A Fundamental Study of the Novel Poppet Valve 2-Stroke Auto-ignition Combustion Engine (2-ACE)

CFD Engine Simulation

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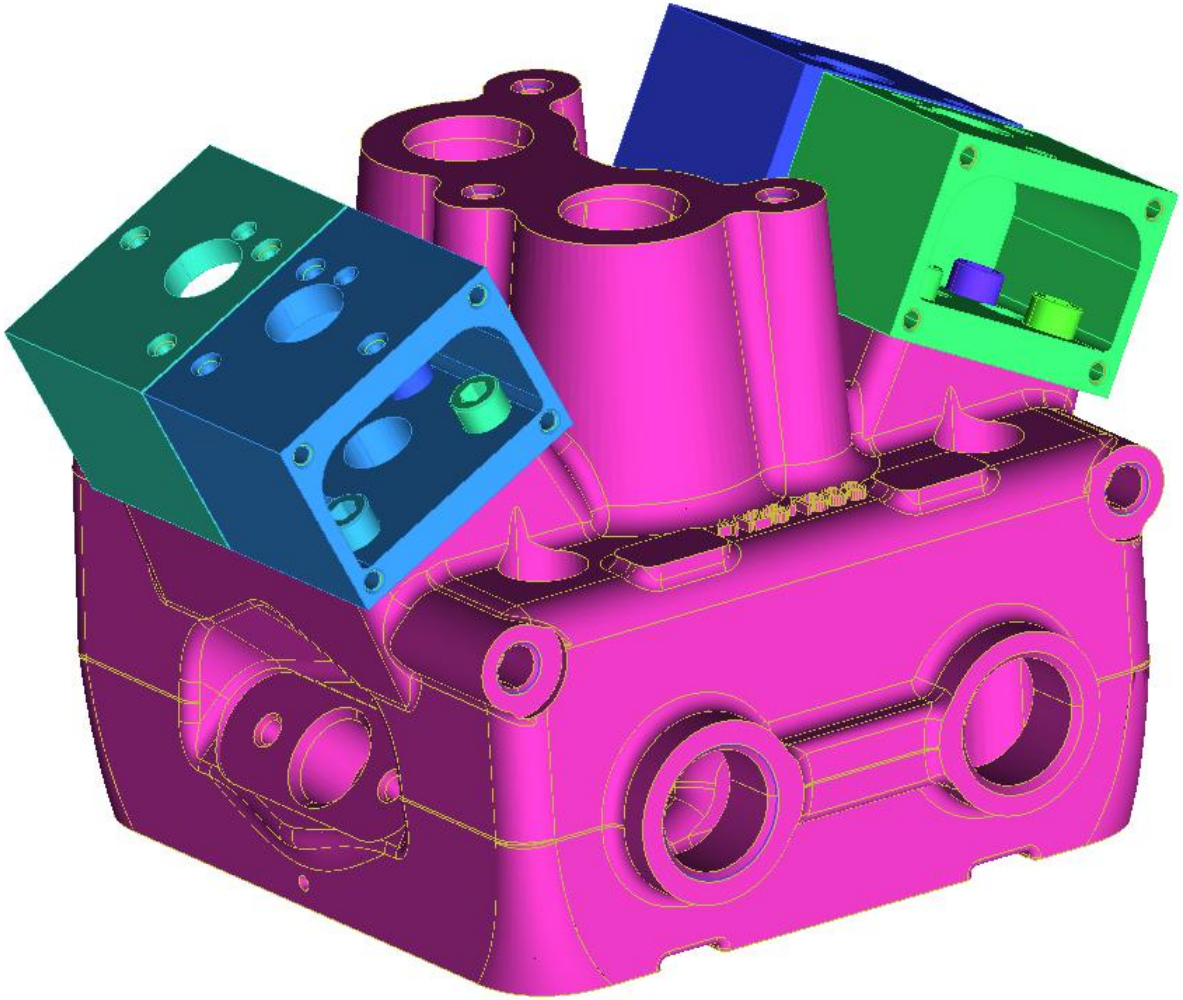
The Sir Harry Ricardo Laboratories
Centre for Automotive Engineering

06/05/2009 Manchester – 2 ACE meeting

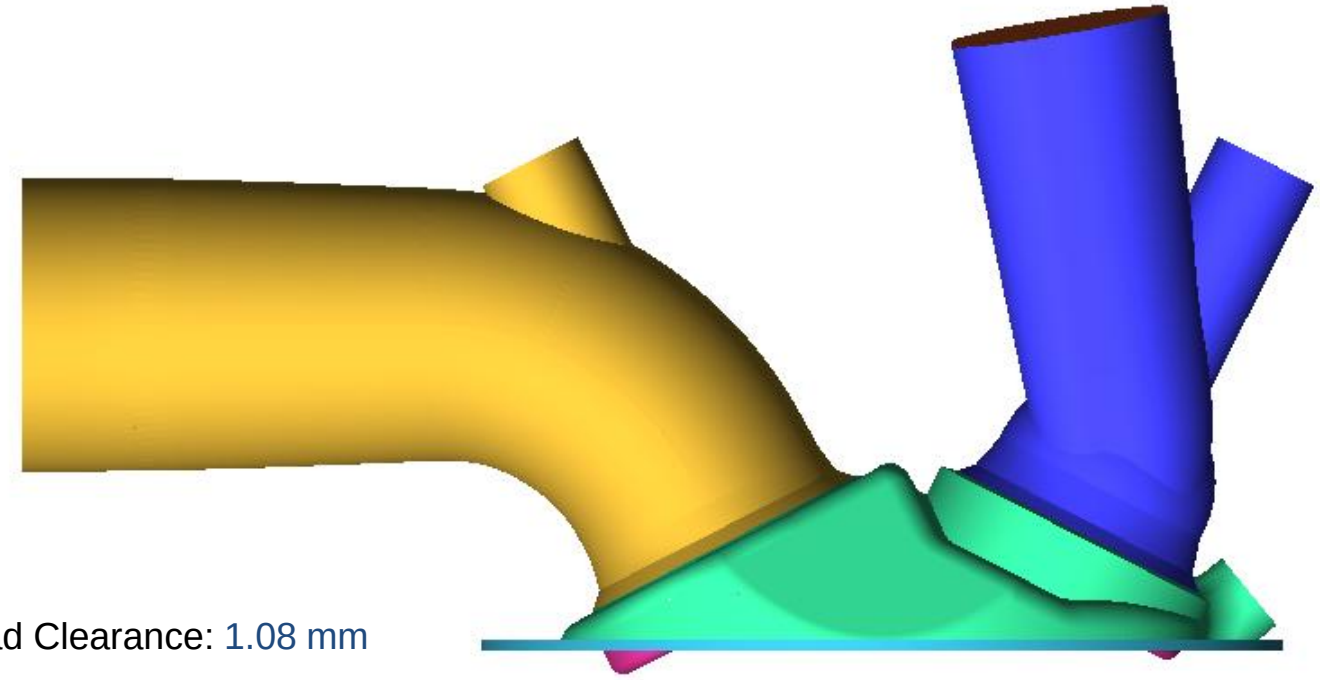
2-ACE Project at University of Brighton

- Implementation of 2-Stroke CFD Engine Simulation
  - Grid Generation and Preliminary Engine Study
  - Spray Simulation
    - Flat Fan Atomizer – DENSO Data
    - Application of the Source Terms Distribution
  - Auto-Ignition Modelling in Rapid Compression Machine
    - Detailed Chemical Modelling (in cooperation with Leeds)
    - Feasibility Study of SHELL Model
    - Non Reactive 2D Simulation

Full Engine Head before Geometry Clean-up

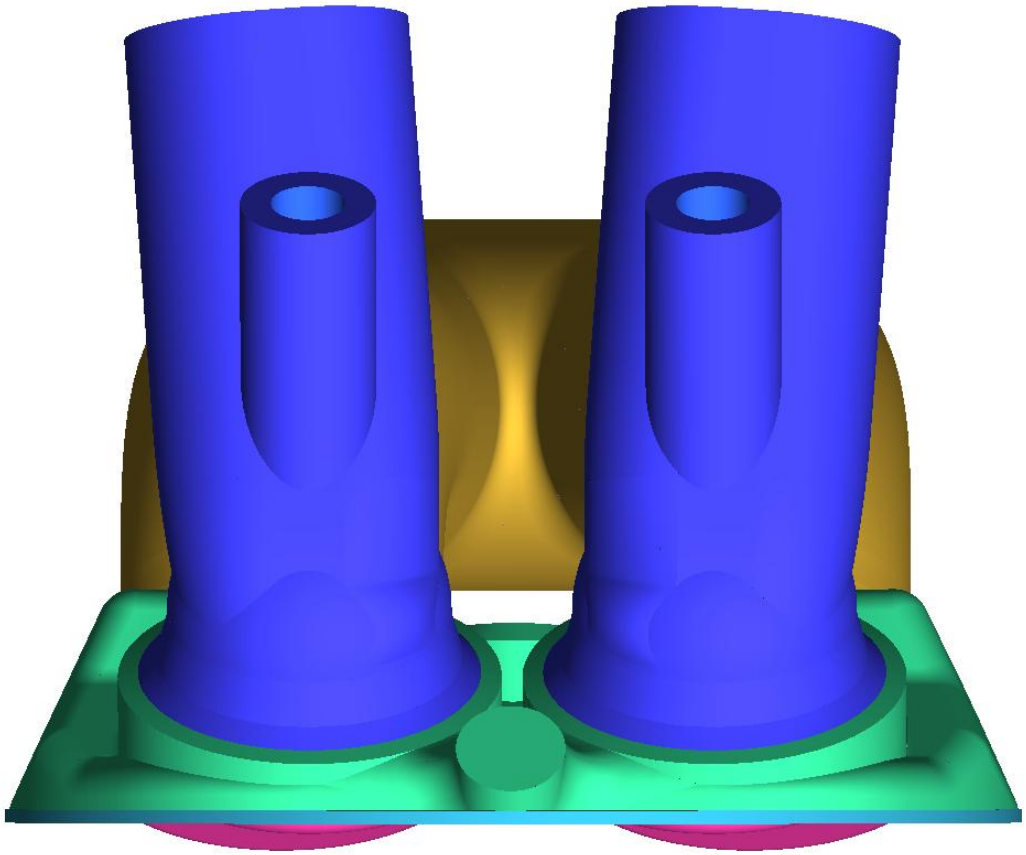


Computational Domain after Geometry Clean-up



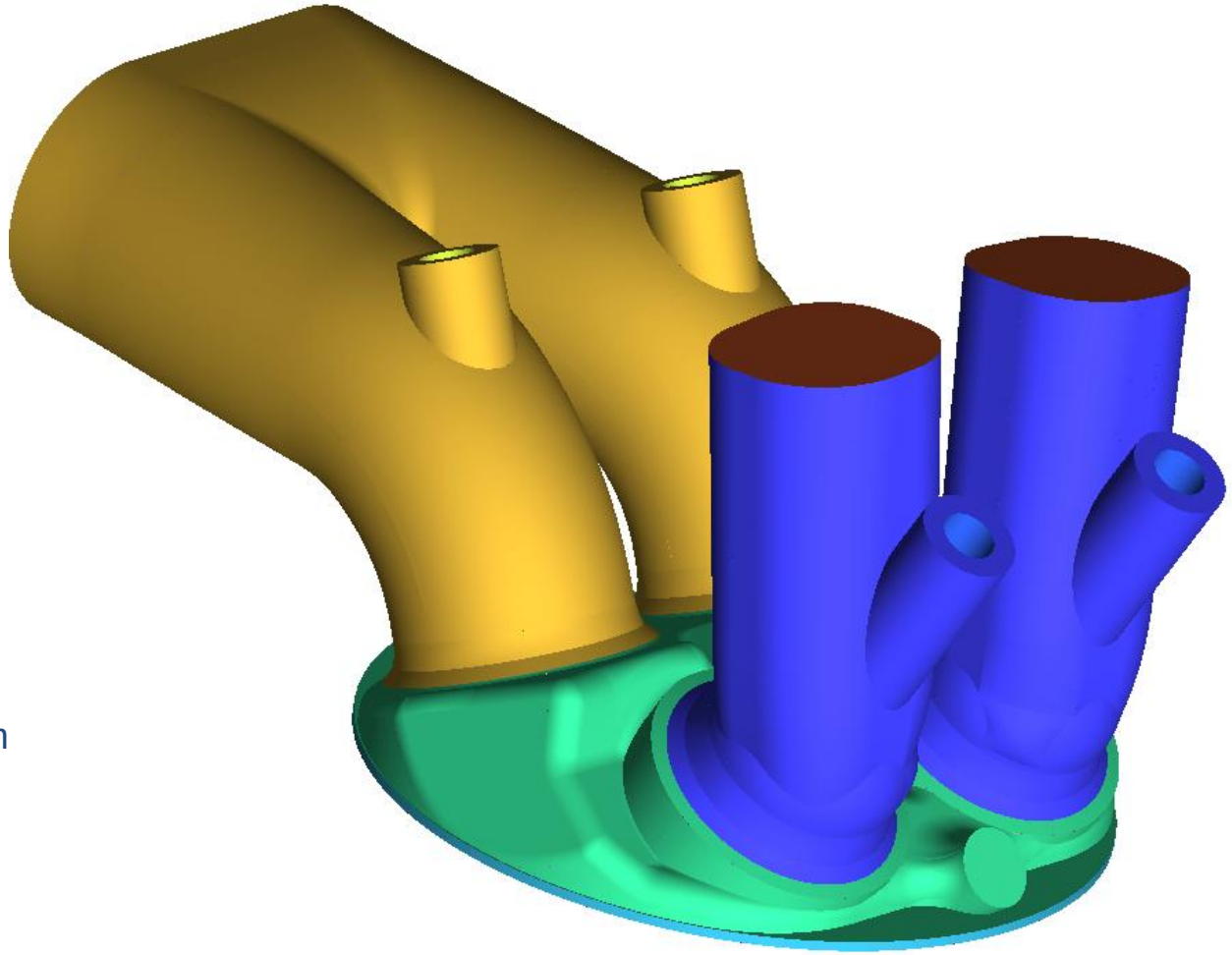
Piston to Head Clearance: 1.08 mm

Computational Domain after Geometry Clean-up



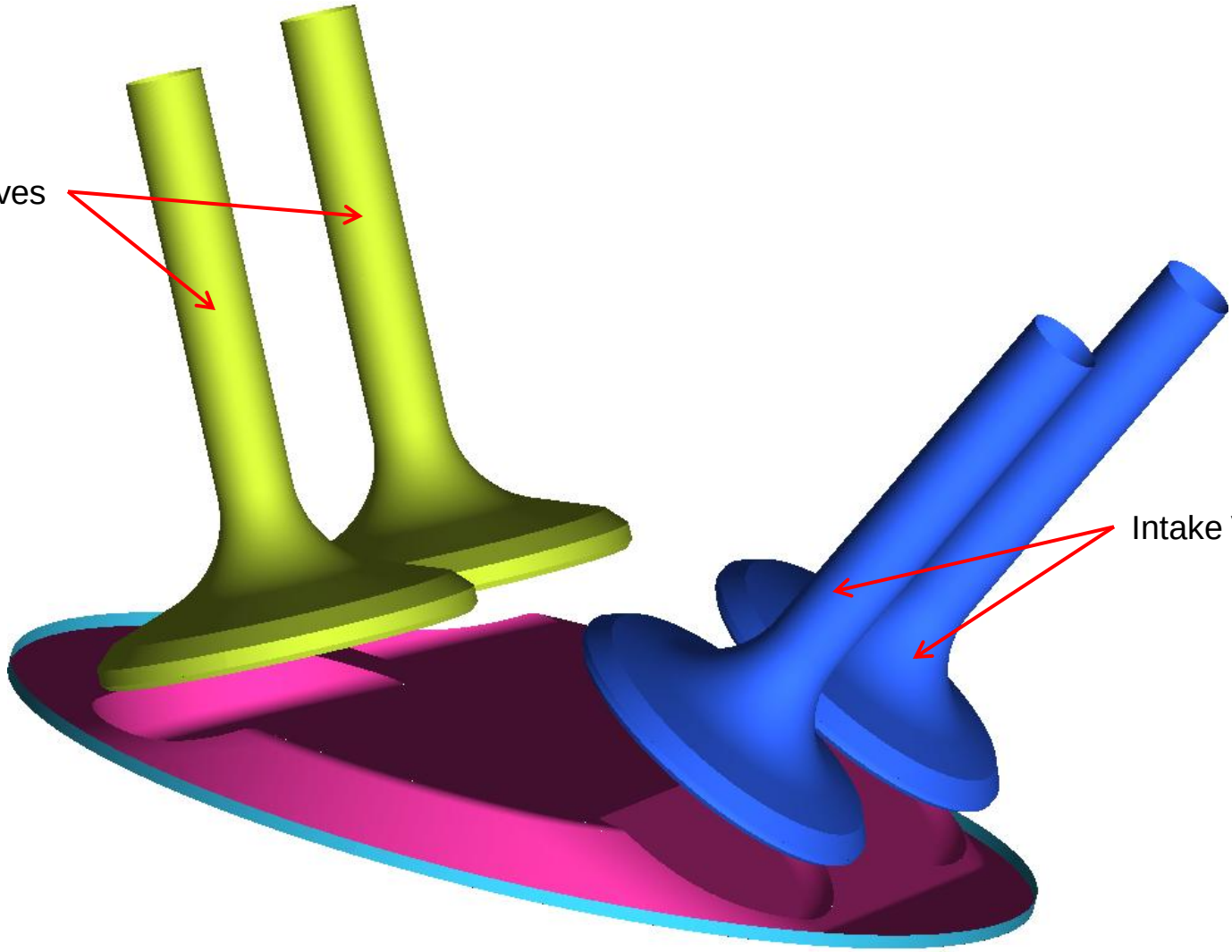
Bore: 81.6 mm

Computational Domain after Geometry Clean-up



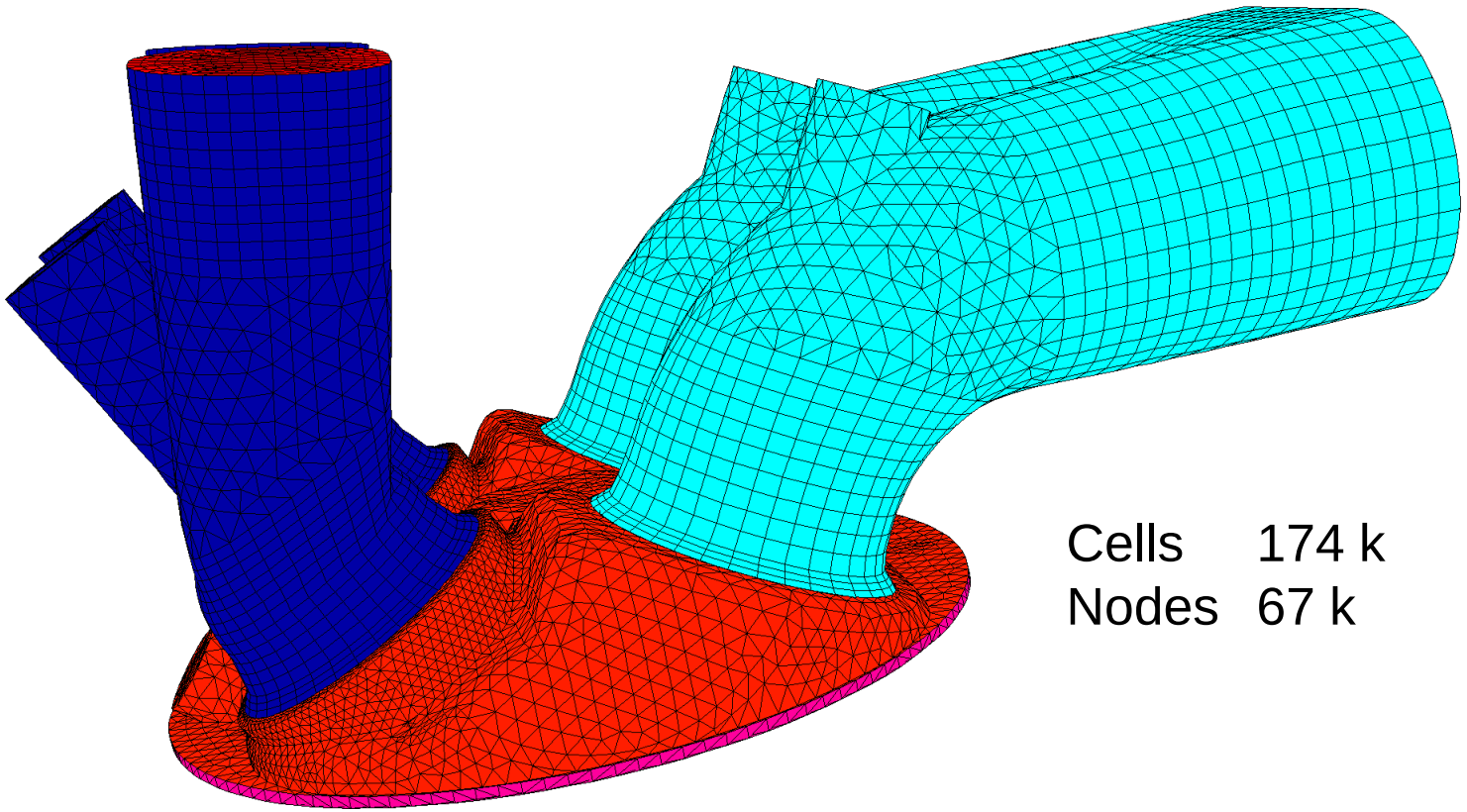
Stroke: 66.8 mm

Computational Domain after Geometry Clean-up



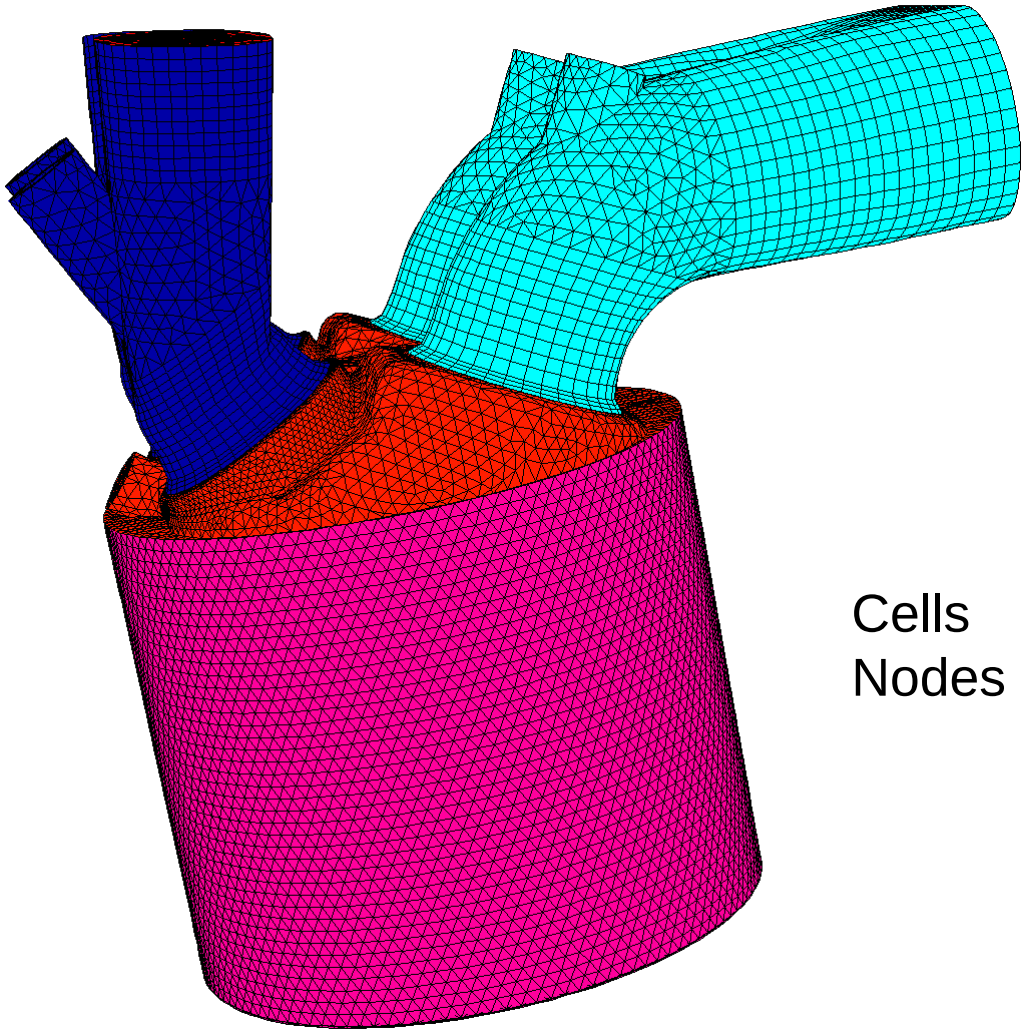
Conrod: 144.5 mm

Grid Specifications at TDC



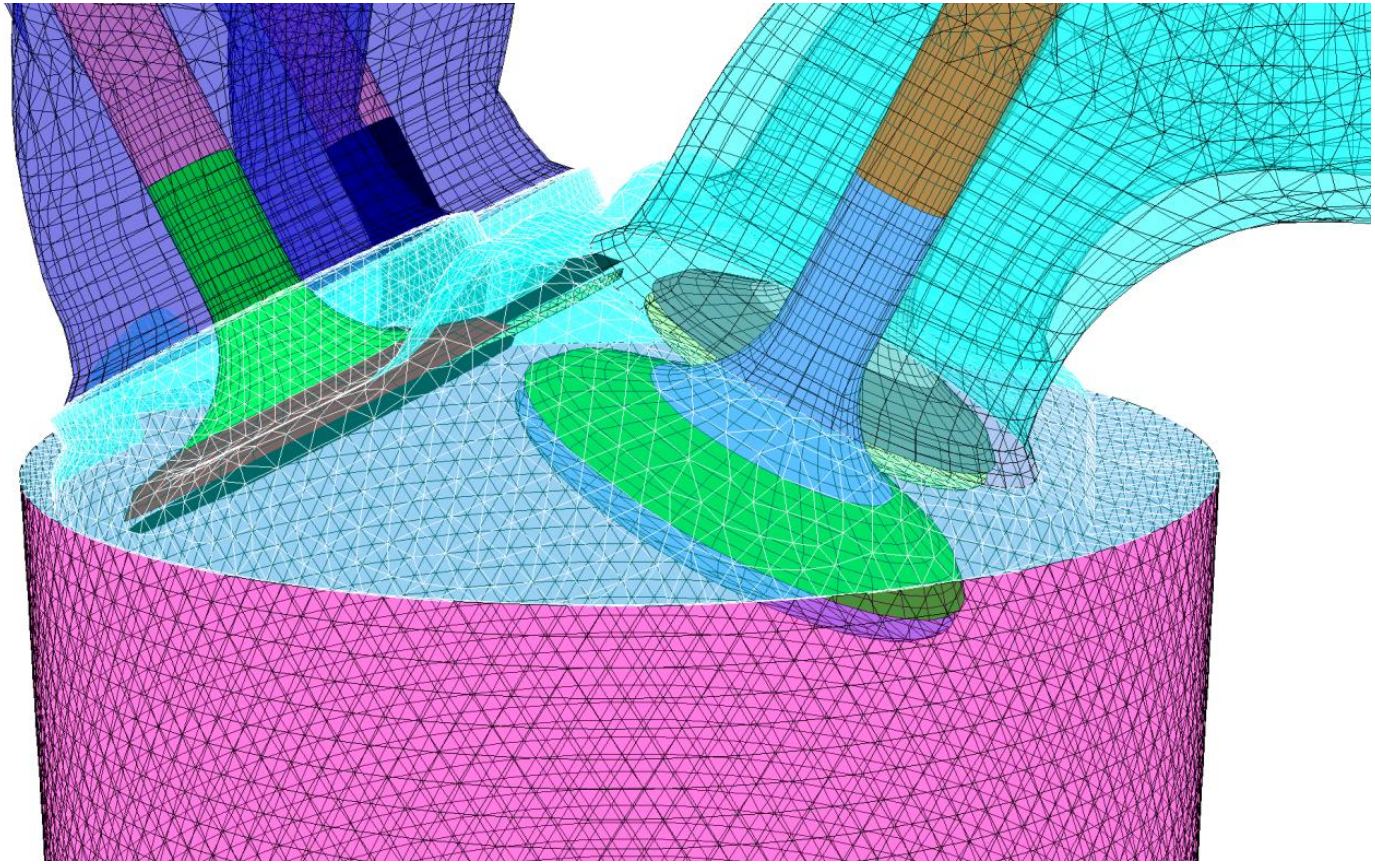
Cells 174 k
Nodes 67 k

Grid Specifications at BDC



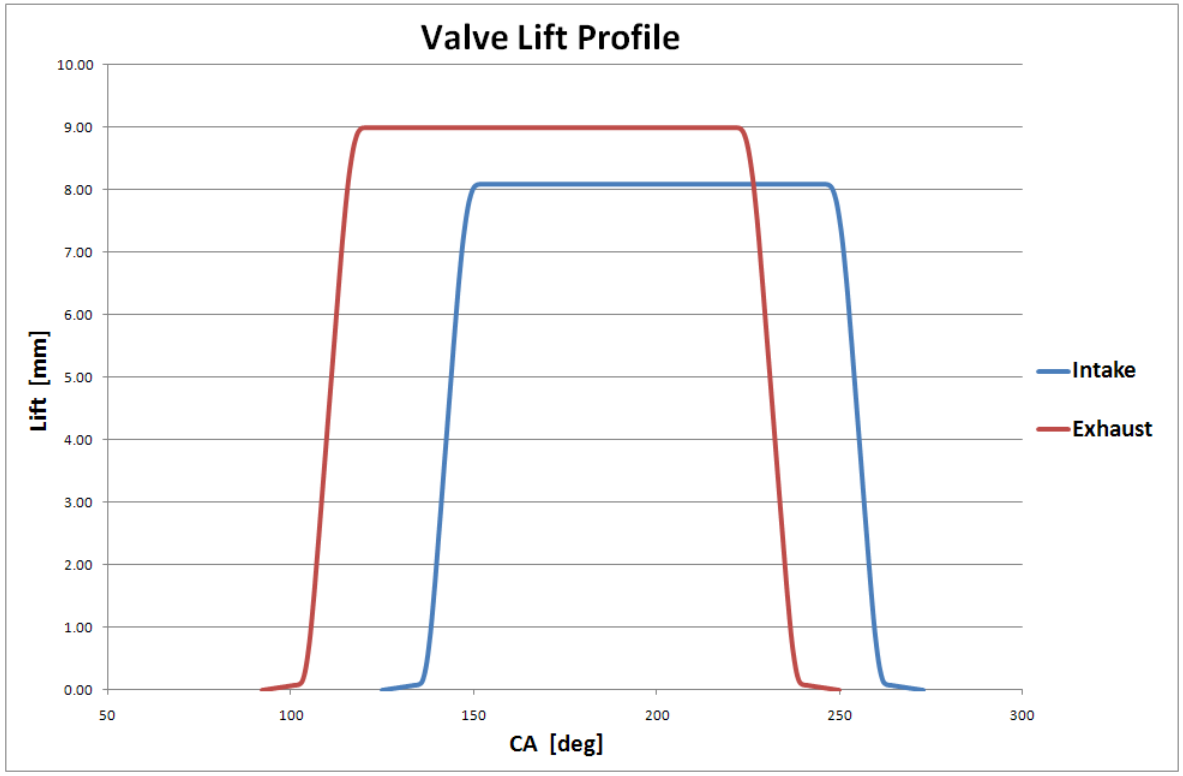
Cells	247 k
Nodes	96 k

Details of the valves at BDC



Preliminary simulations of the 2-ACE engine

- Motored engine results speed 1000 RPM (atmospheric pressure condition at the intake and exhaust)



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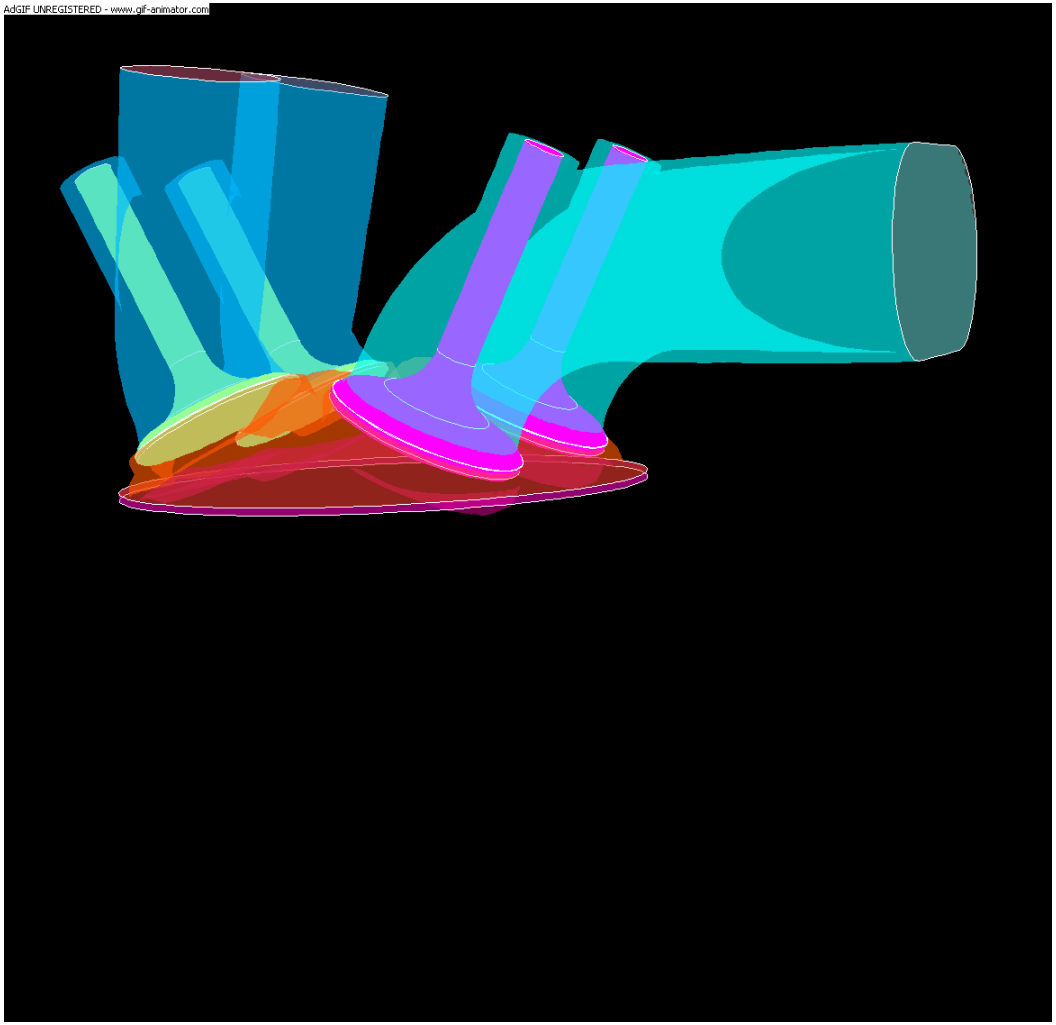
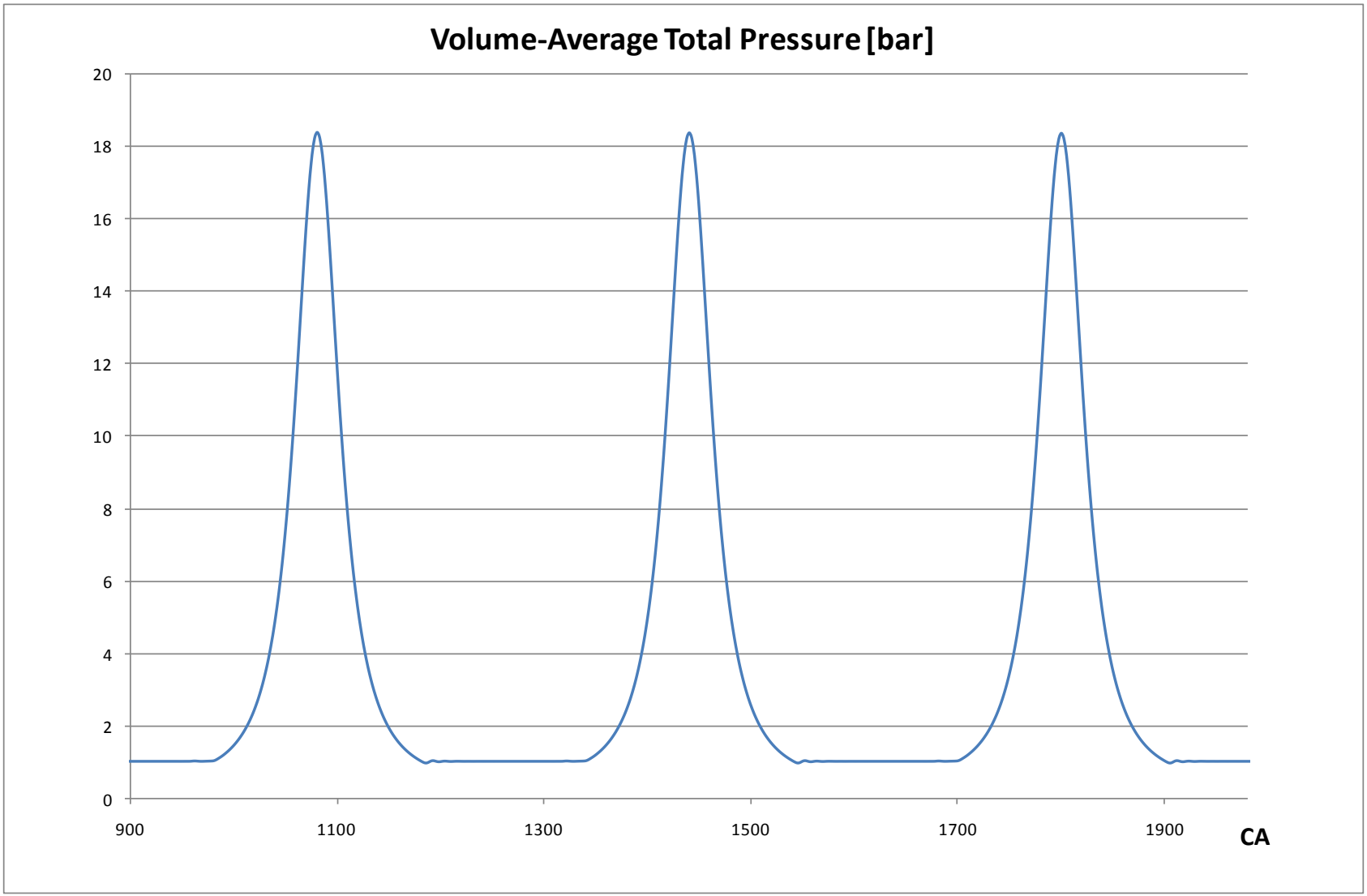
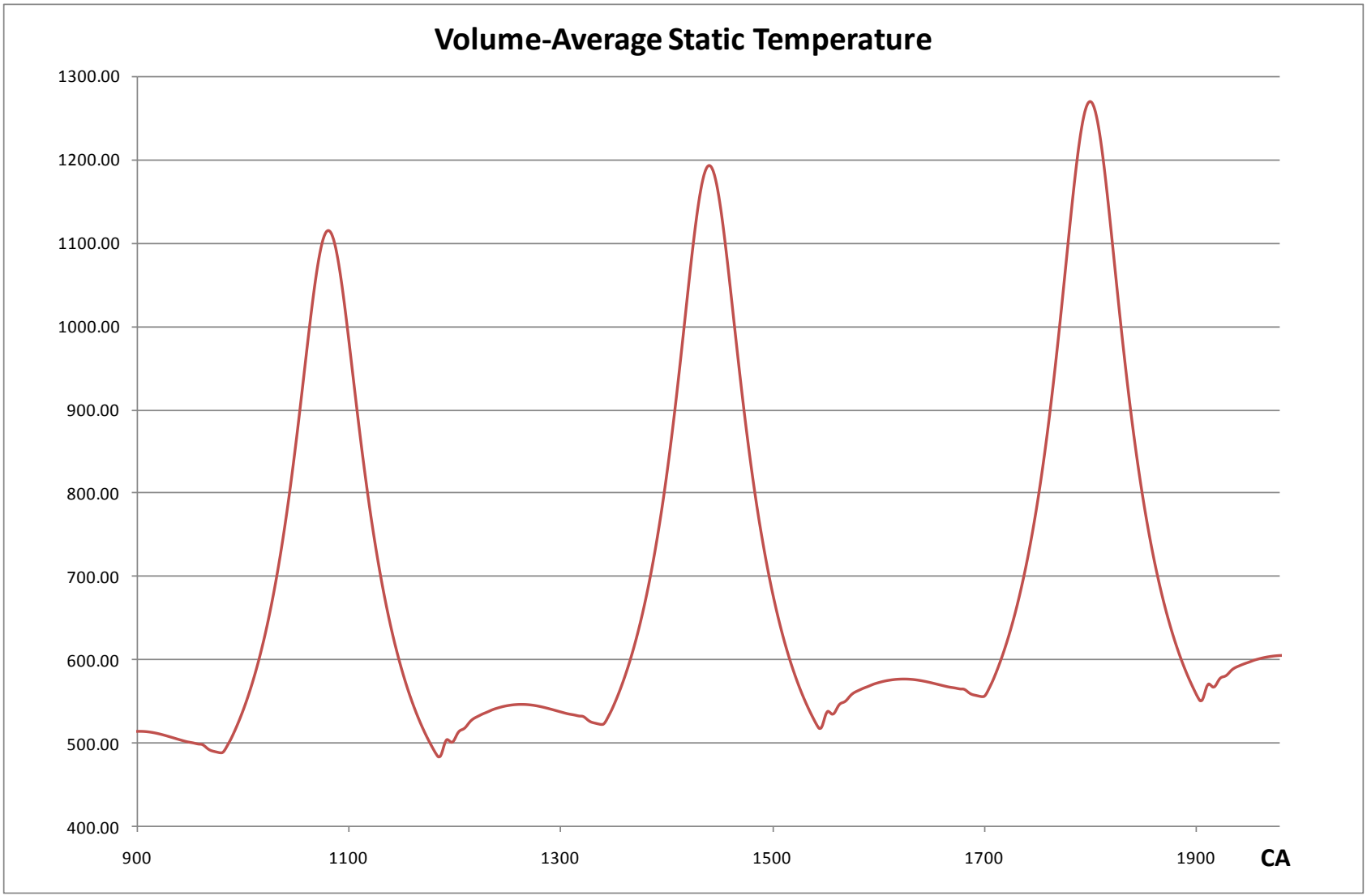



Volume-Average Total Pressure [bar]
20
18
16
14
12
10
8
6
4
2
0
900
1100
1300
1500
1700
1900
CA


Volume-Average Static Temperature
1300.00
1200.00
1100.00
1000.00
900.00
800.00
700.00
600.00
500.00
400.00
900
1100
1300
1500
1700
1900
CA

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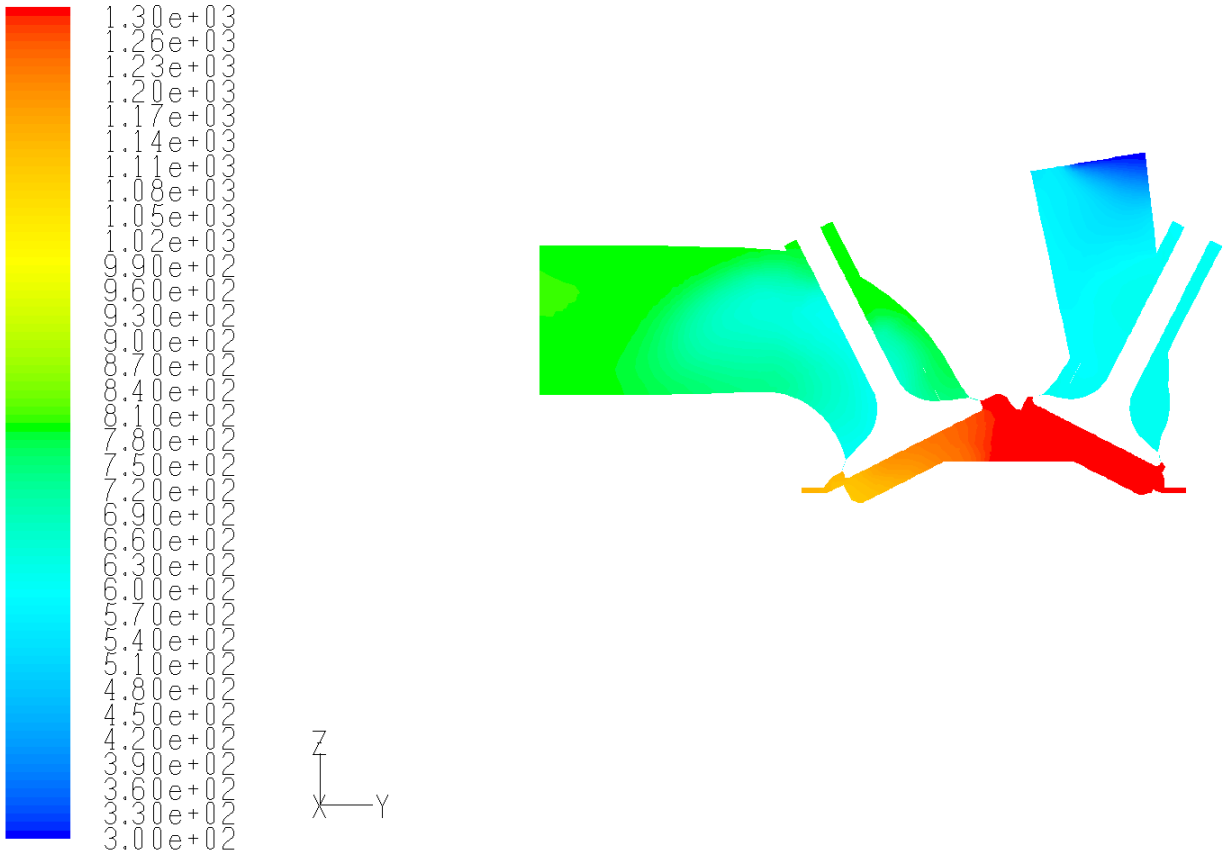
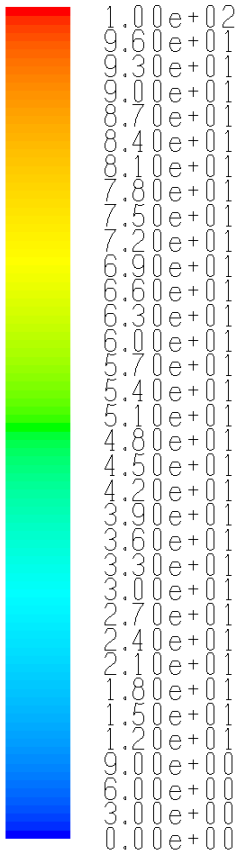
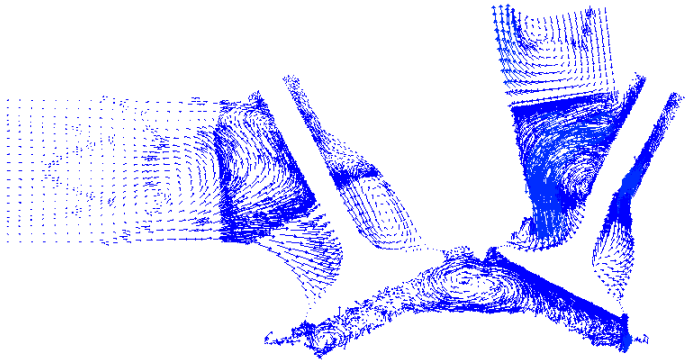


Contours of Static Temperature (k) (Time=3.0000e-01) Mar 30, 2009
Crank Angle=1799.99(deg) FLUENT 6.3 (3d, dp, pbns, dynamesh, ske, unsteady)



1.00e+02
9.60e+01
9.30e+01
9.00e+01
8.70e+01
8.40e+01
8.10e+01
7.80e+01
7.50e+01
7.20e+01
6.90e+01
6.60e+01
6.30e+01
6.00e+01
5.70e+01
5.40e+01
5.10e+01
4.80e+01
4.50e+01
4.20e+01
3.90e+01
3.60e+01
3.30e+01
3.00e+01
2.70e+01
2.40e+01
2.10e+01
1.80e+01
1.50e+01
1.20e+01
9.00e+00
6.00e+00
3.00e+00
0.00e+00



Velocity Vectors Colored By Velocity Magnitude (m/s) (Time=3.0000e-01) Mar 30, 2009
Crank Angle=1799.99(deg) FLUENT 6.3 (3d, dp, pbns, dynamesh, ske, unsteady)

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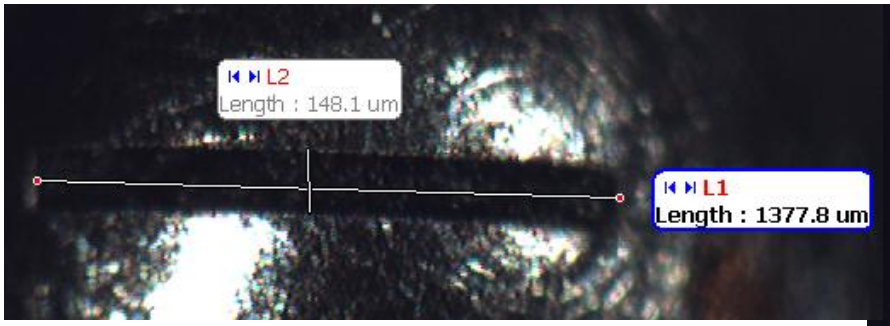
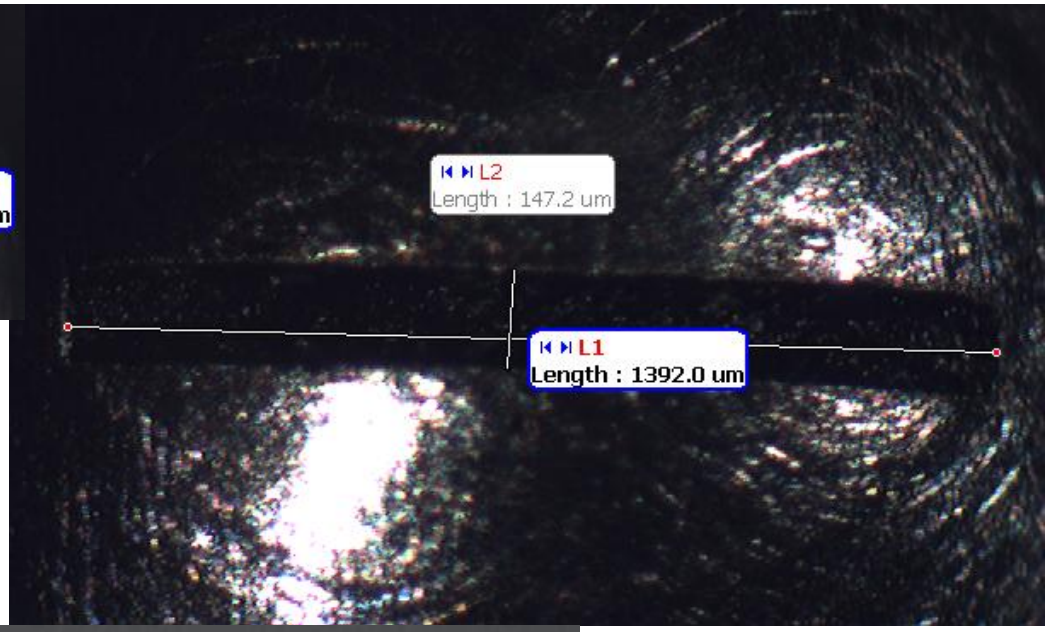
Fan Injector Slot's Dimensions Measured by Optical Microscopy

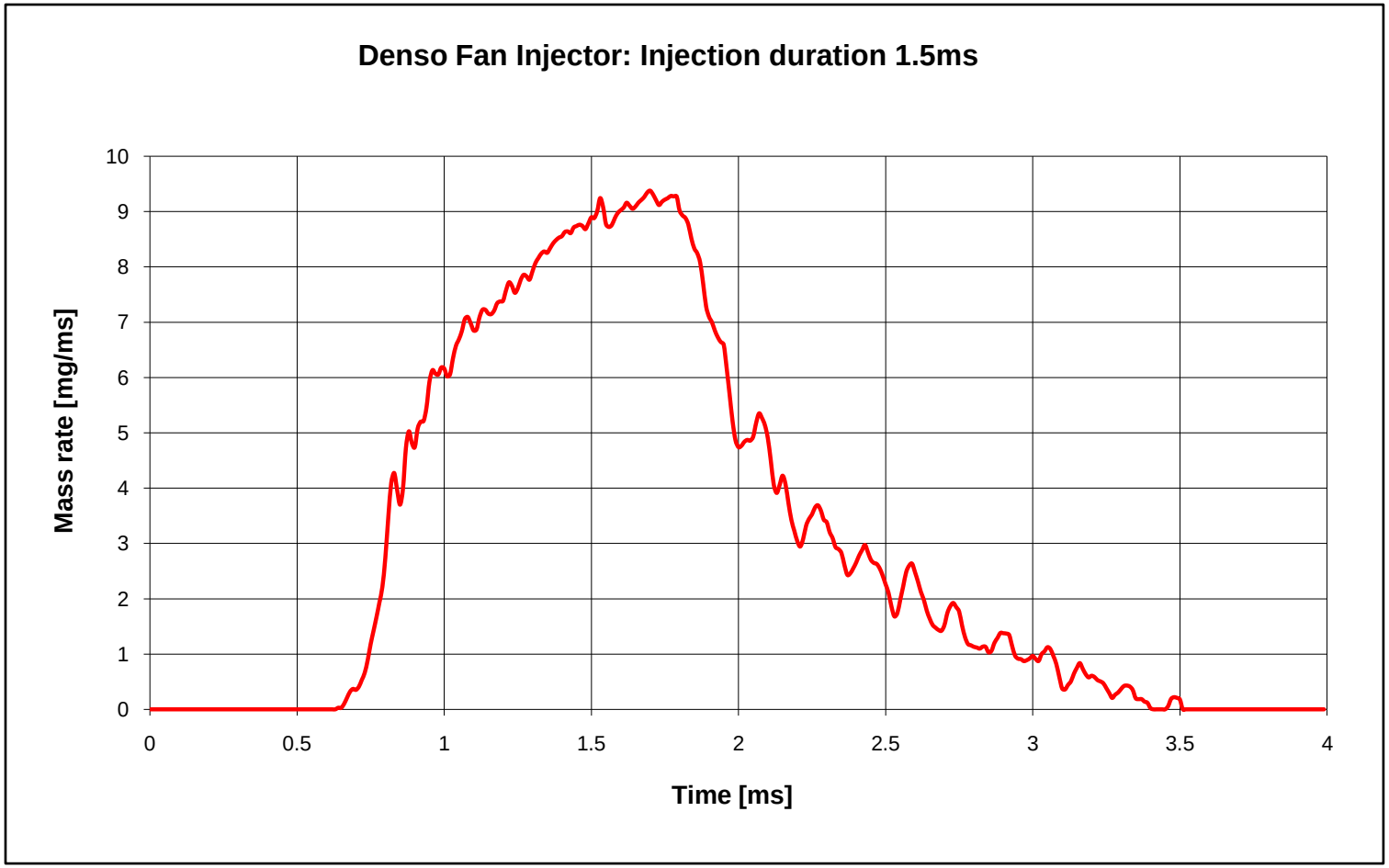




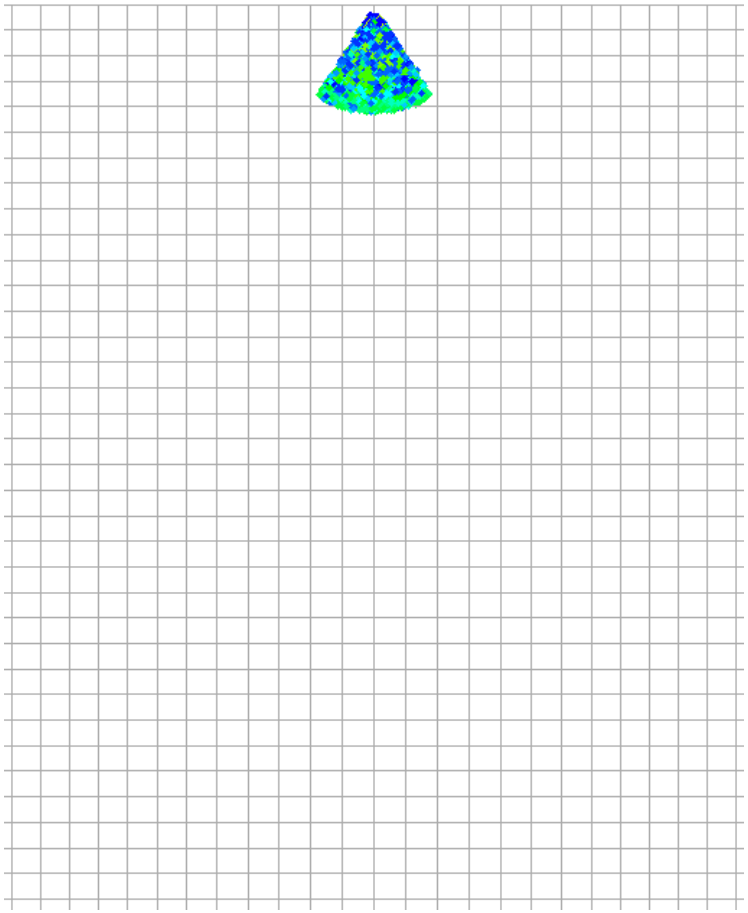
- Average Width = 147,65 µm
- Average Length = 1384,9 µm
- Arc Length = 1405,7 µm

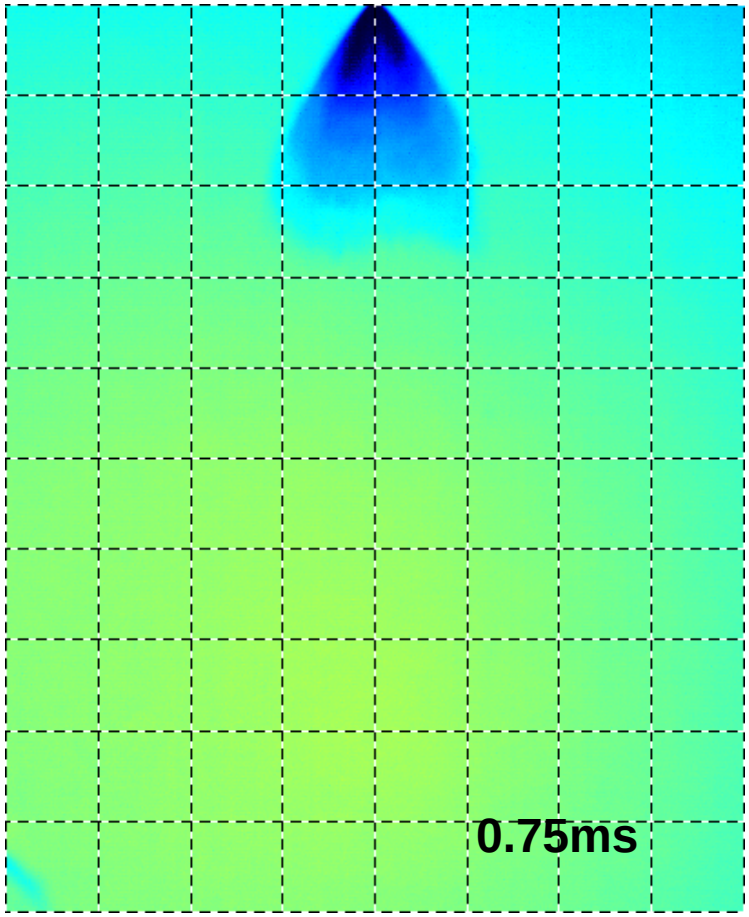
Experimental Condition Considered

Injection Pressure = 150 bar
Fuel Temp = 90˚ C
Air pressure = atmospheric
Air Temperature = atmospheric

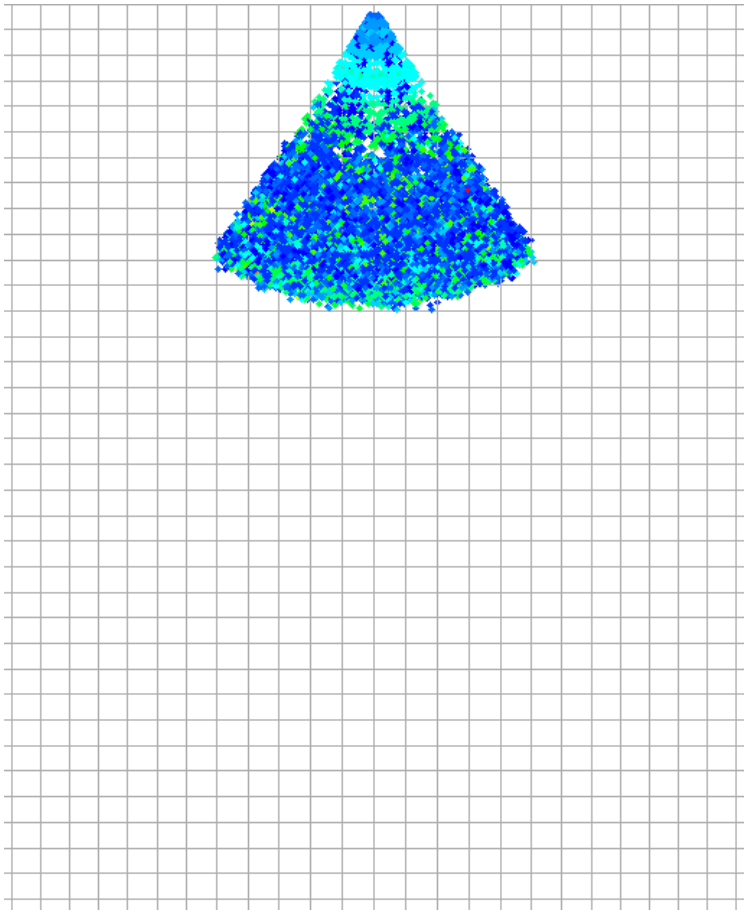


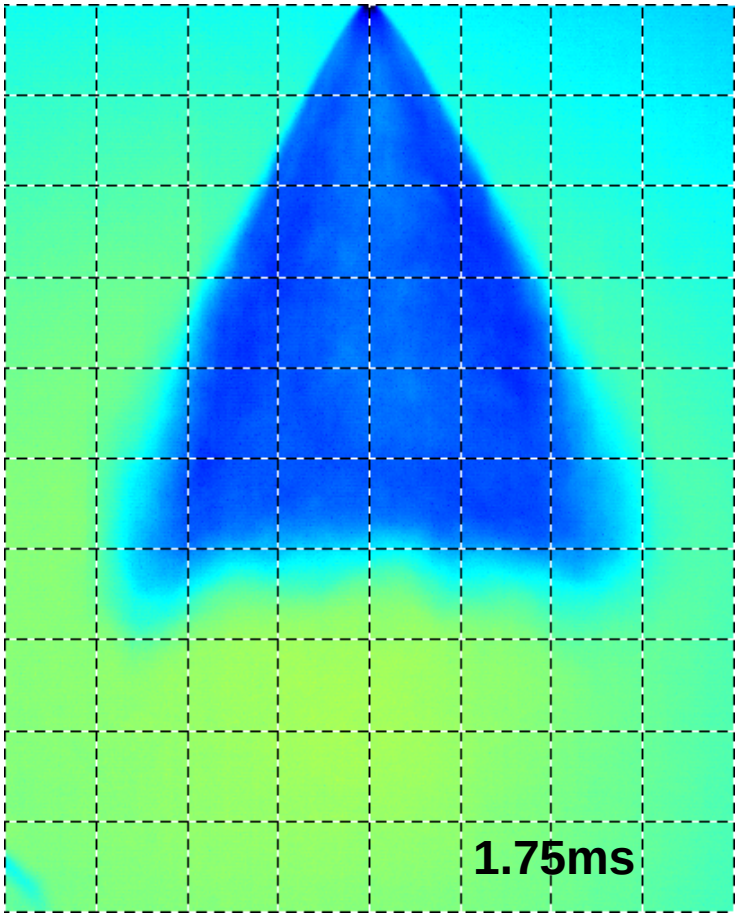
Comparison between Computation and Experiment



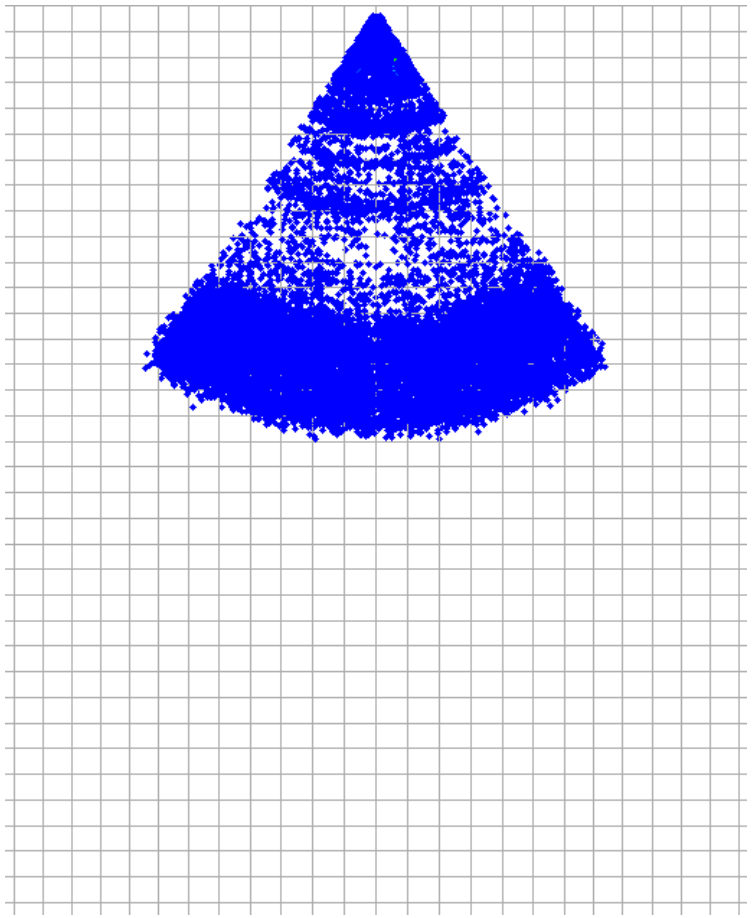


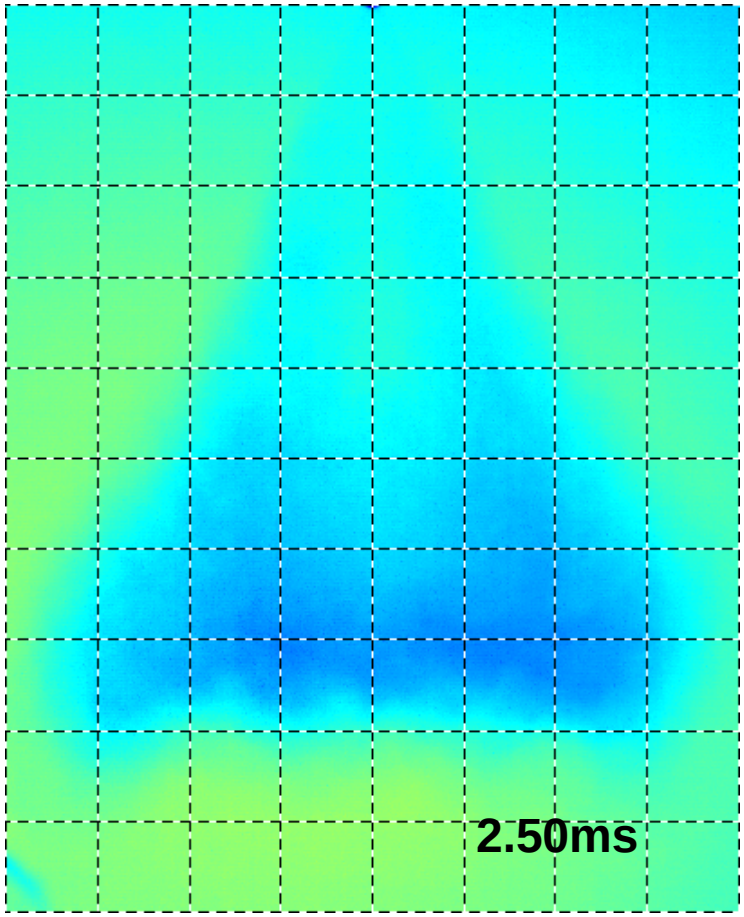
Comparison between Computation and Experiment





Comparison between Computation and Experiment





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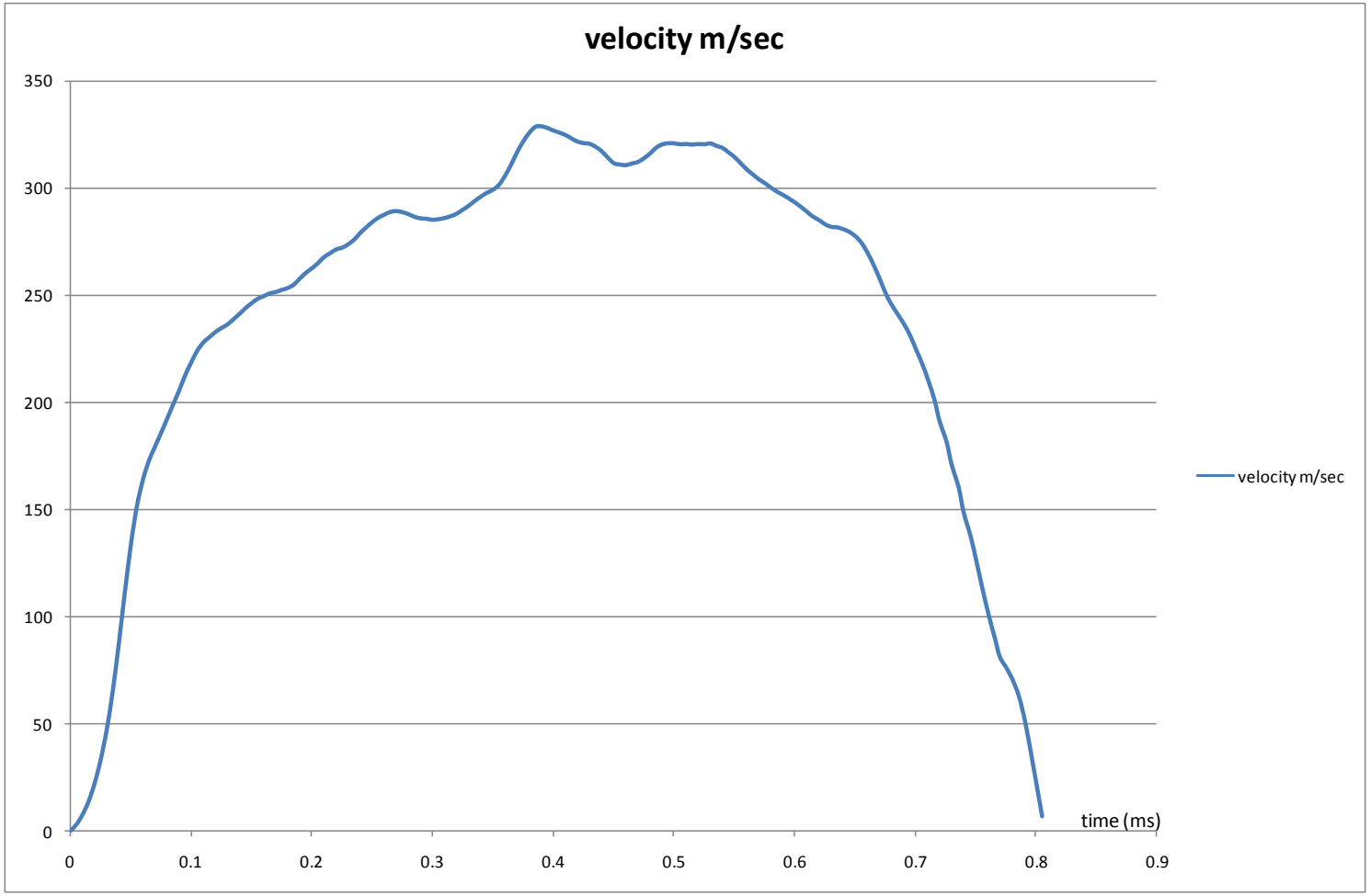
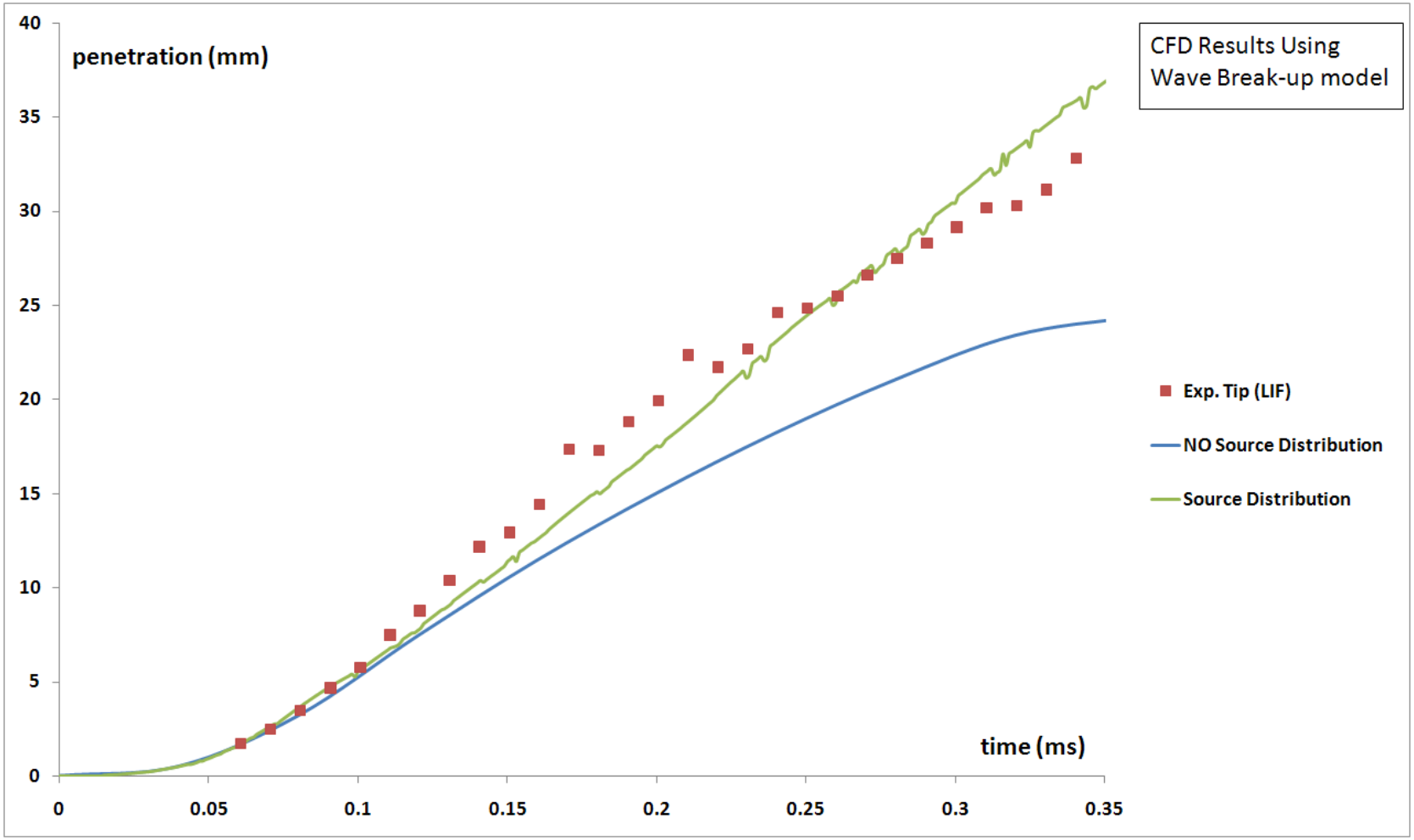
Experimental Condition Considered (PROTEUS Engine)

Injection Pressure = 100 MPa
Fuel Temp = 300 K
Air pressure = 2 MPa
Air Temperature = 350 K




penetration (mm)
time (ms)
CFD Results Using
Wave Break-up model
Exp. Tip (LIF)
NO Source Distribution
Source Distribution
0
5
10
15
20
25
30
35
40
0
0.05
0.1
0.15
0.2
0.25
0.3
0.35

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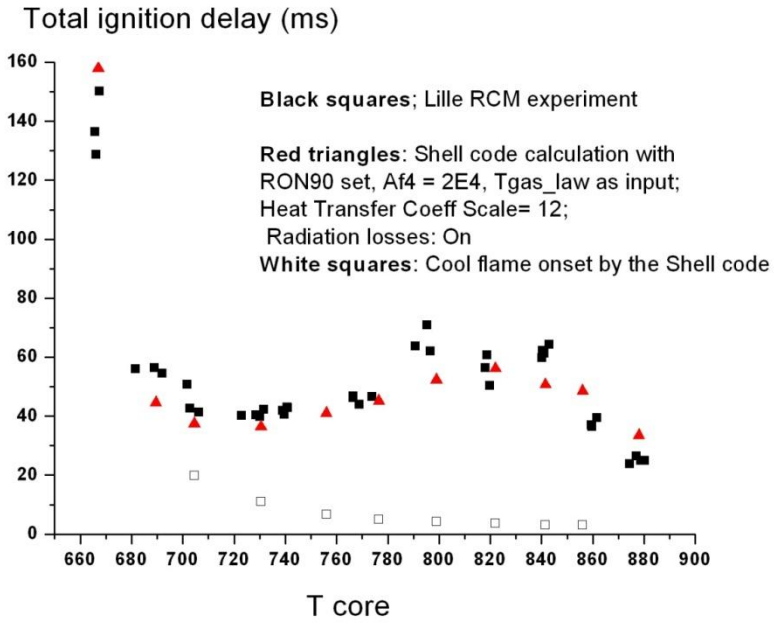
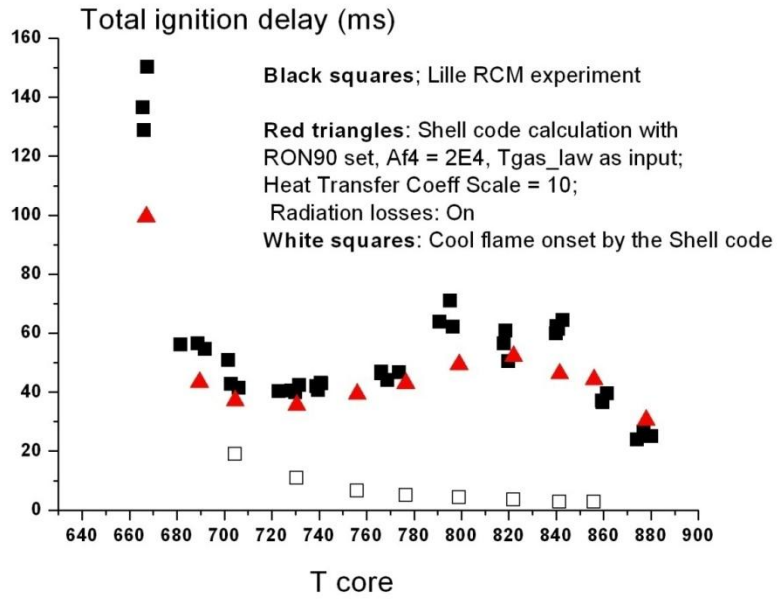
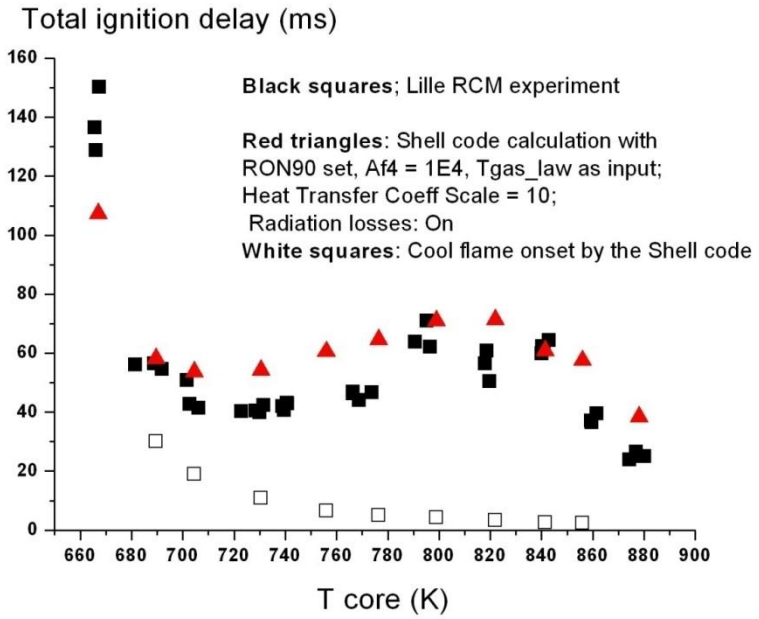
Feasibility Study of the SHELL Model

Cyclo-Hexane as reference fuel

- The Shell model has been extended to Cyclo-Hexane taking into account the different:
  - Molecular Weight
  - Stoichiometry
  - Specific Heat Capacity
- Results compared with experimental data of Lille RCM


Total ignition delay (ms)
Black squares; Lille RCM experiment
Red triangles: Shell code calculation with
RON90 set, Af4 = 2E4, Tgas_law as input;
Heat Transfer Coeff Scale= 12;
Radiation losses: On
White squares: Cool flame onset by the Shell code
T core


Total ignition delay (ms)
Black squares; Lille RCM experiment
Red triangles: Shell code calculation with
RON90 set, Af4 = 2E4, Tgas_law as input;
Heat Transfer Coeff Scale = 10;
Radiation losses: On
White squares: Cool flame onset by the Shell code
T core


Total ignition delay (ms)
Black squares; Lille RCM experiment
Red triangles: Shell code calculation with
RON90 set, Af4 = 1E4, Tgas_law as input;
Heat Transfer Coeff Scale = 10;
Radiation losses: On
White squares: Cool flame onset by the Shell code
T core (K)

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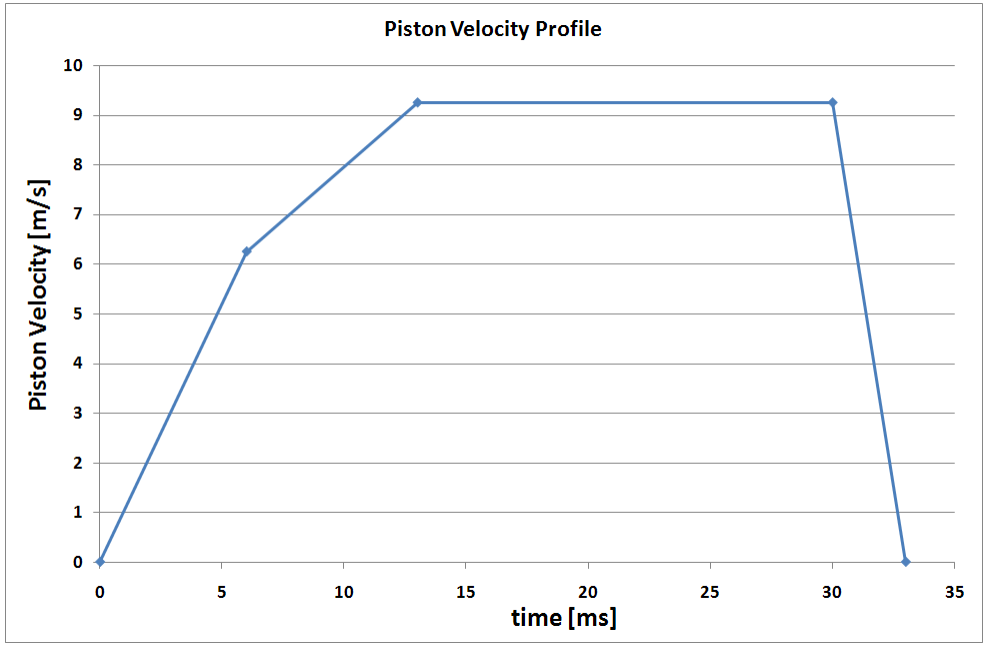
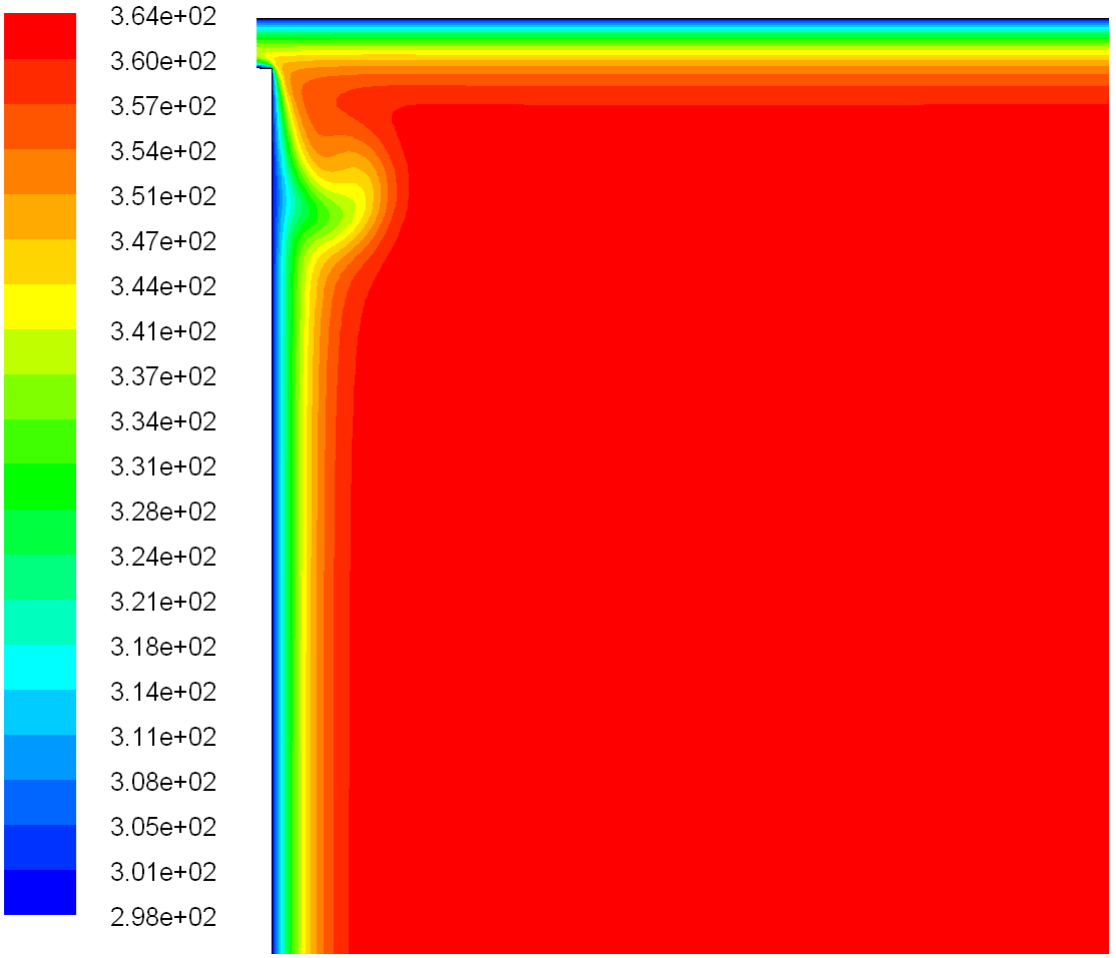
Preliminary Study of RCM Behaviour

Initial Condition

Wall Temperature = 298 K
Mixture Temp = 298 K
Mixture Pressure = atmospheric
Mixture Composition = $H_2/O_2/N_2$/Ar 12.5/6.25/18.125/63.125 % by mole



Preliminary Study of RCM Behaviour



Temperature Field Distribution

2-ACE Project at University of Brighton

Further Work

- Implementation of 2-Stroke CFD Engine Simulation
  - Spray Simulation
    - Application of the Source Distribution to Flat Fan Atomizer
    - Implementation of droplet Heating and Evaporation Models
  - Auto-Ignition Modelling in Rapid Compression Machine
    - Reactive 2D Simulation of RCM using the skeleton mechanism developed by University of Leeds
    - Application of Dynamic Decomposition Technique
  - Full engine Simulations with proper Boundary Condition

Acknowledgment

- Ricardo UK Ltd
- Cardiff University – Denso UK

- Dr Cyril Crua (University of Brighton)
- Dr Pierre-Alexander Glaude (University of Nancy)

Thank You for Your Attention...

Renzo Piazzesi

Centre for Automotive Engineering

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