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A Flow-Driven Cavity as an Air Cycling Model for Window Flow

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Abstract

A lid-driven cavity is flow-driven to describe stress on and circulation inside buildings and small insect-to-UAV-size aircraft due to open windows or sidewall punctures. The transition between steady & unsteady flow is also roughly bounded, by investigating the Reynolds number at 4 values between 10 to 10ˆ4. A sparse simulation of low-speed and much higher-speed incompressible flows is undertaken, estimating feature shapes at the minimum computational cost.

Keywords: computational fluid dynamics, CFD, incompressible, Paraview, R, Python, coe347, spring 2022, window, building, tornado, high, reynolds, unsteady, steady, stress, strain, rate, mixing, volumetric, flow.

1. Motivation

The flow around an infinite, circular cylinder is a well-studied, but yet not completely understood problem in CFD (computational fluid dynamics). A simple exploration of the steady and unsteady flow at low Reynolds numbers is undertaken here, to provide a light overview of the problem.

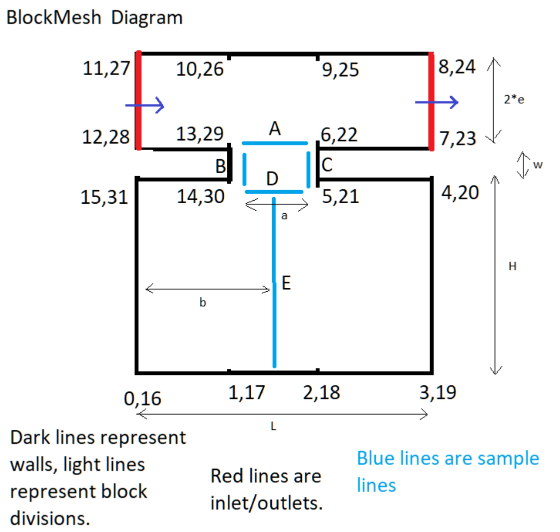
2. Implementation

We implement all simulation with OpenFoam, analysis with Paraview and Python3, and documentation code in R Xie, Dervieux, and Riederer (2020).

3. Mesh Assembly

We assemble a 2D mesh template as below, with the following parameters, all lengths nondimensionalized in terms of dimension L:

mutable: wall thickness w, window width a,
immutable: window location $b = 0.5$, cavity height $H = 1$, cavity width $L = 1$, and free-stream width $2e = 0.1$.



Two sets of simulations are performed, one for the low Reynolds (Re) numbers of 10 and 200, which will be shown to be steady, and another for $Re = 1000, 10000$.

Each mesh also has a corresponding refinement, which is described by the $meshFactor$ parameter, representing the refinement in each dimension.

Full lists are available below.

3.1. Meshes for the Low Reynolds simulations

meshfactor	Reynolds.Number	window.width.a	wall.thickness.w
5	10	0.05	0.05
5	10	0.05	0.10
5	10	0.50	0.05
5	10	0.50	0.10
10	10	0.05	0.05
10	10	0.05	0.10
10	10	0.50	0.05
10	10	0.50	0.10
5	200	0.05	0.05
5	200	0.05	0.10
5	200	0.50	0.05
5	200	0.50	0.10
10	200	0.05	0.05
10	200	0.05	0.10
10	200	0.50	0.05
10	200	0.50	0.10

Table 1:

3.2. Meshes for the High Reynolds simulations

meshfactor	**Reynolds.Number**	**window.width.a**	**wall.thickness.w**
3	1000	0.5	0.1
5	1000	0.5	0.1
3	10000	0.5	0.1
5	10000	0.5	0.1

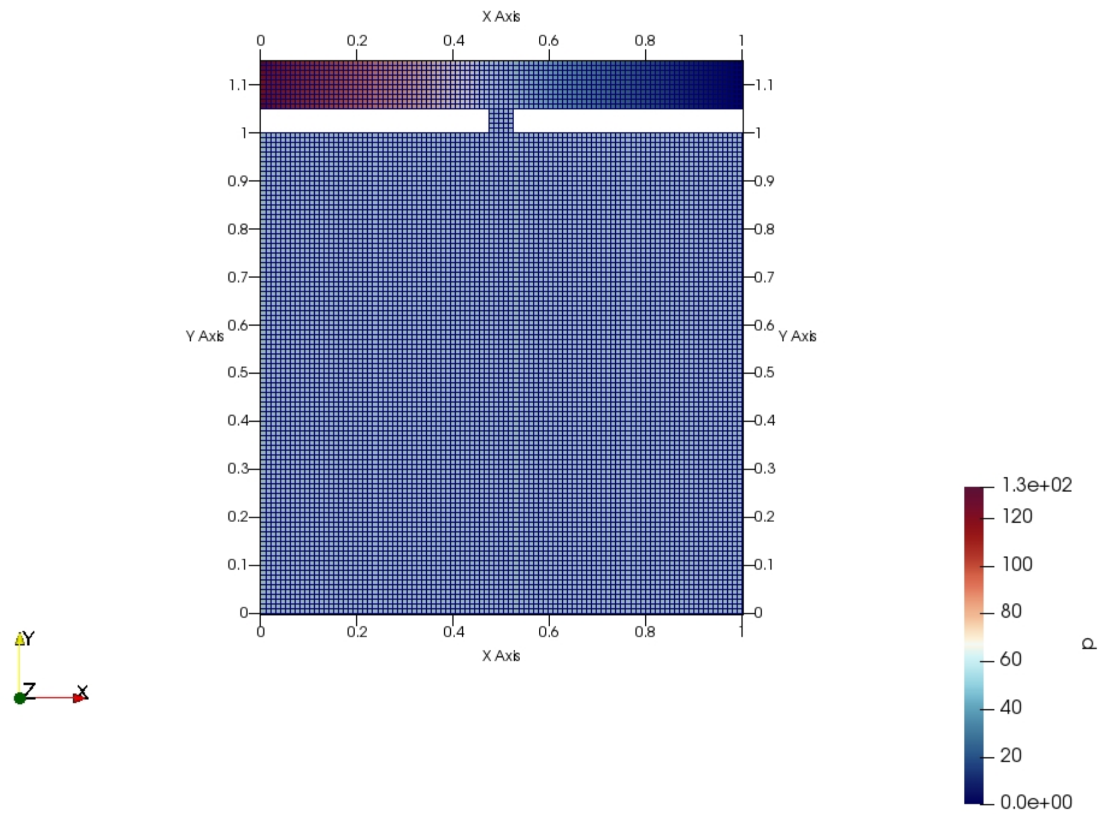
Table 2:

BlockMeshDict and similar files are available at the repository.

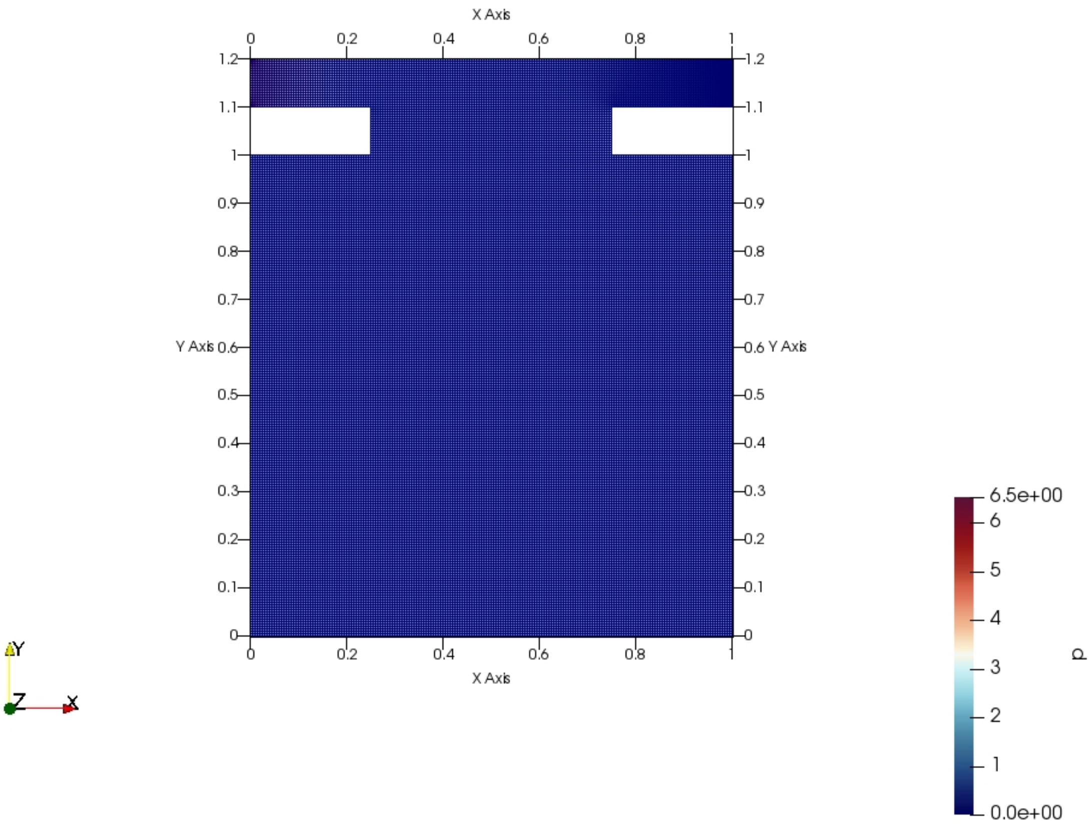
3.3. Mesh Images

A couple mesh samples are shown here; see the appendix for all images.

meshFactor, Re, windowWidth, wallThickness=5, 10, 0.05, 0.05:



meshFactor, Re, windowWidth, wallThickness=10, 200, 0.5, 0.1:



Now that the mesh resolutions can be seen as adequate, we will move to results.

4. Literature Review

- blank at the moment; will put some notes from the articles I sent out and hopefully some comparisions to cavity flow (to be referred to again later).
  # Low Reynolds Number

4.4. General Solution Form

- show basic solution images here

4.5. Vortice Positions

- table of vortice positions

4.6. Window Wall Solution Profiles

- profiles for Left and Right

4.7. Cavity Midline Solution Profile

- midline profiles
  # High Reynolds Number - Part 1

4.8. General Solution Form

- show basic solution images here for both Re and make general arguments

4.9. Strouhal Number and Vortex Shedding

- FFT plots
- STFT plots
- table of values for Strouhal

4.10. Volumetric Flow Rate and Mixing

- plots
- generic argument / example for UAV and

4.11. Window Wall Strain Rate

T = 1.47 (unsteady startup)

T = 60 (steady-state for large-scales of flow)

Maximum Strain Rate over Time

5. High Reynolds Number - Part 2

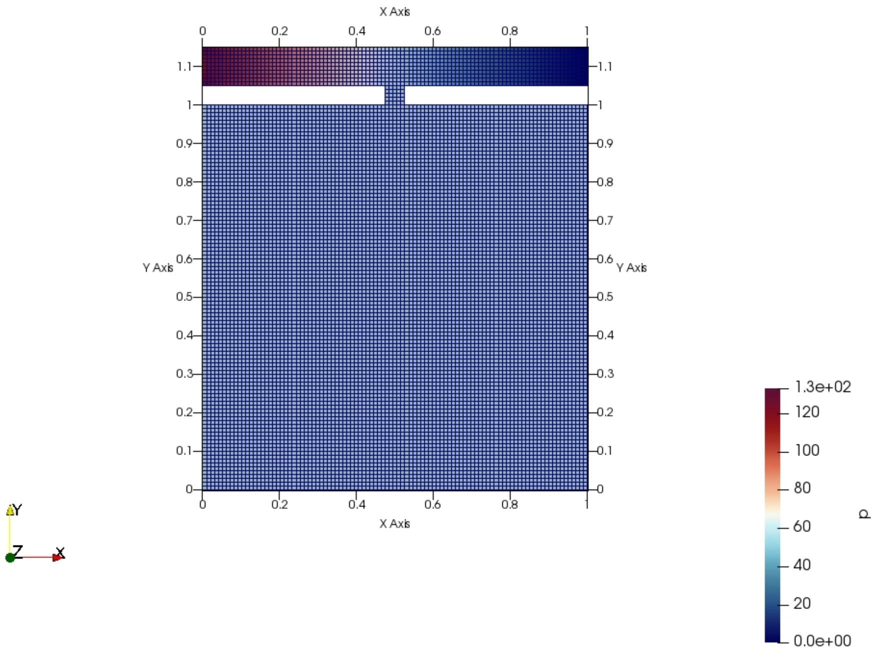
6. Conclusions

7. References

8. Appendix

8.12. Mesh Images

Mesh Images for the Low Reynolds simulations (same order)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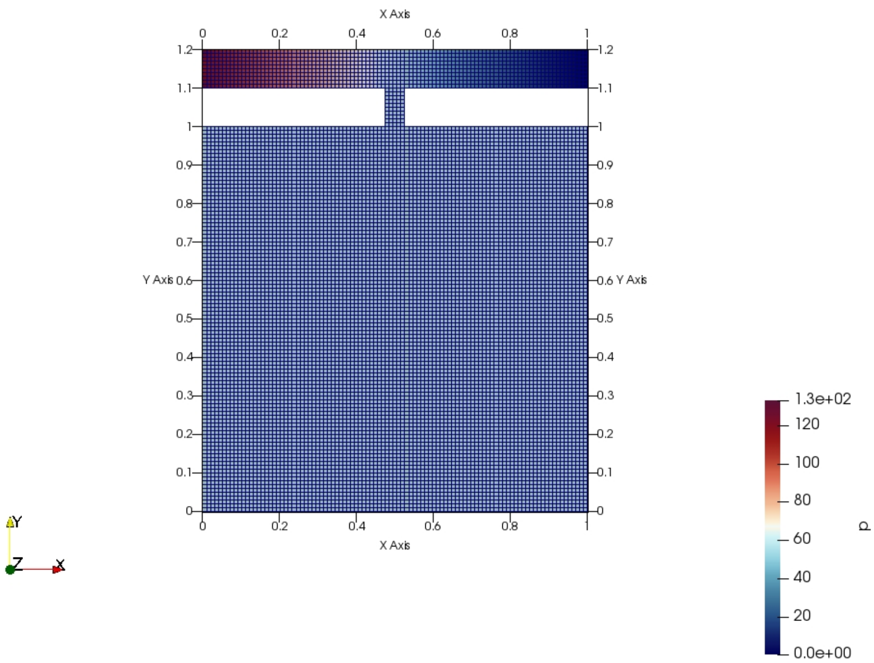
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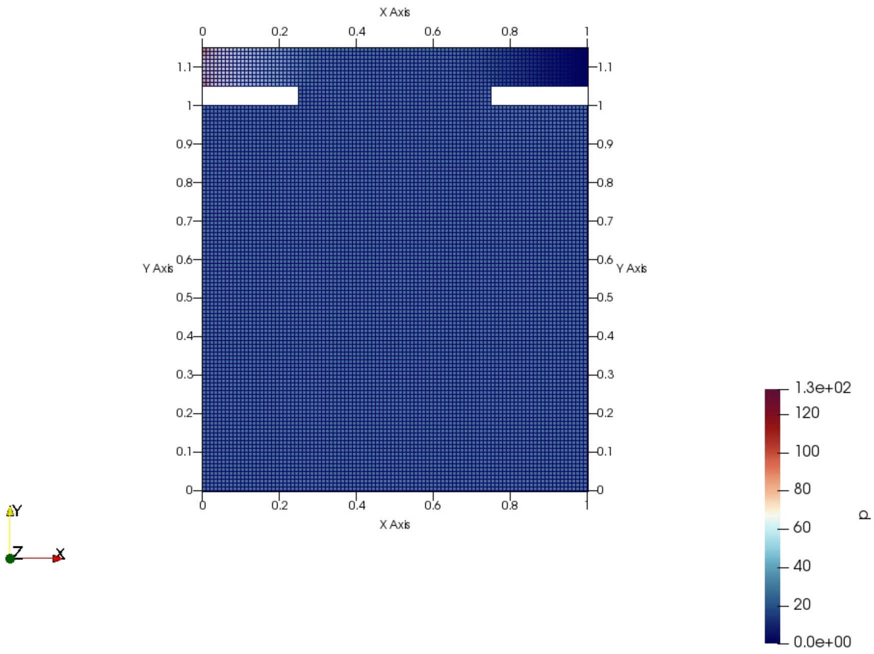
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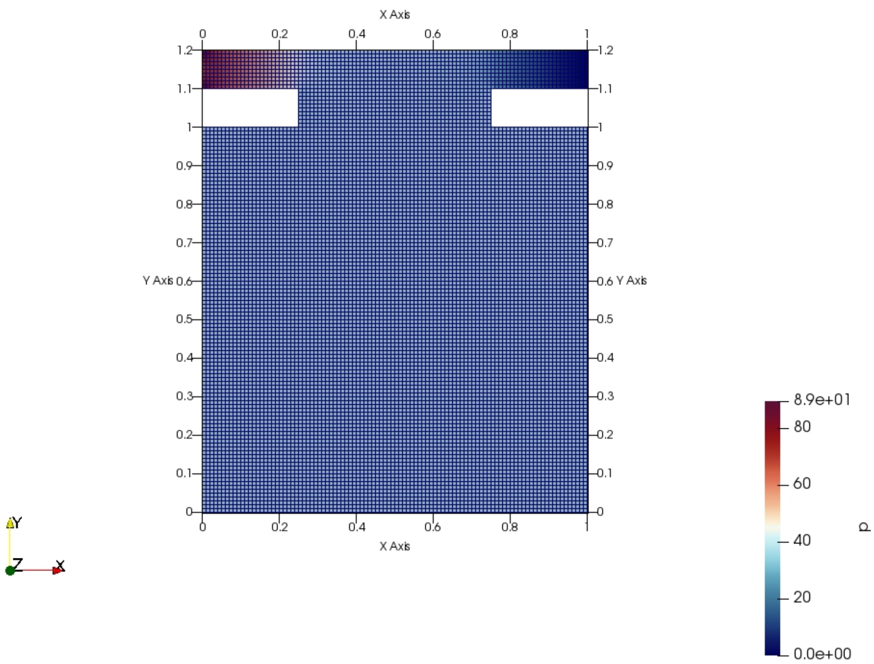
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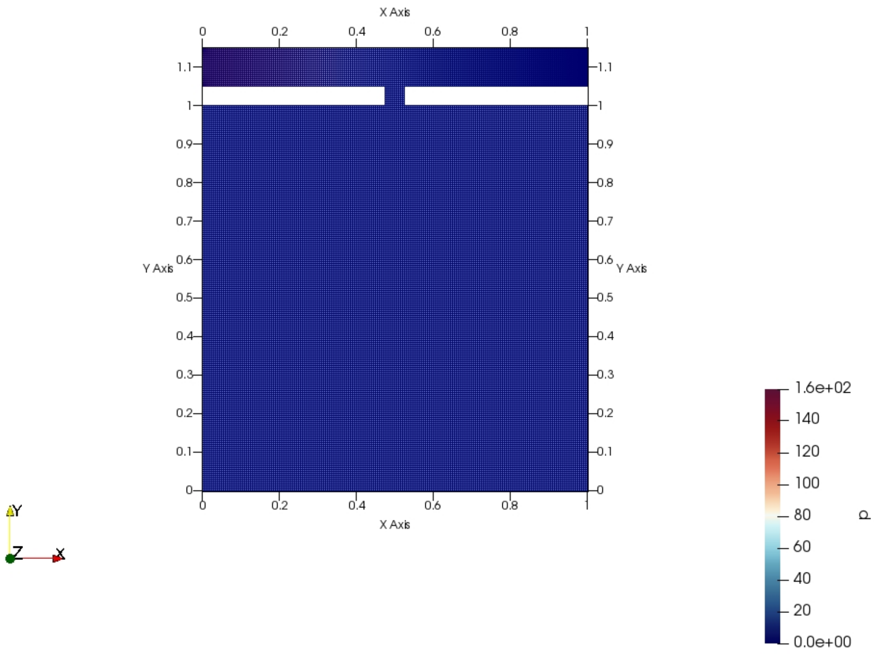
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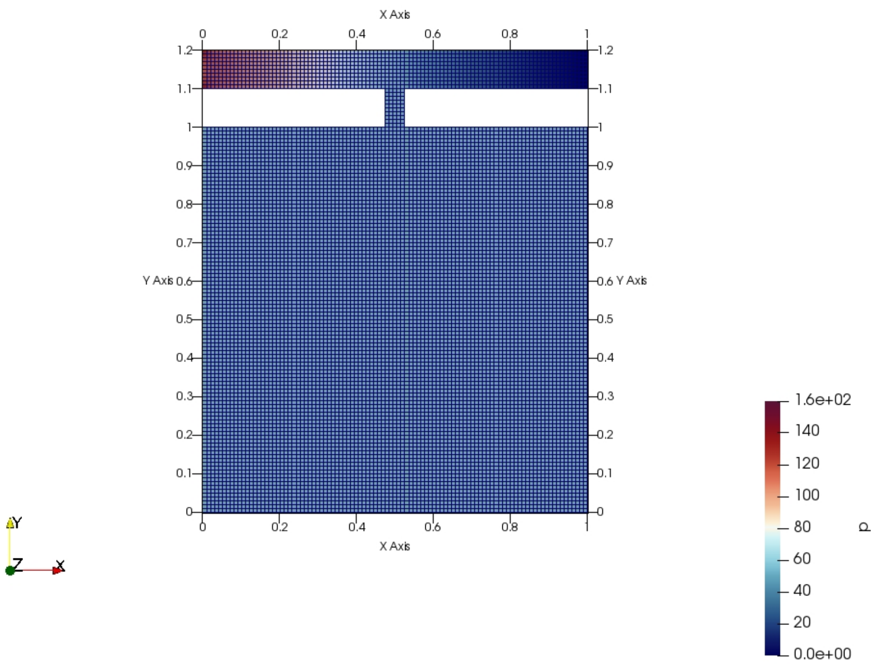
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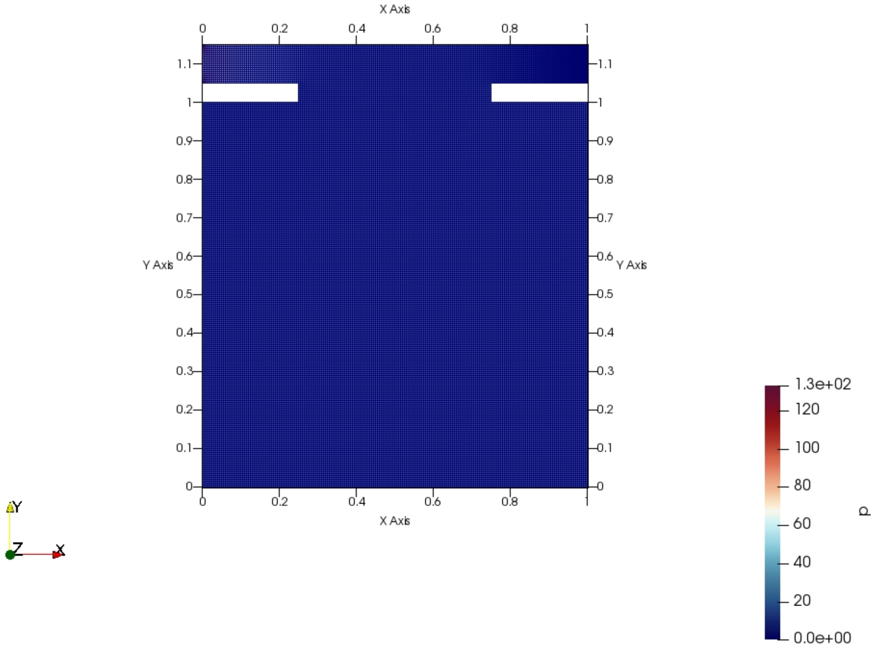
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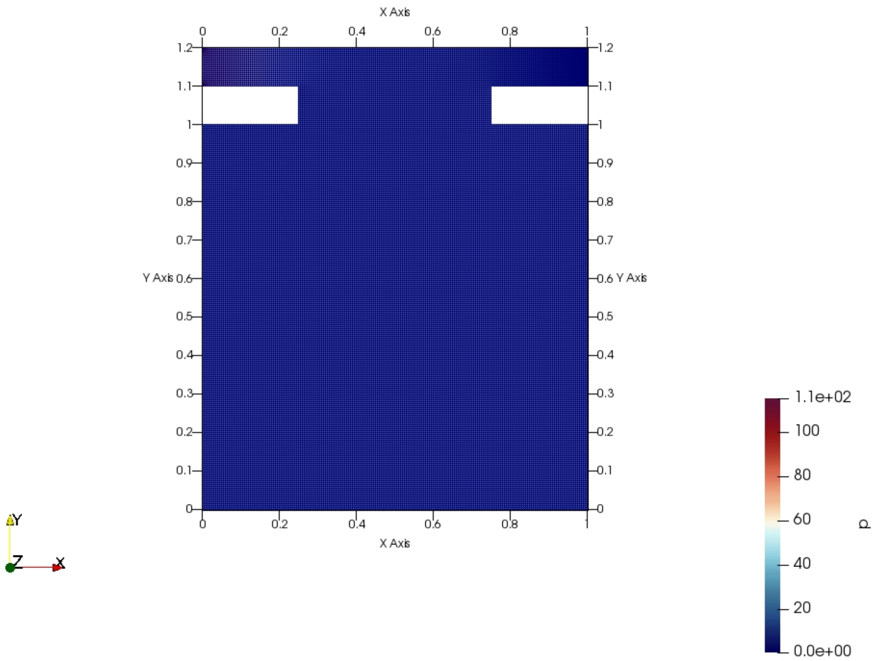
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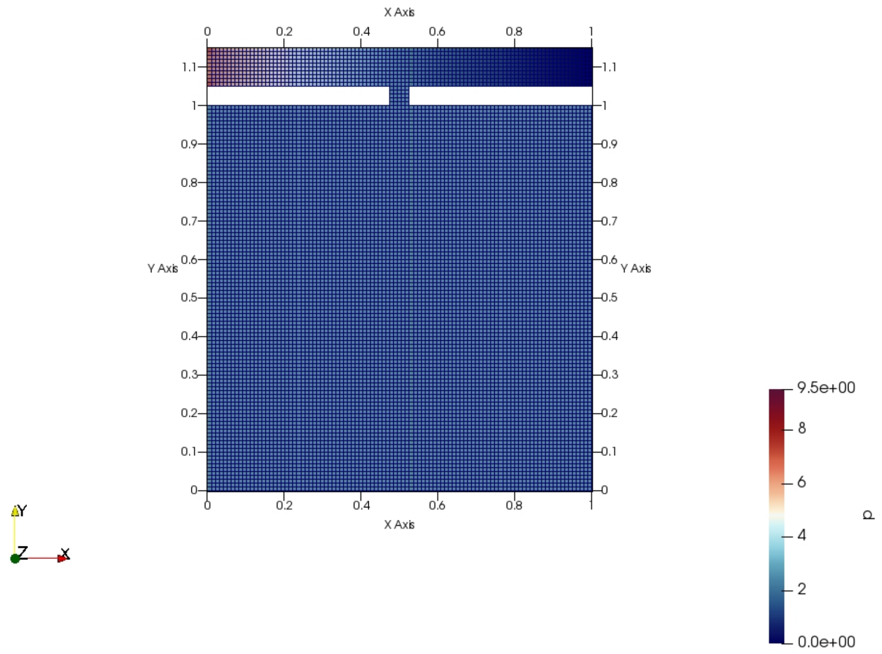
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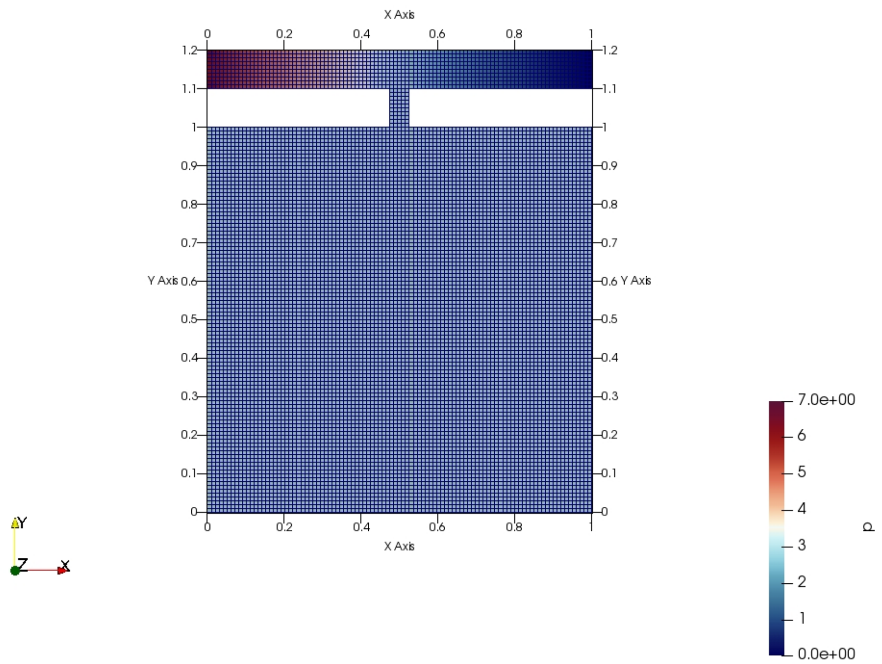
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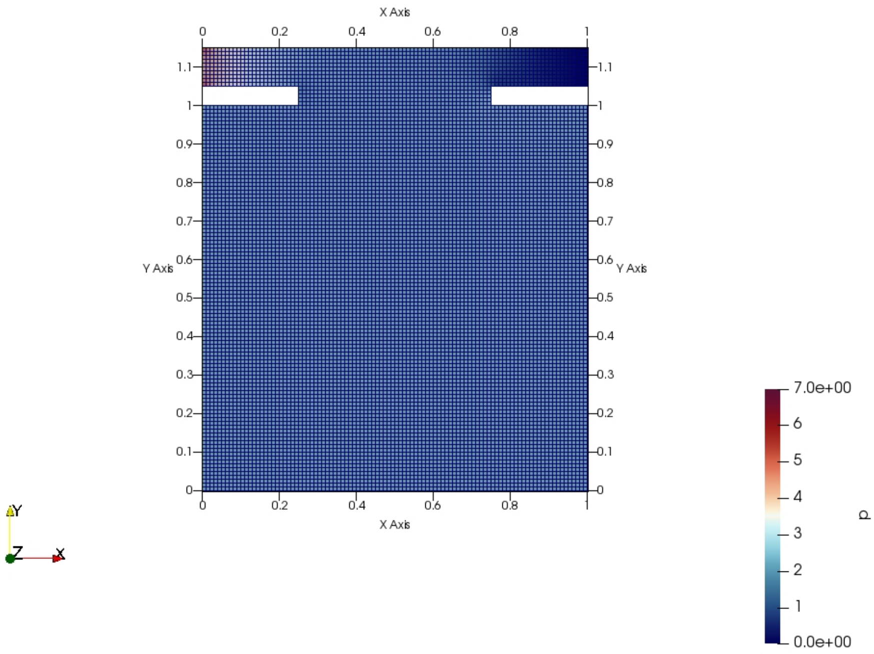
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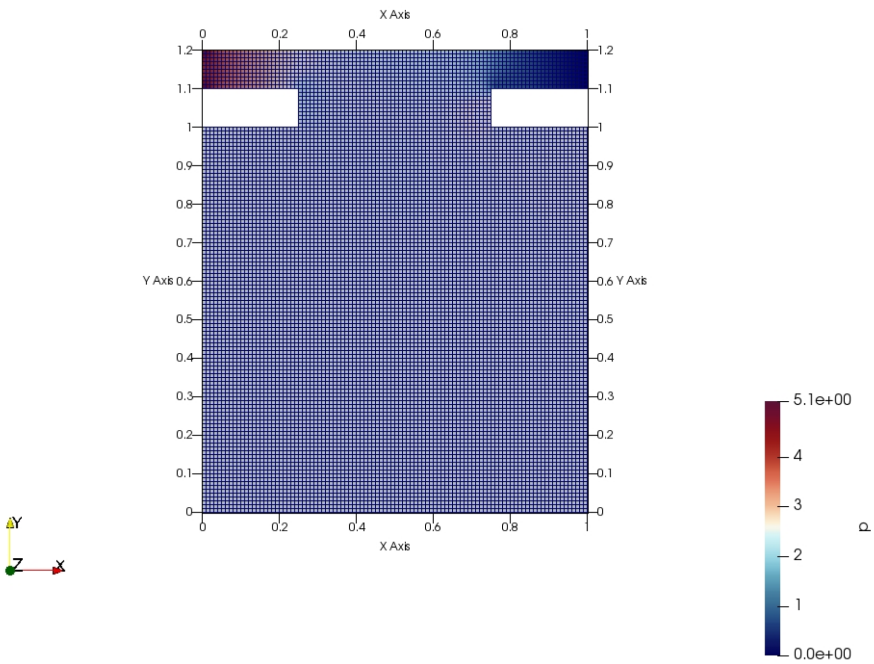
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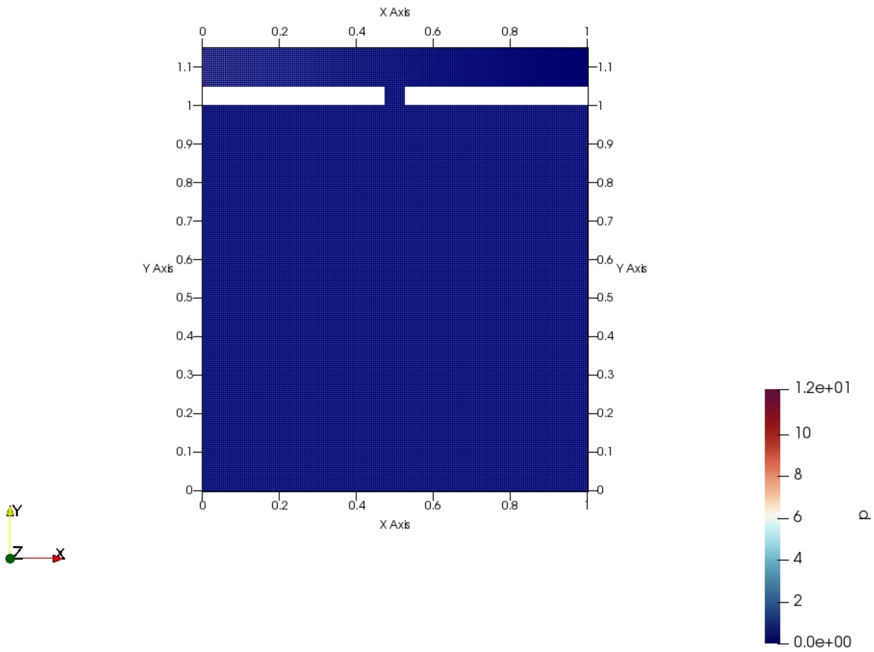
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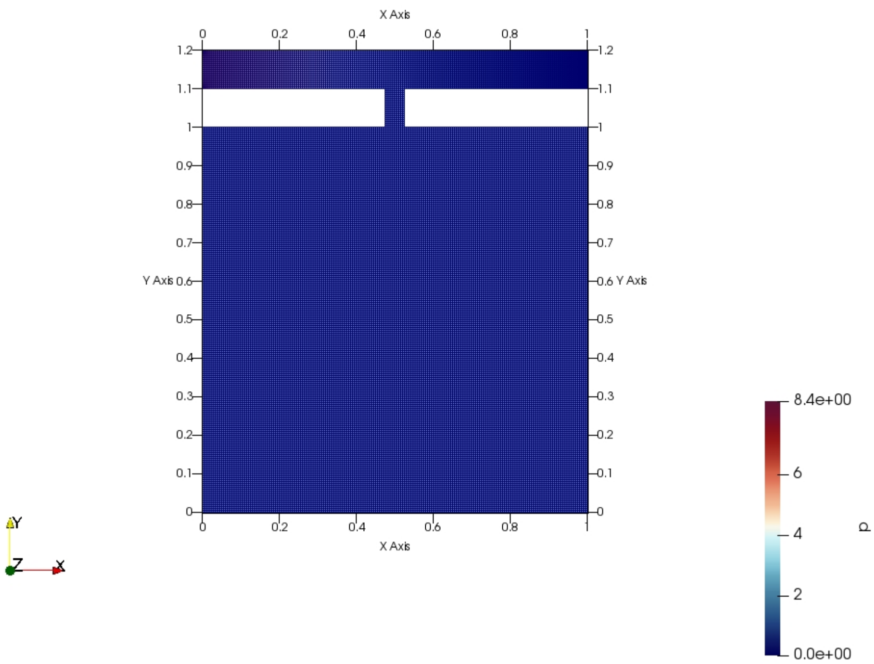
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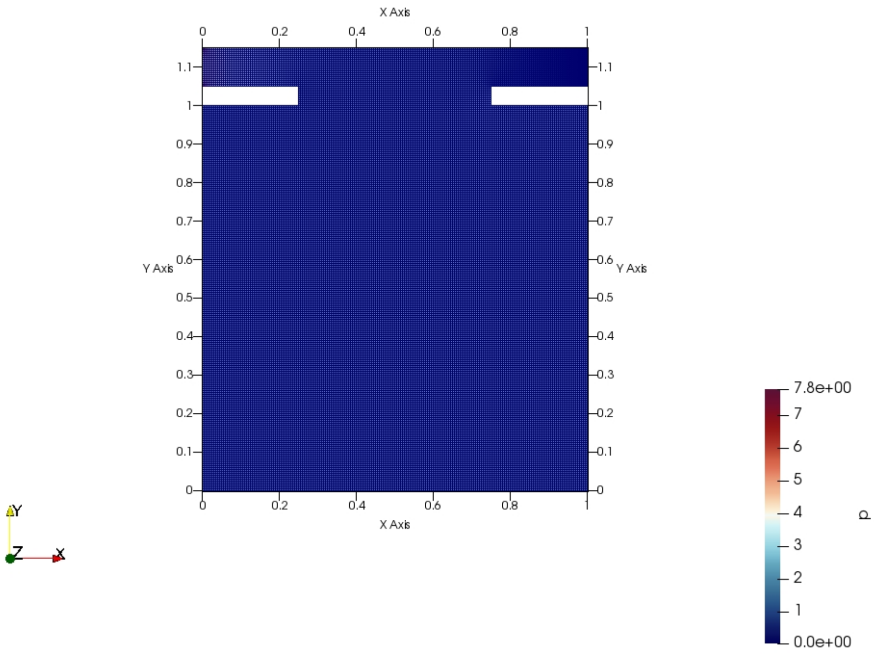
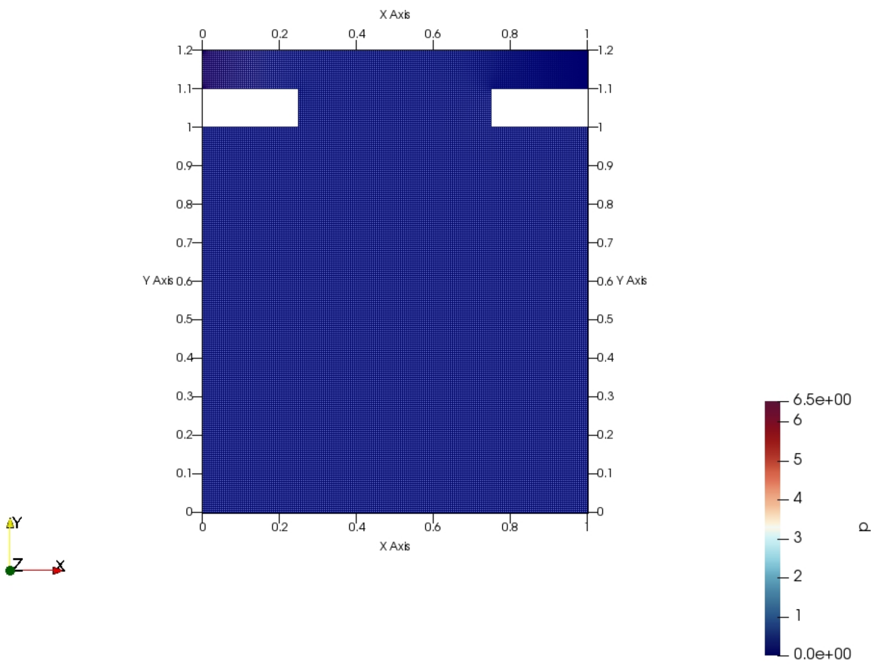
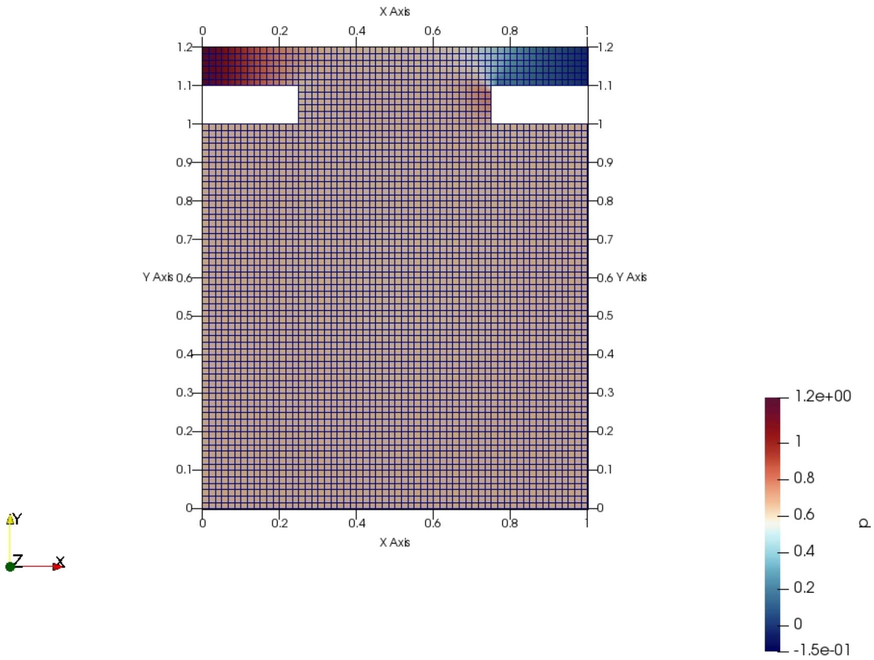




Mesh Images for the High Reynolds simulations (same order)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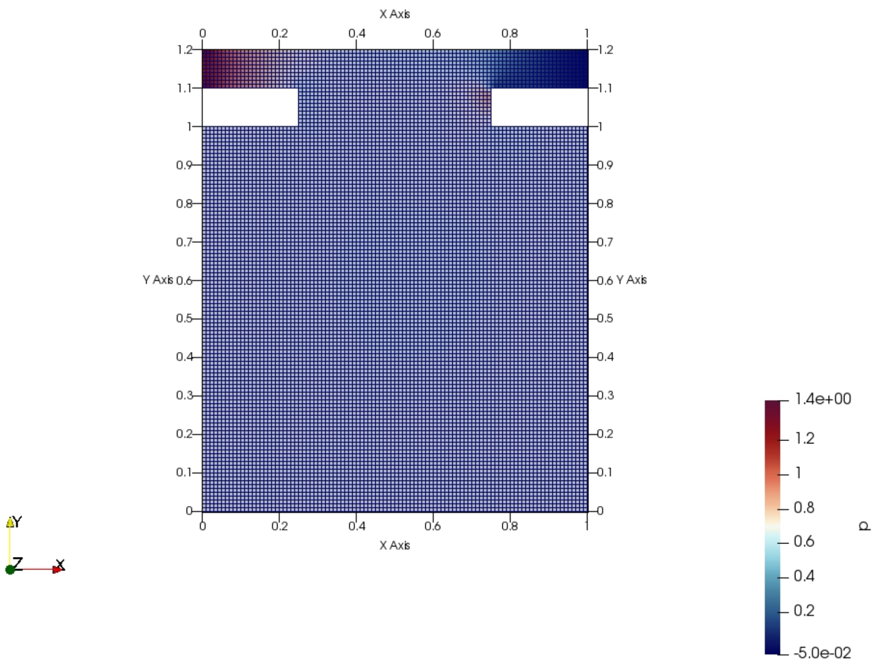
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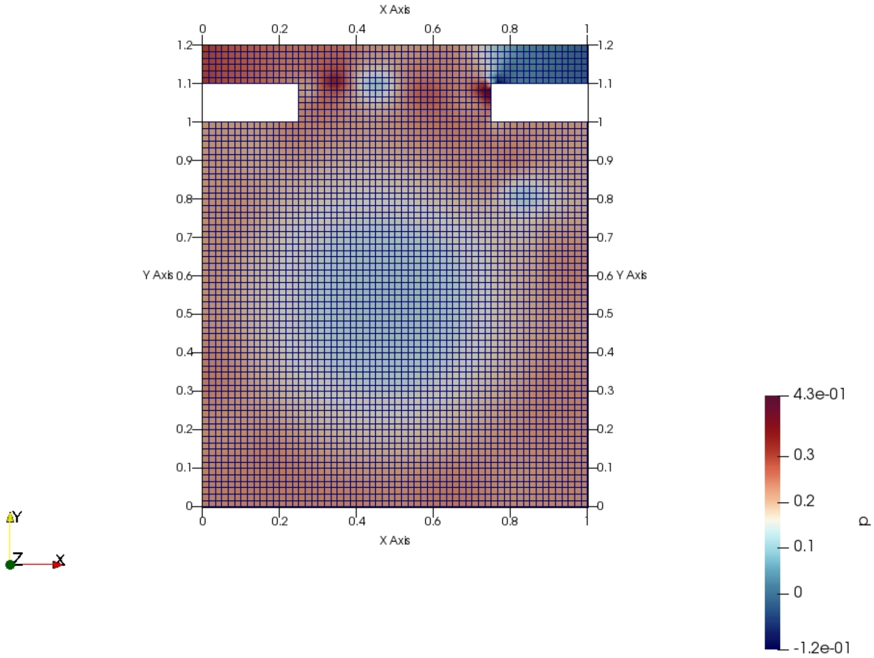

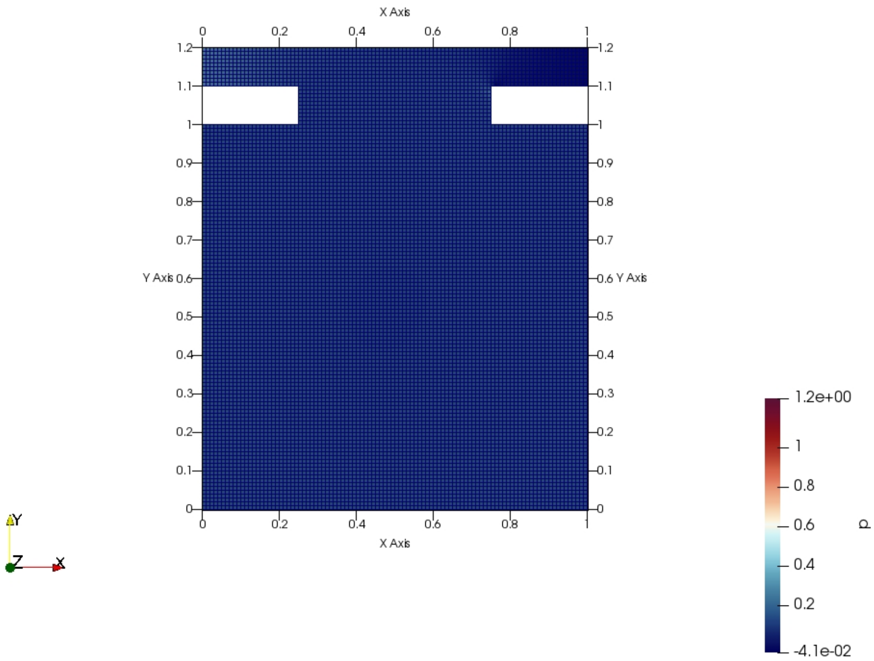

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9. Appendix

Thank you so much for reading this work!

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