Modelling of Fuel Ignition in a Rapid Compression Machine

Renzo Piazzesi
The Sir Harry Ricardo Laboratories
Centre for Automotive Engineering

13/04/2010 Brighton – CAE Research Workshop
2-ACE Project: EPSRC EP/F058276/1

- Development of 2 Stroke Poppet Valve CAI/HCCI Engine
  - Reduce Emissions
  - Reduce Fuel consumption
  - Increase Performances
- University of Brighton Task:
  - CFD Simulation of the Engine
    - Reduced Chemical Mechanism (up to 50 species)
    - Foundation Study of Auto-Ignition in RCM
    - Cyclo-Hexane / Primary Reference Fuel
Lille Rapid Compression Machine

RCM Details

- The RCM chosen is the Lille*
  - Lille RCM main specifications:
    - Bore: 50 mm
    - Squish: 19.3 mm
    - CC volume: 37.9 cm$^3$
    - Stroke: 200 mm
    - Compression ratio: 9.8
    - Compression duration: 60 ms

Lille Rapid Compression Machine

Piston Velocity Profile

Piecewise profile

Leads, over 60 ms, to a stroke of 203 mm
Lille Rapid Compression Machine

Choice of the computational domain: Dimensions chosen

- According to Lille RCM characteristics, the piston velocity profile obtained and the compression ratio
- Computational domain specifications:
  - Bore 50 mm
  - Squish 23 mm
  - Stroke 203 mm
Lille Rapid Compression Machine

Grid Specifications

Grid Details
2D Quadrangular Axisymmetric Grid
49.500 cells @ BDC
12.000 cells @ TDC
Cyclo-Hexane: Boundary and Initial Conditions

- Direct comparison of 0D and CFD simulations
  - Chemical Mechanism of 50 species
  - Quiescent Chamber at TDC
  - Adiabatic Conditions
- Stoichiometric Mixture in Mass Fraction
  - 0.0637 % C$_6$H$_{12}$
  - 0.2181 % O$_2$
  - 0.7182 % N$_2$
- TDC Mixture Temperature [682K, 910K]
- TDC Mixture Pressure [7.27 bar, 9.75 bar]
Cyclo-Hexane: Results from TDC

682 K @ 7.27 bar
Cyclo-Hexane: Results from TDC

702 K @ 7.48 bar
Cyclo-Hexane: Results from TDC
731 K @ 7.83 bar
Cyclo-Hexane: Results from TDC

762 K @ 8.14 bar
Cyclo-Hexane: Results from TDC

788 K @ 8.44 bar
Cyclo-Hexane: Results from TDC

813 K @ 8.69 bar
Cyclo-Hexane: Results from TDC

910 K @ 9.75 bar
Cyclo-Hexane: Comparison with Lille Experiments

Cool Flame and Total Ignition Delays

![Cool Flame Delay vs Compressed Temperature](image1)

![Total Delay vs Compressed Temperature](image2)
Primary Reference Fuel: Boundary and Initial Conditions

- Mixture of iso-Octane (i-C$_8$H$_{18}$) and n-Heptane (n-C$_7$H$_{16}$)
- Chemical Mechanism of 40 species
- BDC at various RONs and Dilutions
- Nitrogen considered as dilution species
- Initial Mixture @ 300 K and 1 bar
- Stoichiometric Fuel to Oxygen ratio
PRF: Results from BDC

Stochiometric mixture: Nitrogen as in air

Stochiometric mixture: Nitrogen Volume 1.5 times

Stochiometric mixture: Nitrogen Volume 2 times
PRF: Results from BDC

- RON = 0
- RON = 60
- RON = 80
- RON = 100

Temperature [K] vs. Time [ms]

- N2 = 1x
- N2 = 1.5x
- N2 = 2x
PRF: Ignition Delay vs RON
PRF: Ignition Delay vs Nitrogen Excess
Conclusions

- Cyclo-Hexane results:
  - Consistent 0D – CFD
  - Qualitative Agreement with Experiments

- PRF results:
  - Ignition Strongly dependent on RON
  - Dilution leading to higher compressed T promoting faster ignition
Thank You for Your Attention...

Renzo Piazzesi
Centre for Automotive Engineering
www.brighton.ac.uk/cae