CFD Simulation of Internal Flowfield of Dual-mode Scramjet

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Outline

- Objectives and Approach
- Model Scramjet Description
- COMSOL Setup
- Isolator
- Combustor
- Conclusions
- Future Work

Objectives and Approach

- Determine COMSOL’S capabilities in generating scramjet flowfield features
- Analyze heat release pattern to reproduce experimental results

- Model geometry as one part
  - Very long simulation times (8+ hours)
  - Unable to generate shock trains
  - Difficult to converge
- Break into 2 separate portions
  - Up to 5x faster
  - Distinct shock train structures

Model Scramjet Description

- Dual-mode scramjet
  - 3 Main Parts:
    - Isolator
    - Combustor
    - Cavity

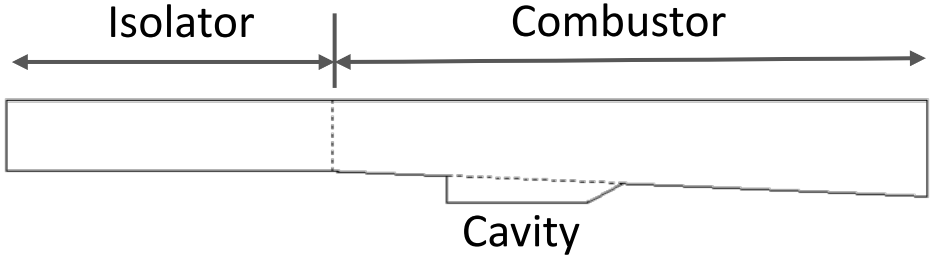


Table 1: Isolator Inlet Conditions. Adapted from [1].

Variable	Value	Units	Description
M_1	2.0419		Mach Number
T_1	699.7	K	Static Temperature
p_1	83304.2	Pa	Static Pressure
p_{o_1}	683928.9	Pa	Total Pressure
Re_h	154,650		Reynolds Number
$\dot{m}_{total}$	0.377	g/s	Total Fuel Mass Flow Rate

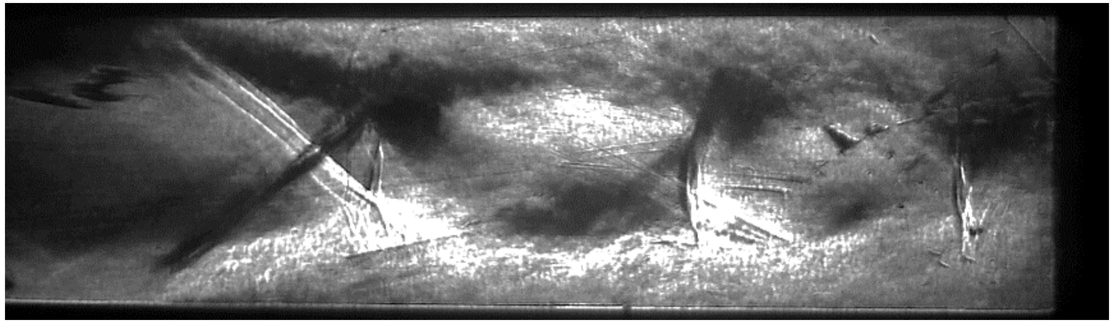
[1] Muñoz

COMSOL Setup

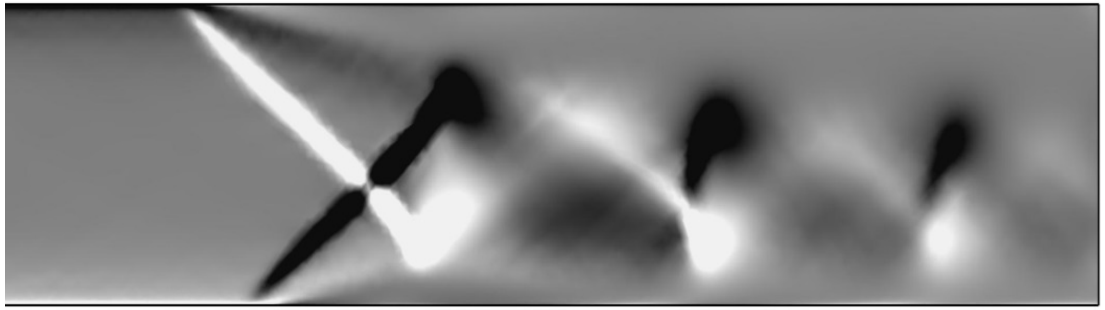
- Geometry: 2-D Space Dimension
- Physics: Turbulent High Mach Number Flow (CFD Module)
  - $k - \epsilon$ (Slip, Wall Functions)
  - Spalart-Allmaras (No Slip)
- Studies: Set of 3 with Auxiliary Sweep for Each
  - Stationary ($k - \epsilon$)
  - Stationary with Initialization (Spalart-Allmaras)

Isolator

- 0.5 [in] high, 8.5 [in] long
- Allows for pressure rise and to prevent inlet unstart
- Boundary layer separation and shock train formation
- Normal/Oblique Shock Trains



(a) Experimental Schlieren Image [2]

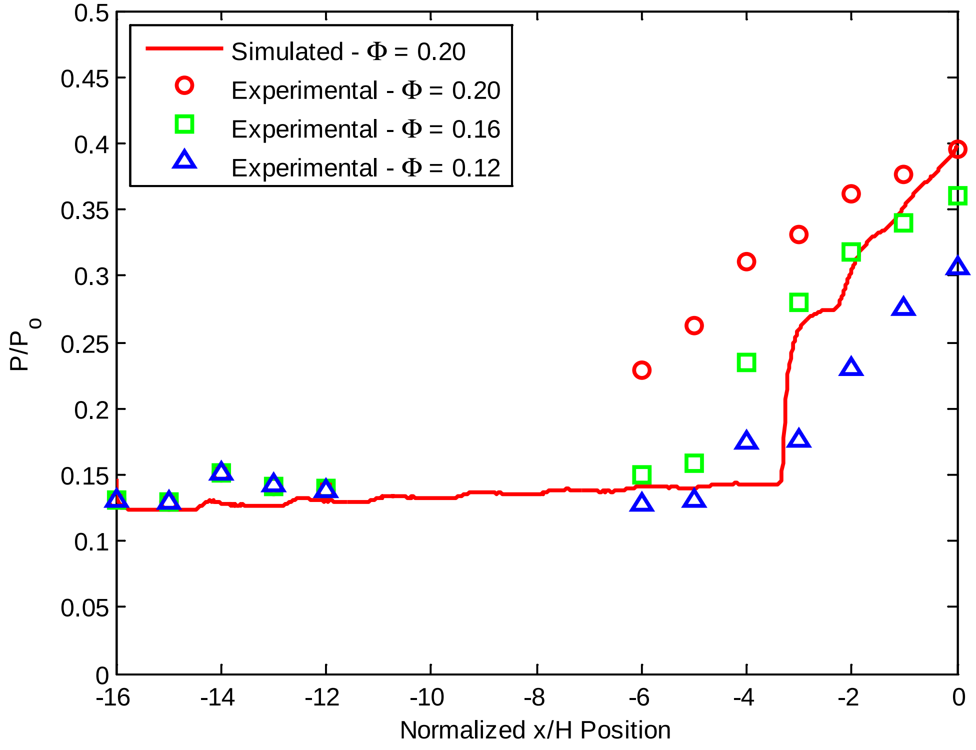


(b) Computational Schlieren Image

[2] Geerts

Isolator (2)

- Matched pressure rise
- Difference in shock structure
- Starting Location

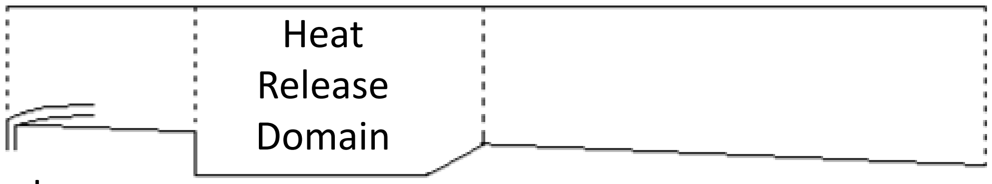


Experimental Data from [1]

[1] Muñoz

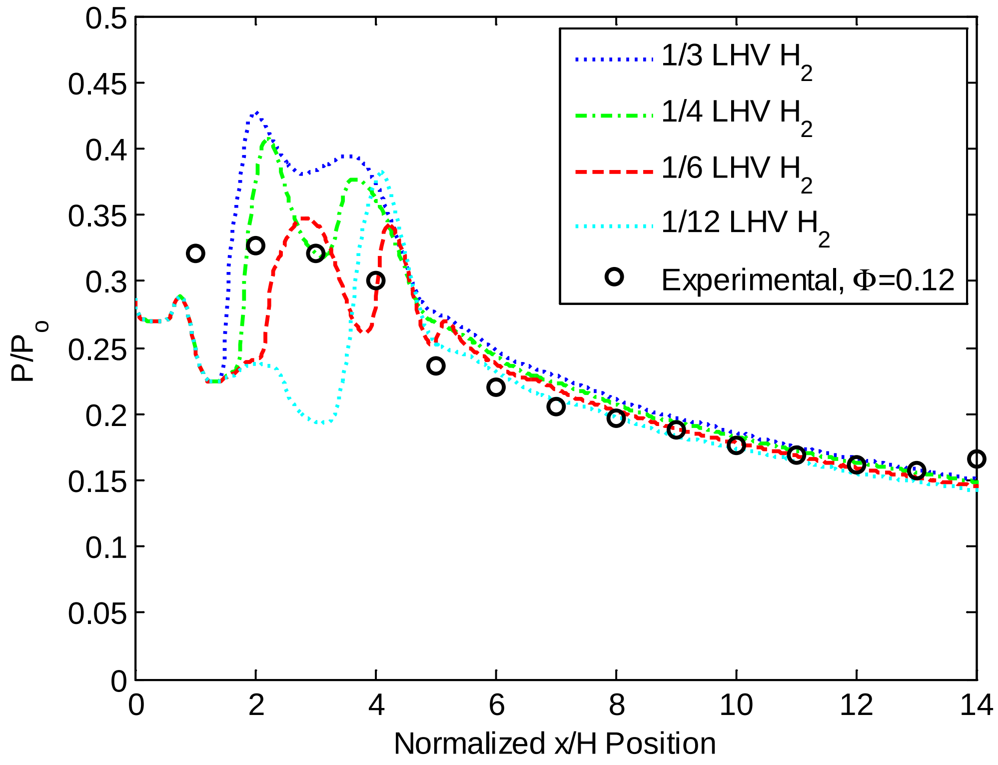
Combustor

- Diverging Area
- Fuel Injection, Ignitor
- Cavity for Flame Holding
- Combustion and Heat Release
- Used isolator exit conditions as combustor inlet



Heat Release Domain

Fuel Injection



Experimental Data from [1]

[1] Muñoz

Conclusions

- Able to generate shock train in isolator
- Found that heat release is closest to 1/6 LHV of H_2
- Several Discrepancies
  - 3D -> 2D
  - Adiabatic Walls

- Pros:
  - Matched pressure at isolator exit
  - Low computational cost when split
- Cons:
  - Shock train structure
  - Difficulties implementing profiles
  - Single heat release domain
  - Full model

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Future Work

- Change heat release domain:
  - Location
  - Size
  - Intensity
- Thermal Choking Comparison

References

[1] Muñoz, Camilo A., Effect of Fin-Guided Fuel Injection on Supersonic Mixing and Combustion, PhD Dissertation, University of Maryland, College Park (2014).

[2] Geerts, Jonathan, PhD Candidate at University of Maryland, College Park (2014).

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