Particulate Matter Emission From Different Combustion Modes in a 2/4 Stroke Switchable Direct Injection Gasoline Engine

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Overview

- **Introduction**
- **Experimental Apparatus and test method**
- **Results and Discussion**
- **Conclusion**

Introduction

- CO2 legislation/Global Warming mandates the development of more efficient IC Engines
  - Better Fuel Economy through the engine down-sizing by boosting or 2-stroke operation, and possibly stratified charge combustion or Controlled Auto Ignition (CAI) at part load operations.
- Increased use of bio-fuels to combat the limited fossil fuels:
  - Gasoline and Ethanol mixtures: E15 to E85
- Particulate Matter (PM) emission legislation (Euro VI)
  - Direct Injection gasoline engines produces much more PM emissions than Port Fuel Injection gasoline engines

Objectives

- In response to the above challenges, an extensive research programme has been set up at Brunel:

1. To develop an advanced single cylinder research facility for research and development of more efficient and cleaner IC combustion engines;

2. to operate the engine in different combustion modes and cycles and evaluate their effects on engine efficiency and emissions;

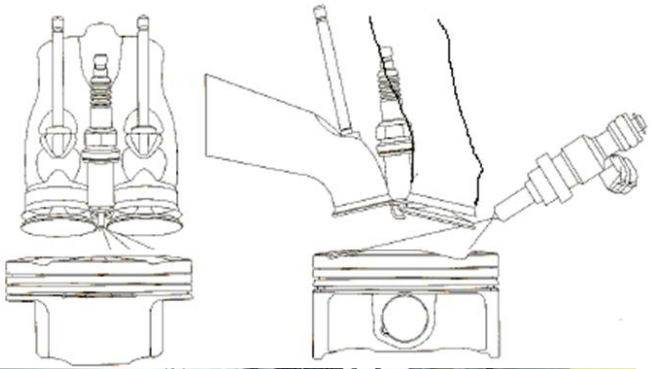
3. to investigate the effect of bio-fuels on the combustion and emissions.

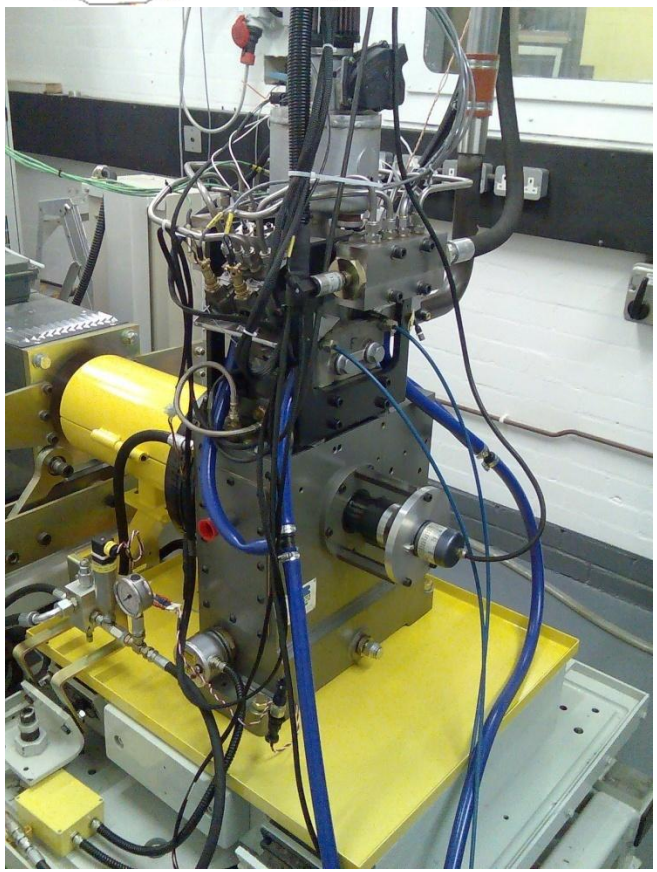
In particular, the PM emissions were measured under various combustion modes and with different ethanol contents.

2/4 Stroke Camless Engine

Table 1 Engine specifications

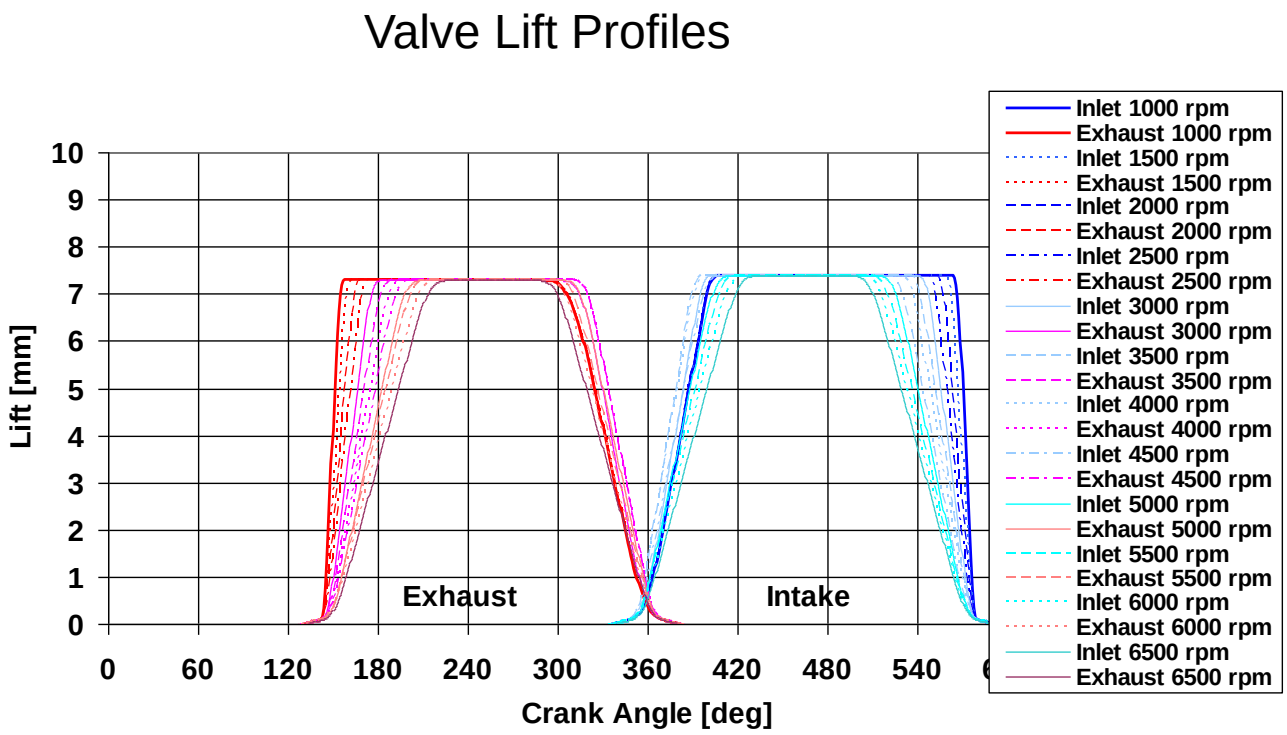
Bore × Stroke	**81.6mm×66.94mm**
Swept volume	0.35L
Compression ratio	11.78:1
Combustion chamber	Pent roof / 4 valves
Valve train	Electro-hydraulic actuation
Fuel injection	Direct injection
Fuel	Standard gasoline (RON 95)
Injection Pressure	100bar
air/fuel ratio	Stoichiometric
Intake temperature	25^{o}C



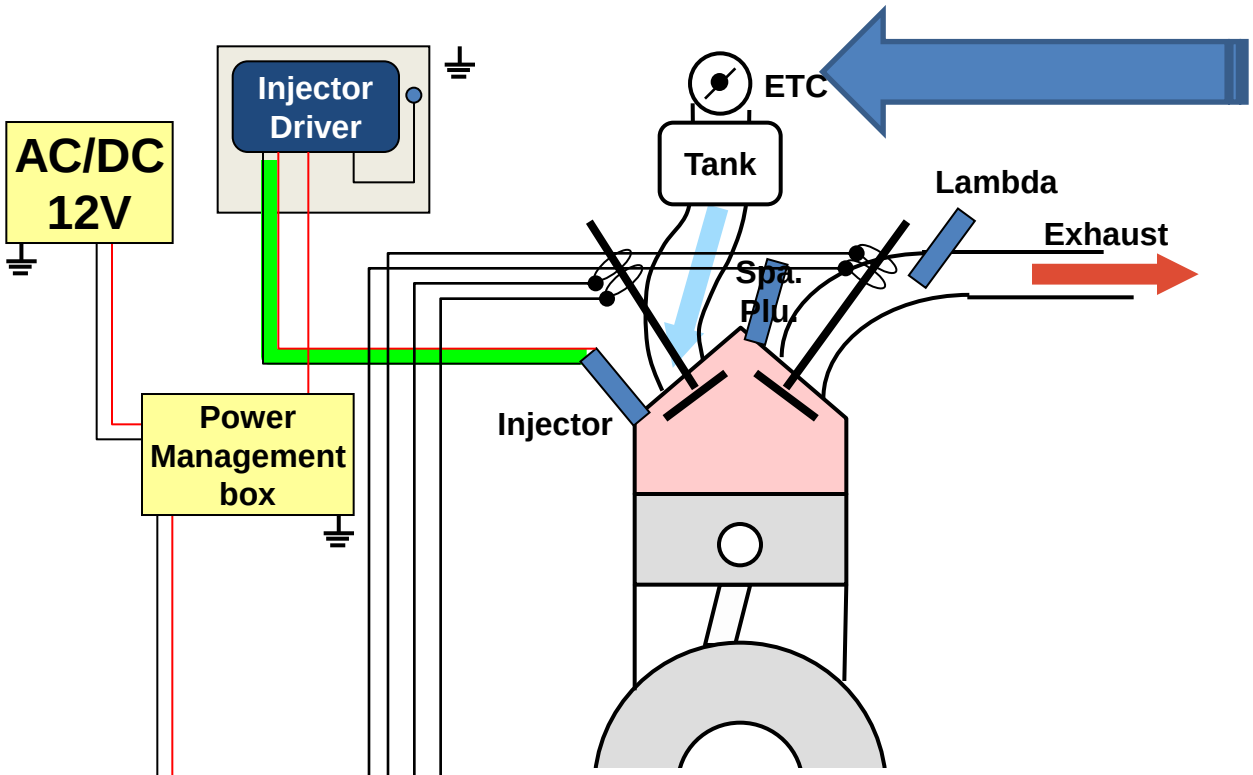


Camless Valve System

- Oil pressure: 100bar.
- Valve Lift: 0~7.3mm.



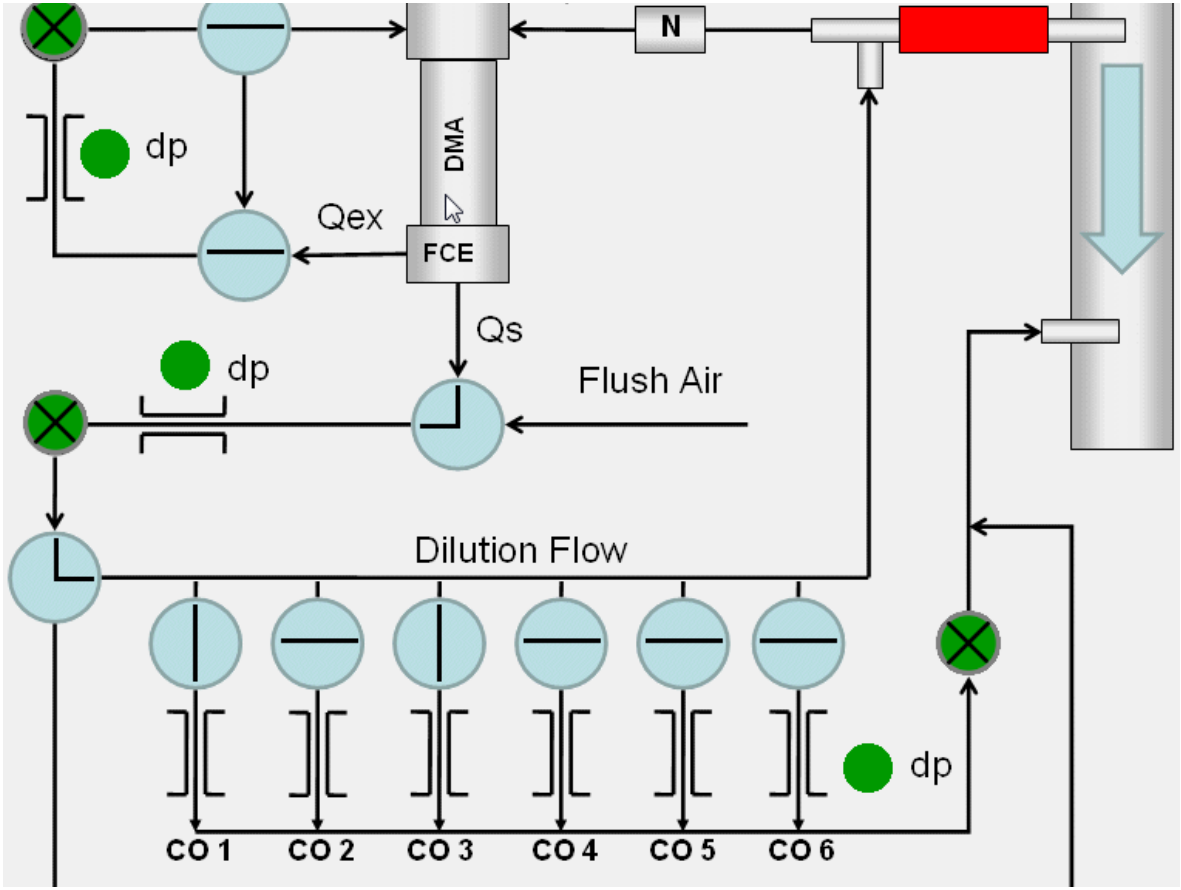
Engine Control System



Supercharger system

- Spark timing
- Injection Timing
- Injection Pulse Width
- Valve Timings
- Valve Lifts

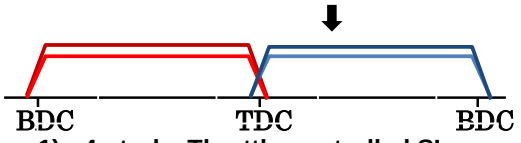
EMS VIE PM Measurement System



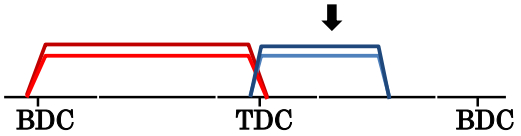
- The sample from the exhaust was allowed to pass through a charger to establish a well defined distribution of electrical charges on the particles before it is fed into the DMA.
- EMS VIE measures particles within the size range of 5 to 700 nm,
- Sampling point is 15cm downstream of the exhaust valves using 100% Dilution.
- Particulate number is displayed on the Y axis in #/cm3, while the soot diameter is displayed on the X axis in nm

Engine Operating Modes

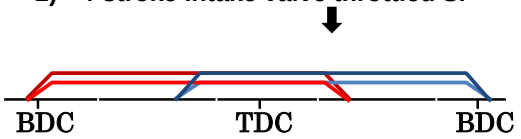
Operating point:



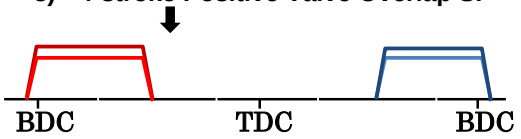
1) 4-stroke Throttle-controlled SI



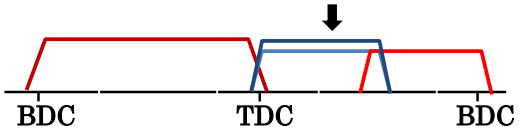
2) 4-stroke Intake vaive throttled Si



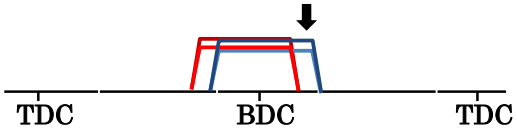
3) 4-stroke Positive Valve Overlap SI



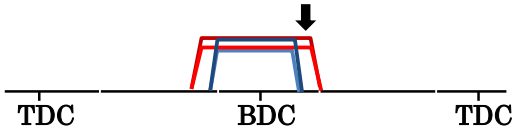
4) 4-stroke Negative Valve Overlap CAI



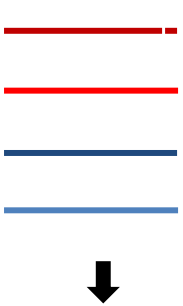
5) 4-stroke Exhaust Rebreathe CAI



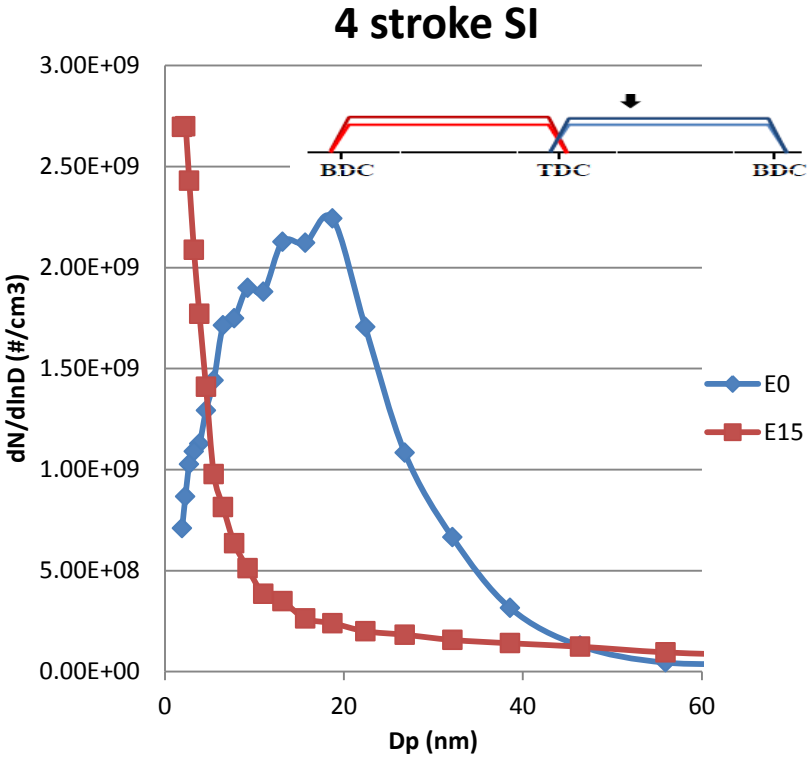
6) 2-stroke CAI

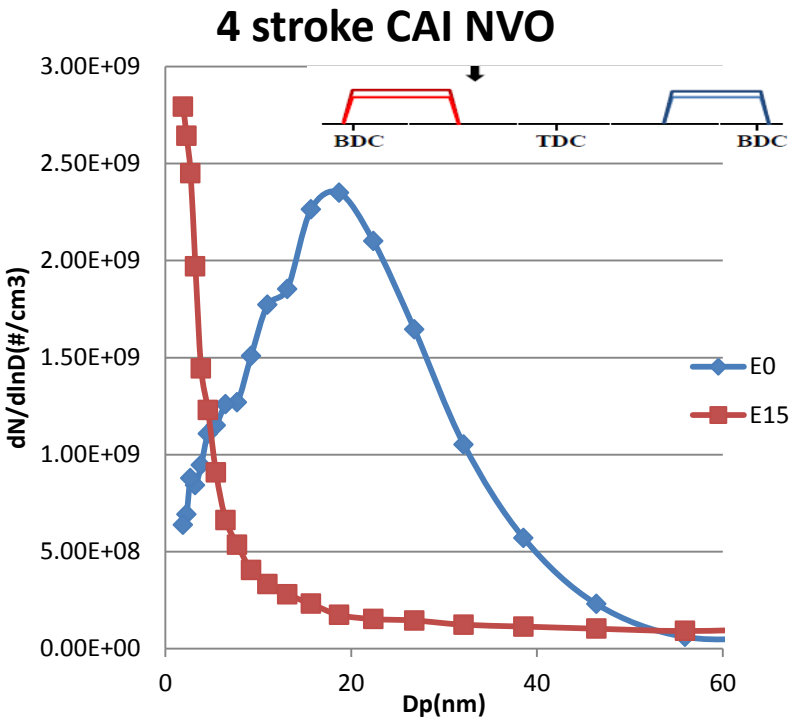


7) 2-stroke SI



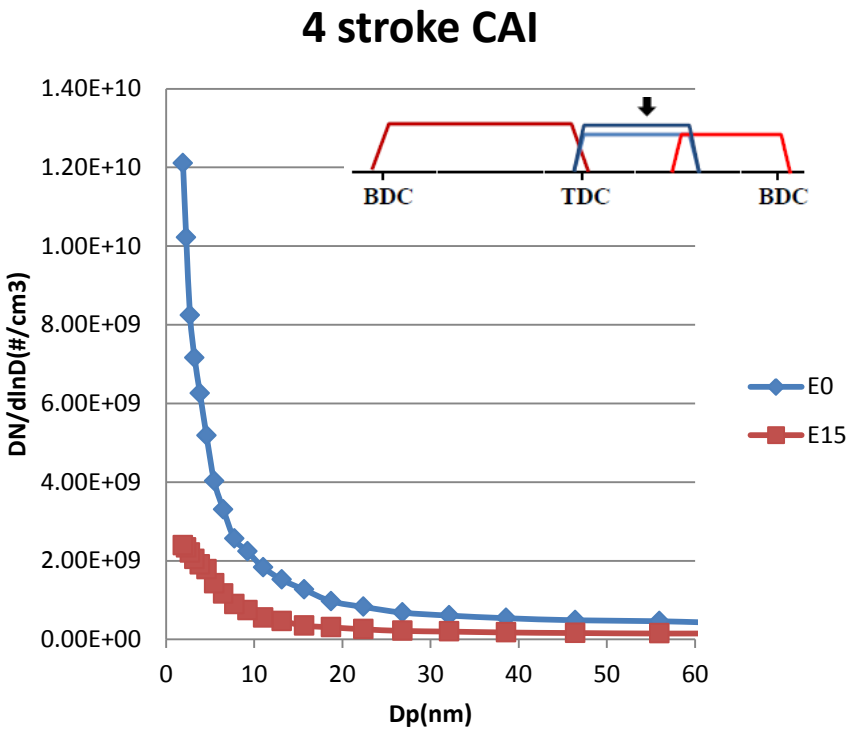
PM Emissions Results (1)

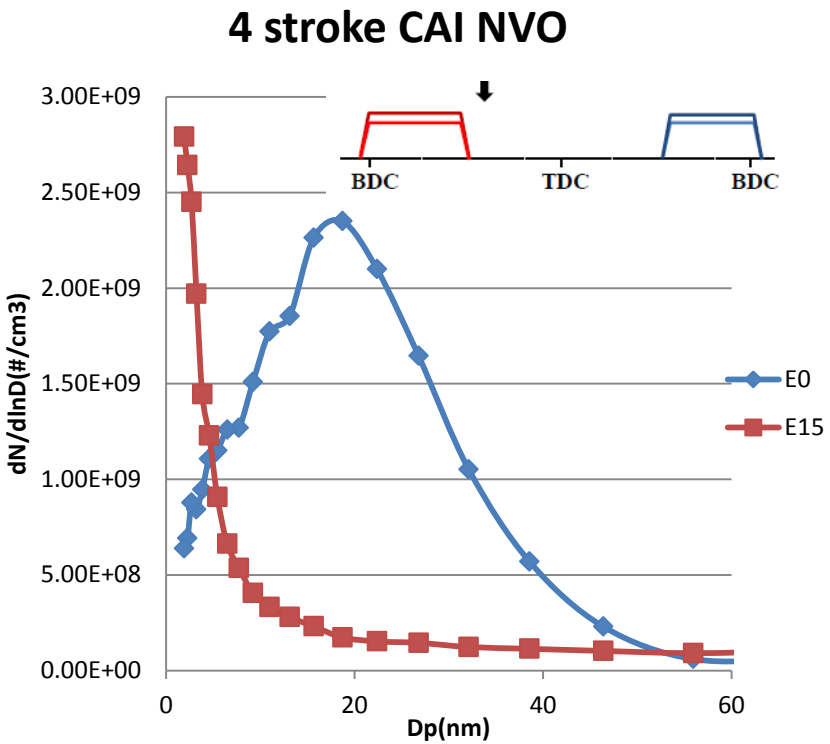




- SI and CAI with NVO produce similar PM emission.
- The number of particles of 15nm or larger in diameter decreases rapidly when the ethanol content is increased from zero to 15%.
- The particle number reaches its minimum value for particles of diameters greater than 18nm.
- Pure gasoline emits more particles at around 20nm diameters.

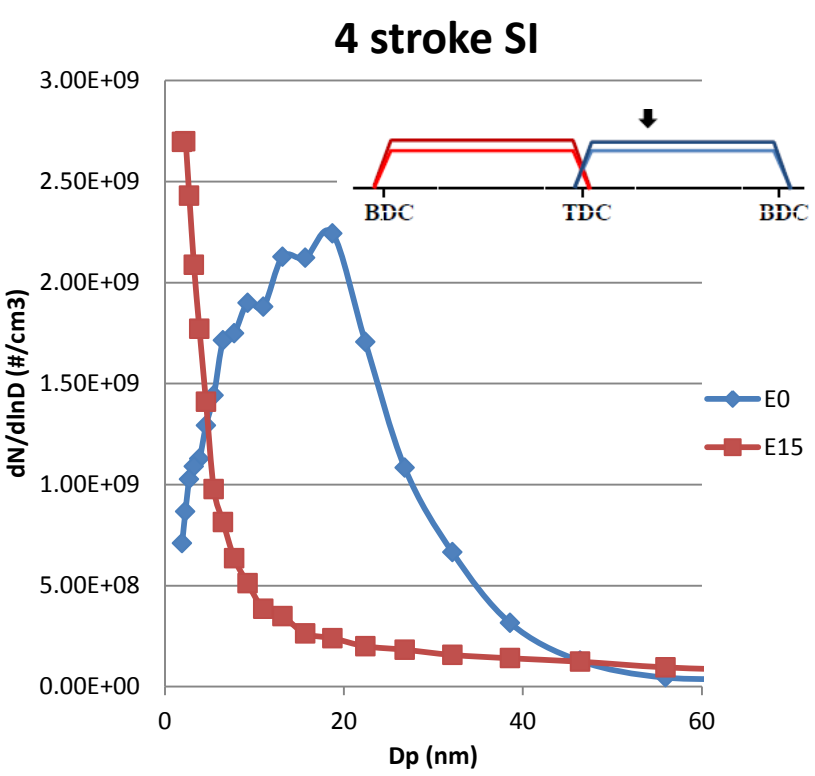
PM Emissions Results (2)

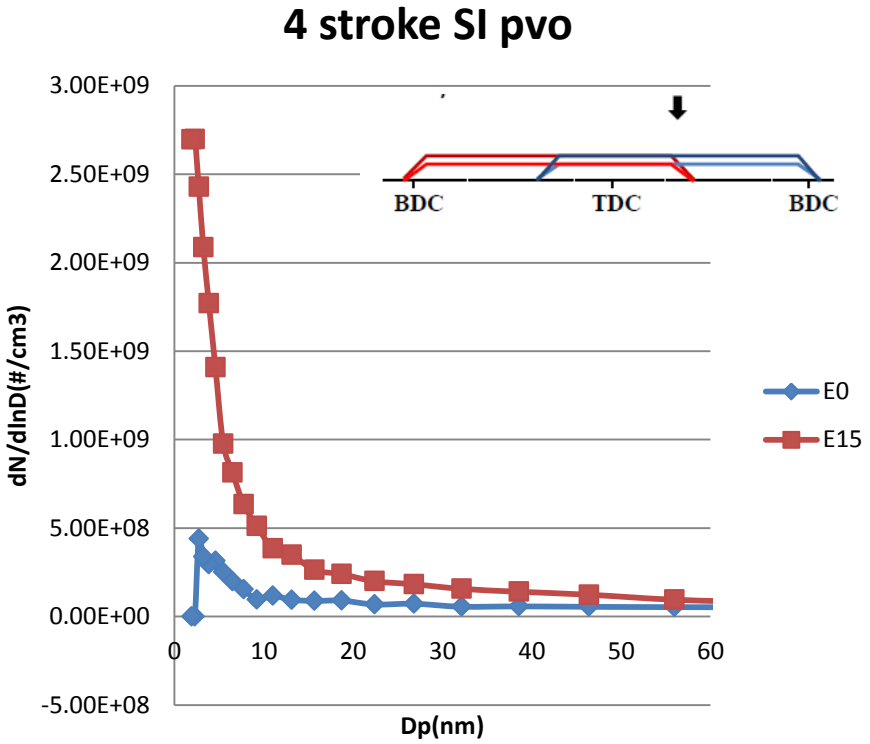




- Different PM emissions from two CAI modes
- There is no PM peak at 20nm from CAI with rebreathing
- Similar PM emissions for E15 fuel for both CAI modes

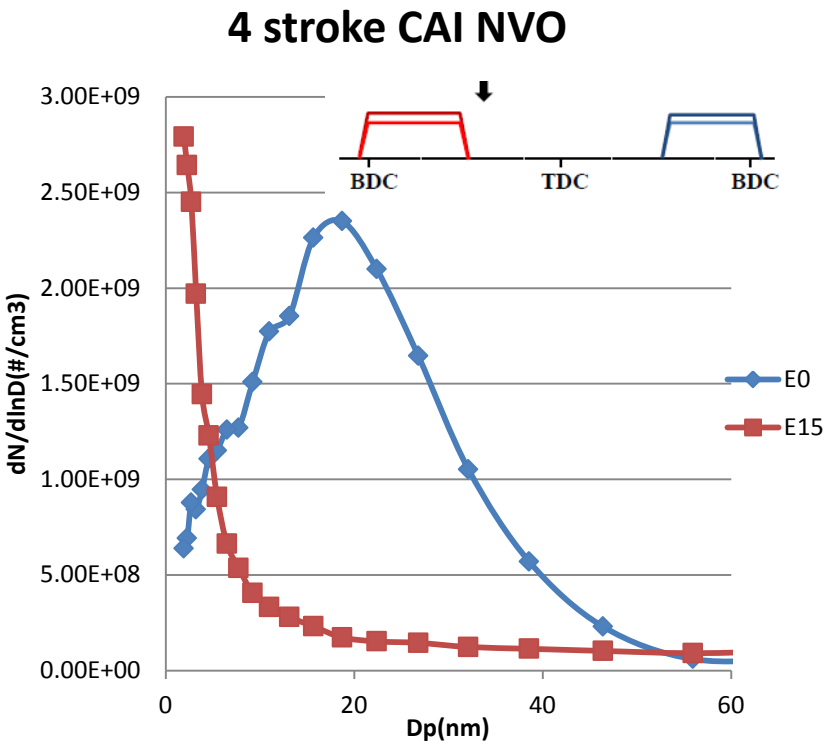
PM Emissions Results (3)

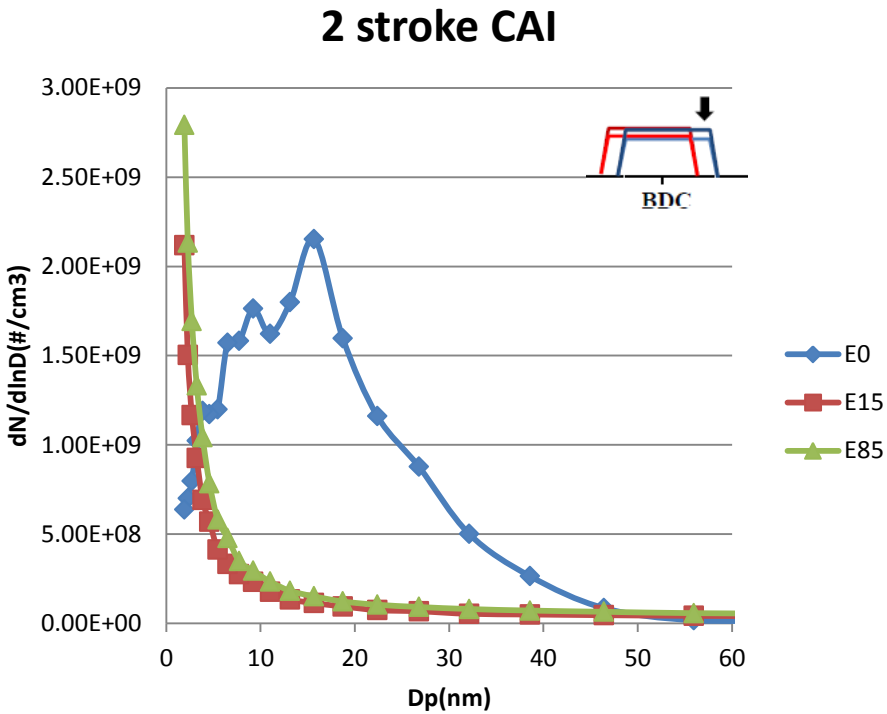




- E15 generates similar quantity of particles for both modes.
- SI with PVO produces much less particle emissions than standard SI operation.
- The enhanced evaporation of gasoline fuel leads to less fuel rich regions in the combustion process and hence the disappearance of soot particles in the size range of 20nm.

PM Emissions Results (4)

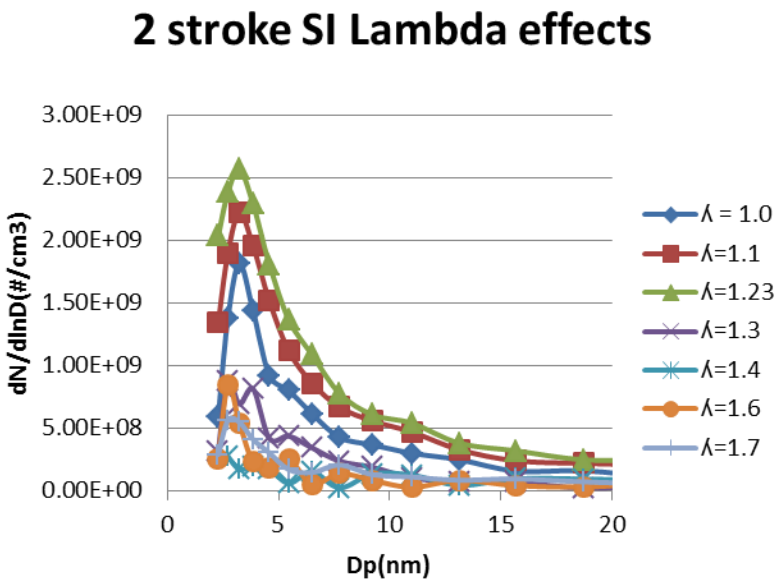


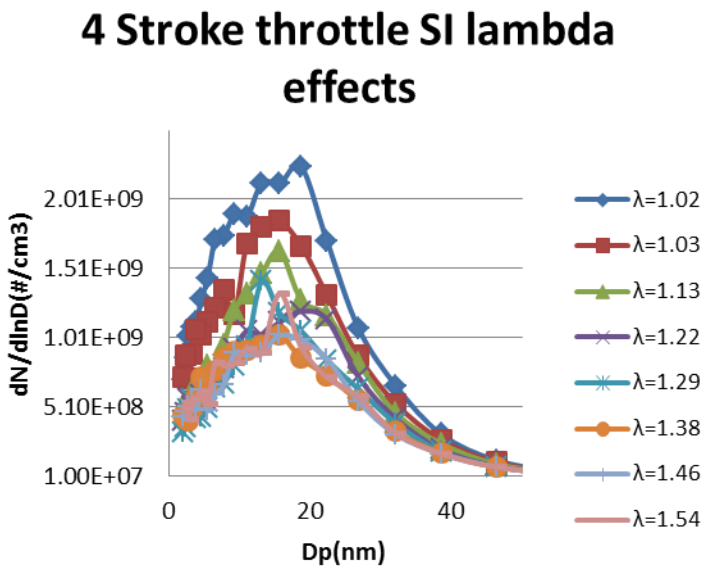


- The PM emission from 4- stroke SI and the 2-Stroke CAI display the same trend.

- Increasing the ethanol contents from 15% to 85% has little effect on particle size but it does increases the particle number.

PM Emissions Results (5)

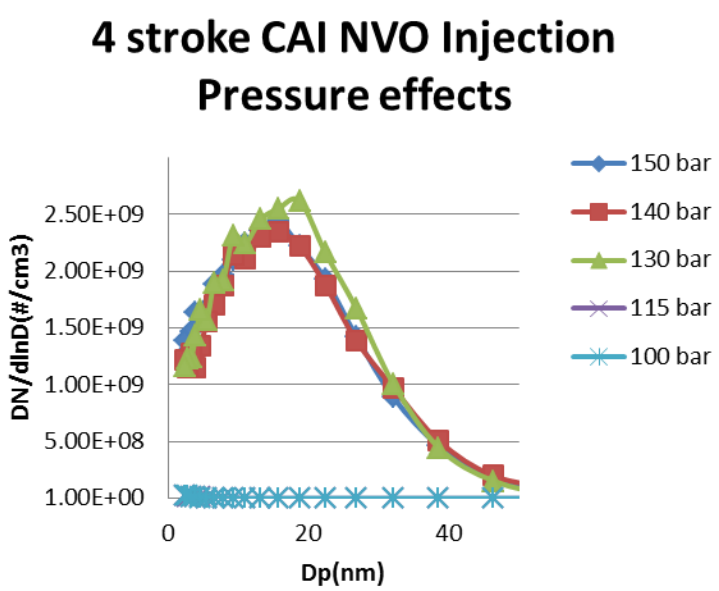


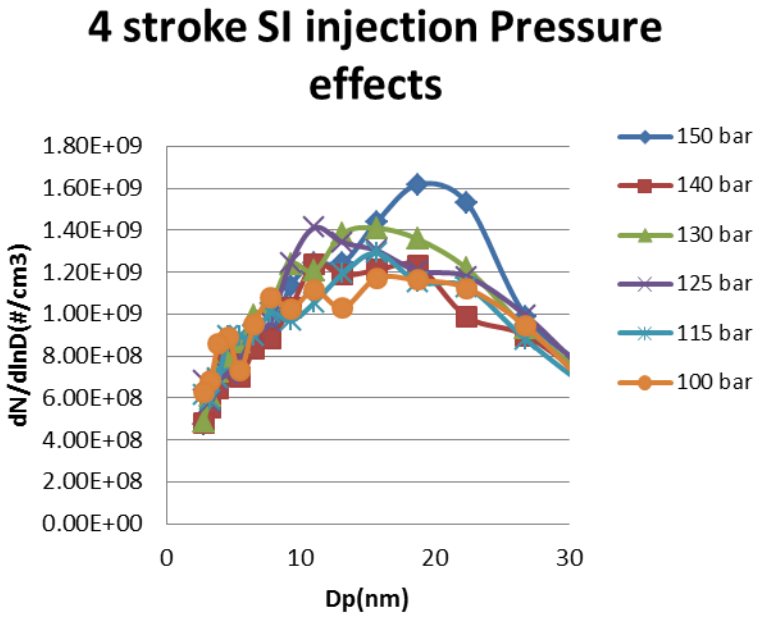


- The PM emission from 4-stroke SI and the 2-stroke SI display the same trends of reducing particulate numbers as lambda increases

- Increasing lambda from lambda=1 to about lambda=1.7 have some 2 fold effects in particulate number reductions

PM Emissions Results (6)

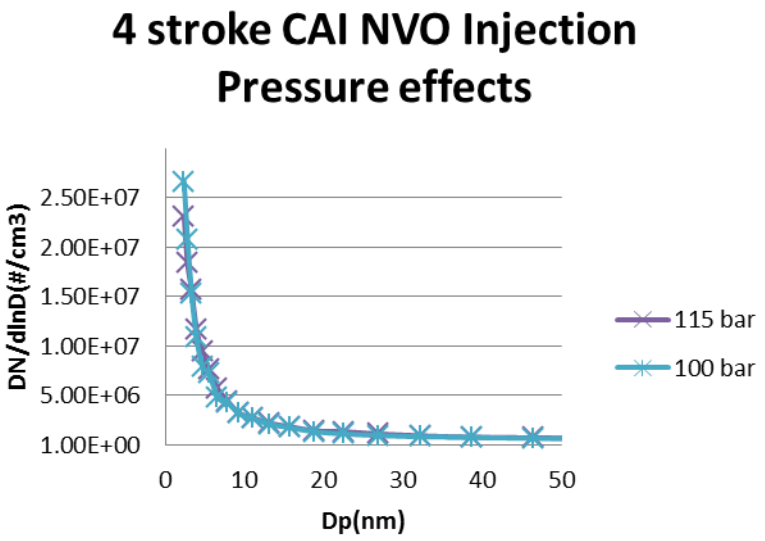


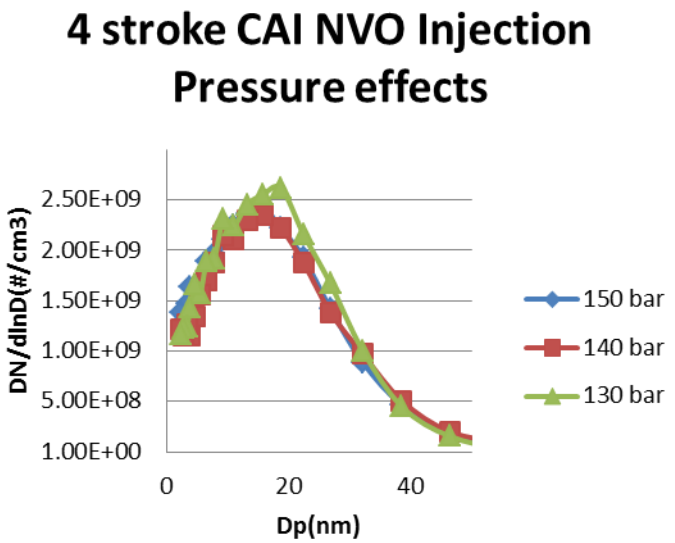


- SI and CAI with NVO shows similar trends for injection pressures of 130 bar to 150 bar., and both peak at about 18nm

- For 4 stroke SI there is no much effects of increasing the injection pressure on particles emissions.

PM Emissions Results (7)

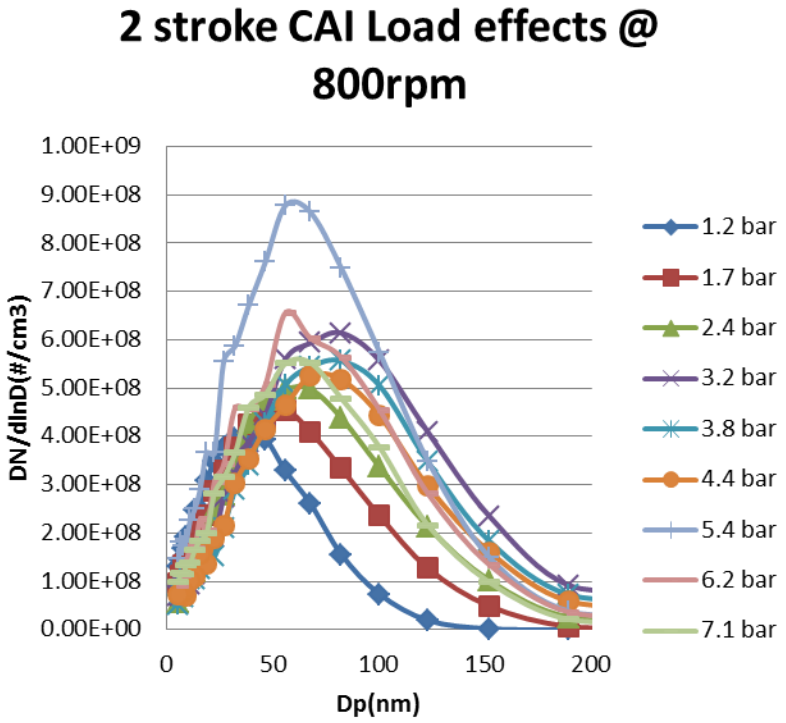




- There is no PM peak at 18nm for 100 and 115 bar this may possibly be because of the gas exchange process
- For pressures of 130 bar to 150 bar, the PM peak at 20nm and decreases slightly as the injection pressure increases to 150 bar

PM Emissions Results (5)

- Load is varied by boost pressure. Large amount of residuals was trapped in the cylinder when the exhaust valve closes earlier.
- Particles are dominated by soot particles between 50-150nm in diameter.
- The concentration of larger particles between 50nm-150nm increases with increasing load up to 5.4 bar and decreasing for very high loads of 6.2 and 7.1 bar.
- The reduction in smaller particles may be due to faster evaporation of liquid fuel due to higher residual gas temperature at high loads .



Summary

- The particle emissions from the DI gasoline engine are dominated by smaller particles.
- The effect of ethanol content on soot reduction becomes saturated when ethanol concentration reaches 15%, irrespective of the combustion modes.
- The combustion of ethanol and gasoline blends minimises the presence of soot particles in peak regions of 10nm to 30nm.
- Hotter charge and better mixing are the main parameters affecting the soot particles in the exhaust irrespective of the combustion mode.

Thank You