Community Christmas Competition IV (2020) - Simulation of the backward facing step

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Background

- **Background**

- Turbulent shear layer is important flow structure in industrial combustors
- Backward facing step combustor is a simple experimental configuration incorporating the aspects of premixed combustion stabilized in a turbulent shear layer

- **Objectives**

- **Compare length of re-circulation zone for non-reacting flow behind the step between RANS and LES turbulence models**

  For RANS, k-epsilon model is used and inlet step assuming turbulent boundary layer

  For LES, k-Eqn model is used and boundary layer (y+ ~ 3) is resolved at inlet step

- **Model Extent**

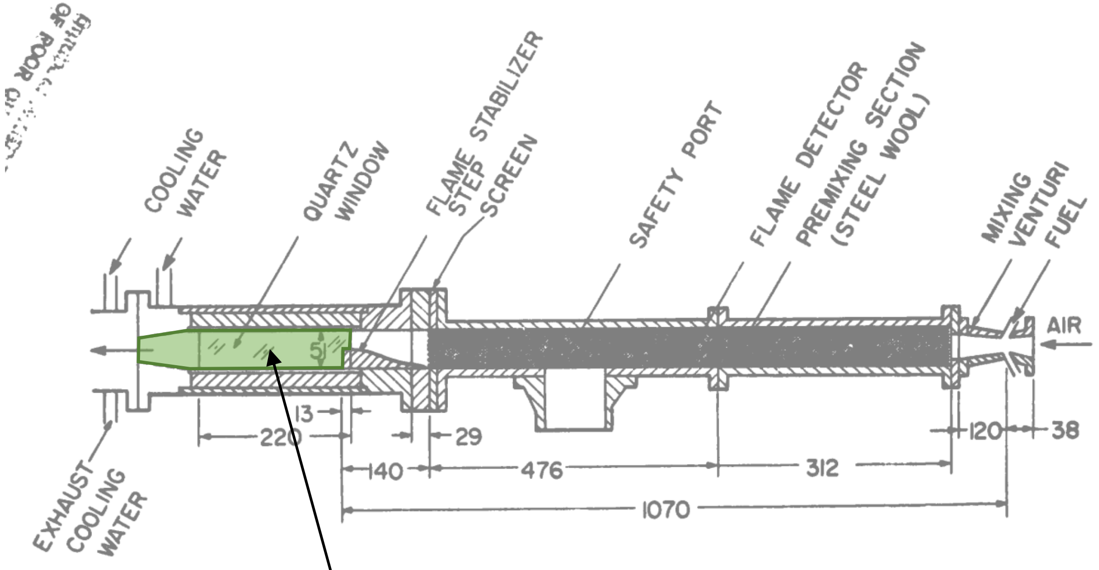


Figure 2.2 Cross section of the two-dimensional combustor (all dimensions in mm).

Combustor & flat part of flame stabilizer step are modeled

Reference: Robert W. Pitz and John W. Daily, 1981. An experimental study of combustion: The turbulent structure of a reacting shear layer formed at a rearward-facing step. NASA Contractor Report 165427.

Parameters & Mesh

- Inlet conditions (Section 3.1 of Pitz and Daily, 1981)

- U at inlet = 9.1m/s, 13.3m/s and 22.2m/s
- Turbulence intensity at inlet = 2%
- Initial conditions are important as Reynolds number is well below 2×10^6 (p.58 of Pitz and Daily, 1981)
- Condition of boundary layer for all three flow velocities/Reynolds numbers is best described as "transitional" (p.60 of Pitz and Daily, 1981)

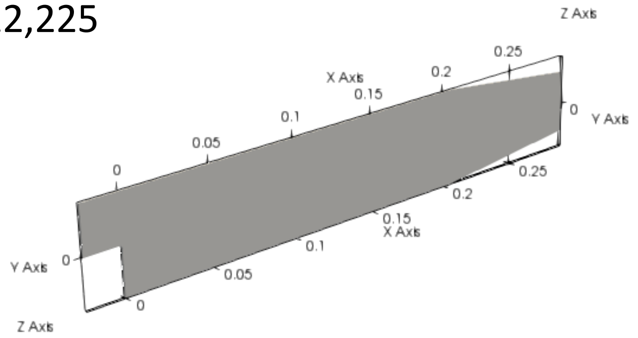
- Outlet boundary conditions

- Pressure = $0 m^2/s^2$

- Solver: pimpleFoam

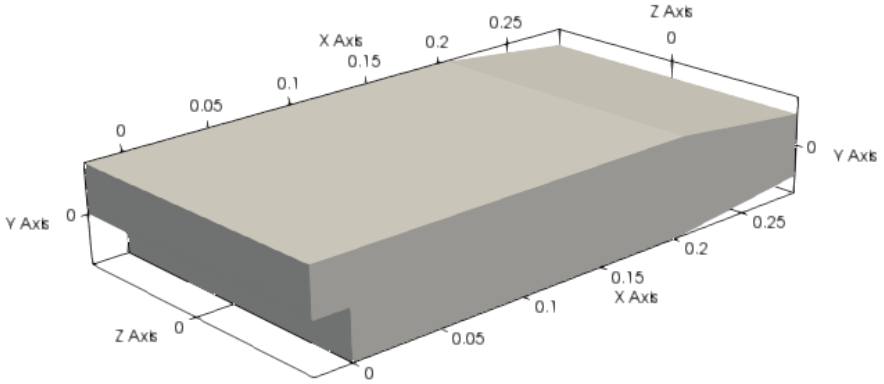
- Mesh (2D) for RANS model

- No of cells = 12,225



- Mesh (3D) for LES model

- No of cells = 7,335,000

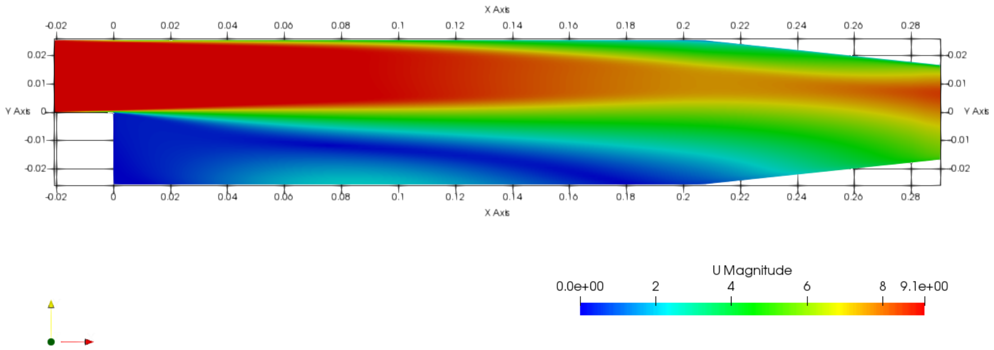


Simulation 1 – Using k-epsilon RANS 2D model

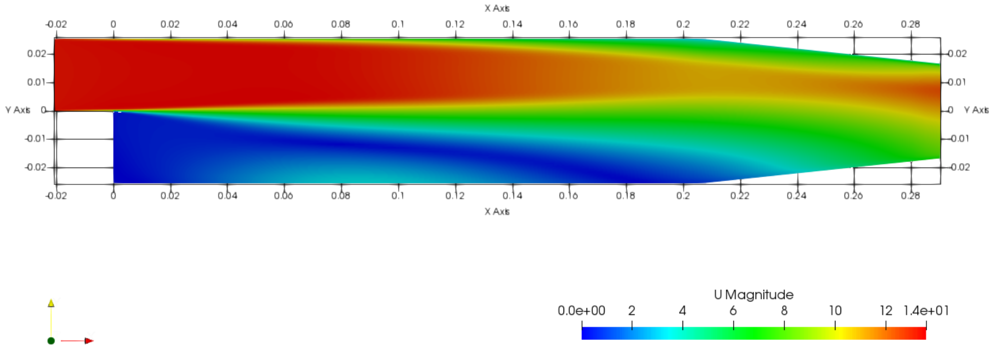
- Length of re-circulation zone

Model	U (m/s)	X_R/H (Simulated)	X_R/H (Pitz and Daily, 1981)
1a	9.1	7.0	6.5
1b	13.3	7.2	7.0
1c	22.2	7.2	6.8

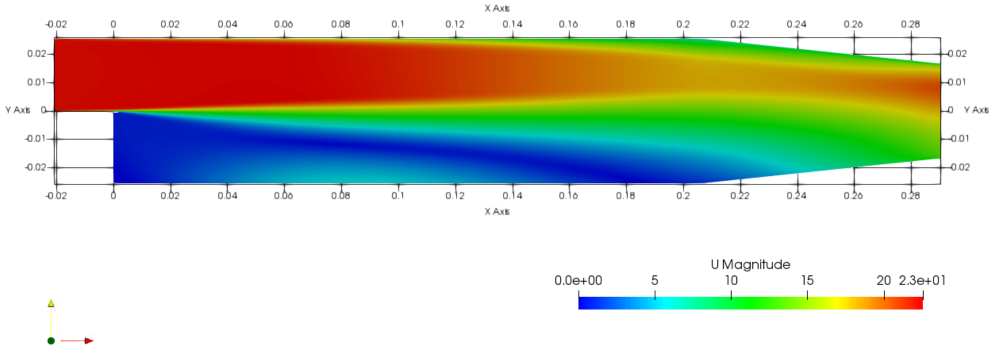
- Model 1a



- Model 1b



- Model 1c



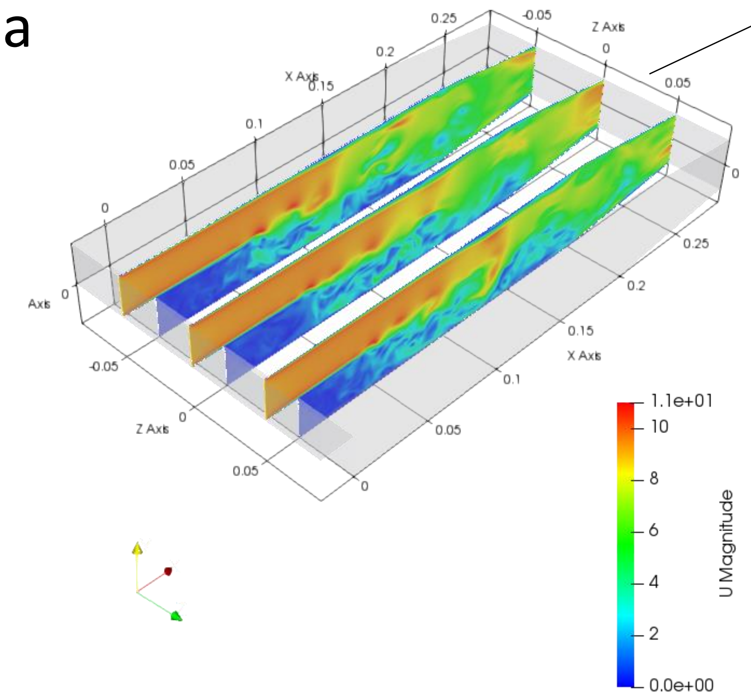
Simulation 2 – Using k-Eqn LES 3D model

- Length of re-circulation zone

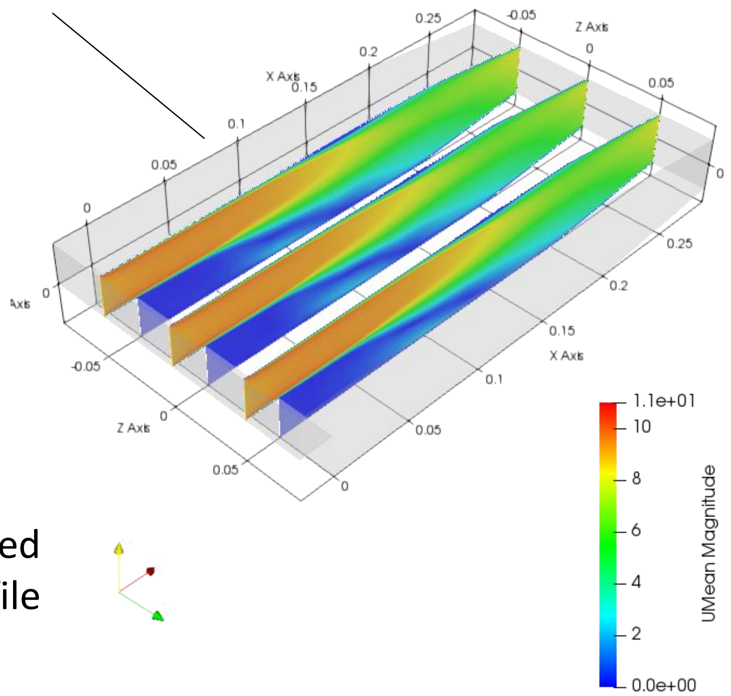
Model	U (m/s)	X_R/H (Simulated)	X_R/H (Pitz and Daily, 1981)
2a	9.1	6.0	6.5

3 slices are cut at z=-0.05m, 0m and 0.05m

- Model 2a



Instantaneous velocity profile



Time-averaged velocity profile

Conclusions

- As length of re-circulation zone is defined in average sense, RANS model gives reasonable estimates
- 2D RANS model is computationally very efficient
- Assuming turbulent boundary layer at inlet step by RANS model appears acceptable, may be because inlet boundary layer is actually “transitional”
- LES model, by time averaging to obtain length of re-circulation zone, gives no advantage over RANS model
- LES model gives insight into turbulent shear layer and mixing process, which is good to understand the process