Modelling of Fuel Ignition in a Rapid Compression Machine

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13/04/2010 Brighton – CAE Research Workshop

University of Brighton

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

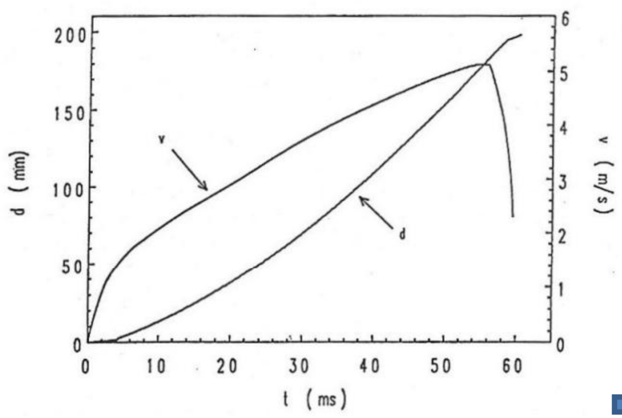
RCM Details

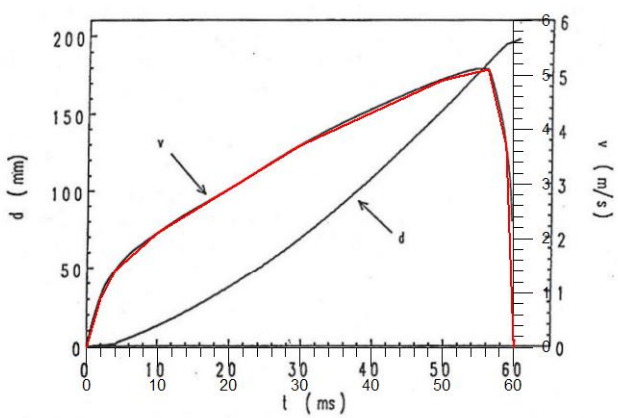
- The RCM chosen is the Lille*
  - Lille RCM main specifications:
    - Bore 50 mm
    - Squish 19.3 mm
    - CC volume 37.9 cm^3
    - Stroke 200 mm
    - Compression ratio 9.8
    - Compression duration 60 ms

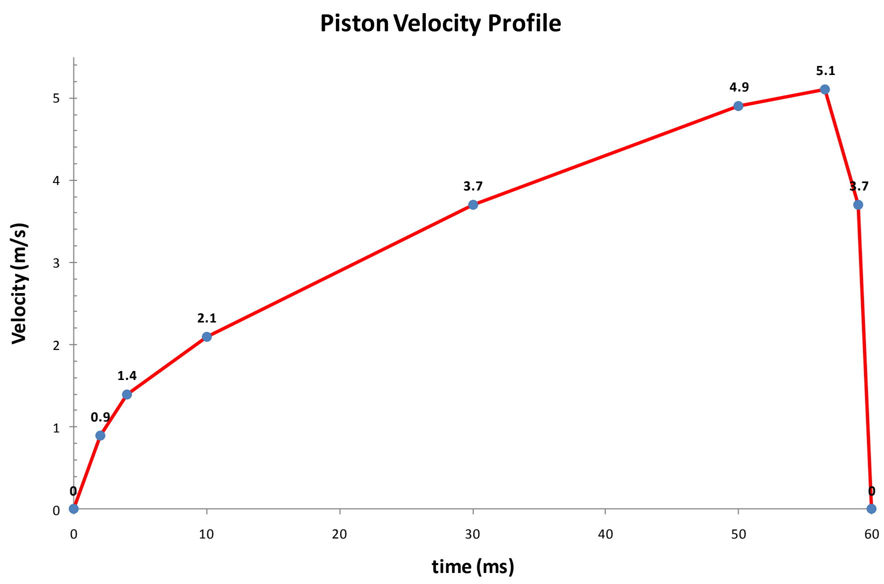
* ref. *"Autoinflammation à haute pression. Conception, réalisation et test d'une machine à compression rapide"* M. Ribaucour et al, J Chim Phys 1992, pp. 2137

Lille Rapid Compression Machine

Piston Velocity Profile







Piecewise profile
Leads, over 60 ms, to a stroke of 203 mm

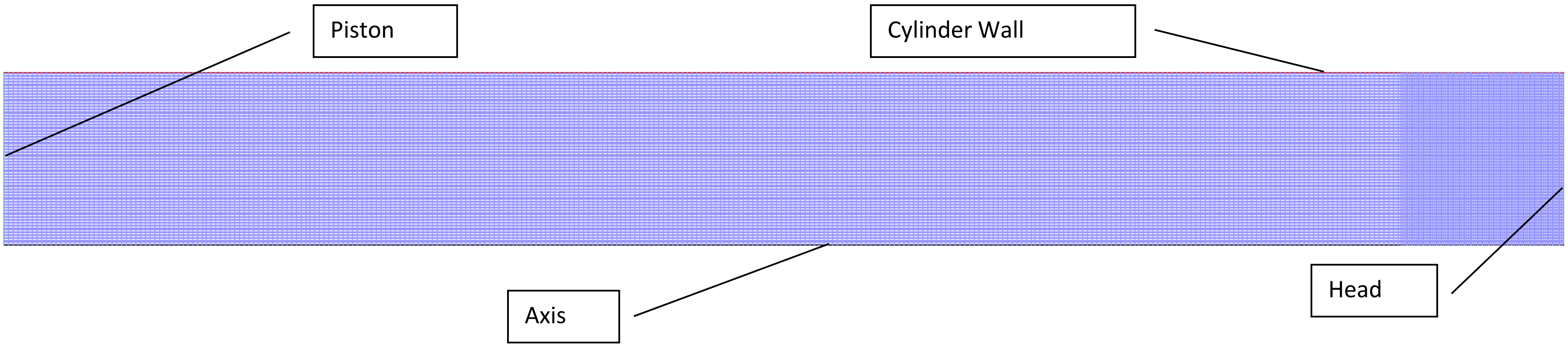
Lille Rapid Compression Machine

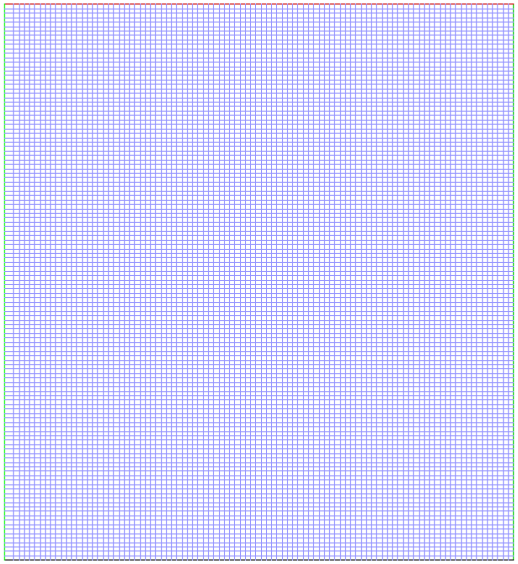
Choice of the computational domain: Dimensions chosen

- 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

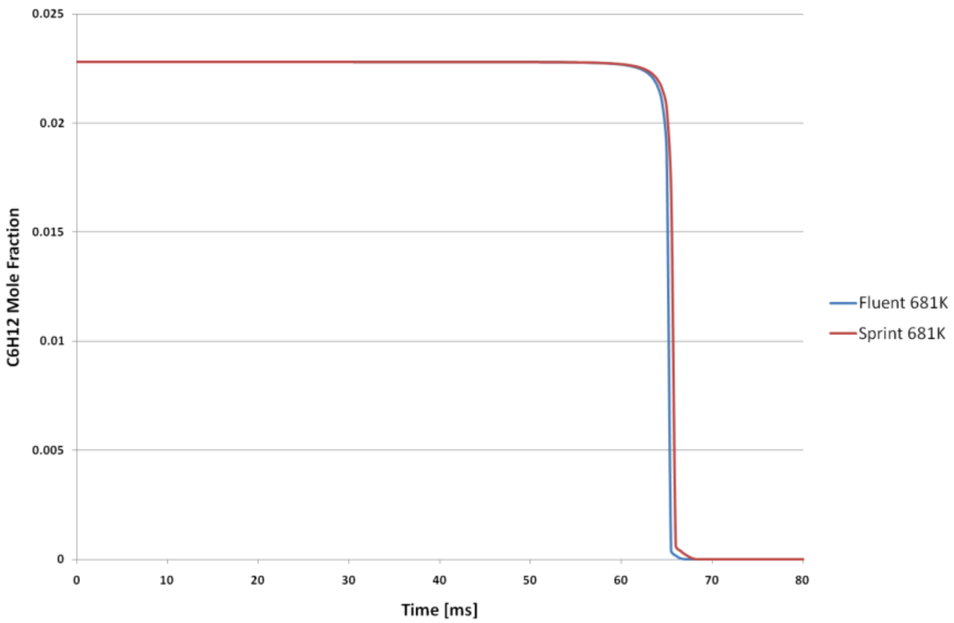
12.000 cells @ TDC

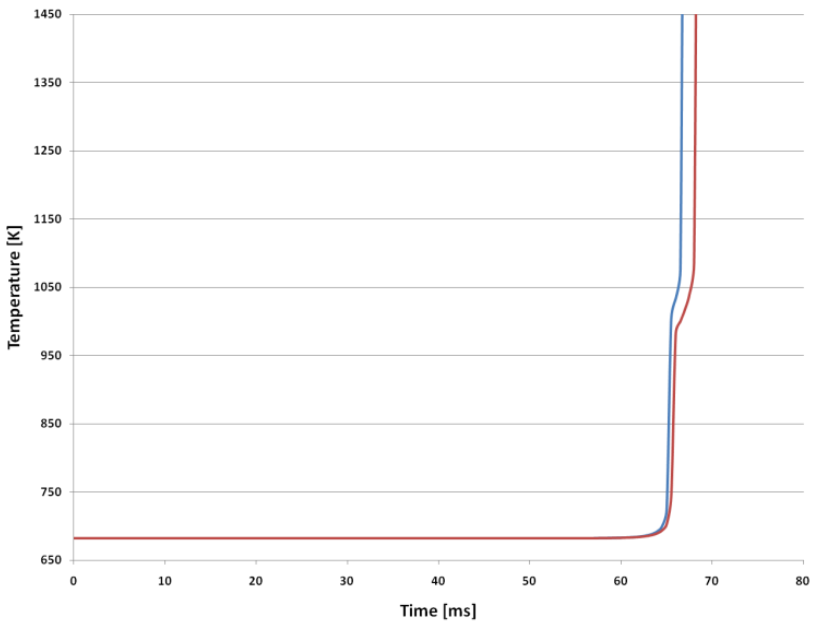
Cyclo-Hexane: Boundary and Initial Conditions

- 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_6H_{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

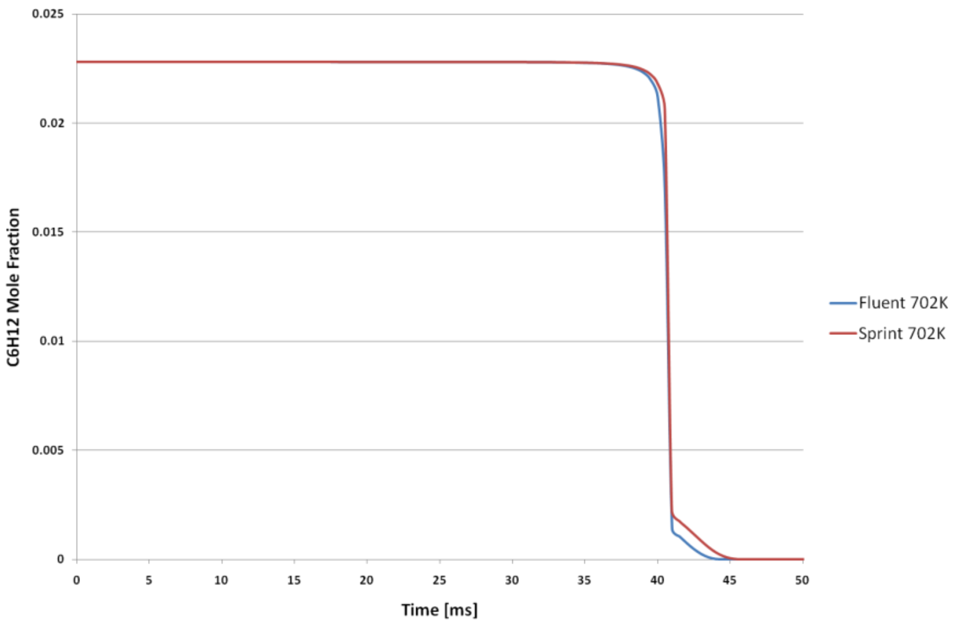
682 K @ 7.27 bar

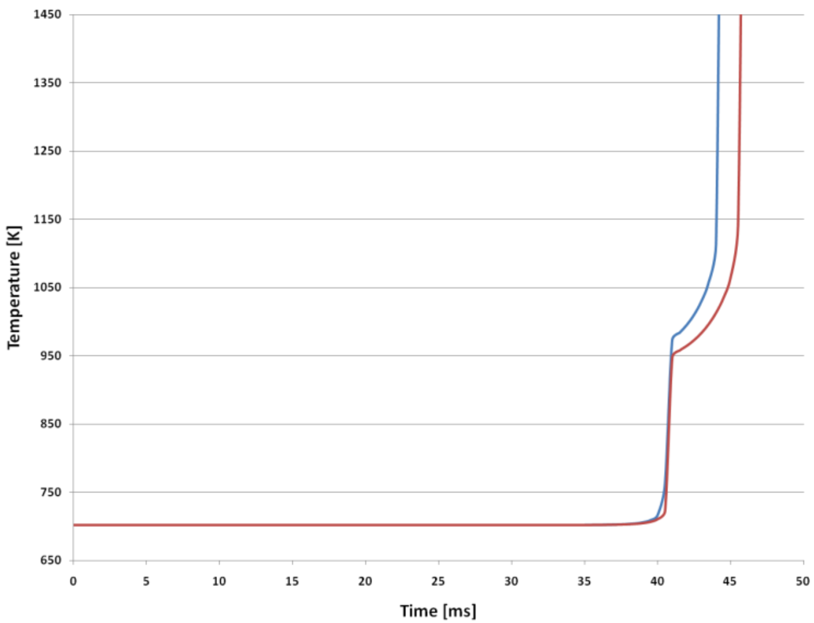




Cyclo-Hexane: Results from TDC

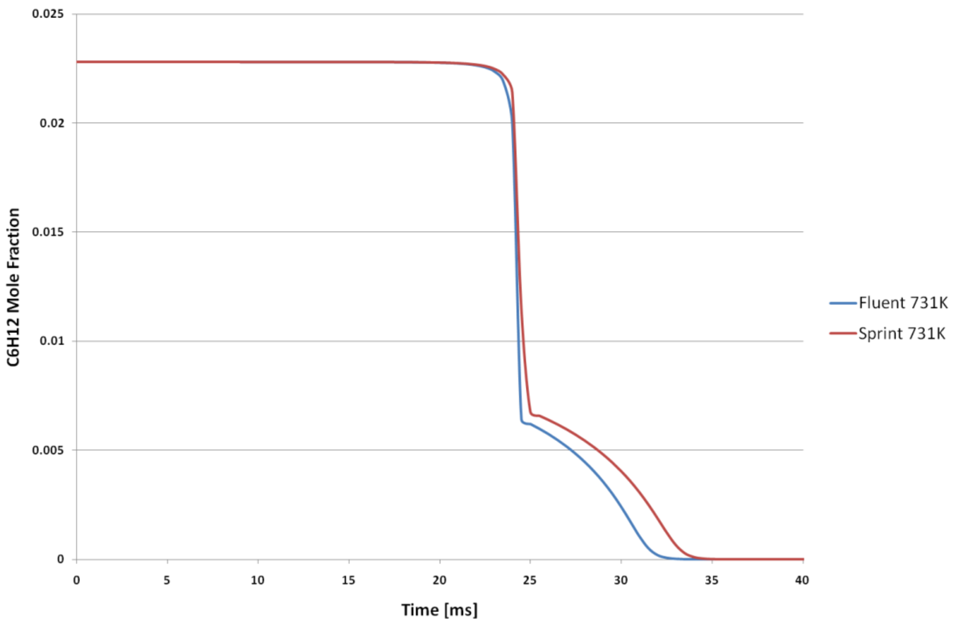
702 K @ 7.48 bar

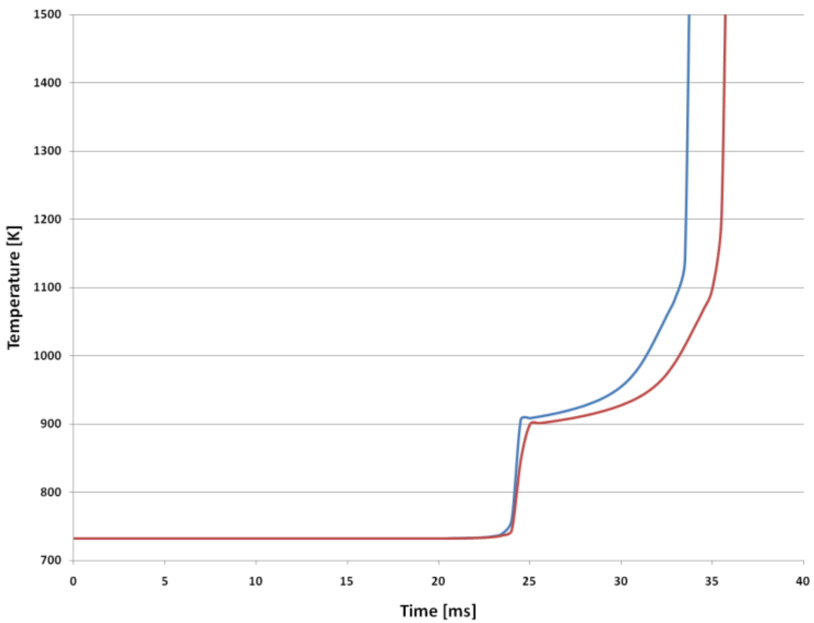




Cyclo-Hexane: Results from TDC

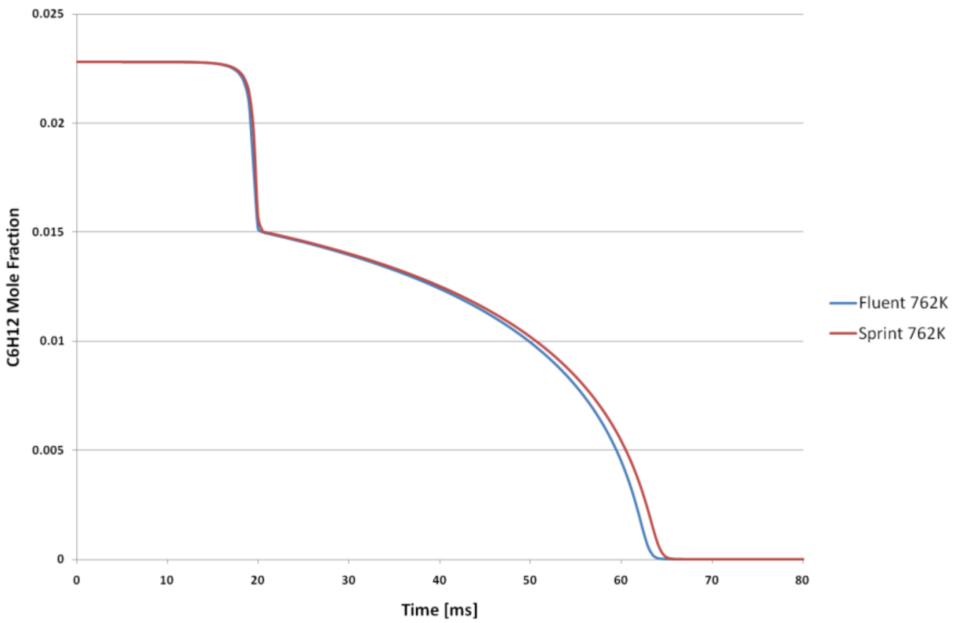
731 K @ 7.83 bar

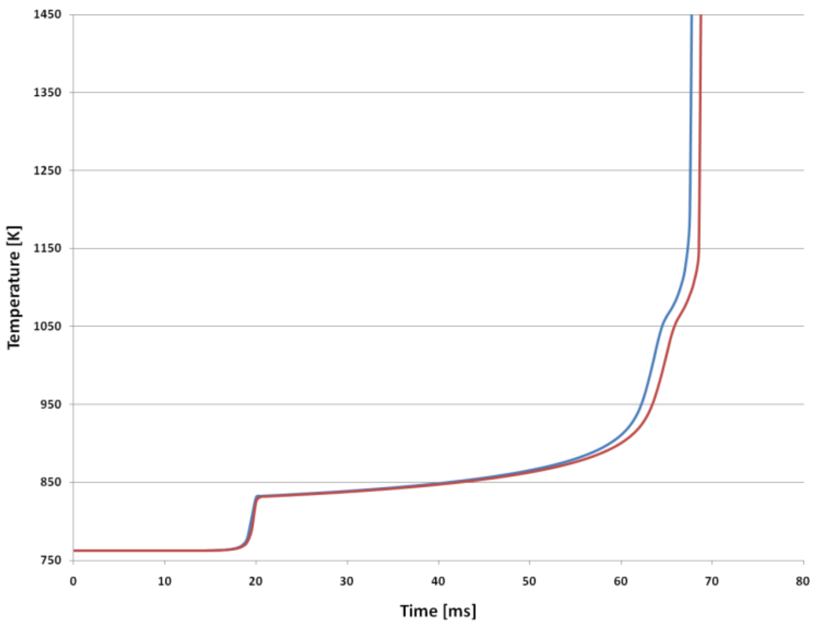




Cyclo-Hexane: Results from TDC

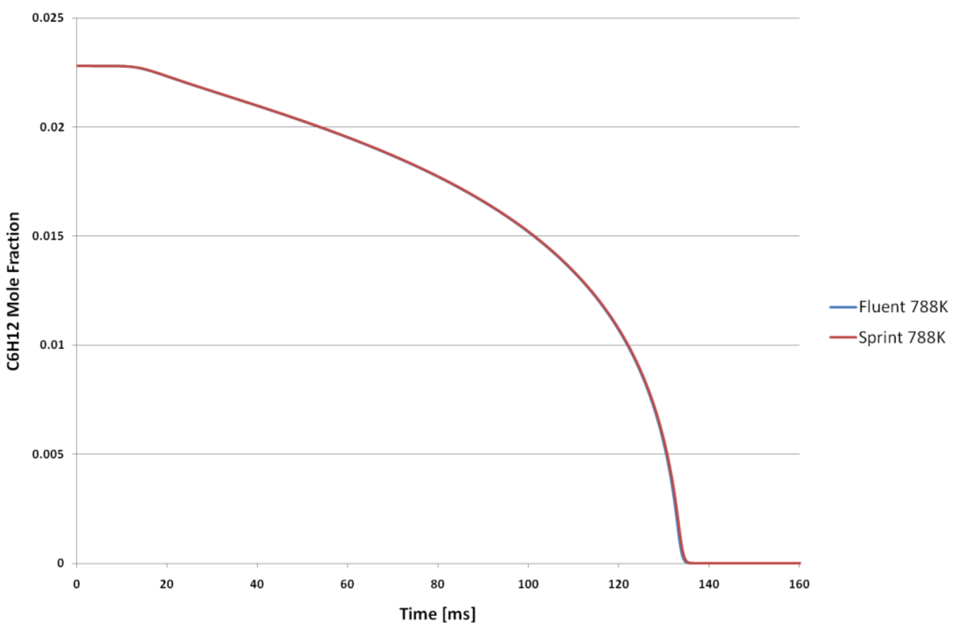
762 K @ 8.14 bar

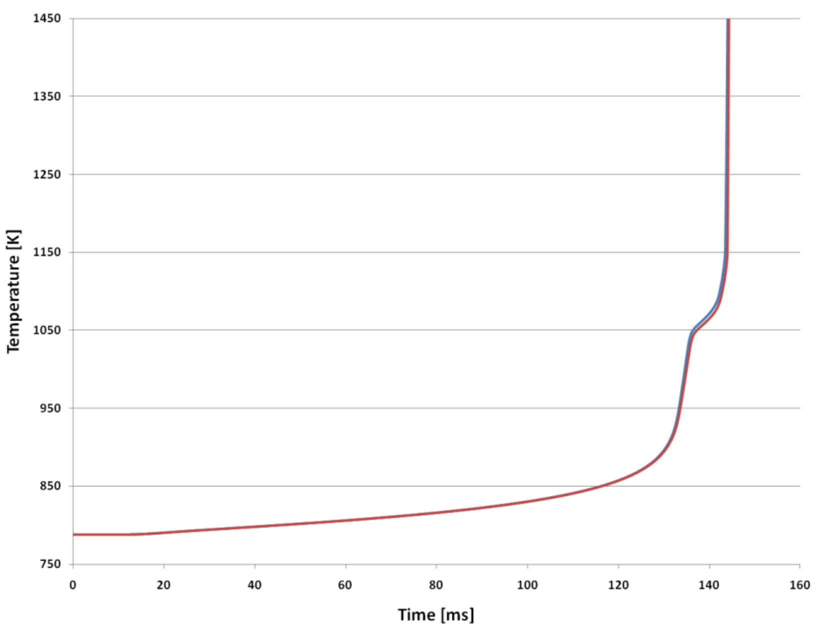




Cyclo-Hexane: Results from TDC

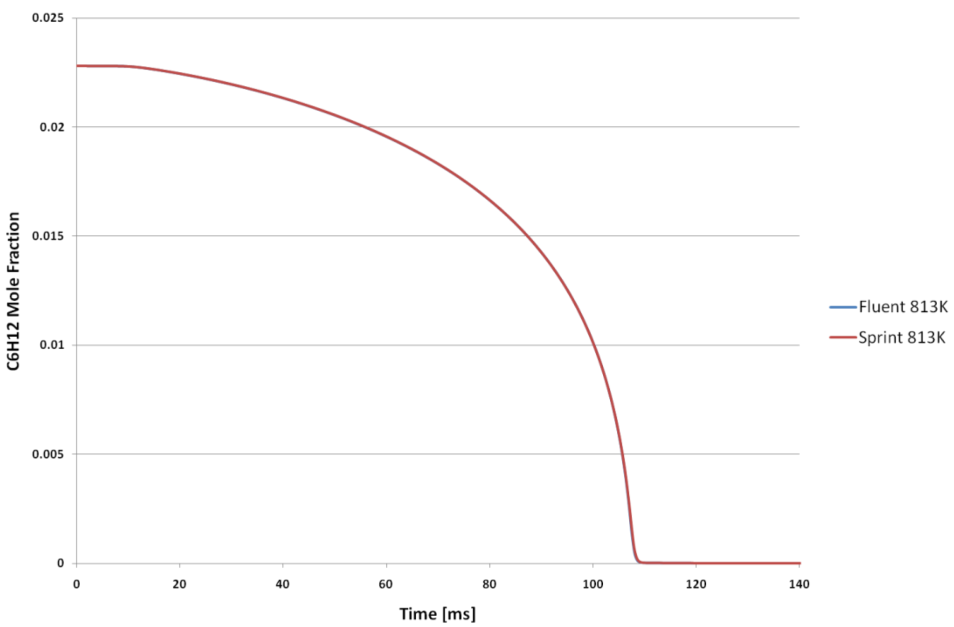
788 K @ 8.44 bar

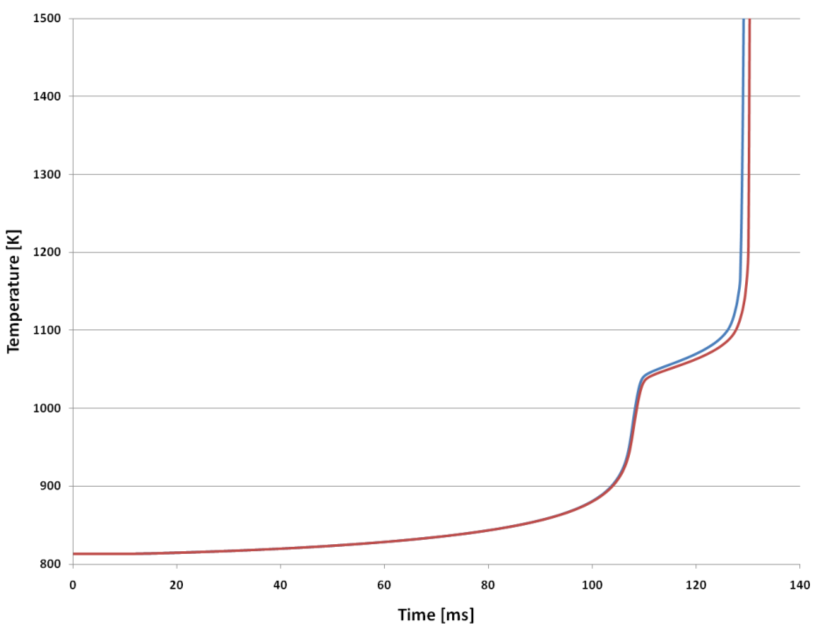




Cyclo-Hexane: Results from TDC

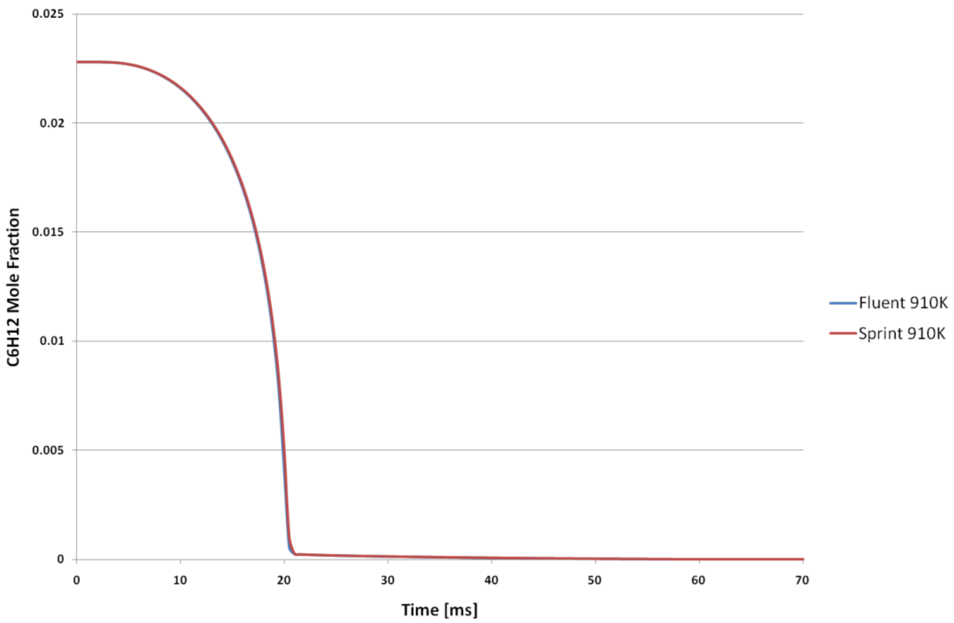
813 K @ 8.69 bar

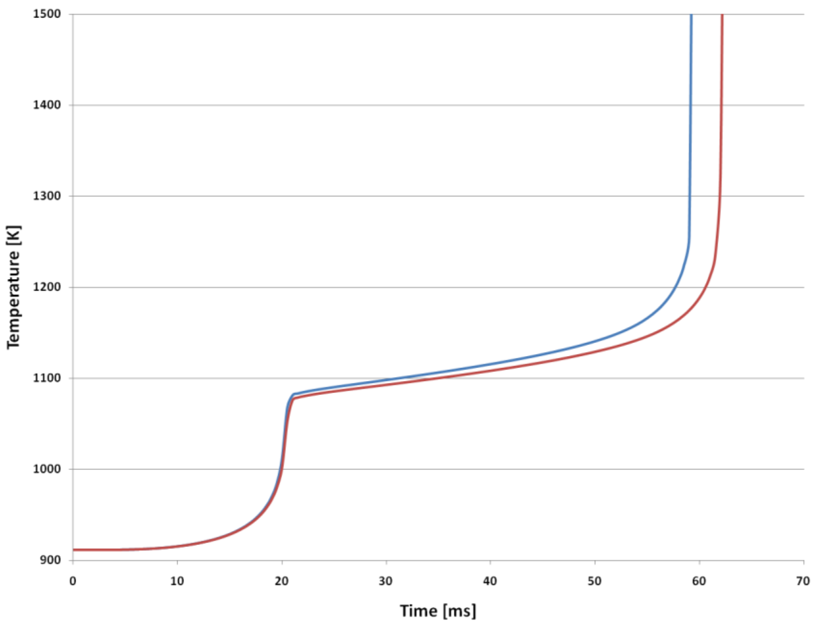




Cyclo-Hexane: Results from TDC

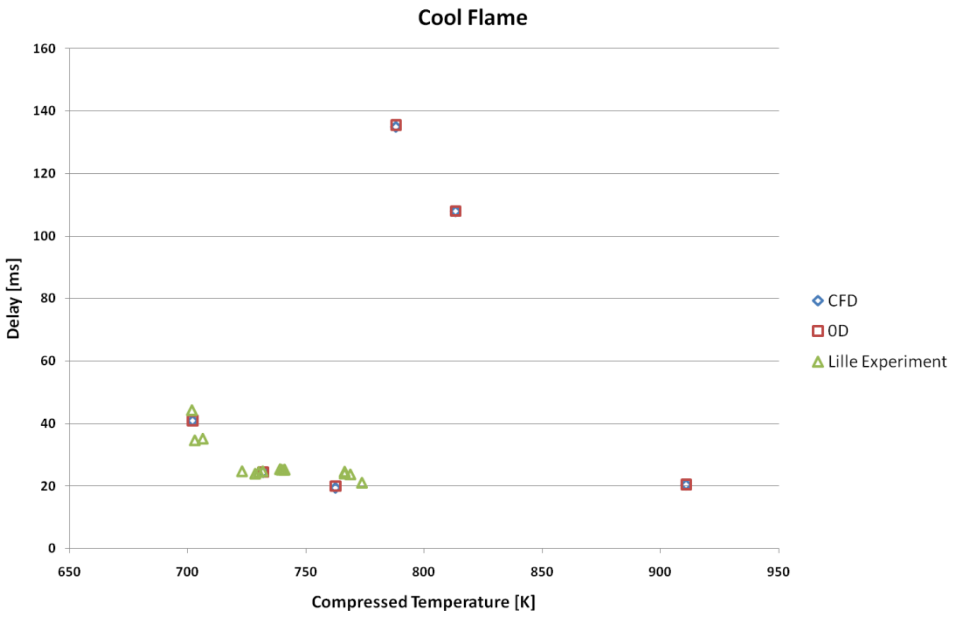
910 K @ 9.75 bar

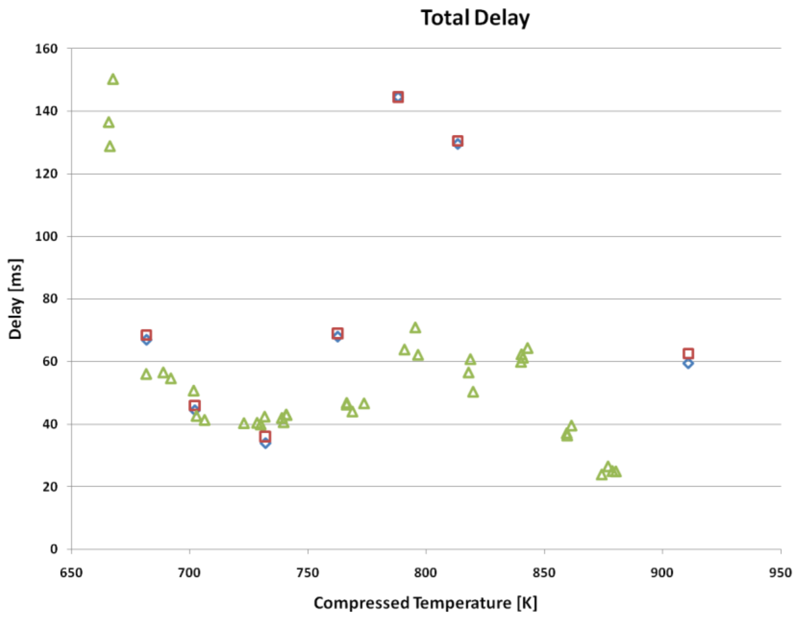




Cyclo-Hexane: Comparison with Lille Experiments

Cool Flame and Total Ignition Delays

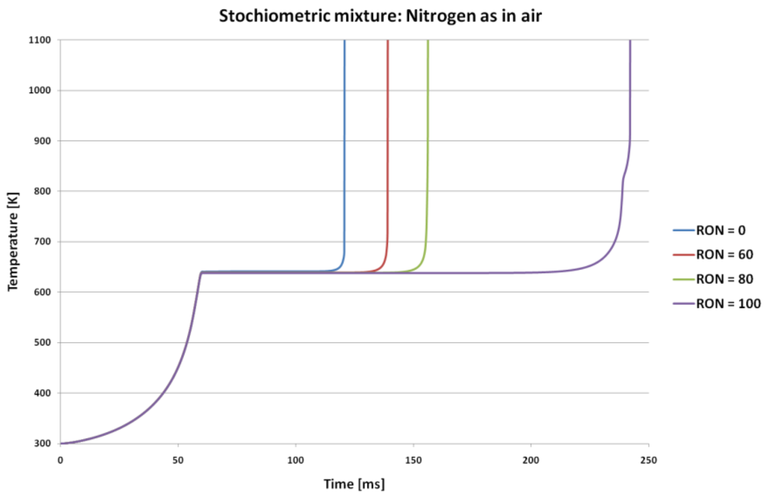


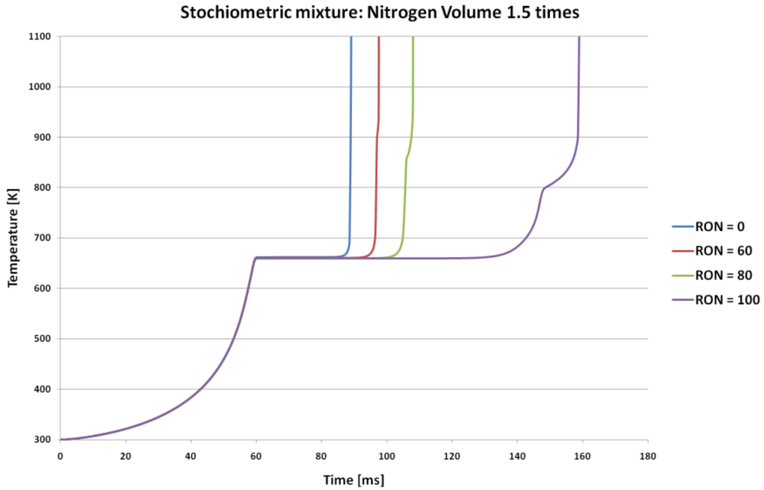


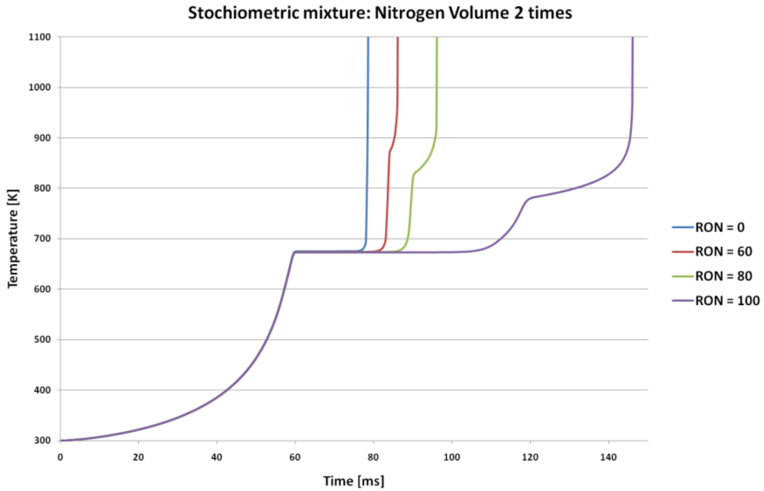
Primary Reference Fuel: Boundary and Initial Conditions

- Mixture of iso-Octane ($i\text{-}C_8H_{18}$) and n-Heptane ($n\text{-}C_7H_{16}$)
- 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

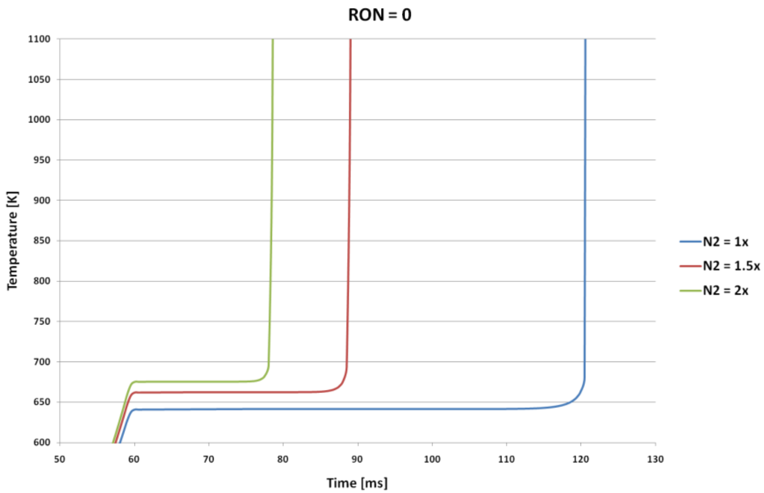
PRF: Results from BDC

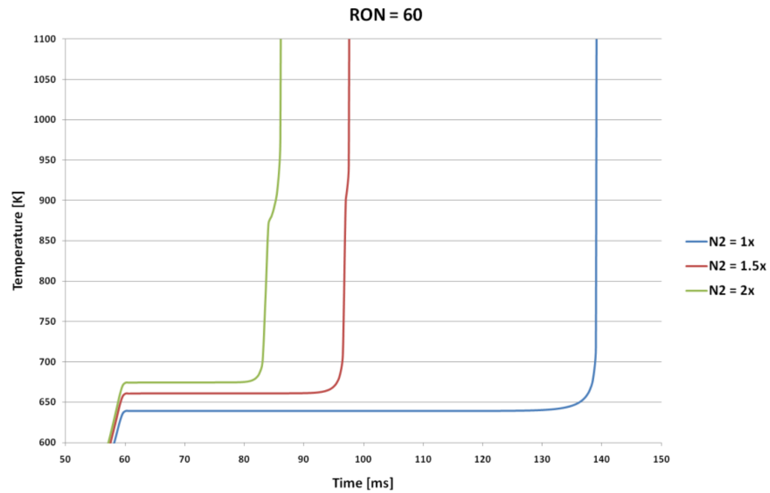


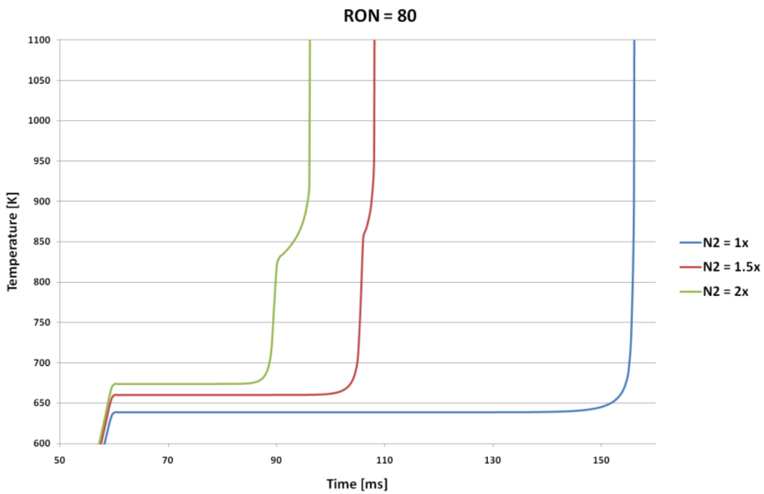


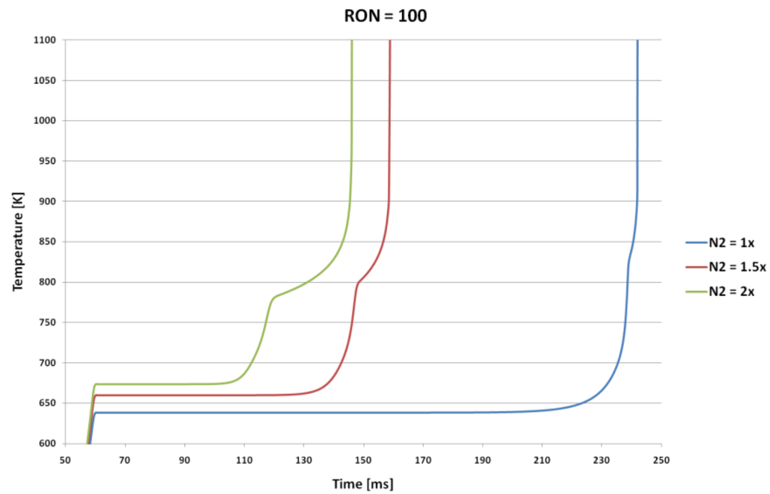


PRF: Results from BDC

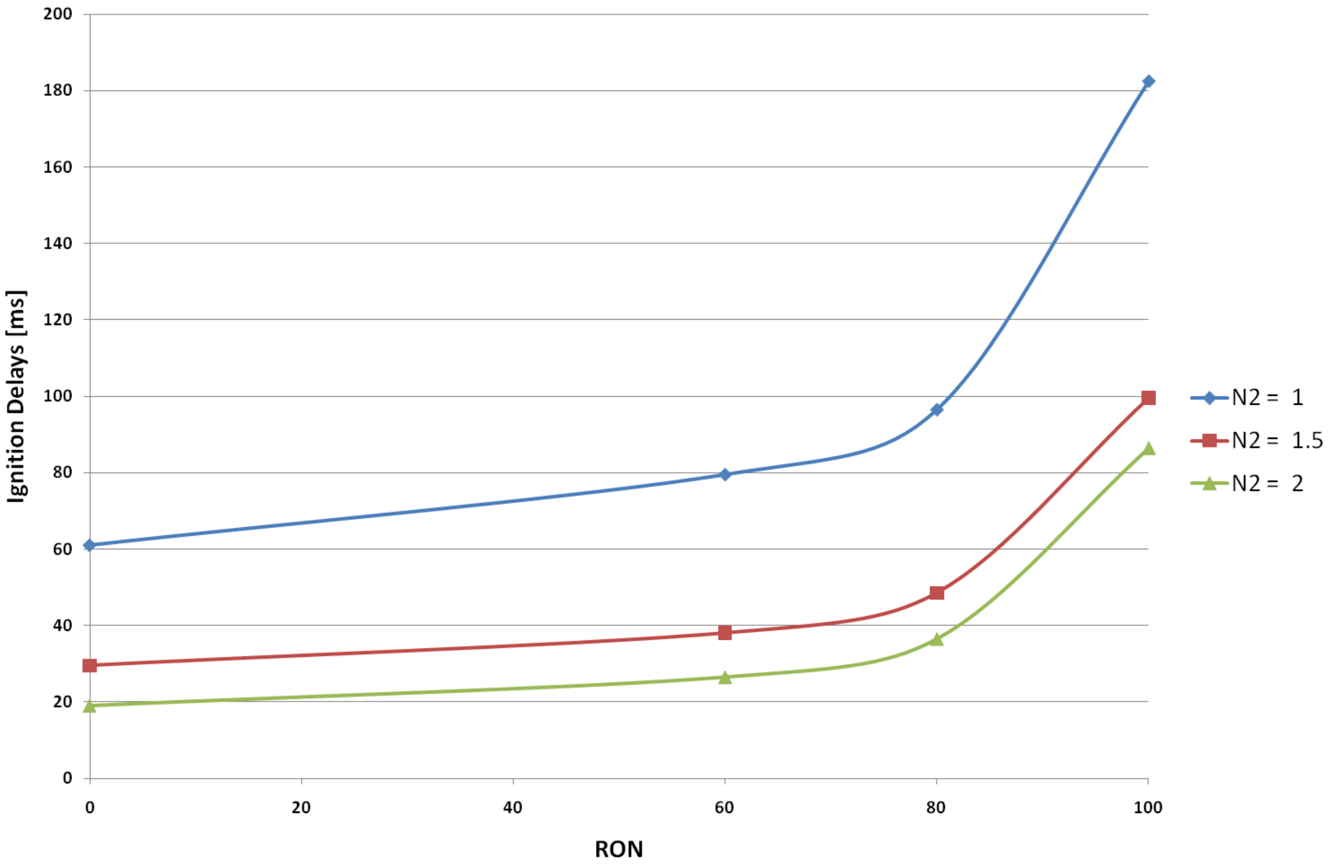




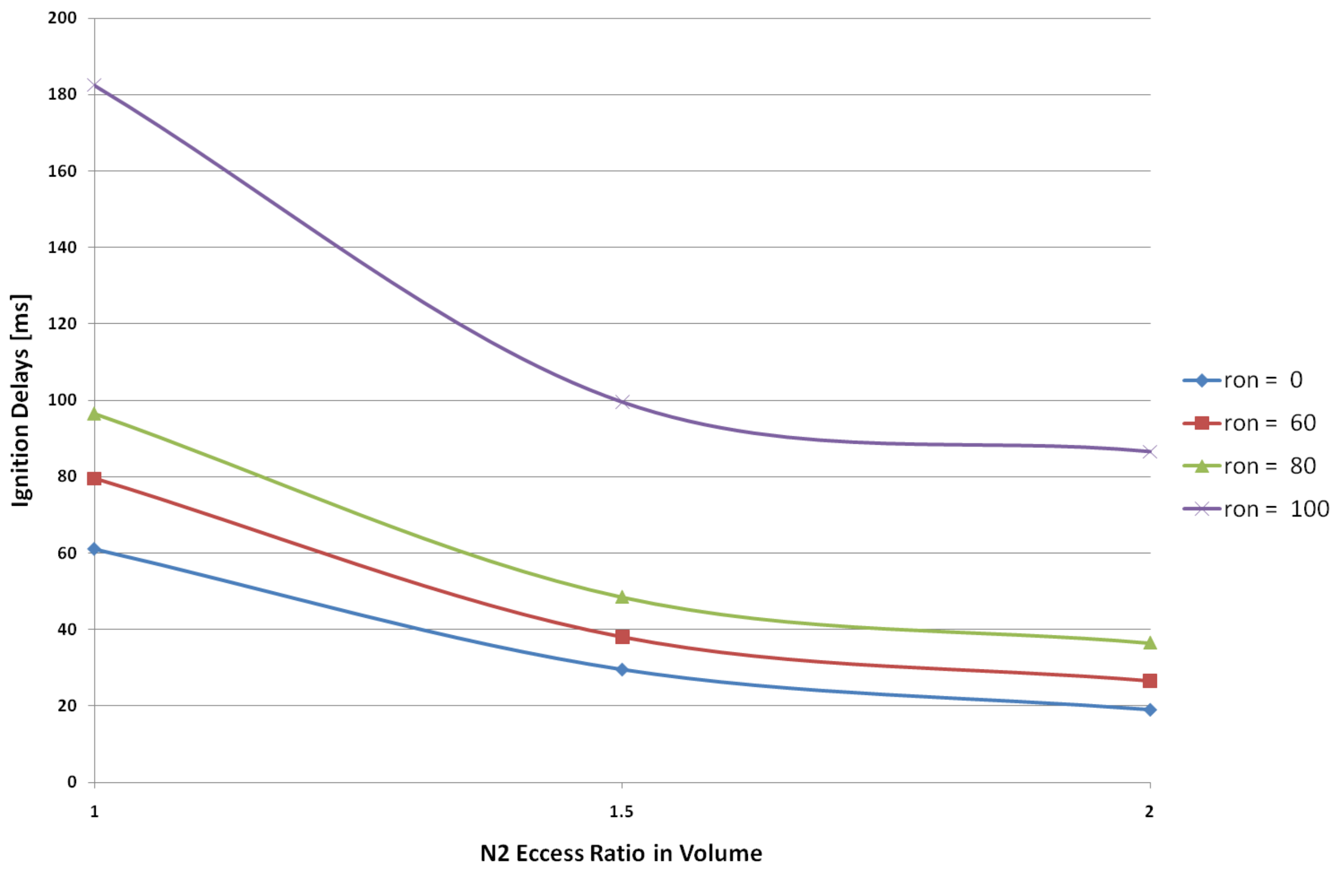




PRF: Ignition Delay vs RON



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...

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