Computational Energy Sciences

Advanced Modeling of Diesel Engines

Development of a Computational Tool for Simulation of Internal Combustion Engines

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Motivation

- Diesel engines
  - Higher fuel efficiency than gasoline engines
  - More pollutant emissions than gasoline engines
- Oxygenated liquid fuels offer significant reduction in
  - Particulate emission
  - NO_x emission

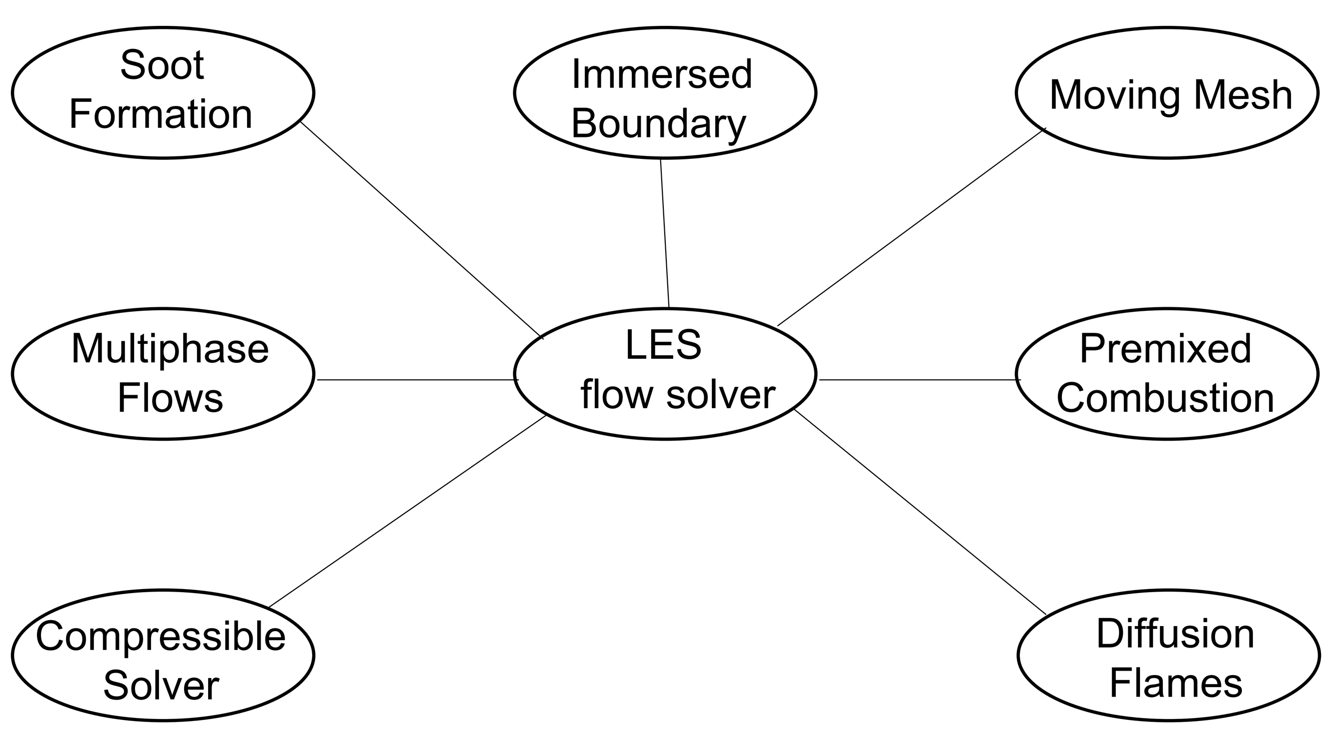
  from diesel engines

Objectives

- To systematically study the effectiveness of oxygenated fuels in actual Diesel engine
- To perform three-dimensional numerical simulations of flow and combustion in realistic Diesel engine configurations to study pollutant formation processes
- Development of a computational tool capable of modeling the flow and combustion in an internal combustion engine.

Capabilities of the Code

- Parametric study using an experimental set up is prohibitively expensive
- Large Eddy Simulation (LES) is an ideal tool for modeling the highly unsteady and non-homogenous flow in an internal combustion engine.
- To perform wide range of parameter study at a low computational cost, a structured code is being developed
- To accurately resolve complex moving geometries in a strutured code
  - Immersed Boundary technique
  - Moving mesh technique



Immersed Boundary Technique

- Algorithm implemented for proper representation of all geometrical complexities of an internal combustion engine
  - Immersed Boundary (IB) technique
    - The numerical algorithm for the mesh across irregular boundaries is modified to account for the body surface as a boundary condition
    - To be used to represent moving valve and piston bowl in a Diesel engine

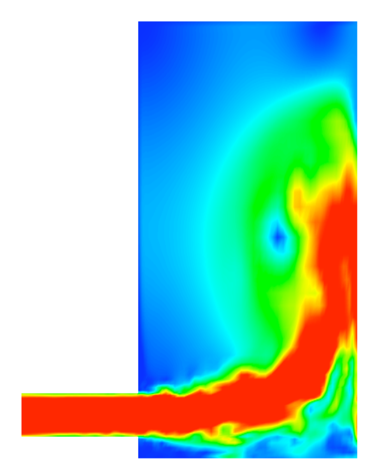
Moving Mesh Algorithm

- Algorithm implemented to model the motion of the piston in an internal combustion engine
  - Arbitrary Lagrangian Eulerian (ALE) technique
    - The computational mesh could be either fixed (Eulerian) or moving with material (Lagrangian) or can be specified in an arbitrary manner for better resolution

Code Validation

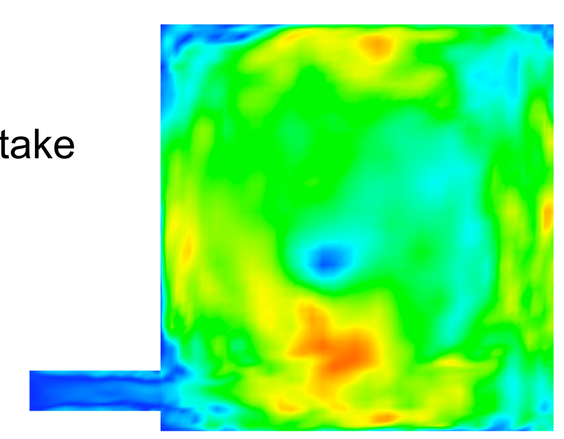
LES of flow in simplified piston-cylinder assembly

- IMFT square piston test case
  - Square cylinder with flat head
  - Volumetric ratio of 4
  - Piston driven at 200 rpm
  - 4 stroke cycle

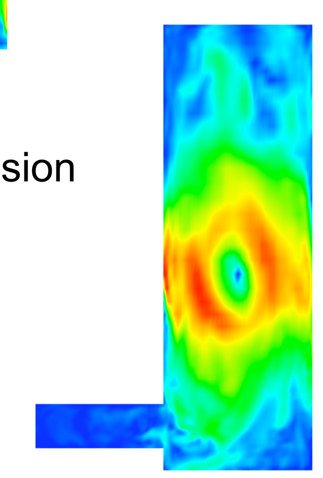


Intake stroke

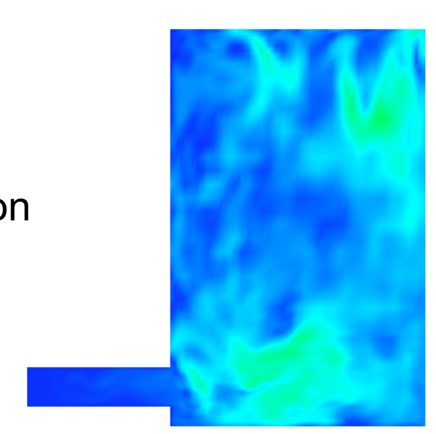
End of intake stroke



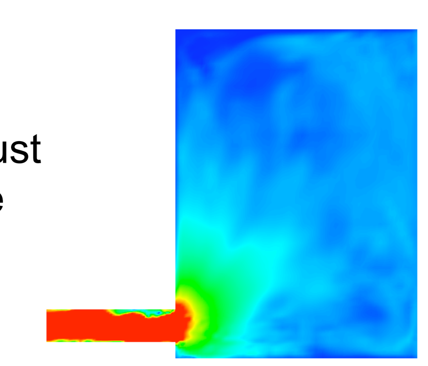
Compression stroke



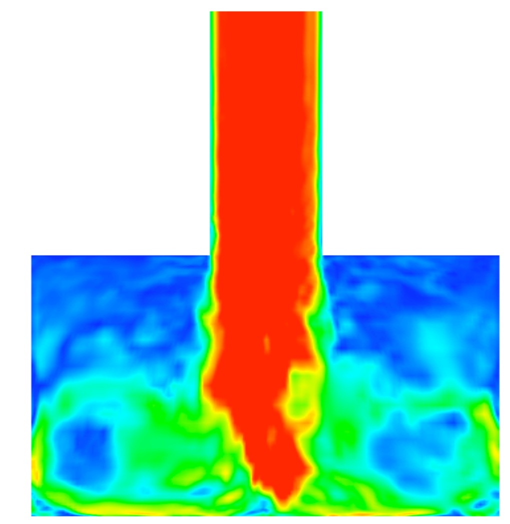
Expansion stroke



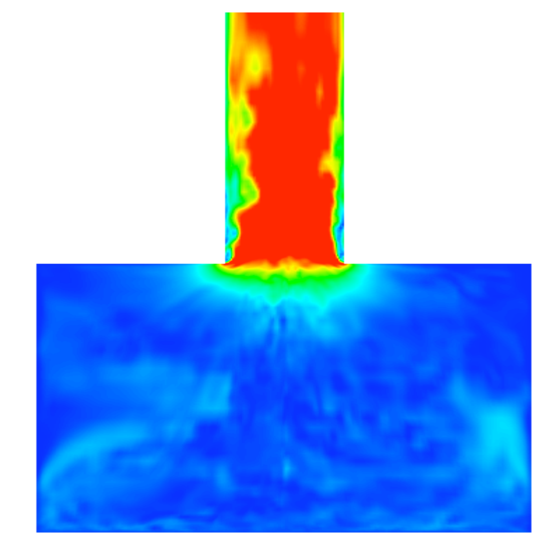
Exhaust stroke



- Imperial College Whitelaw test case
  - Cylinder with flat head
  - Swept to clearance ratio of 2
  - Piston driven at 200 rpm
  - 2 stroke cycle (no effective compression)

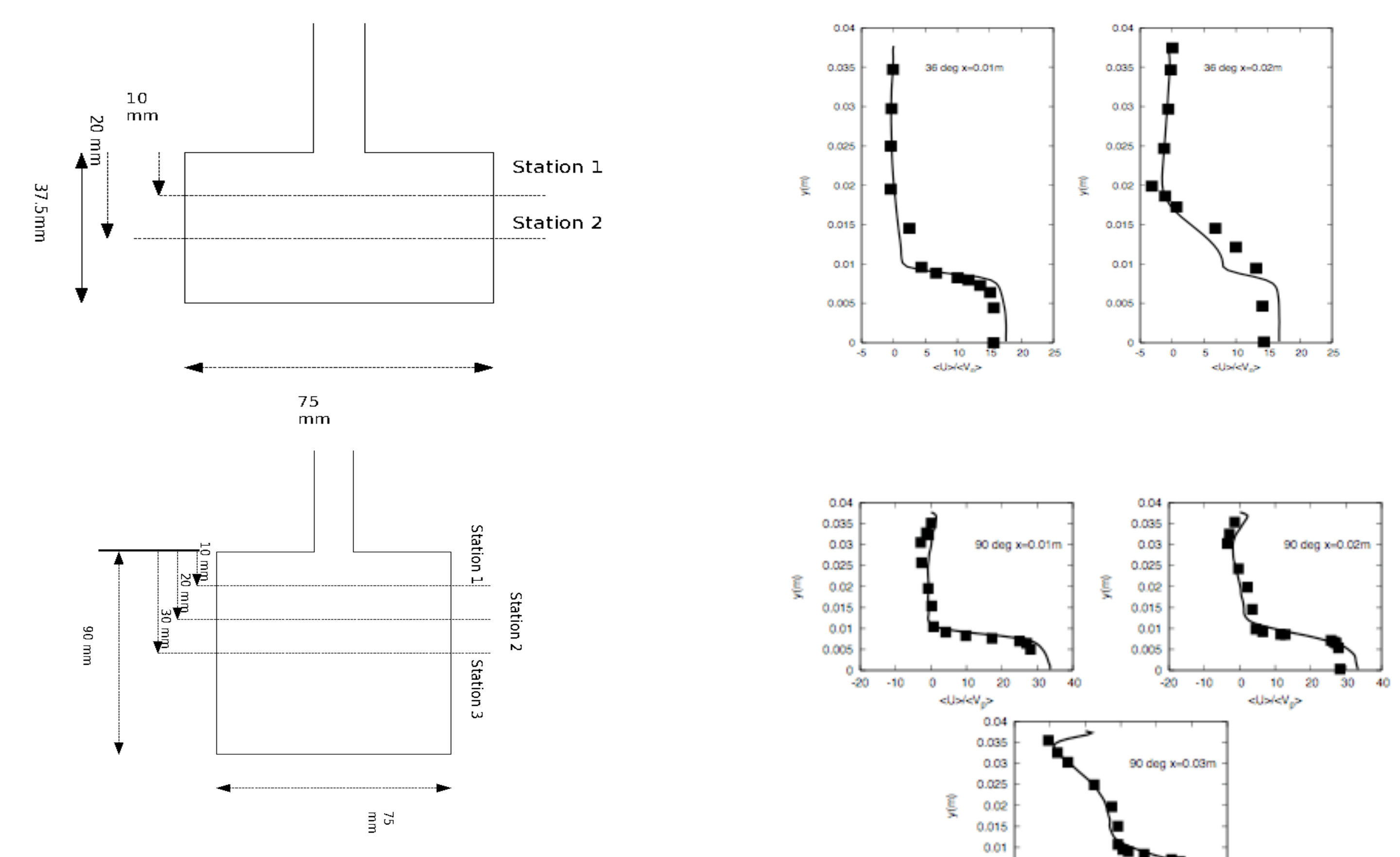


Intake stroke



Exhaust stroke

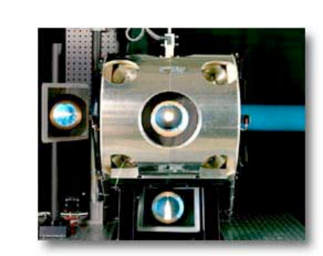
Comparison of phase averaged velocity with experimental data



Symbols - Experimental Measurement
Lines - Numerical Simulation

Future Direction

- Validate against the data on oxygenated fuels from Sandia Diesel combustion simulation vessel
- Performing simulations in realistic engine configurations to study the effectiveness of oxygenated fuels



Picture taken from Sandia national laboratories