Transient two-phase flow interactions on the surface of a diesel injector nozzle

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EPSRC
Engineering and Physical Sciences Research Council

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Contents

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Introduction: Motivation

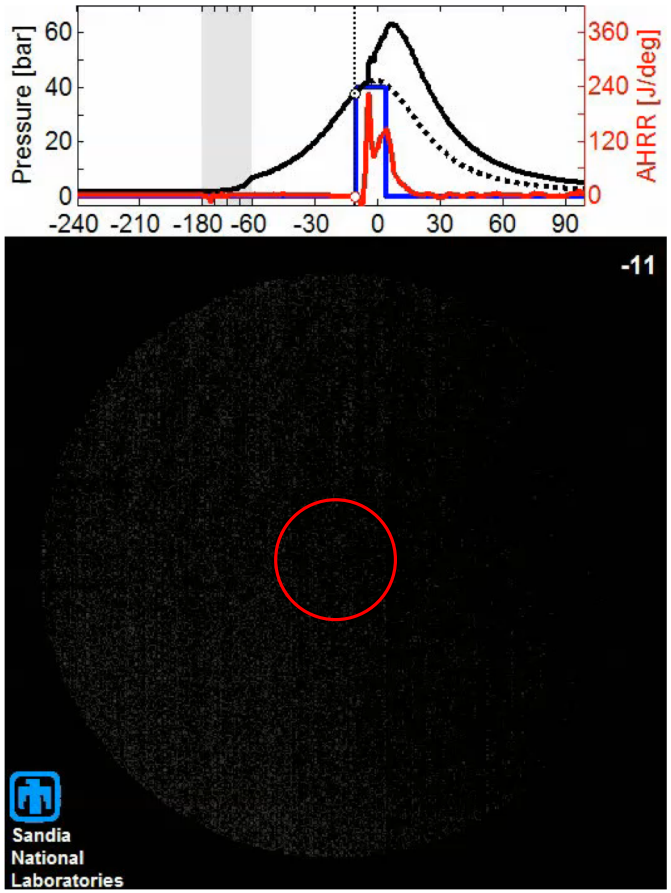
- Progressively increasing vehicle emissions regulations
- Fuel-air mixing is highly dependent on fuel injection equipment (FIE)

New designs incorporate:

- Higher injection pressures ➔ Increased fuel stresses
- Higher ICP & ICT ➔ Higher nozzle temperatures
- Reduced nozzle geometries ➔ Increased susceptibility to deposits
- Multiple injection strategies ➔ **More transient injection phases**

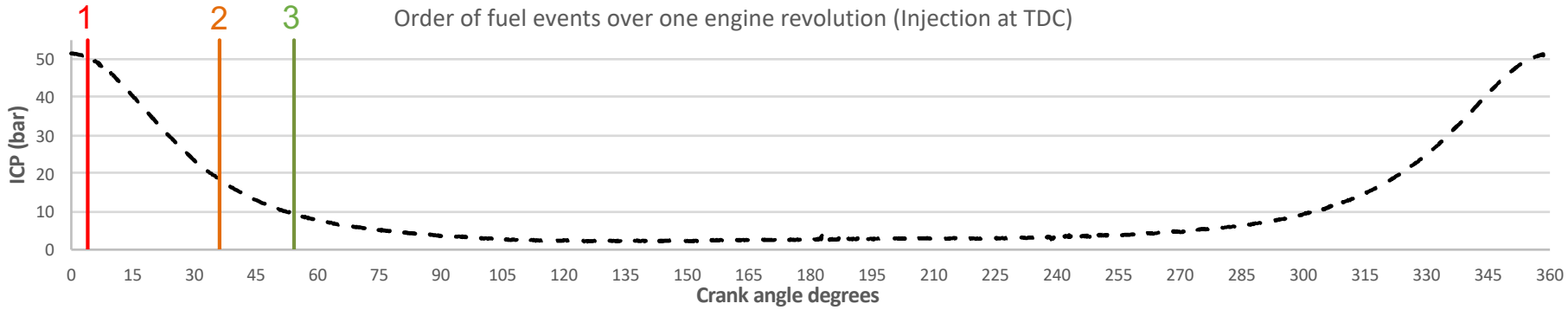
➔ **Accelerated deposit formation and increased uHC emissions**

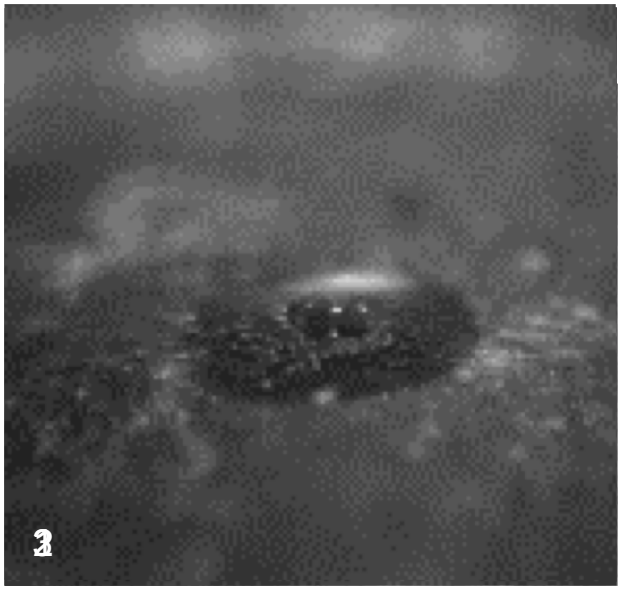
Lack of information in the near-nozzle region post-injection



ECN 2018

Introduction: Previous findings (Turner 2016)





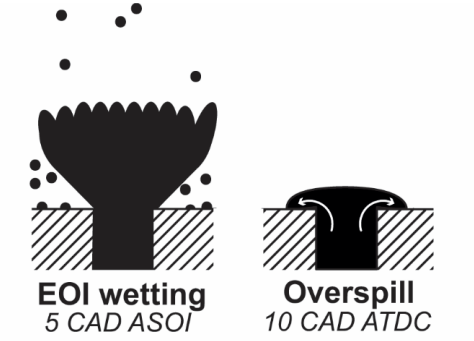
3. Expansion and spill:

Engine	Proteus RRCM
Strokes	2
Engine speed	500 rpm
Fuel	n-dodecane
Motored pressure	5 MPa
Injection pressure	50; 150 MPa
Peak ICT	~700 K

Introduction: Research questions & hypothesis

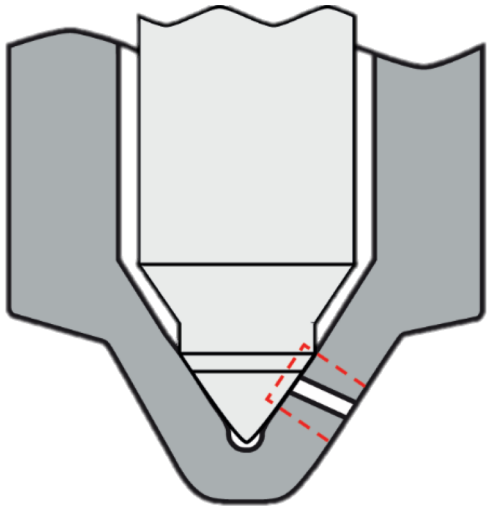
Research questions

- Does surface wetting occur primarily due to end of injection (EOI) wetting or overspill?

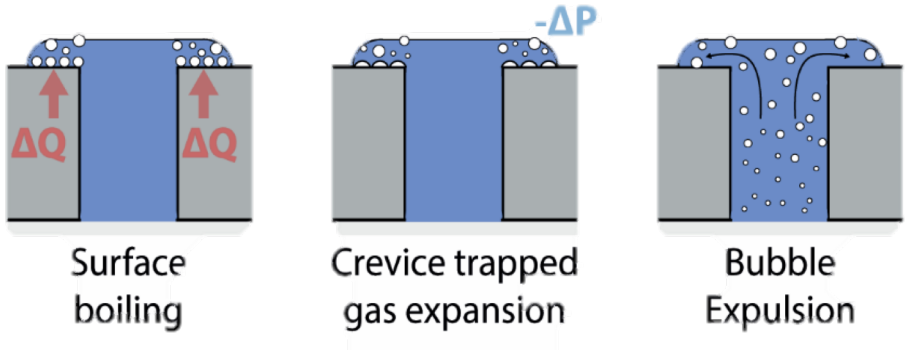


- By which mechanisms are large fluid structures released into the cylinder?

- What are the mechanisms that result in surface bubbling?
  - Surface boiling?
  - Crevice trapped gas expansion?
  - Bubble expulsion?



Valve covered orifice (VCO) injector



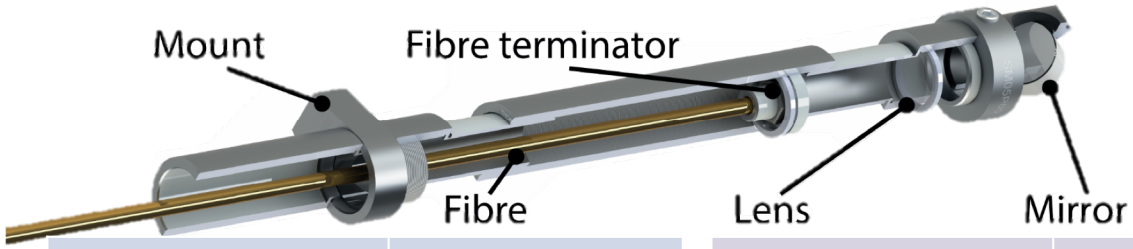
Methodology

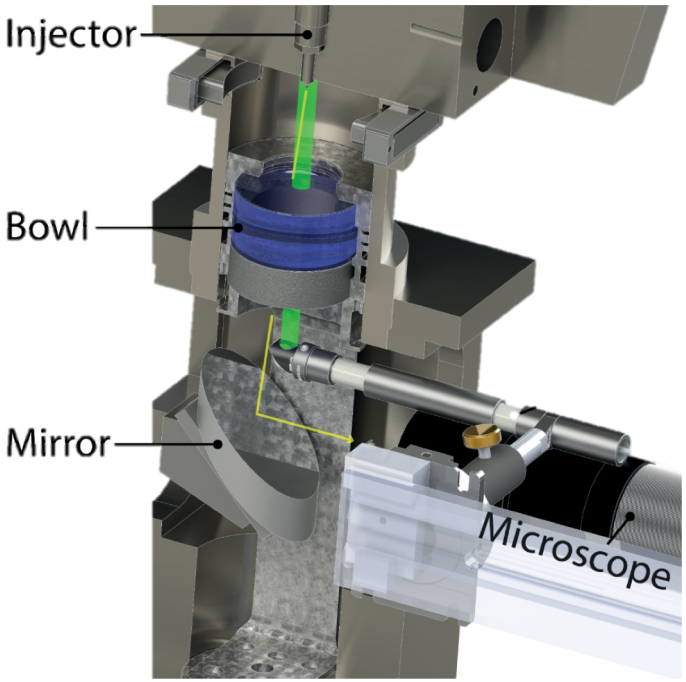
Engine

- 4-stroke optical research engine with Ford PUMA head
- Motored at idling-like conditions
- Delphi, DFI 1.3 valve covered orifice (VCO) injector

Optics

- Long-distance microscopy
- Copper vapour laser illumination
- Collimated 8 mm diameter beam





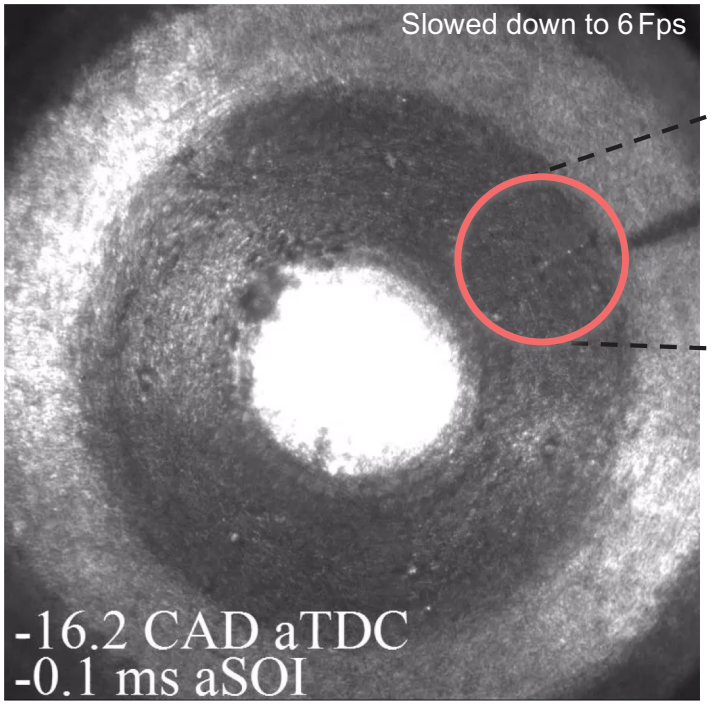
Engine speed	1,000 rpm
Compression ratio	16
Fuel	EN590 Diesel
Skip-cycle	1:7

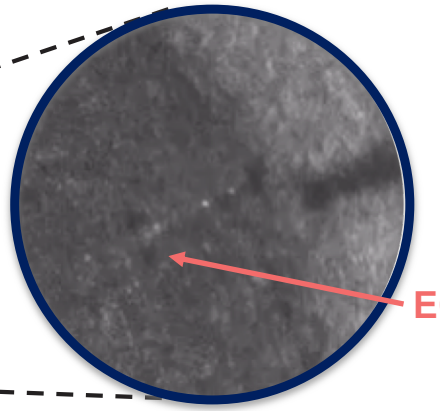
Orifice diameter	135 µm
Injection pressure	20 MPa
Start of injection	-18 CAD
Injection pulse	600 µs

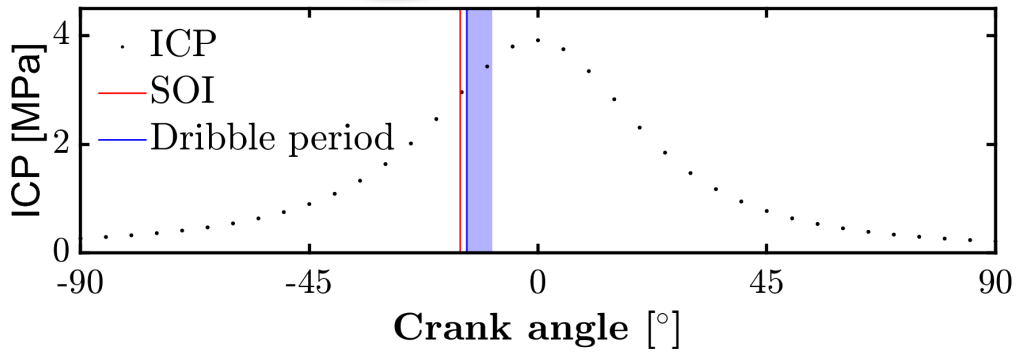
Camera	Phantom V12.1
Frame rate	10,000 fps
Frame resolution	752 × 752 pixels²
Field of view	5.22 × 5.22 mm²

Results: The end of injection

- Large liquid structures released into the cylinder
  - ➔ May contribute towards engine-out emissions
- Dispersion angle reduced into large liquid columns
- Ligaments tore away close to the nozzle surface
- Fluid structures left adhering to the surface retracted back causing **EOI wetting**





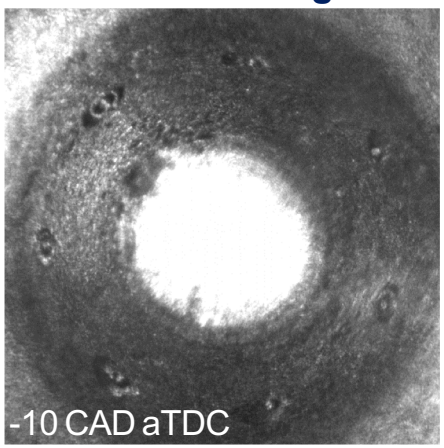


Results: The expansion stroke

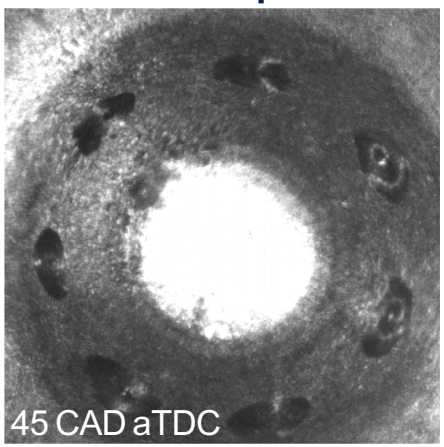
- Fuel overspills from the orifices as the ICP drops (15:135 CAD)
- Overspill is frequently interrupted by vapour pockets
- Orifice-trapped gas expands, dislodging residing fuel

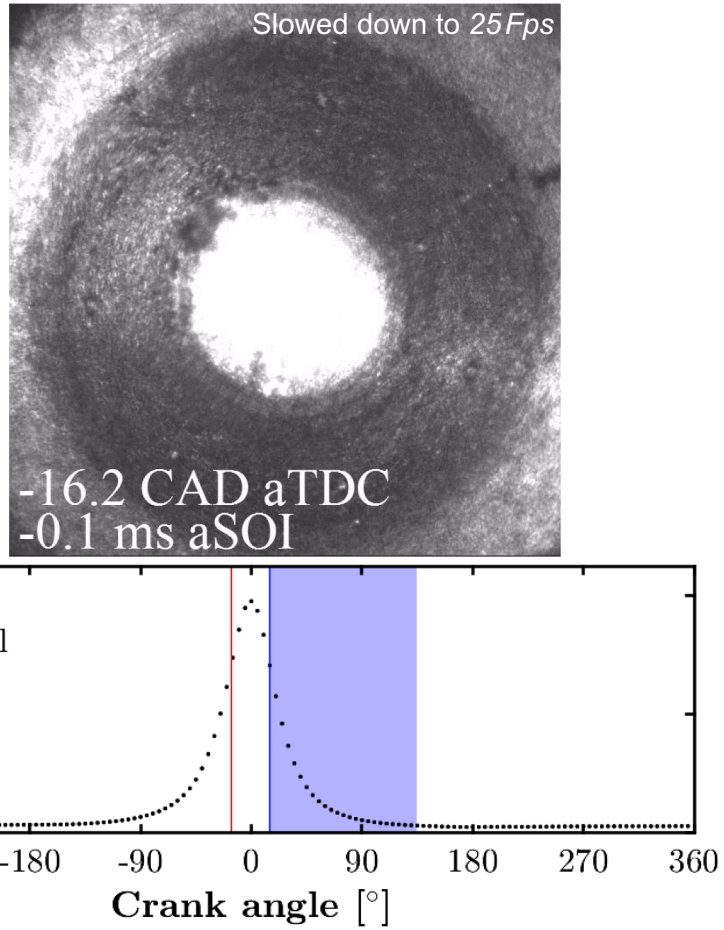
➔ Overspill caused significantly more surface wetting than EOI wetting

EOI wetting



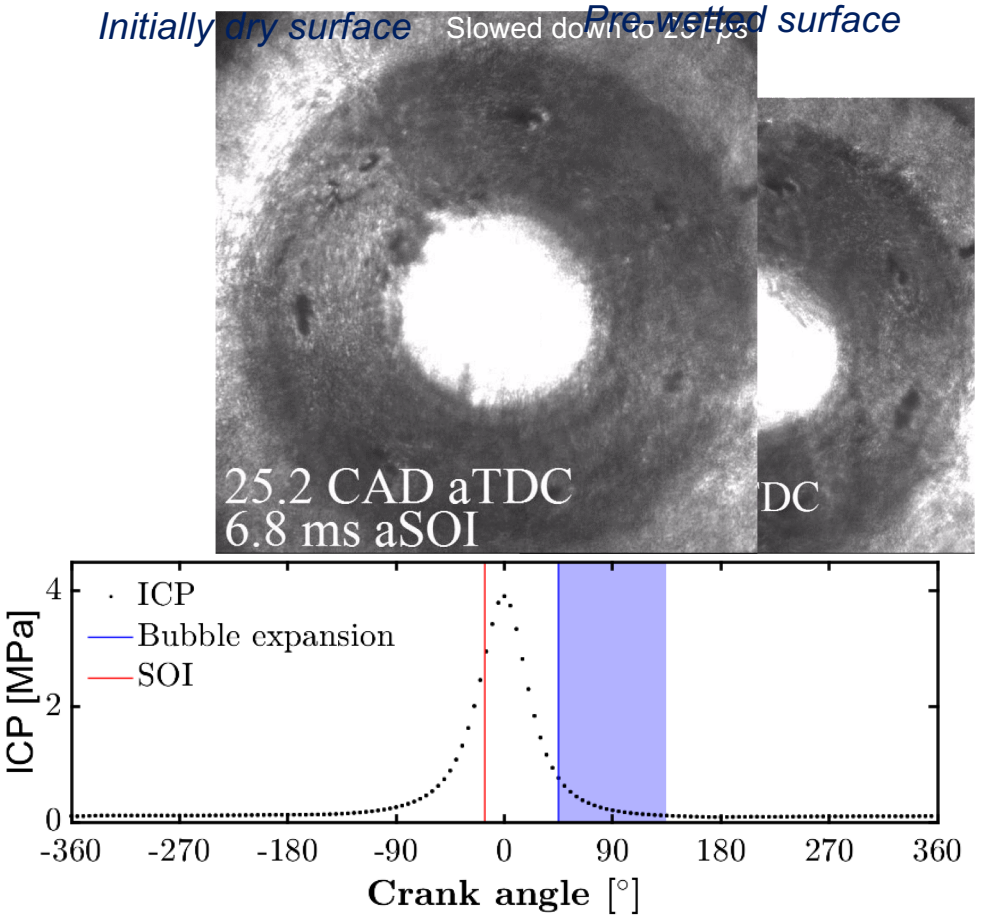
Overspill





Results: The expansion stroke

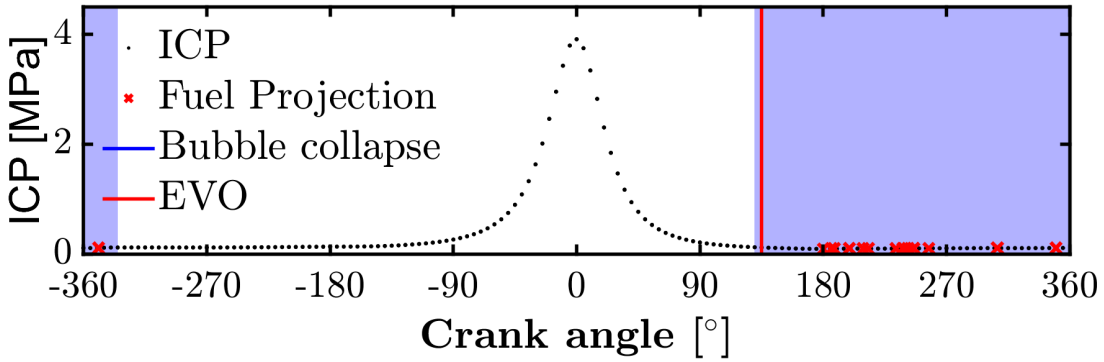
- Bubbles agglomerations become visible at 45 CAD ATDC
- They continually grow until exhaust valve opening (EVO)
- Boiling is unlikely at 45 CAD due to Diesels high vapour saturation temperature at high ICPs
- Comparison made with a nozzle pre-wetted by the previous injections
  - Bubbling is only observed close to the orifices, **disputing boiling** and **crevice trapped gas expansion**
  - Bubbles appear to emerge from the orifices, **supporting bubble expulsion**

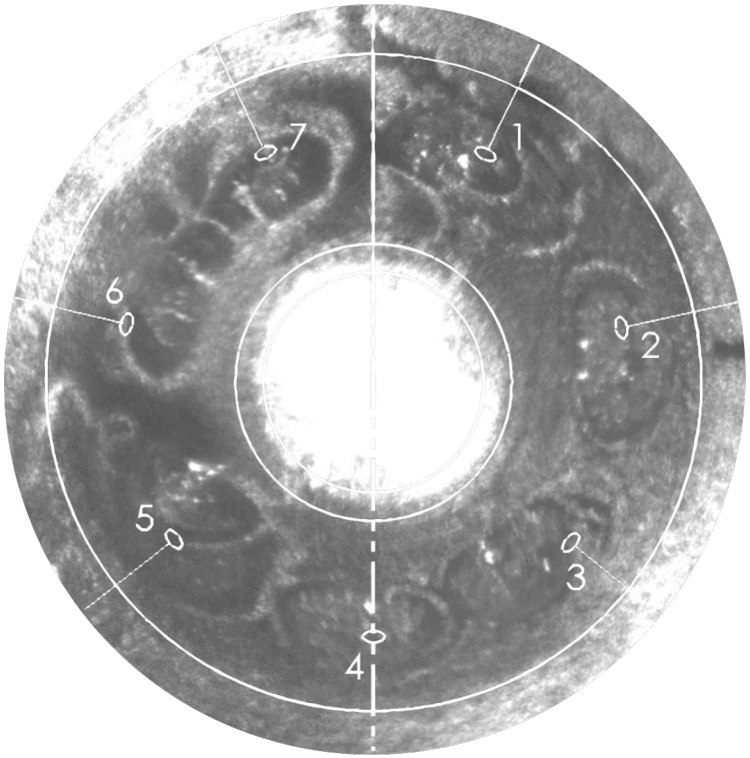


Results: The exhaust stroke

- Bubble agglomerations became unstable around exhaust valve opening (EVO), 130 CAD ATDC
- Main mechanisms of collapse:
  - Chain collapse: Orifice 2
  - Agglomeration collision: Orifices 1 & 7
  - Giant bubble collapse: Orifice 5
- Bubble collapse regularly projected fuel into the cylinder

➔ Large air-borne droplets may result in engine-out emissions

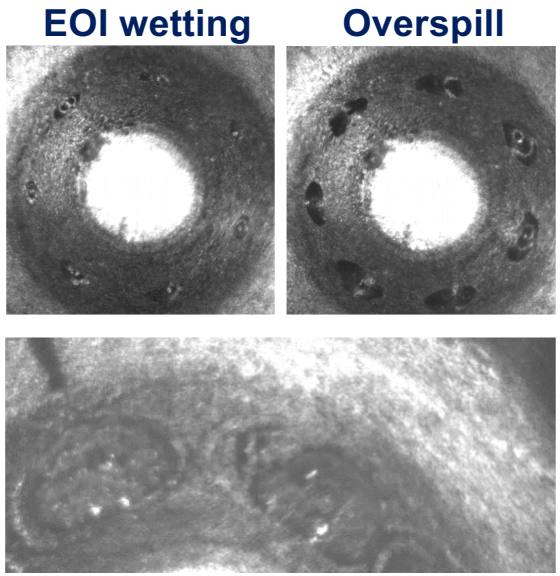




Conclusions

Does surface wetting occur primarily due to EOI wetting or overspill?

- The expansion of orifice trapped gas resulted in a large volume of over-spilled fuel
- End of injection wetting was insignificant in comparison

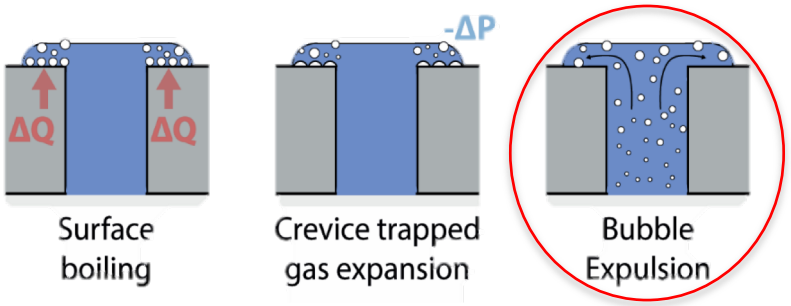


By which mechanisms are large fluid structures released into the cylinder?

- Dribble, fuel projection during bubble collapse
- The removal of nozzle residing fuel had a high dependence on the timing due to the varying ICP

What are the mechanisms that results in surface bubbling?

- Boiling and crevice trapped gas expansion were disputed
- Evidence of bubbles emerging from within the orifices
- Further research required



Thank you for your attention

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