A Micro-Variable Circular Orifice (MVCO) Fuel Injector for Zoned Low Temperature Combustion

Deyang Hou, Principle Investigator, QuantLogic Corp., Texas

Jianzhao Li, Ming Jia, Dalian QuantLogic Tech Co., China
Zhi Wang, Shijin Shuai, Jianxin Wang, Tsinghua Univ., China

DOE 12th DEER Conference
Detroit, MI, August 20-24, 2006

Agenda

- **Mixed-mode Combustion**
  - Why Mixed-mode (HCCI/PCCI + Conventional) Combustion
  - Why Mixed-mode Variable Orifice Fuel Injector
- **Mixed-mode MVCO Injector**
  - Feature of Ideal Variable Nozzle
  - Feature of MVCO Injector
- **Simulation**
  - Nozzle Internal Flow
  - Spray Atomization
  - Combustion Analysis
- **Experiments**
  - Spray Visualization
- **Summary and Conclusions**

Why Mixed-Mode Combustion?
Why Mixed-Mode Variable Fuel Injector?

- HCCI – Advantages in reducing emissions, but difficult to control combustion starting point & rate, not ready for full load applications
- Conventional – Mixing controlled combustion, many years' experiences, emissions issues
- Near-term Solution:
  - HCCI/PCCI (Premixed) + Conventional
- Do we need a dual-mode variable injector?

  Conventional multi-hole nozzles are hard to make the spray penetration adaptive for low & high load given different back pressure; issues with early injection
- Wall wetting & HC emissions are key issues

What Do We Want Control ?

1. Control Local λ

- Variable Air Breathing (attributes & quantity, complex)
  VVT (Promising); EGR (Intrinsic Contradiction);

- Variable Nozzle (Flexible, Fast Response)
  Variable Orifice Exit Area;
  Variable Penetration and Spray Pattern;
  Variable SMD;

2. Control Reaction Rate

sensors, fuel dose and timing, EGR;

Ideal Variable Nozzle (Structure)

- Continuous vs. step variable
- Easy to find optimization in design parameter space
- *Simple structure*
- *Robust*
- *Low cost*

- *For over 50 years, people have been making different efforts for a practical variable nozzle for Diesels, but practical results are limited – it's challenging*

Cutting Edge Technologies (Ref. Roger Bosch, DEER 2004)

- Bosch's Piezo-injector with coaxial-vario-nozzle CRI4-PV

  Novel design, however, it's *step variable, complex to fabricate, it has dual needles;*

- Bosch's CRS4 – hydraulically amplified diesel injection systems

  Rail pressure – 1350 bar, amp 1:2

  cost increase along with rail pressure;

  Will rail pressure continuously keep going up?

MVCO Injector Feature (patents issued and pending, PCT/IB2005/051474)

The moving needle and nozzle body generate a micro-variable circular orifice, which is coupled with micro-channels, is equivalent to a 7~50 variable micro-hole nozzle with hole-diameters less than 0.10mm, with minimum goes to 0.05mm; It can generate a conical spray only or mixed-mode conical-multi-jet spray patterns to meet the needs of different engine operating conditions.

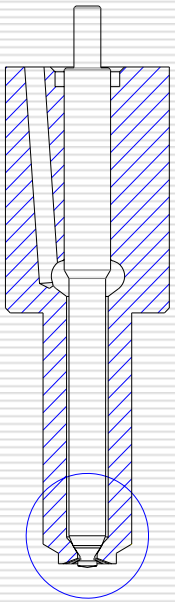


Fig. 1

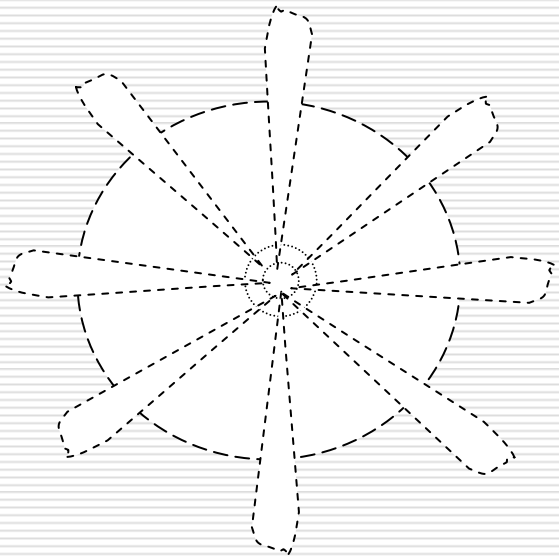
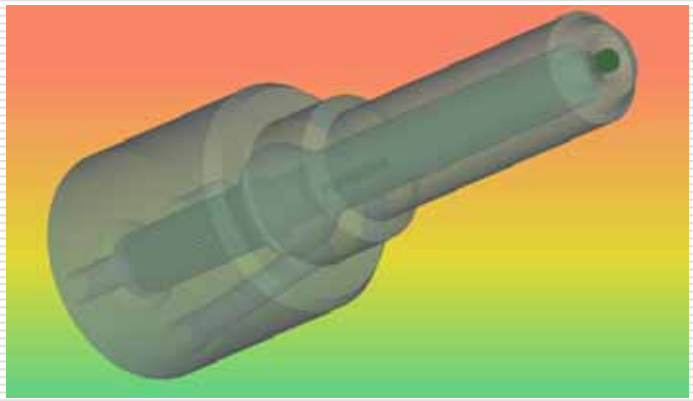


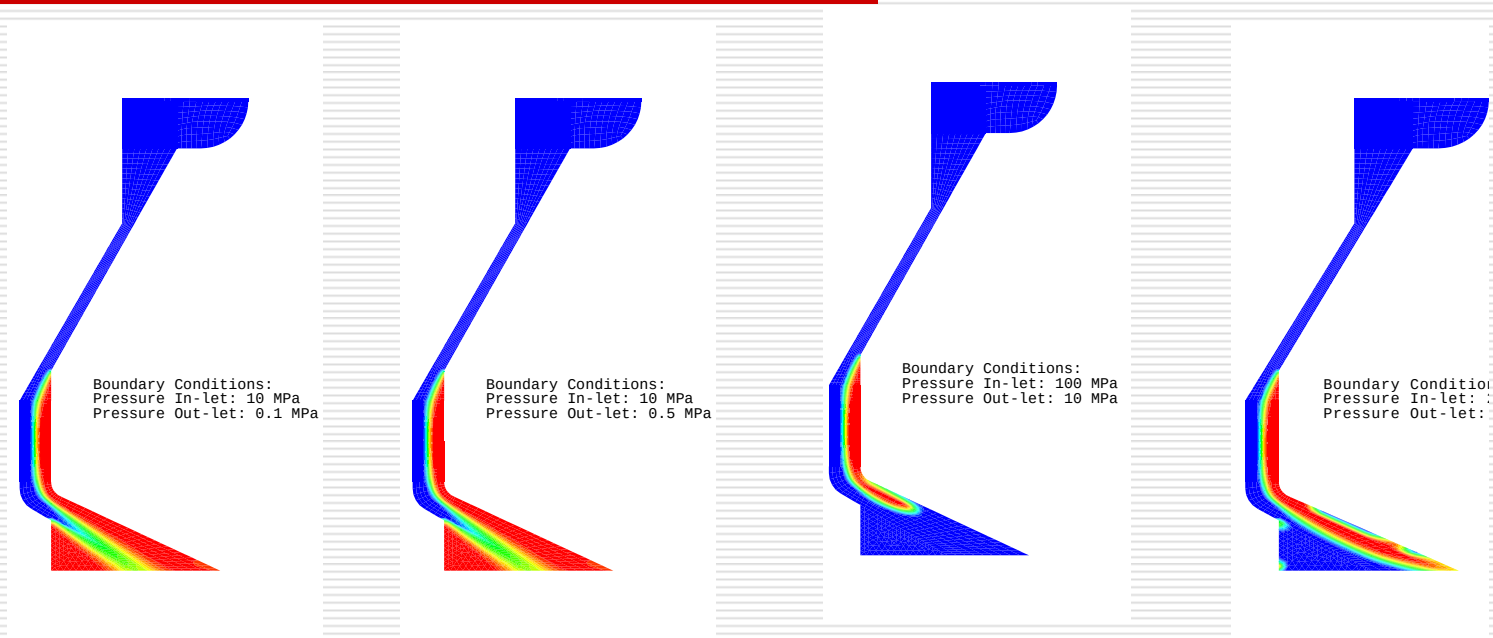
Fig. 4



Advantages of Mixed-Mode MVCO Nozzles

- Self-cleaning variable orifice - eliminates clogging
- demands less common rail pressure
- Realize rate shaping
- Small lift, fast response
- Low cost – key advantages over other inventions
- Durable
- Dual mode – HCCI + conventional
- Continuously variable
- High injection rate, provides adaptive SMD and penetration;

Nozzle Internal Flow Simulation (volume fraction of gas phase)



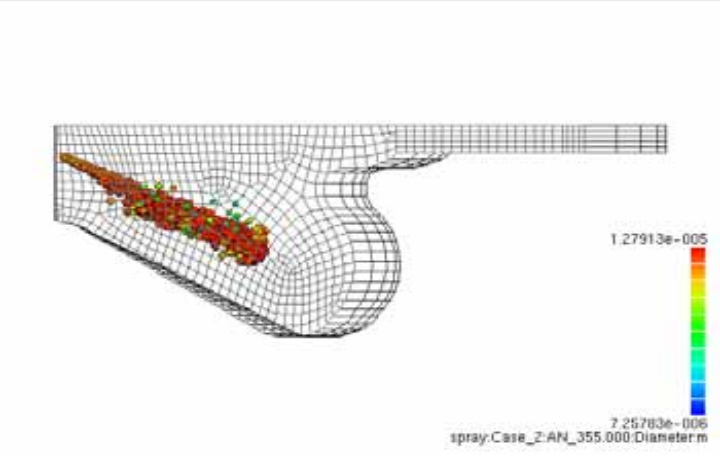
a b c d

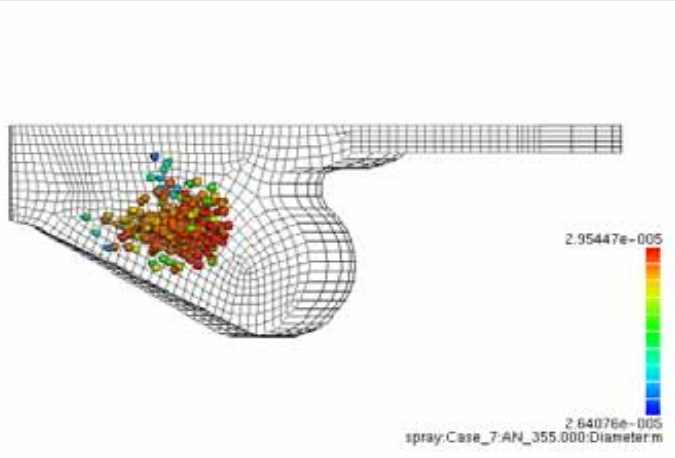
a. Po=10MPa, Pb=0.1 MPa; b. Po=10MPa, Pb=0.5MPa

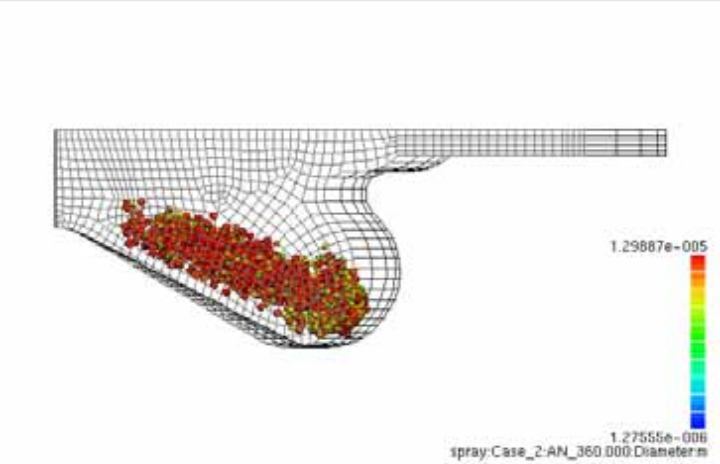
c. Po=100MPa, Pb=10 MPa; b. Po=250MPa, Pb=10MPa

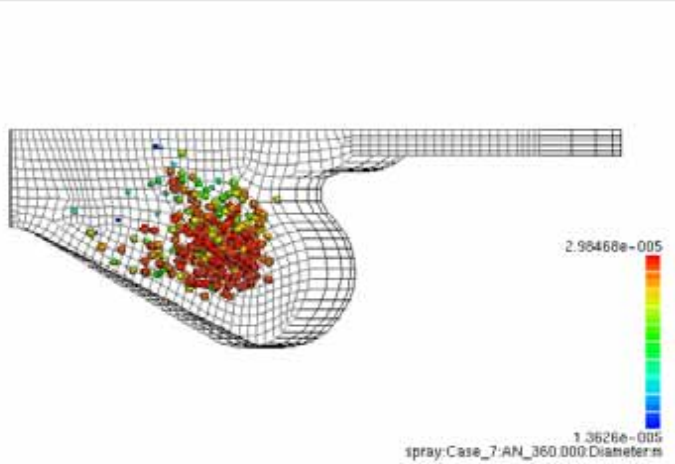
Drop Distribution

Comparing with conventional fuel injector, MVCO injector provides more dispersed drop distribution in combustion chamber space, which facilitates lean combustion, reduces emissions

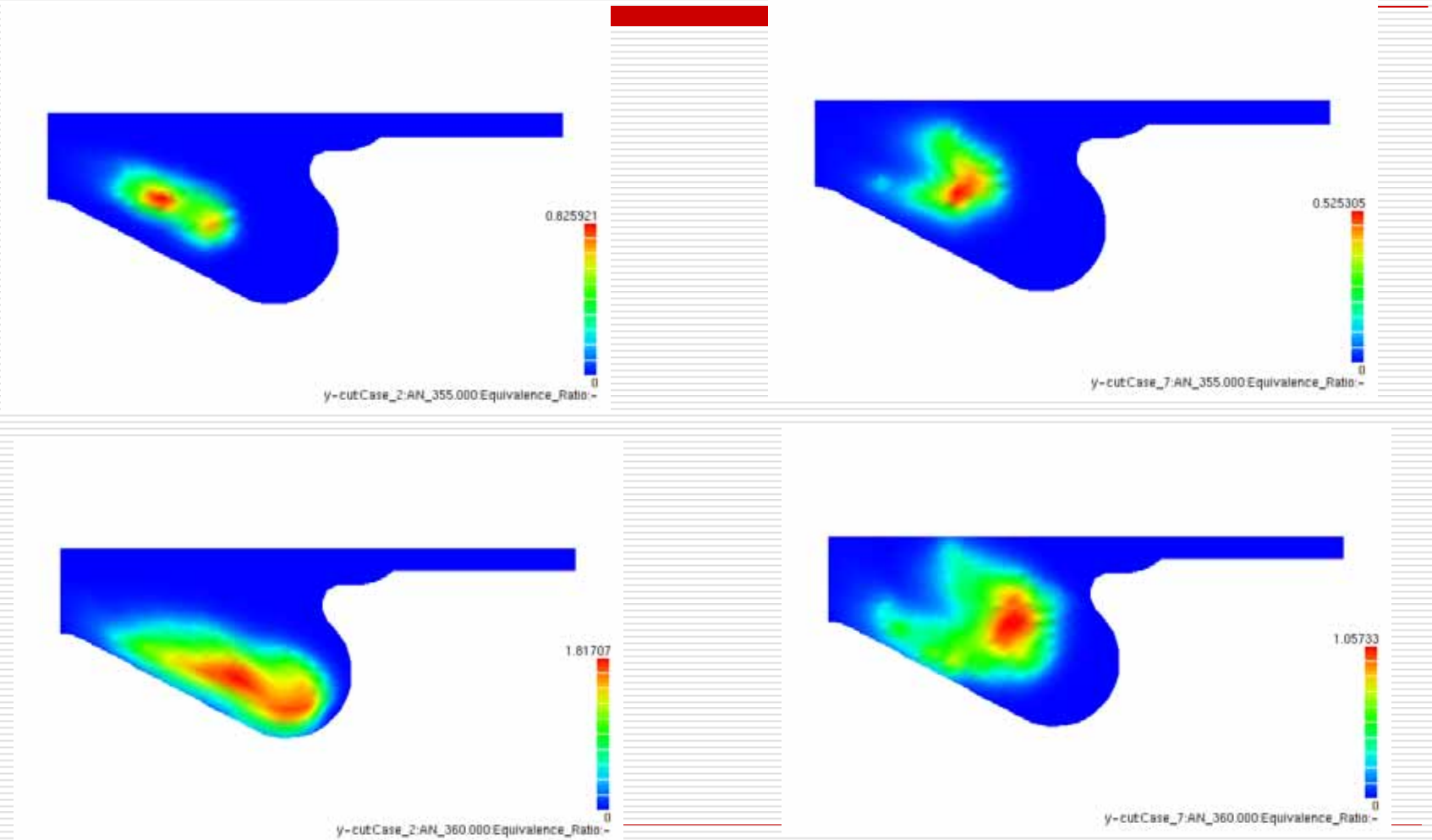




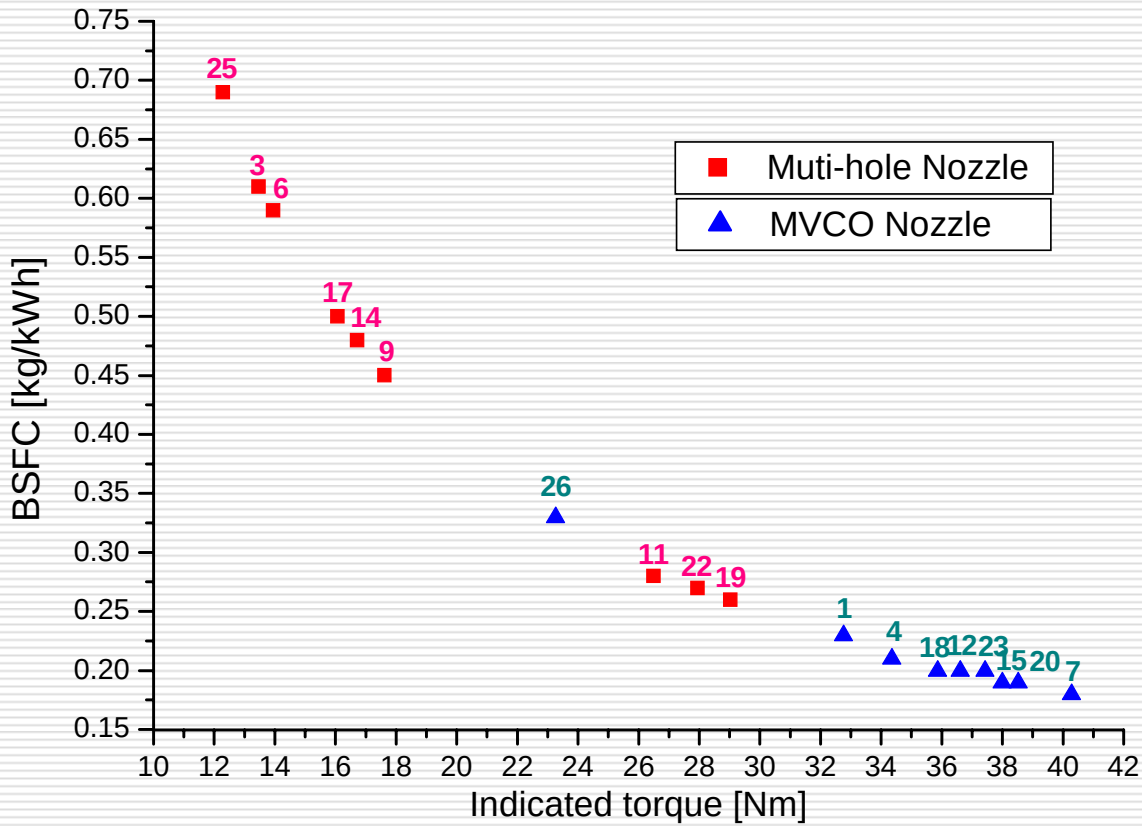




Fuel/Air Equivalence Ratio

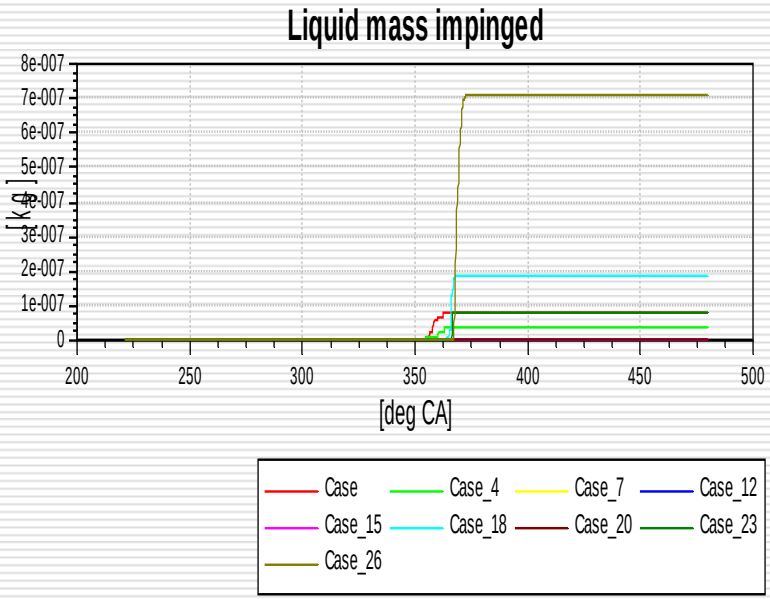


Torque & BSFC Sensitivity Analysis for Engines Using Conventional & MVCO Fuel Injectors Given Same Design Parameter Variations

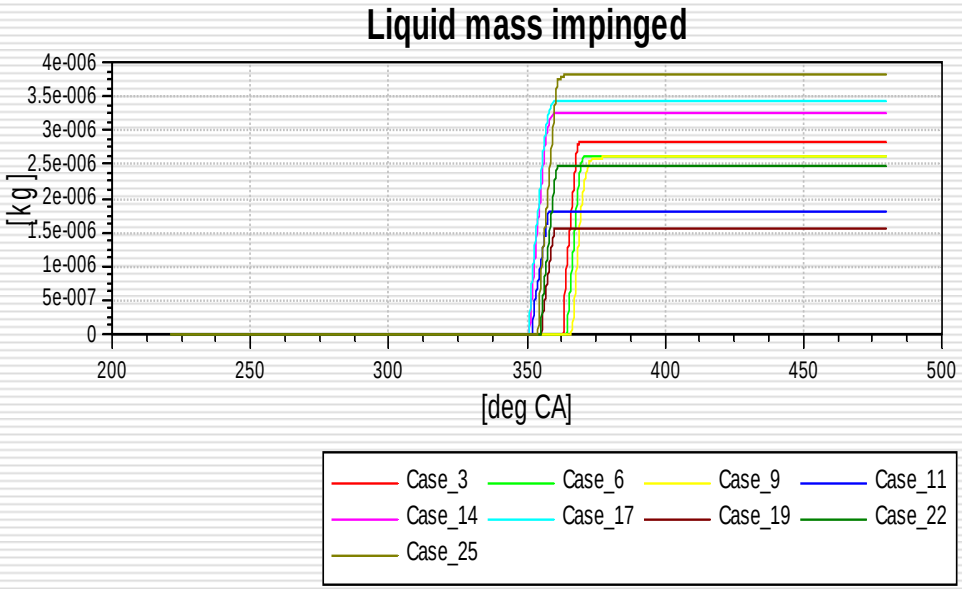


MVCO Conical Spray – Reduces Wall Wetting
Multi-hole Spray - Wall Wetting

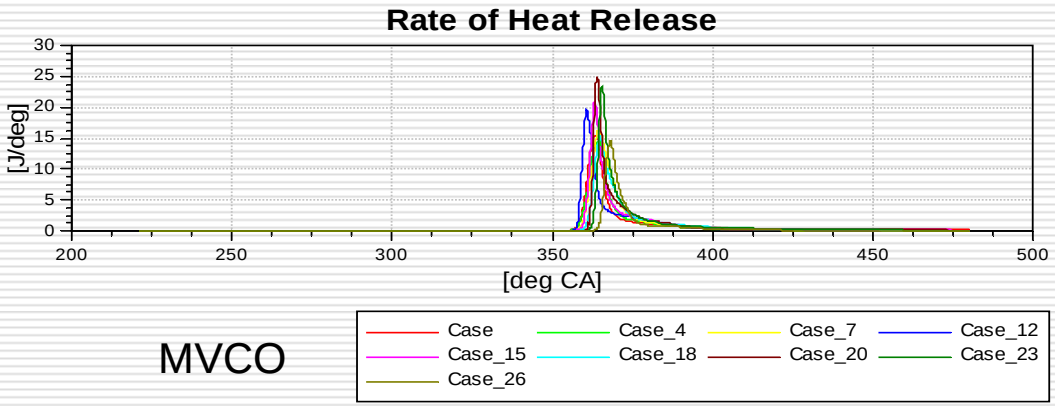
MVCO



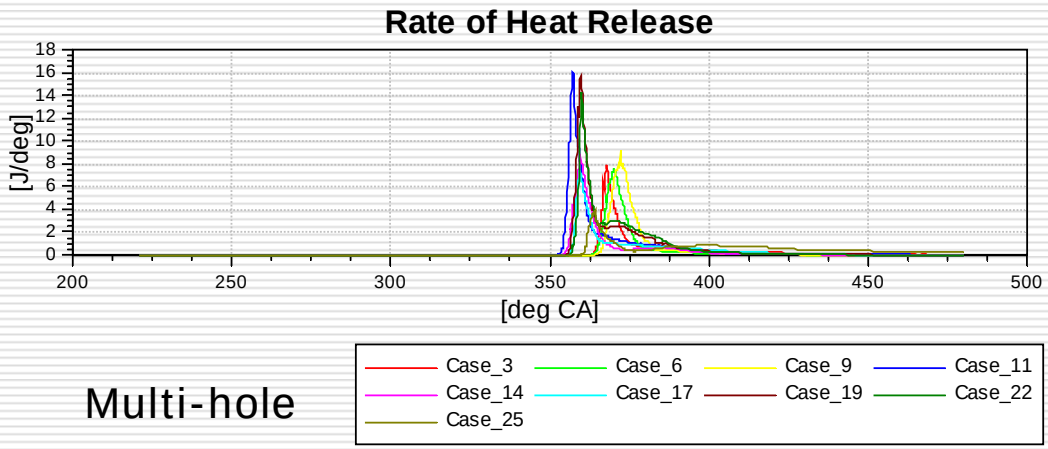
Multi-hole



MVCO Spray Combustion Heat Release (narrow heat release curve improves efficiency)



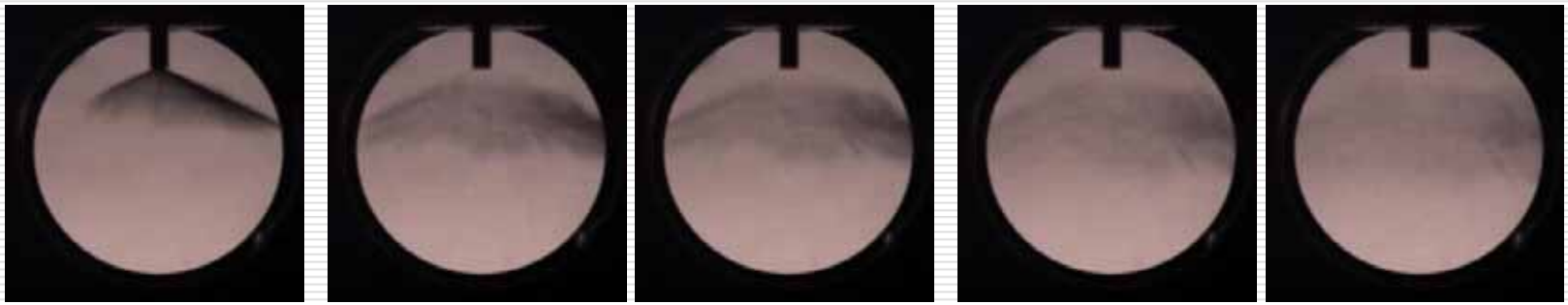
MVCO



Multi-hole

Spray Visualization

MVCO fuel injector is capable of generating mist-like mixture rather than conventional fuel jets, thus reduces combustion chamber wall-wetting, and enables earlier injection for low temperature combustion or premixed/HCCI combustion



1ms 2ms 2.25ms 3ms 4ms

Summary and Conclusions

- Mixed-mode diesel combustion is viable for near-future engine emission control
- The mixed-mode MVCO fuel injector can provide adaptive spray penetration, variable spray patterns and SMD, thus is flexible for different modes of combustion
- MVCO fuel injector is a key enabler for high performance and better fuel economy
- MVCO fuel injector is a candidate for light-duty to medium-duty direct injection diesel (and gasoline) engines to meet future emission legislations

Thank You !

Contact: Dr. Deyang Hou

dalianglc@aol.com