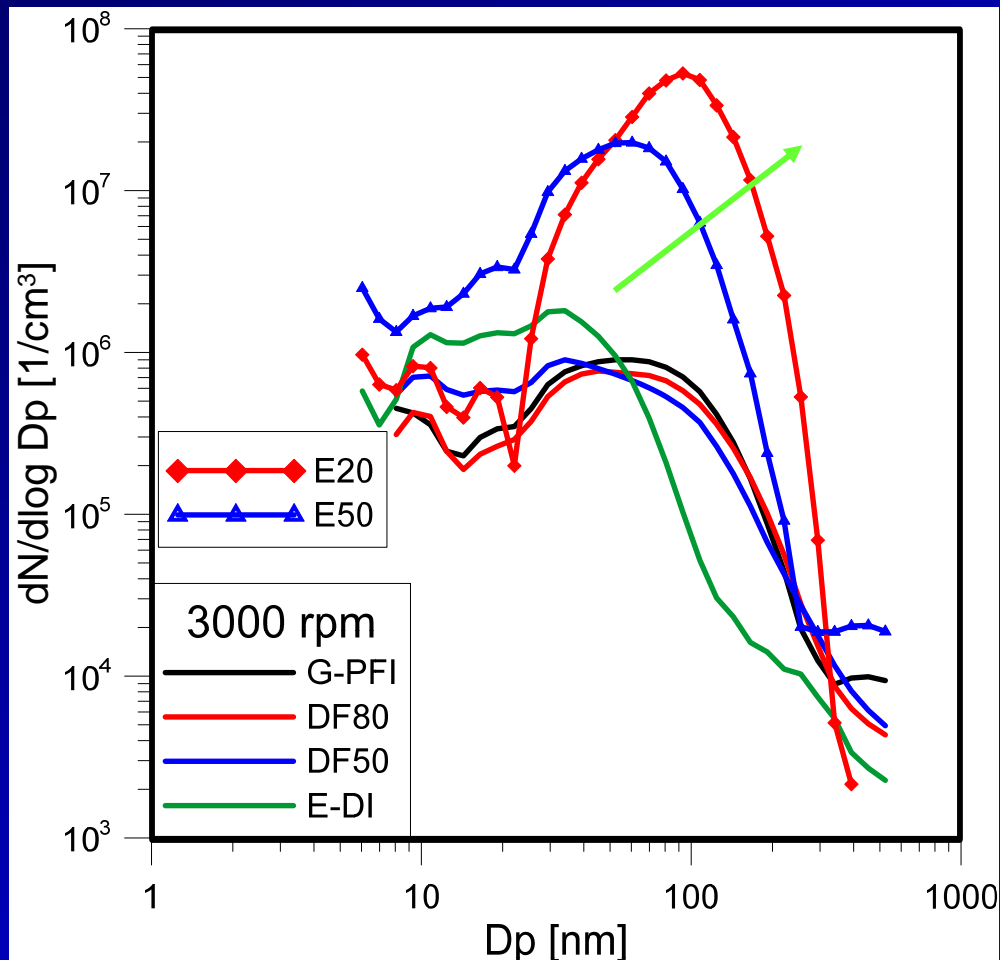


G-PFI

G-DI

DF

Particle Emissions: DF vs Blends



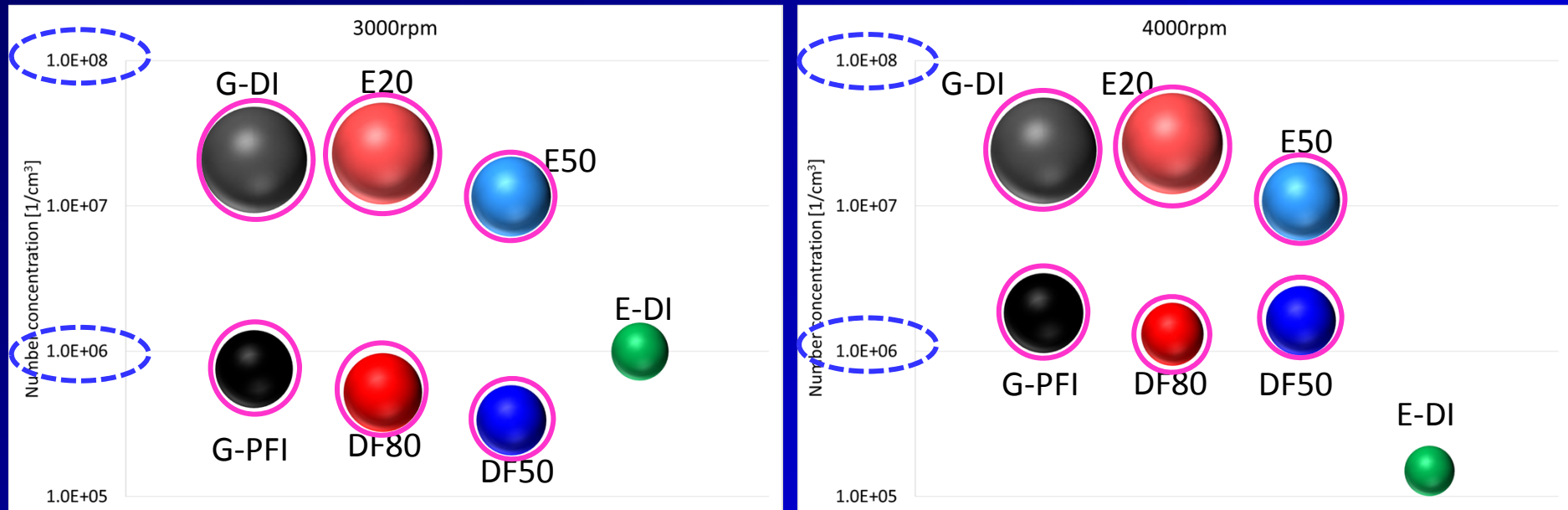
DF80
80% gasoline (PFI)
20% ethanol (DI)

E20
80% gasoline (DI)
20% ethanol (DI)

DF50
50% gasoline (PFI)
50% ethanol (DI)

E50
50% gasoline (DI)
50% ethanol (DI)

Exhaust Particle Size and Number



DF80:

80% gasoline (PFI) 20% ethanol (DI)

E20:

80% gasoline (DI) 20% ethanol (DI)

DF50:

50% gasoline (PFI) 50% ethanol (DI)

E50:

50% gasoline (DI) 50% ethanol (DI)

Conclusions 1/2

The effects of the **ethanol/gasoline dual fueling** on the particle emissions in a small **SI** engine was investigated.

Engine worked at **3000 rpm**, **4000 rpm** and **5000 rpm full load** representative of urban driving conditions.

Engine was fueled with pure ethanol and gasoline and different dual fuel ratio of ethanol in gasoline (**DF80-DF50**).

A smoke meter were used for particle concentration measurement.

A Engine Exhaust Particle Sizer (**EEPS**) was used for counting and sizing of the particles in the size range **5.6-560 nm**.

Conclusions 2/2

Particle mass decreases with ethanol content except for **DF50 @ 4000 rpm**;
Particle number & size decreases with ethanol content except for **DF50 @ 4000 rpm**.

The particle emissions is strongly affected by:

➤ **Fuel:**

- oxygen content: sooting reduction tendency;
- evaporation rate: selective and enhanced evaporation of ethanol and lighter compounds of gasoline: favorable conditions for the formation of particles from the sooting compounds of gasoline;

➤ **Engine operating point:**

- In-cylinder temperature: affects evaporation conditions.



Thank you for the attention



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