# Active Fuel Design and Management for Homogeneous Charge Compression Ignition (HCCI)

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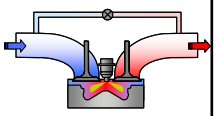
# Shanghai Jiao Tong University (SJTU)


# for the Next Generation of Vehicles in SJTU

Clean Engine Combustion

***HCCI, PCCI, LTC***

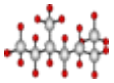


Energy strategy and policy

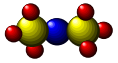
***LCA, Future fuel scenario***

New energy conversion system

***Free Piston Linear Alternator***



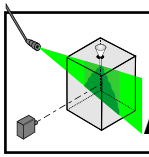
Alternative Fuels:



***Coal Based fuel, Bio-fuels, Synthetic fuels, Hydrogen***

Fuel injection and Spray

***Atomization, Spray characteristics***



Optical Measurement and Simulation of Combustion

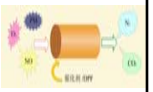
***PDPA, PIV, High speed photography, CFD, Chemkin, HCT***

Urban Air Pollution Control

***Pollutants transport and dispersion, Ultrafine Particle, Environmental impacts***

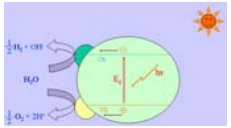
Engine Aftertreatment

***Catalyst design, NOx-PM removal, SCR***



Hydrogen Production

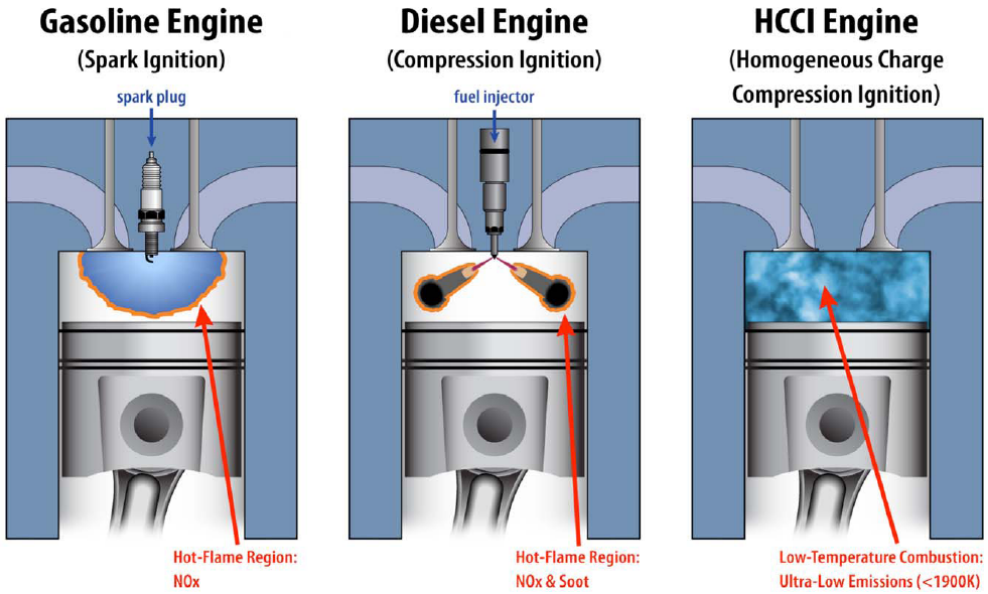
***Photocatalysts design, Solar energy***



# Presentation Outline

1. **Active Fuel Design for HCCI**
2. **Active Fuel Design and Management for Hybrid Combustion**
3. **Conclusions**

# HCCI Challenges



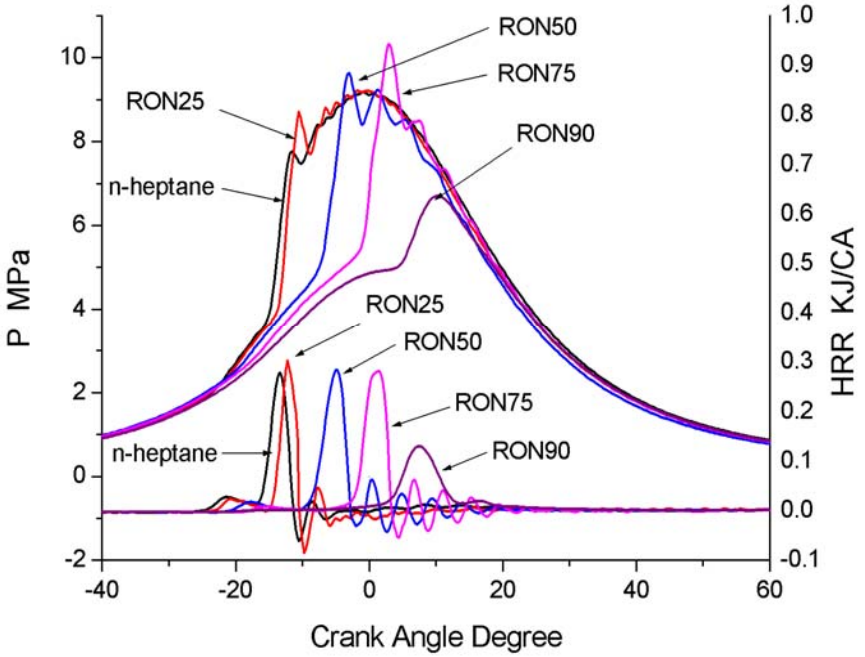

Source:www.erc.wisc.edu/symposiums/2007_Symposium/June%206%20PM-1/Mueller.pdf

- There are some difficulties and obstacles that must be overcome before applying HCCI combustion to internal combustion engine.
  - Homogeneous mixture preparation
  - Ignition control over a range of loads and speeds
  - Limitation in power output
  - Unburned HC and CO

## Control method

- FTM (Fast Thermal Management)
- VCR (Variable Compression Ratio)
- VVA (Variable Valve Actuation)
- **AFDM (Active Fuel Design & Management )**

# Effect of octane number and cetane number on HCCI combustion




n=1800r/min□Φ=0.35

coolant temp.: 85 degree

92 degree (RON 90)

Fuel with high cetane number:

- Early auto ignition, deterioration of thermal efficiency
- Knocking problem at high load
- Limitation in power output

Fuel with high octane number:

- Difficult to compression ignition,
- Misfire or partial burn at low load.
- Limitation in power output

In terms of fuel properties, neither high cetane nor high octane number fuel is suitable for HCCI in wide operating range.

# Active Fuel Design for HCCI

## Active fuel design

High octane fuel

High cetane fuel

**Variable cetane and octane number for optimizing fuel properties suitable for HCCI**

To control ignition and combustion phase

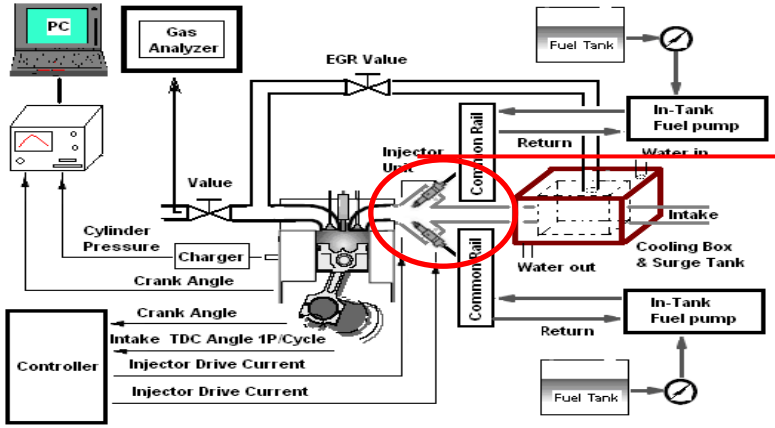
To extend engine load

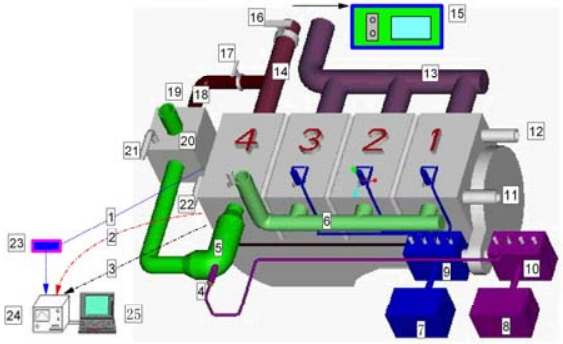
To reduce exhaust emissions

# Active Fuel Design and Management for HCCI

**Active fuel design** iso octane n-haptane

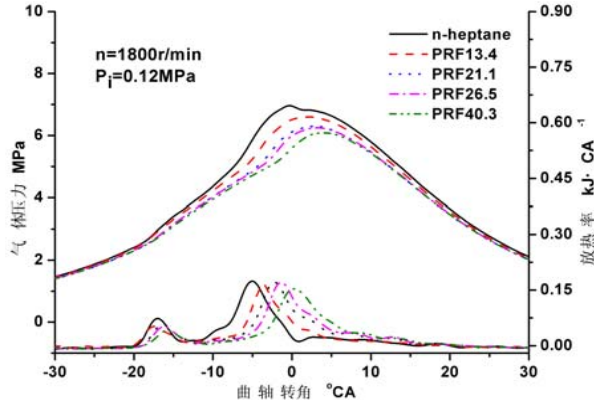
**Fuel injection management** Port Injection



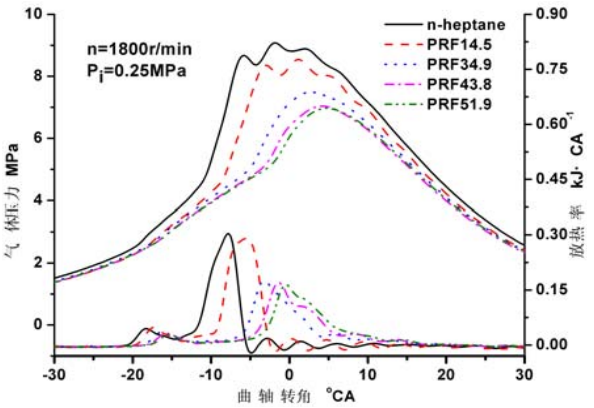




| | |
|---|---|
| **Engine Type** | **4-stroke, water-cooled** |
| **Cylinder diameter/stroke** | **98mm×105mm** |
| **Compression ratio** | **18.5** |

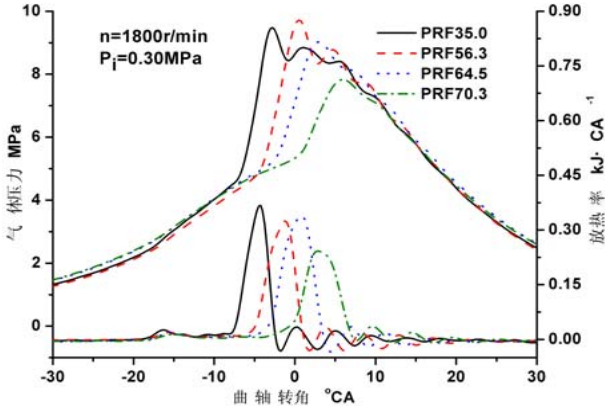
# means of AFDM



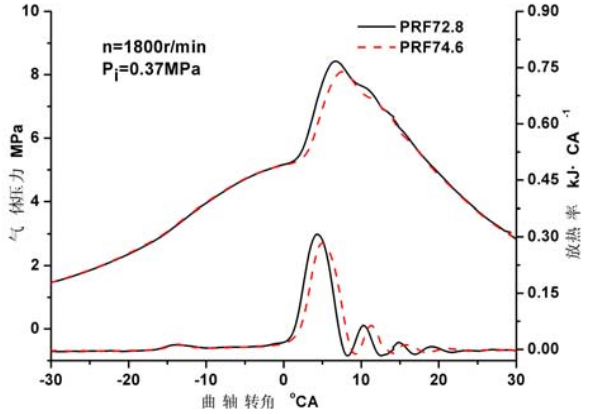

Pi 0.12MPa




Pi 0.25MPa

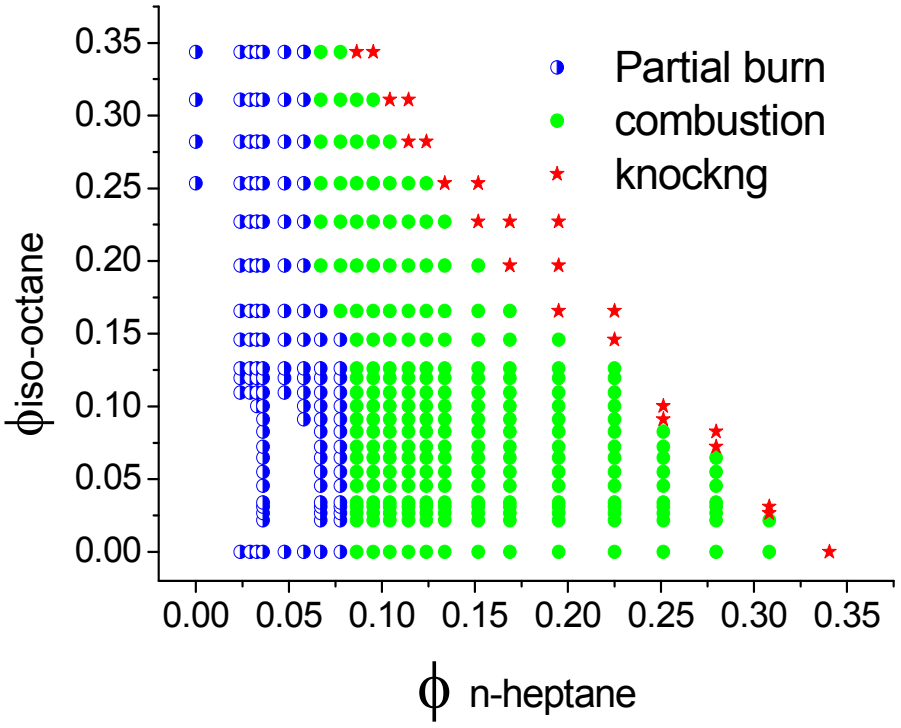


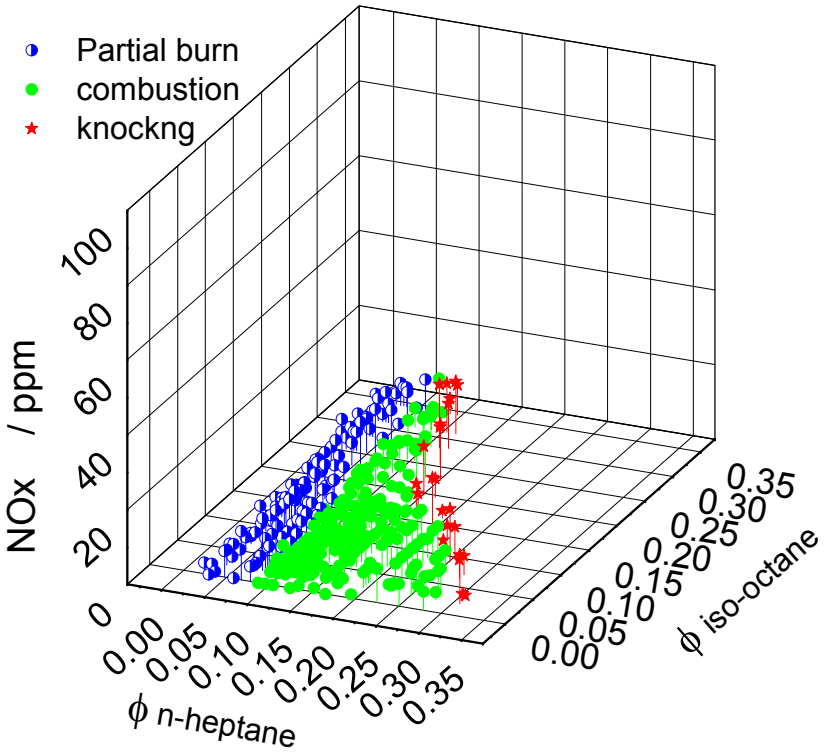

Pi 0.30MPa



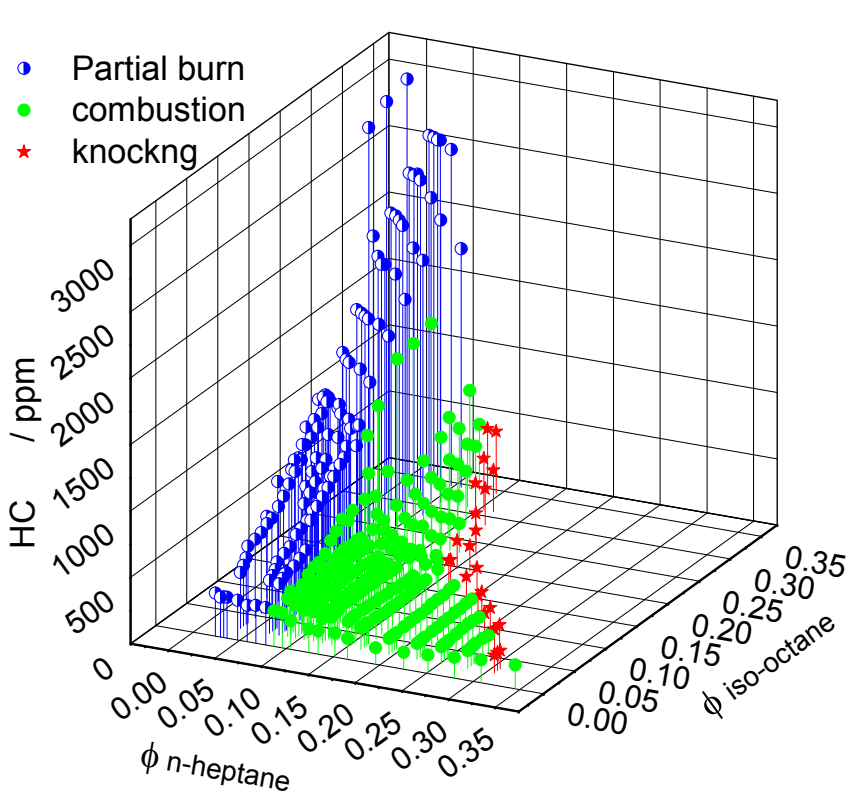

Pi 0.37MPa

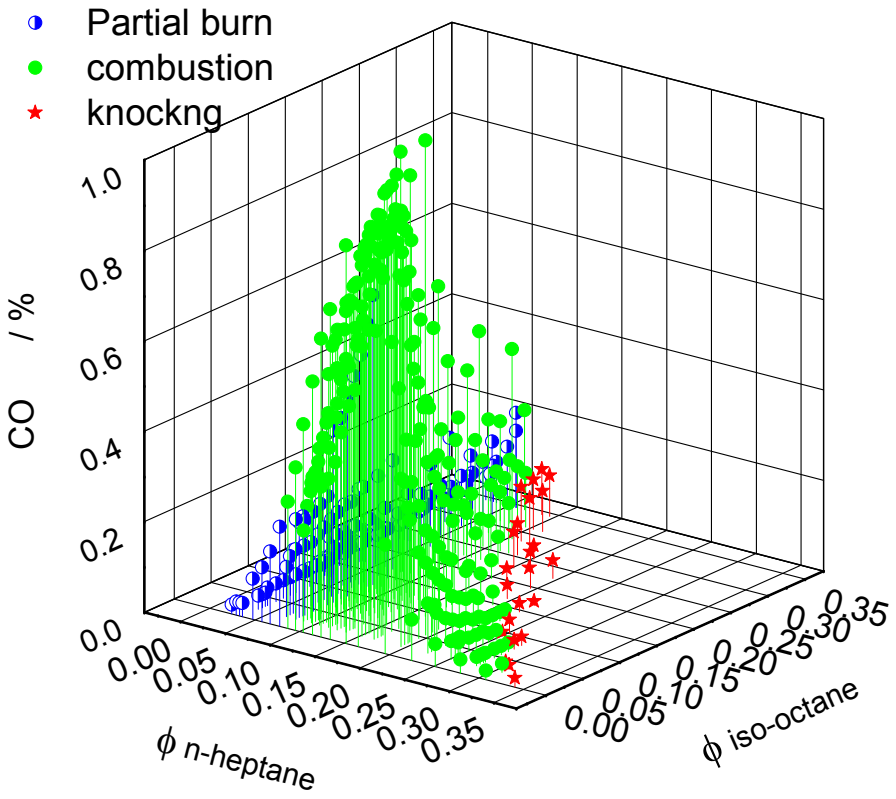
# AFDM (parametric investigation)



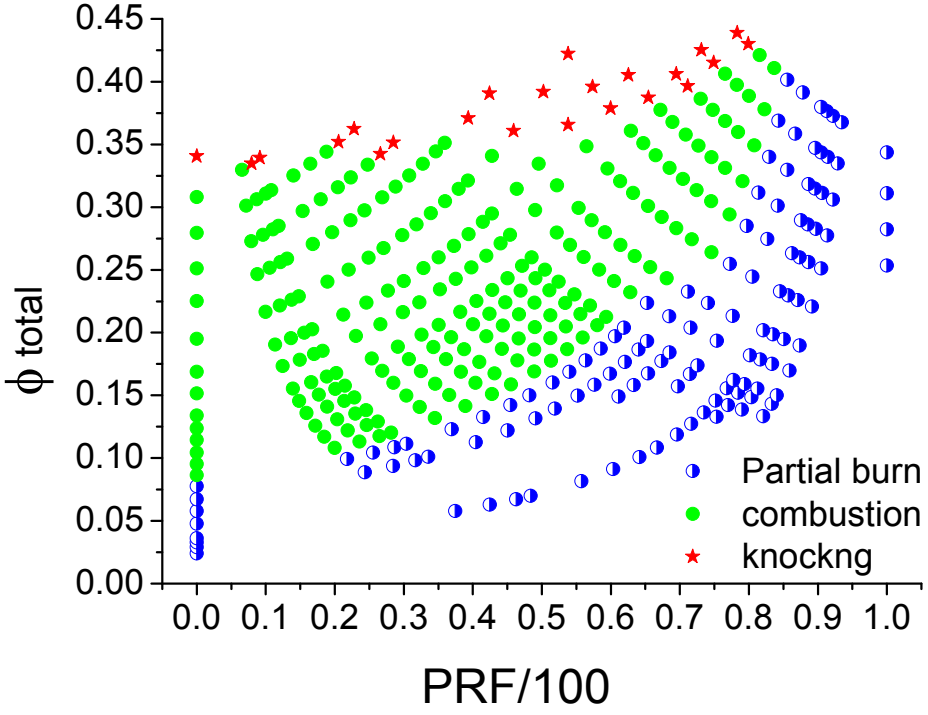



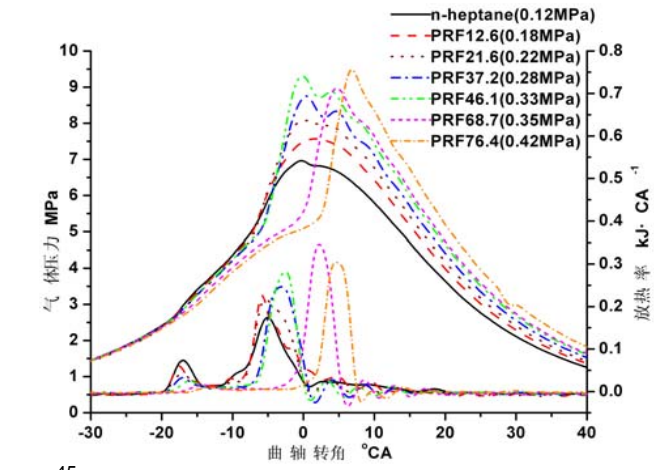
# CO and HC emission by means of the AFDM

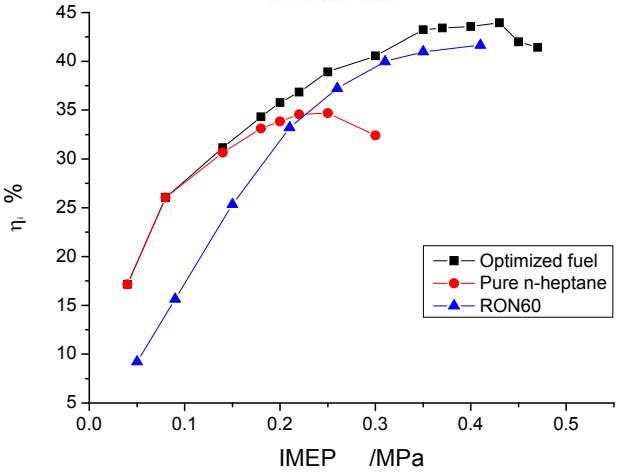


# by the AFDM



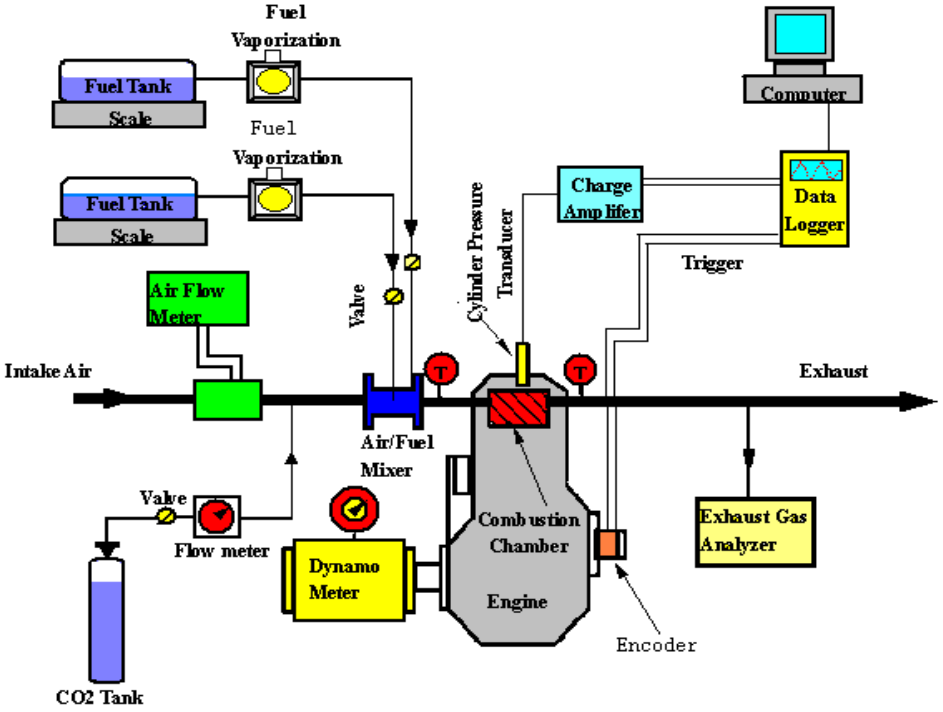




According to engine load, by means of parametric investigation and optimization of fuel blending ratio through dual fuel port injection, engine load is increased by 80%. Thermal efficiency is improved. HC and CO emissions decrease.

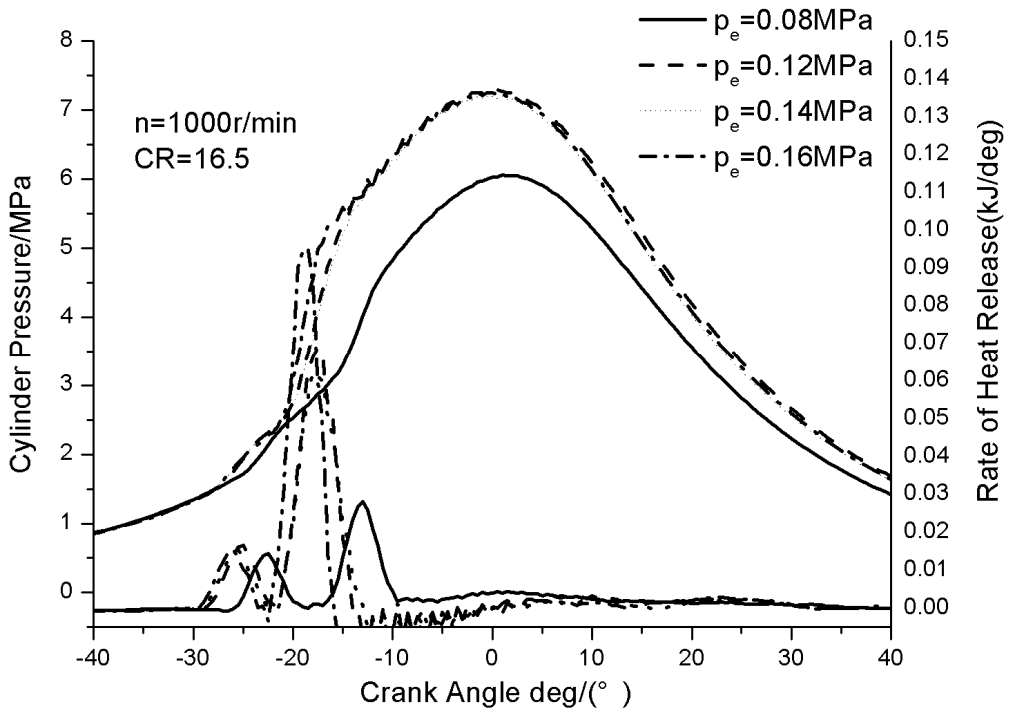
# Active Fuel Design and Management for HCCI

**Active fuel design** DME LPG




| Engine Type | Natural aspiration |
|---|---|
| Cylinder diameter/stroke | 135mm×145mm |
| Compression ratio | 16.5, 12.2 |

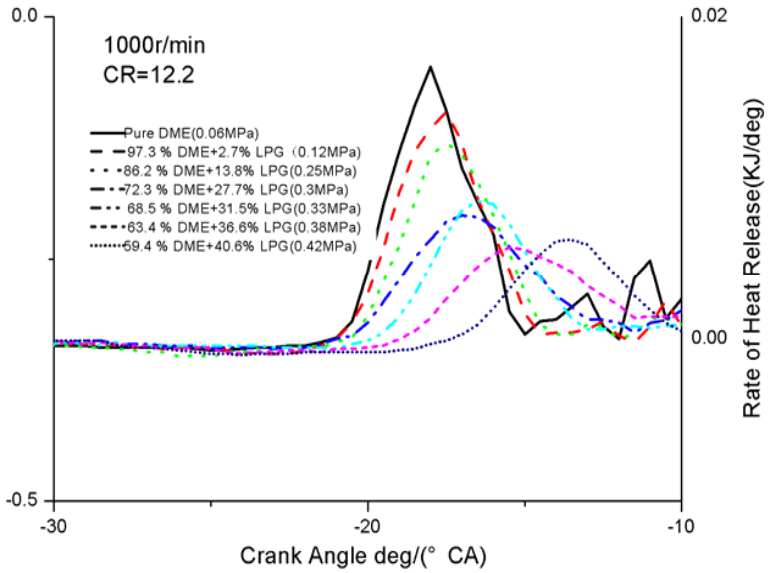
# DME HCCI Combustion



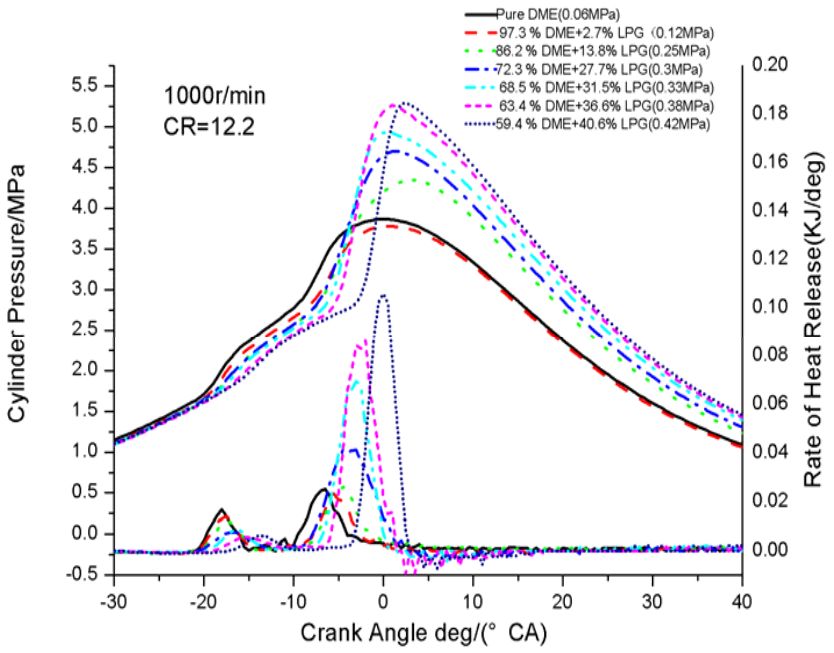

Variation of cylinder pressure and heat release rate with engine load

For HCCI combustion of DME, engine operation range is very narrow.

# HCCI combustion with optimized DME/LPG ratio




Low-temperature kinetic reactions

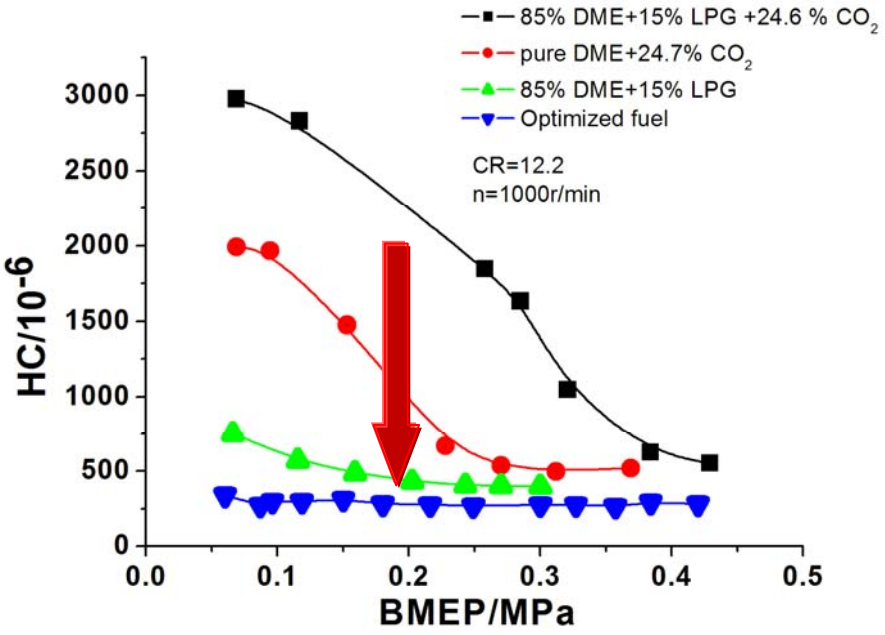



High-temperature reactions

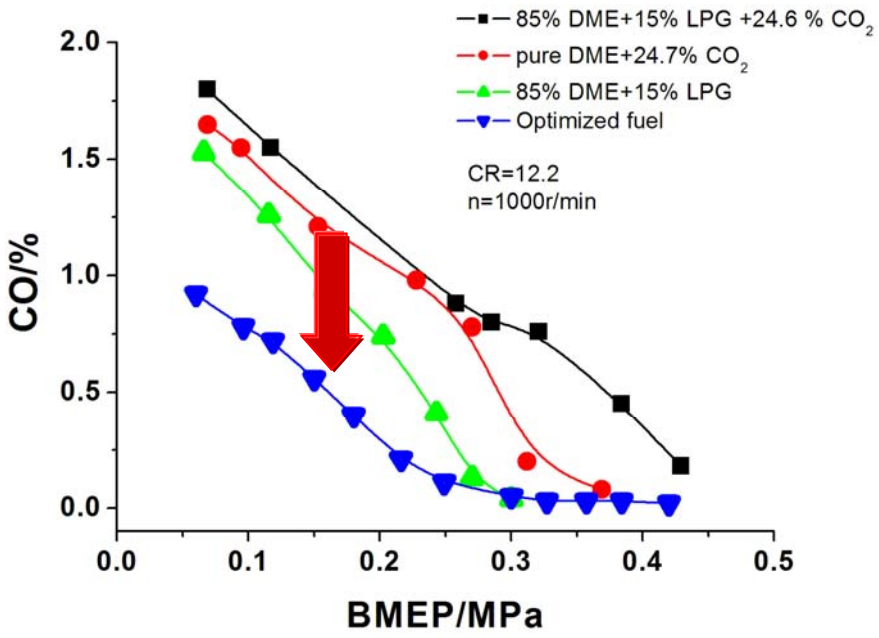
Variations of cylinder pressure and heat release rate with engine load at optimized DME/LPG blending ratio

Through parametric investigation, optimal HCCI combustion was obtained by variable DME/LPG blending ratio.

# Beneficial effect of optimized DME/LPG ratio on engine exhaust emissions

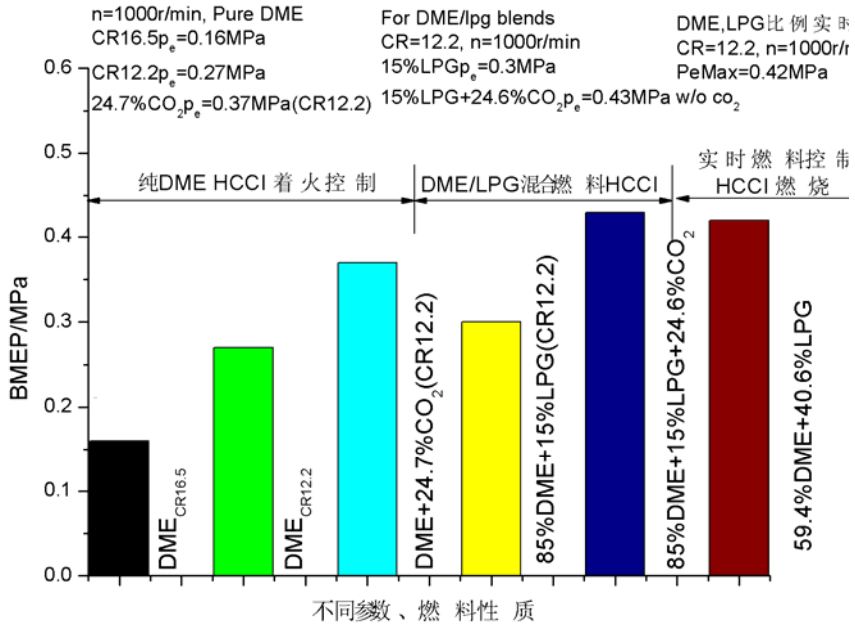



a HC

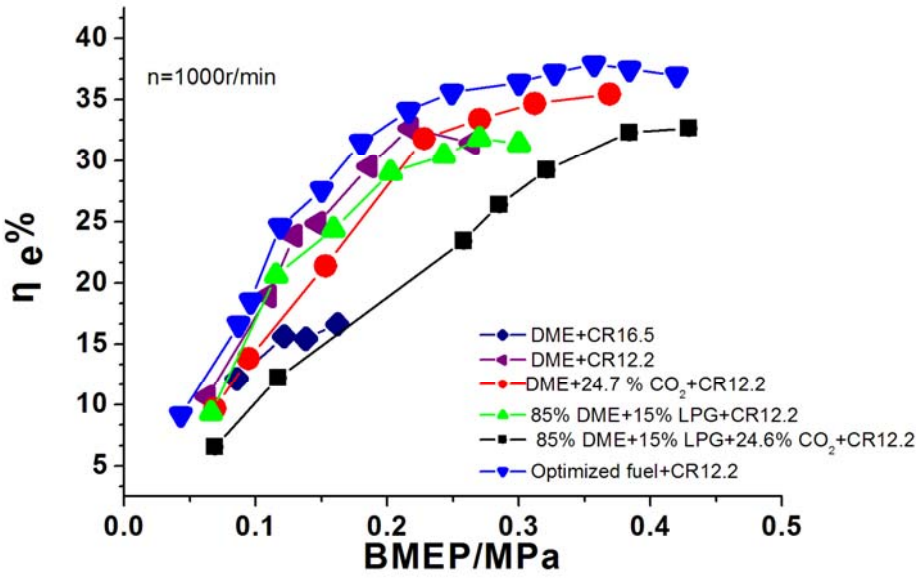



b CO

# Beneficial effect of optimized DME/LPG ratio on engine thermal efficiency and load extending




Extend of engine load




Improvement of engine thermal efficiency

# Presentation Outline

1. Active Fuel Design for HCCI
2. **Active Fuel Design and Management for Hybrid Combustion**
3. Conclusions

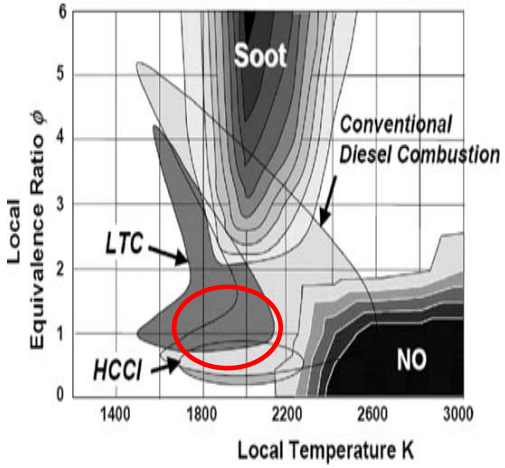
# Active Fuel Design and Management

## Active fuel design

Octane number

Cetane number

## Fuel injection management




Source: Neely, G.D

Port injection + In cylinder direction injection

HCCI + Third stage combustion

**Variable octane number** **Direct injection timing**

**Premixed ratio**

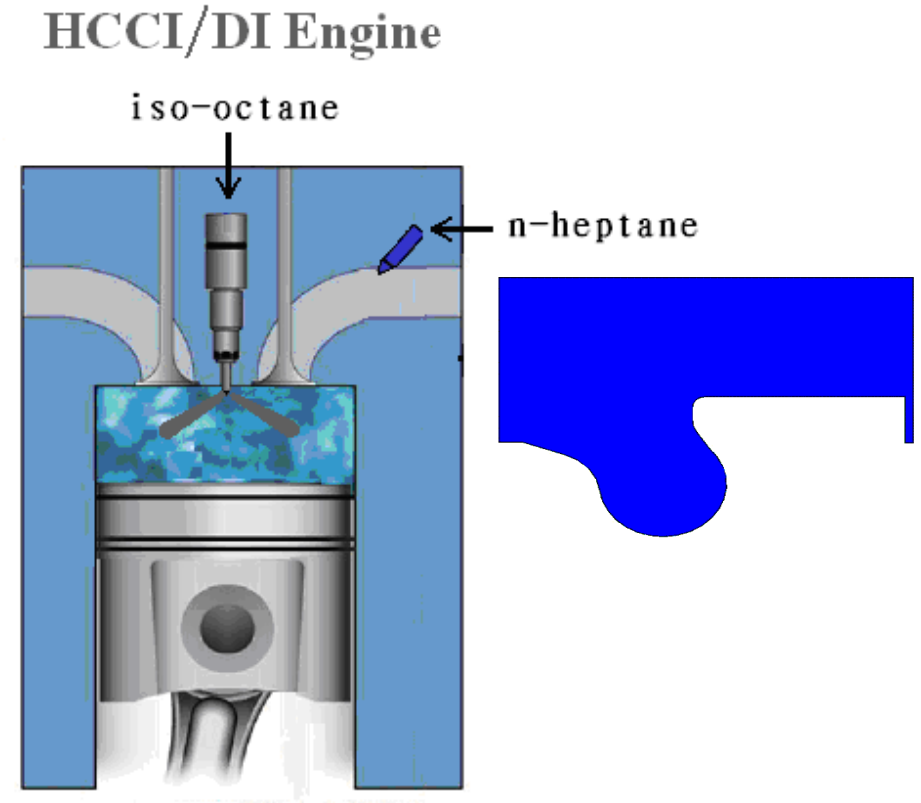
Ignition timing Combustion phase

Distributed heat release – hybrid combustion

Full load with high efficiency and ultra-low emissions

# Active Fuel Design and Management

Port injection – variable octane number,  Direct injection - n-heptane

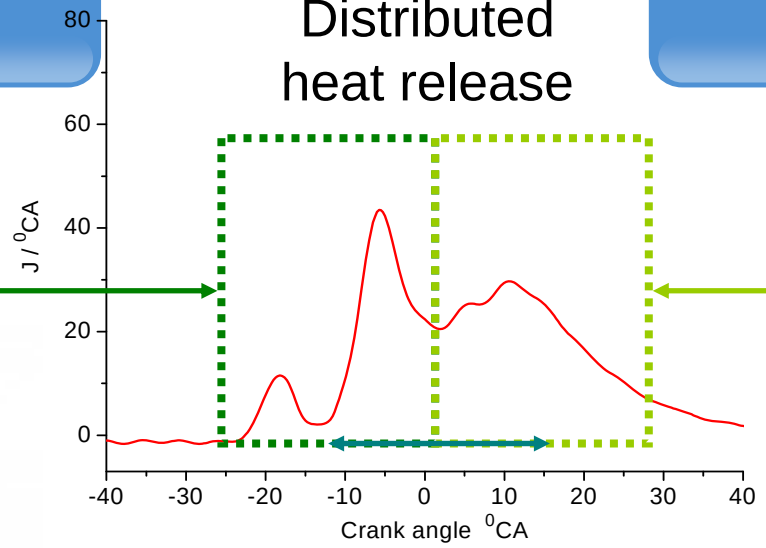


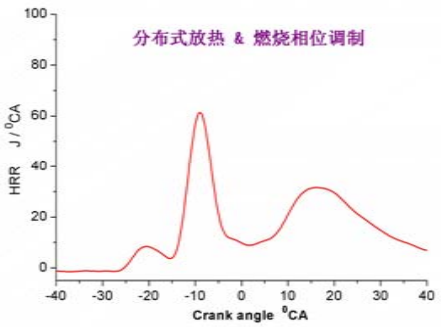
# Active Fuel Design and Management

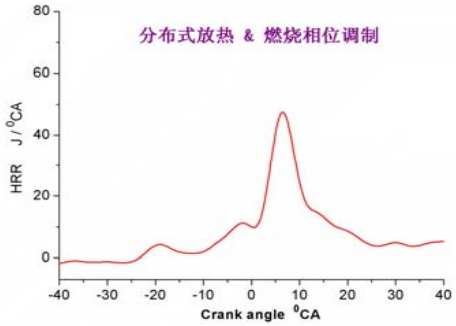
**Variable octane number**

**Direct injection timing**

Distributed heat release



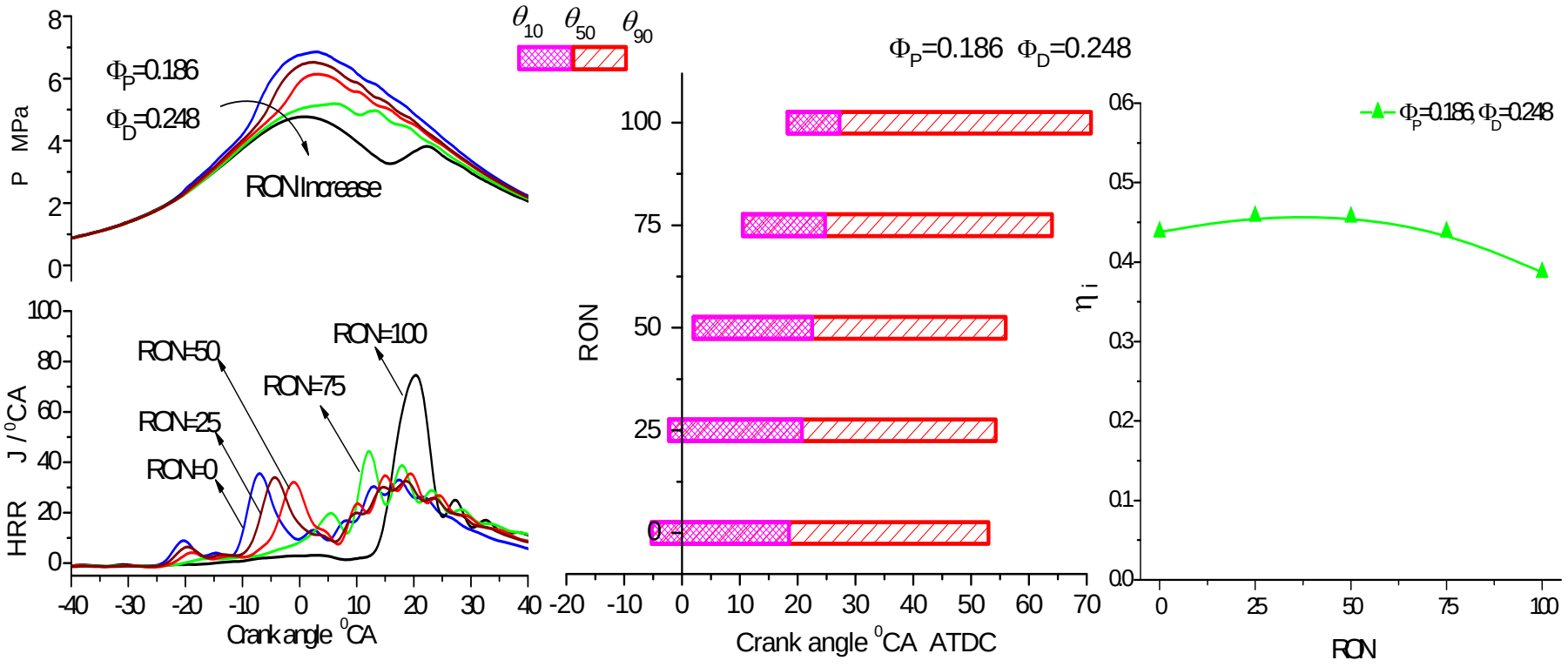




**Premixed ratio**

Heat release and combustion mode modulation

Combustion and emission control

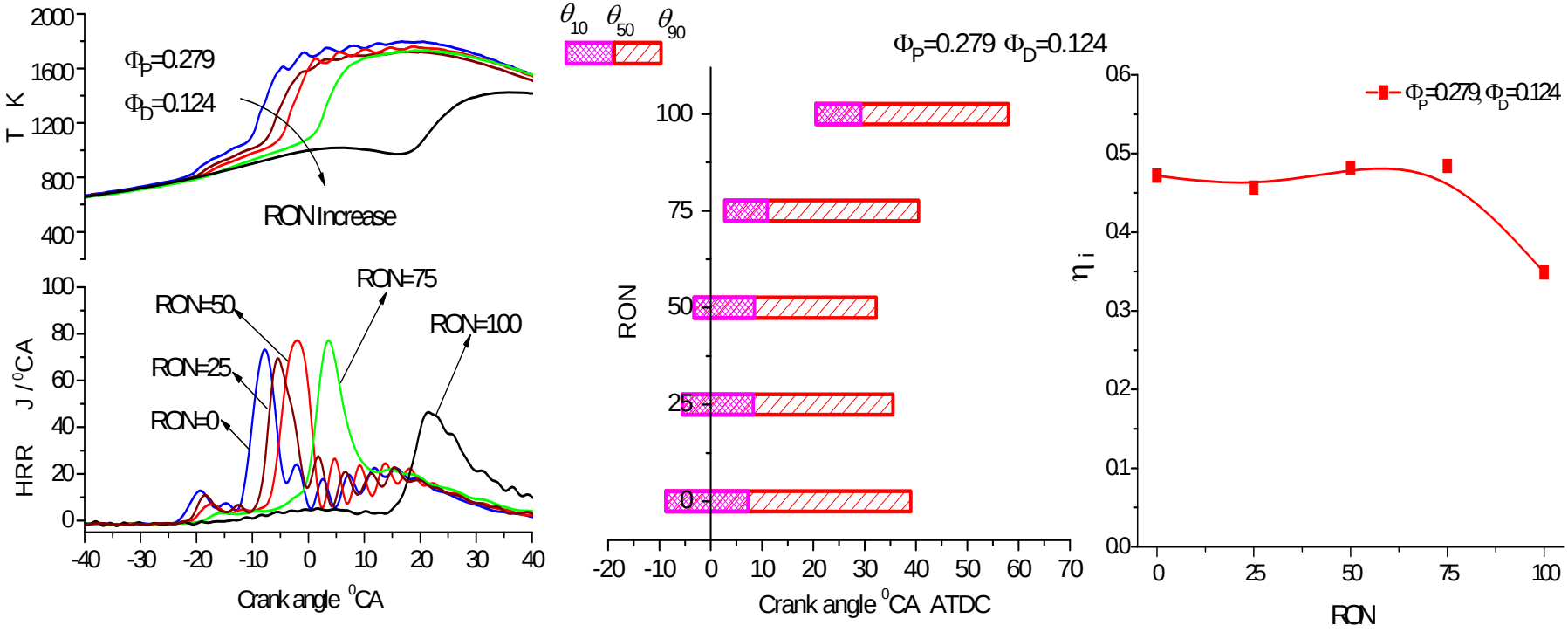
# Effect of Fuel Octane Number of Port Injection on Indicated Thermal Efficiency




Port injection – variable octane number, Direct injection - n-heptane

Fuel octane number of port injection has importance influence on distributed heat release and combustion pattern.

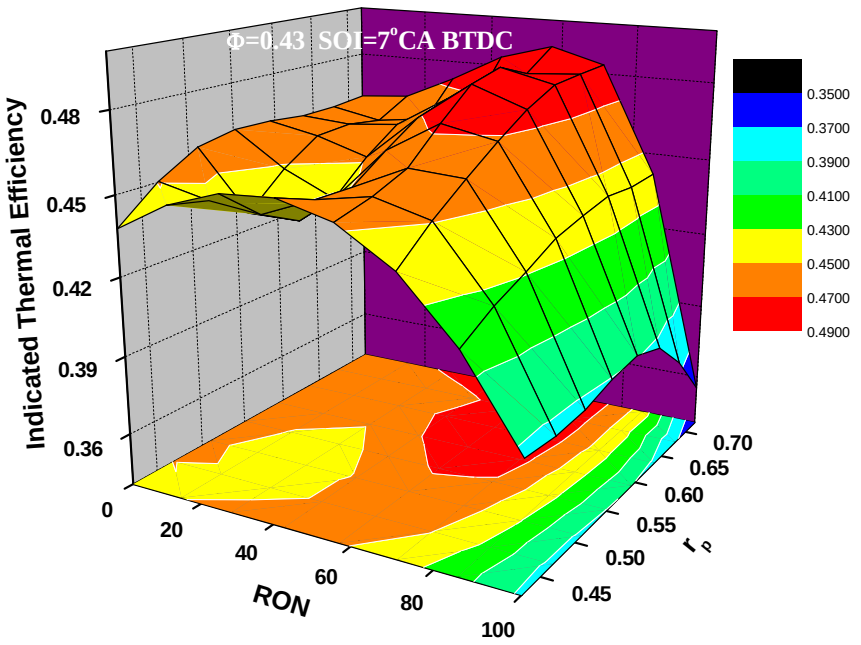
# Effect of Fuel Octane Number of Port Injection on Indicated Thermal Efficiency

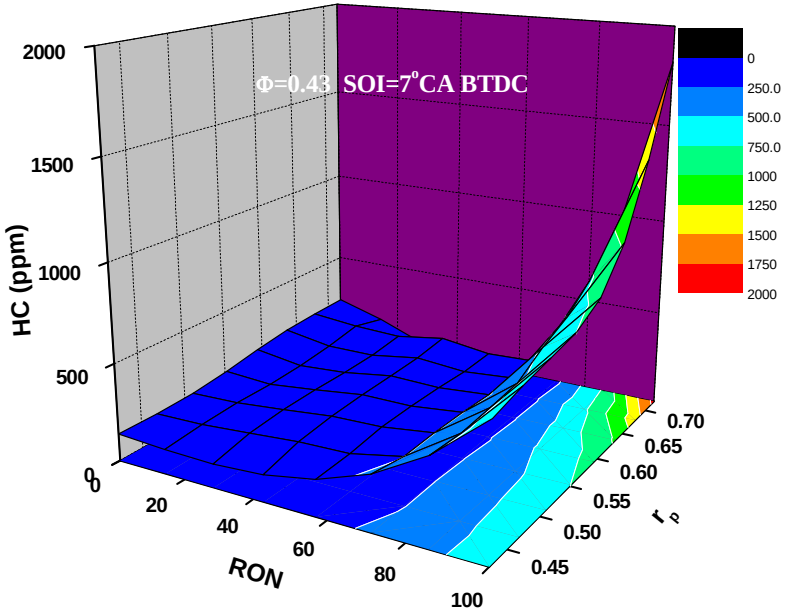



Port injection – variable octane number, Direct injection - n-heptane

The distributed heat release and combustion pattern determine engine thermal efficiency.

# Effect of Fuel Octane Number of Port Injection on Indicated Thermal Efficiency and HC emission

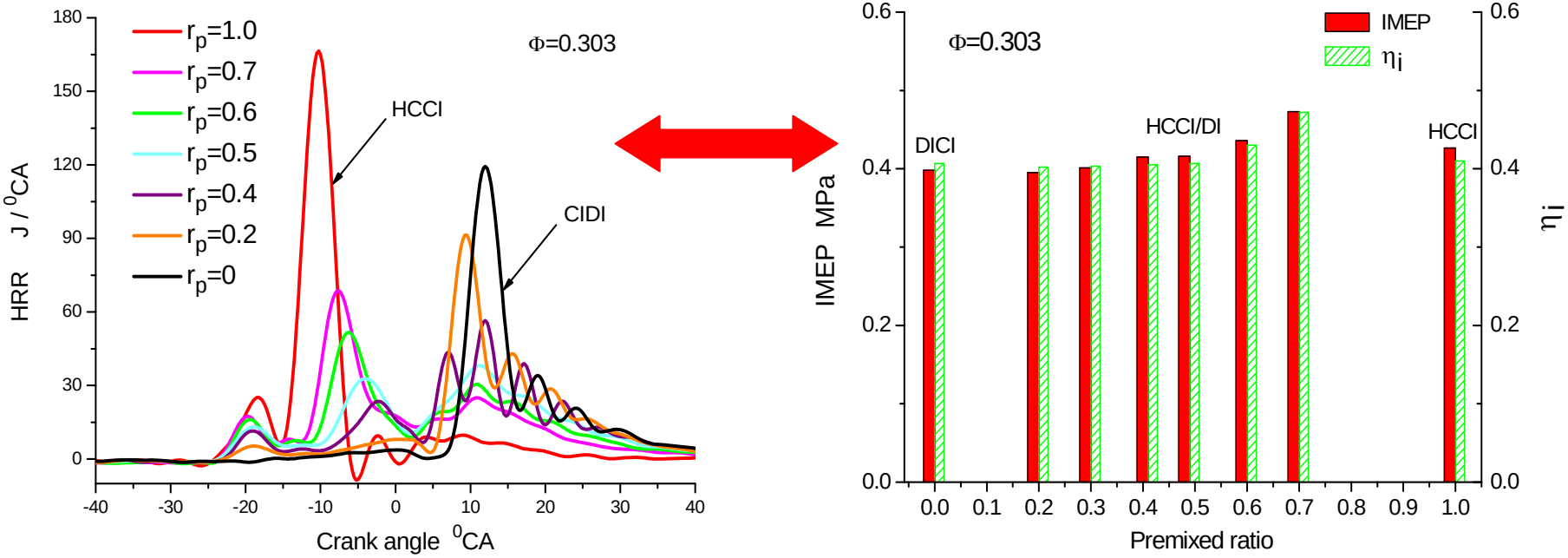



Port injection – variable octane number, Direct injection - n-heptane

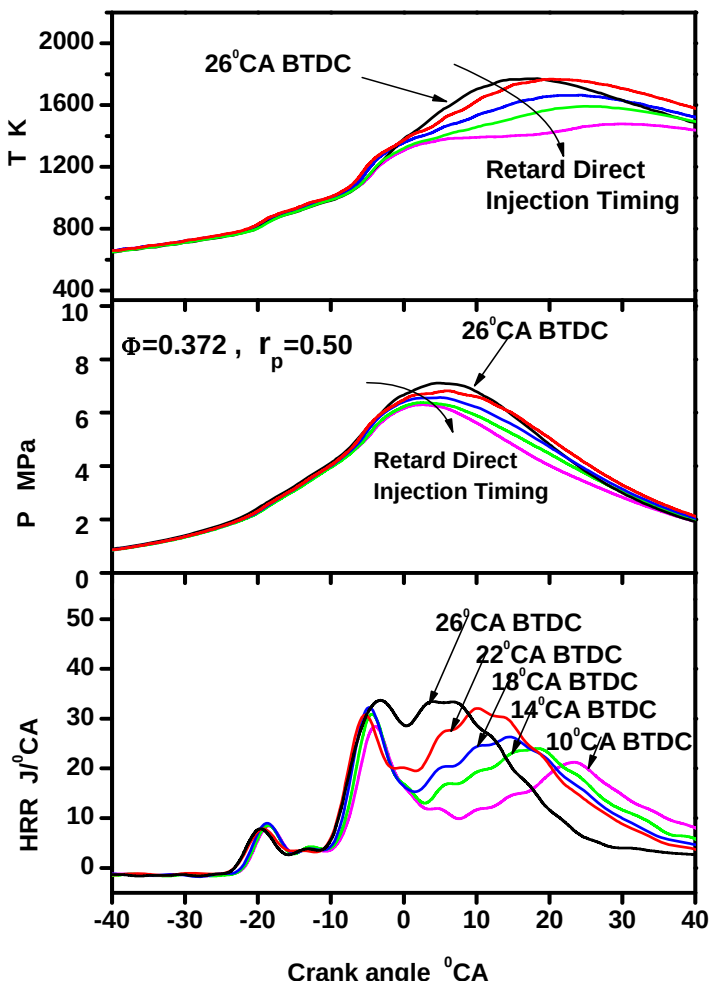
Fuel with RON 50 has highest indicated thermal efficiency and low HC emission

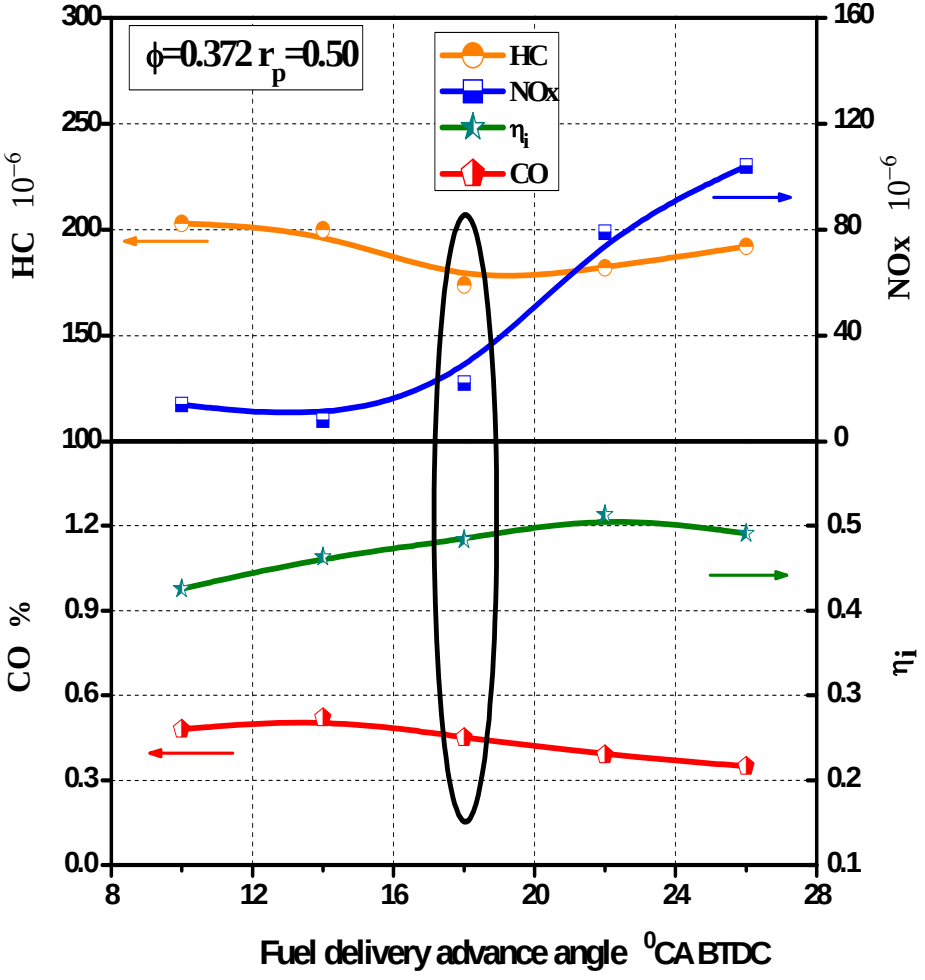
# Effect of Premixed ratio on on Indicated Thermal Efficiency




Port injection - n-heptane, Direct injection - n-heptane

# Effect of In Cylinder Direct Injection Timing on Indicated Thermal Efficiency and Exhaust Emissions

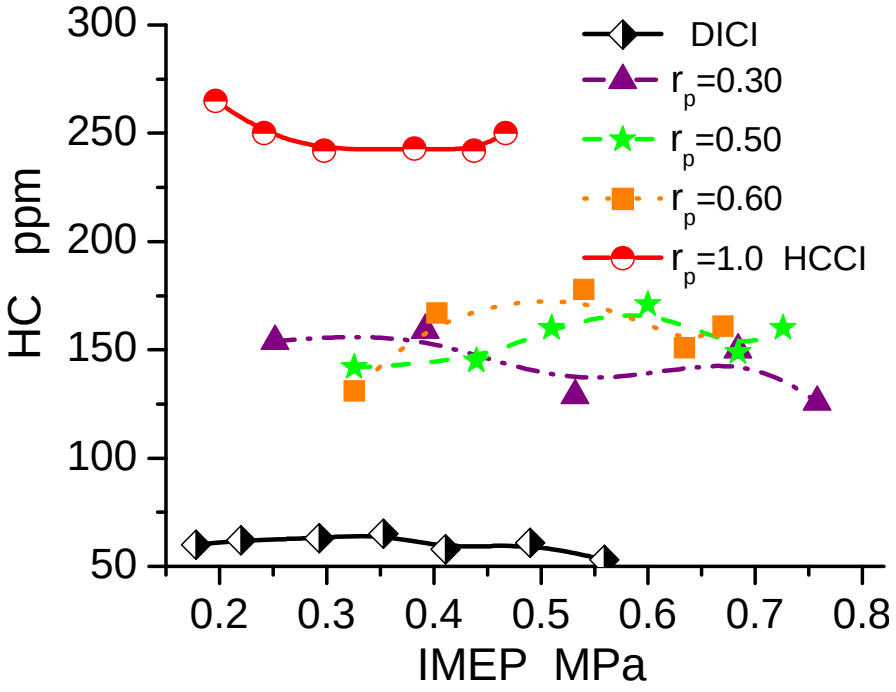


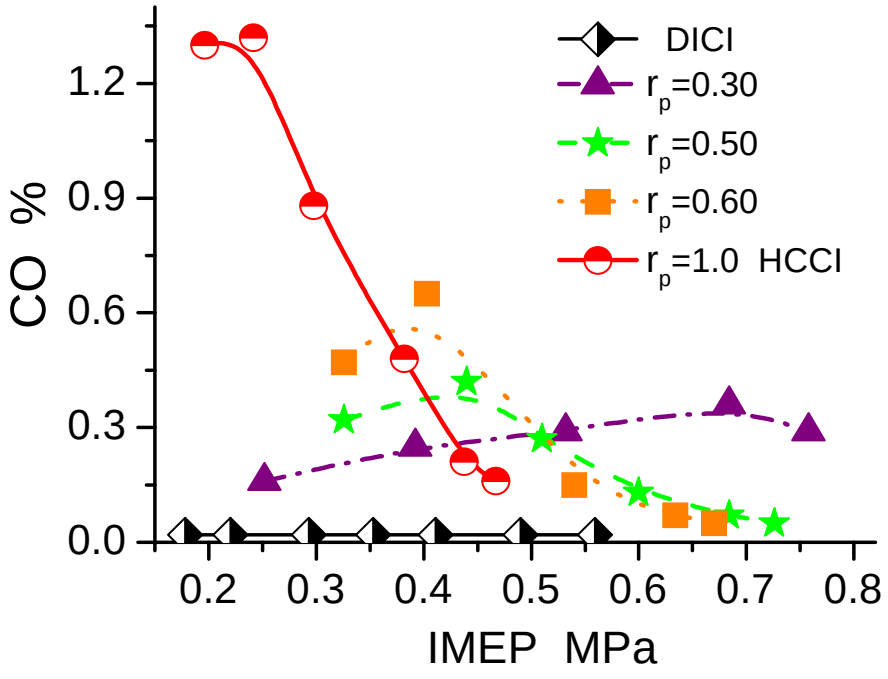




Port injection - n-heptane, Direct injection - n-heptane

# Comparison of HC and CO emissions among HCCI, PCCI and CIDI

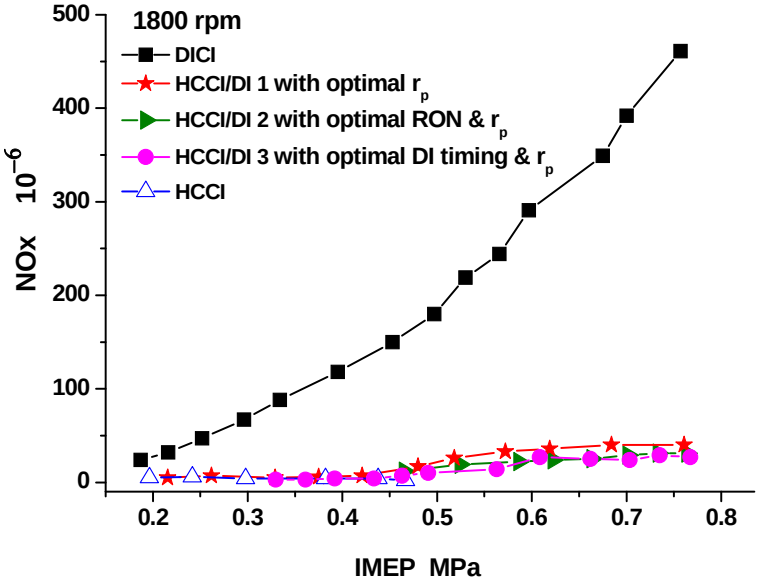
Port injection - n-heptane,  Direct injection - n-heptane

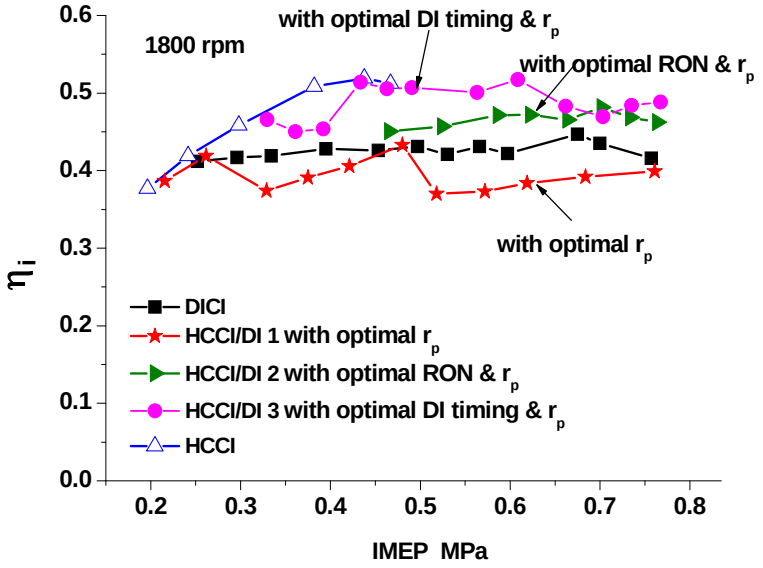



With optimization of premixed ratio, CO and HC emissions of PCCI is much lower than that of HCCI, is higher than that of CIDI.

# Comparison of indicated thermal efficiency and NOx emission among HCCI, hybrid combustion and CIDI




| | DICI | HCCI/DI 1 | HCCI/DI 2 | HCCI/DI 3 | HCCI |
|---|---|---|---|---|---|
| **Port Injection** | N/A | n-heptane | RON | n-heptane | n-heptane |
| **Direct Injection** | Diesel | n-heptane | n-heptane | n-heptane | N/A |

- With optimization of premixed ratio, fuel octane number of port injection and direct injection timing, indicated thermal efficiency could be improved and NOx emission of engine could be decreased substantially, compared with CIDI. Engine could extend to fuel load with low NOx emission.

# Presentation Outline

1. Active Fuel Design for HCCI
2. Active Fuel Design and Management for Hybrid Combustion
3. **Conclusions**

# Conclusions

- By means of variable fuel properties and injection strategy, the active fuel design and management (AFDM) offers important advantages for load extension, thermal efficiency improvement and exhaust emission reduction for

**1. For HCCI**

- Ignition control
- Engine load extension
- CO and HC emission reduction
- Thermal efficiency improvement

**2. For hybrid combustion**

- Ignition control
- Combustion phase control
- Full load operation
- Misfire and knocking avoidance
- Thermal efficiency improvement
- Low CO and HC, **Compared with HCCI**
- Low NOx, **Compared with CIDI**

**3. For engine control**

- Fast response
- Cycle to cycle control
- Closed-loop control

# Acknowledgements


- **This work was supported by the National Fundamental Research Program.**
- **I would like to give my thanks to my colleague Dr. Lu Xingcai, Dr. Xiao Jin, my students Mr. Hou Yuchun, Mr. Ma Junjun and Mr. Ji Linbin for their contribution.**

- ***Thank You!***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