Advanced Problem 1

Jacob Mills and Isaac Smith

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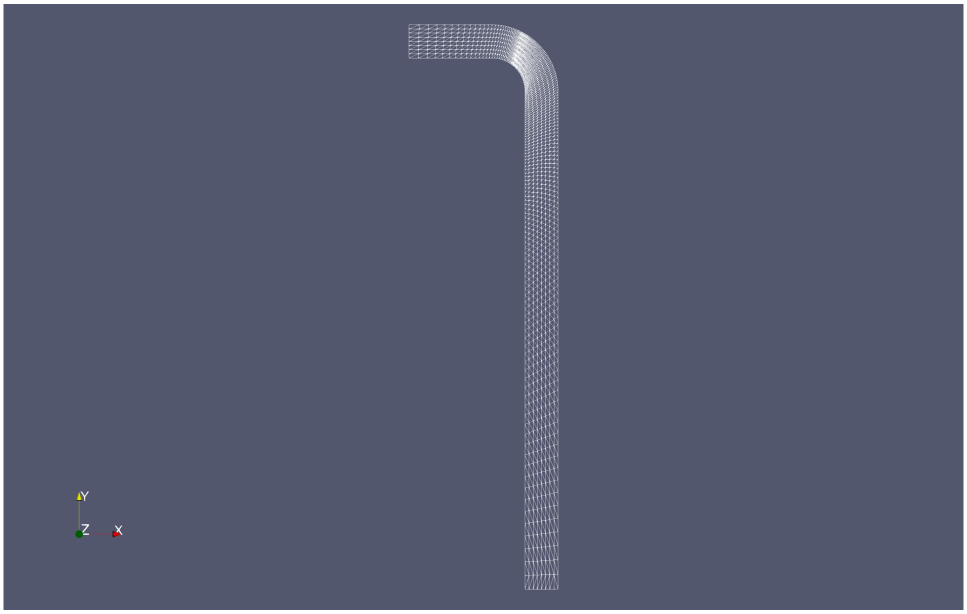
1 Setup and Grid Generation

1.1 Coarse Grid

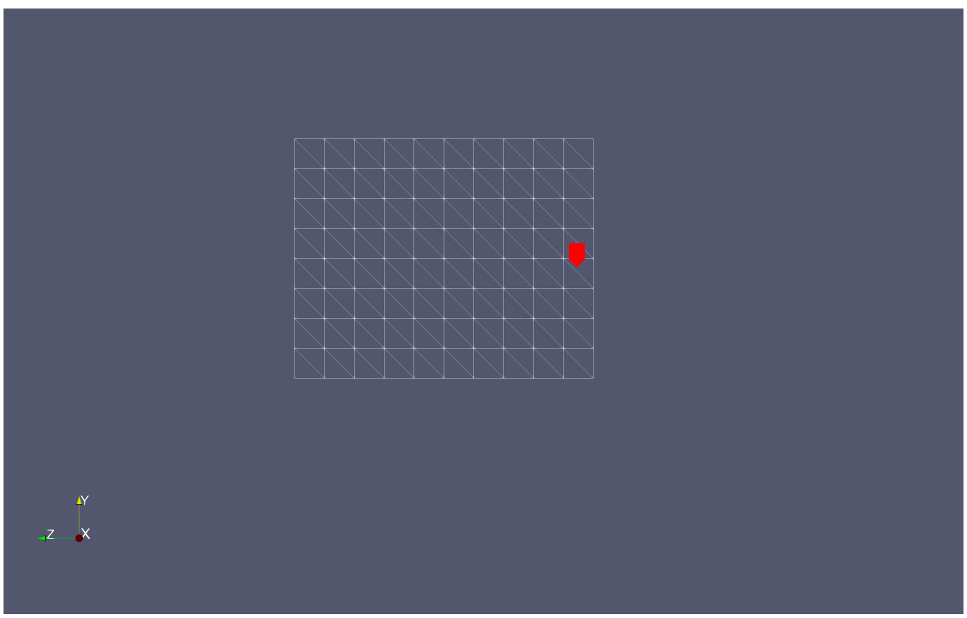
A course grid was constructed along the required geometry using 12000 cells, using 150 cells along the length of the duct, and the cross section was 8 cells by 10 cells (shown in Figure 1. Slight grading was used towards the bend away from the ends of the duct. A uniform inlet velocity of 1 m/s was used, with no velocity gradient at the exit. The outlet pressure was defined as atmospheric pressure wit no pressure gradient at the inlet. Having a defined Reynold's number of 1000, the kinematic viscosity (ν) was calculated to be $8.88 \times 10^{-5} m^2/s$. Running simpleFoam resulted in the velocity flood and convergence plots shown in Figures 2 and 3.

1.2 Grid Refinement

Due to high velocity gradients shown in Figure 2, a fine grid was constructed using 190 along the length, and a cross section of 13 and 16 cells. The highest velocity gradients were closer to the bend, and close to the walls of the duct. Multi-Grading was used to refine the grid in these areas as seen in Figure 4.



(a) Wireframe of Coarse Grid in XY plane



(b) Wireframe of Coarse Grid in YZ plane

Figure 1: Coarse Grid of 12000 cells

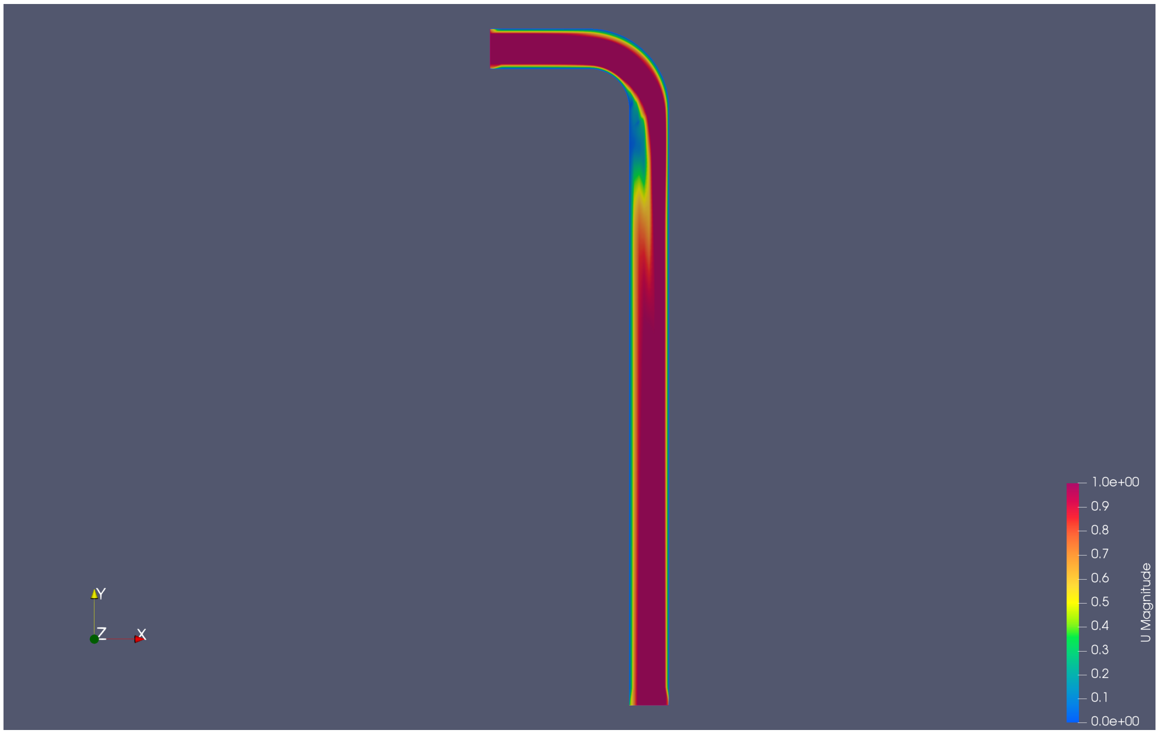


Figure 2: Velocity Flood Plot on Coarse Grid

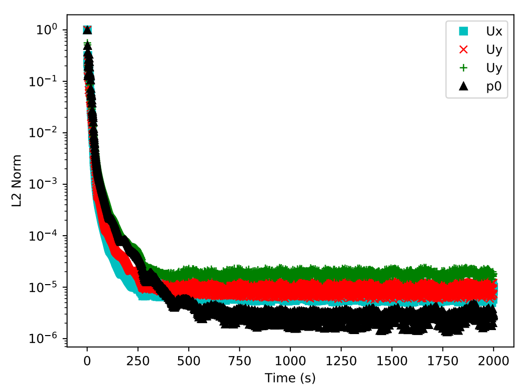
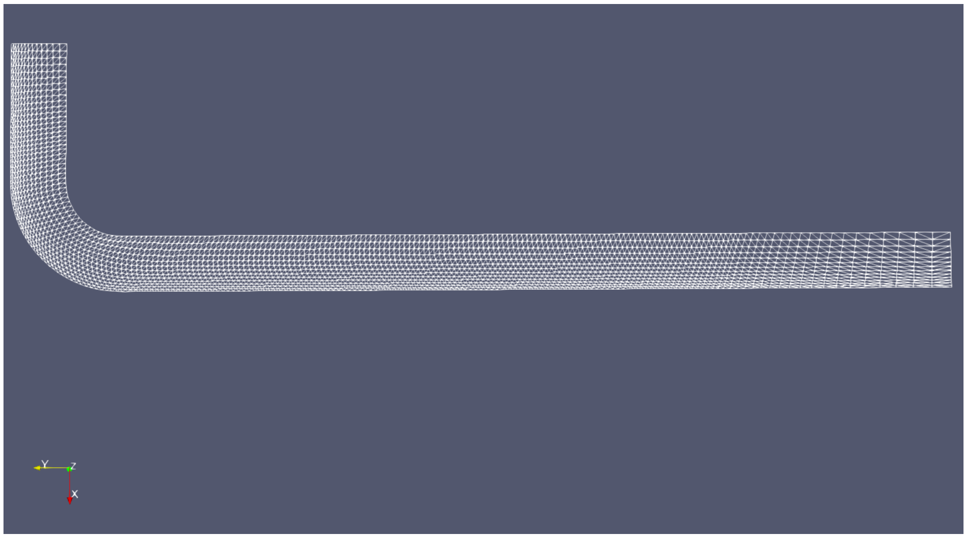
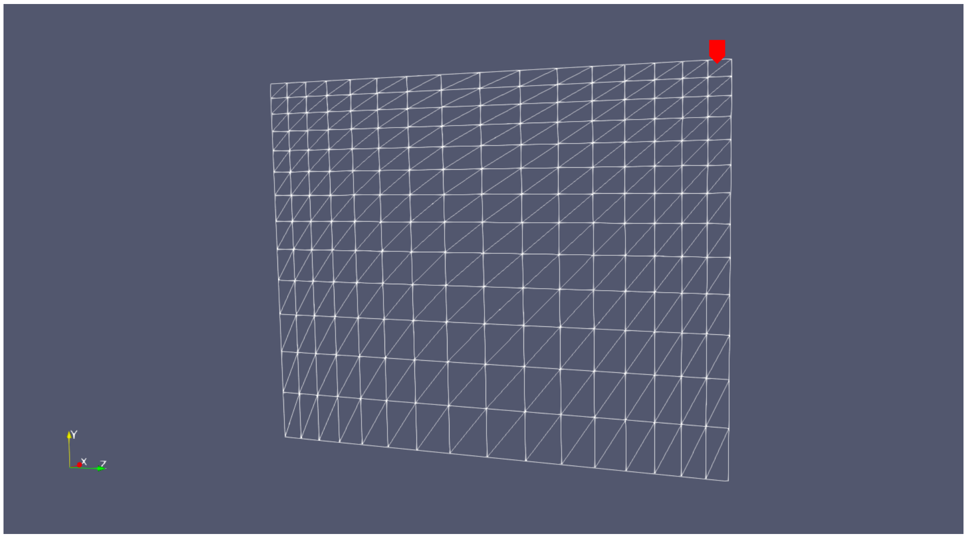


Figure 3: Coarse Grid Convergence Plot



(a) Wireframe of Fine Grid in XY plane

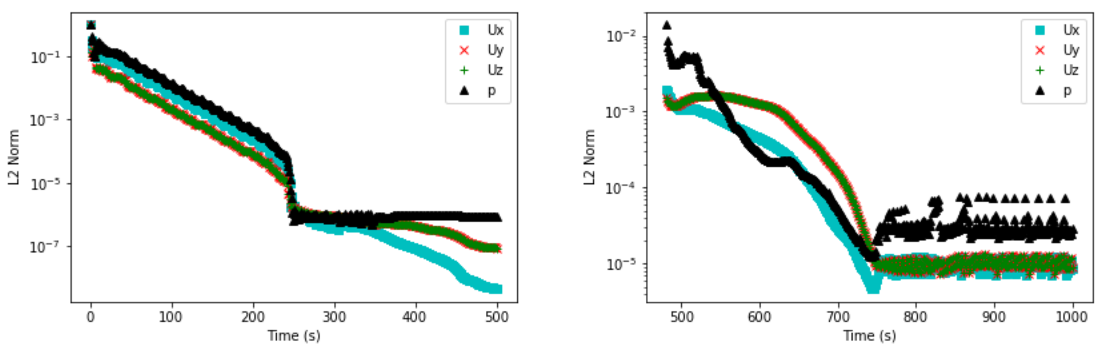


(b) Wireframe of Fine Grid in YZ plane

Figure 4: Wireframe of Fine Grid

2 Solver Comparison

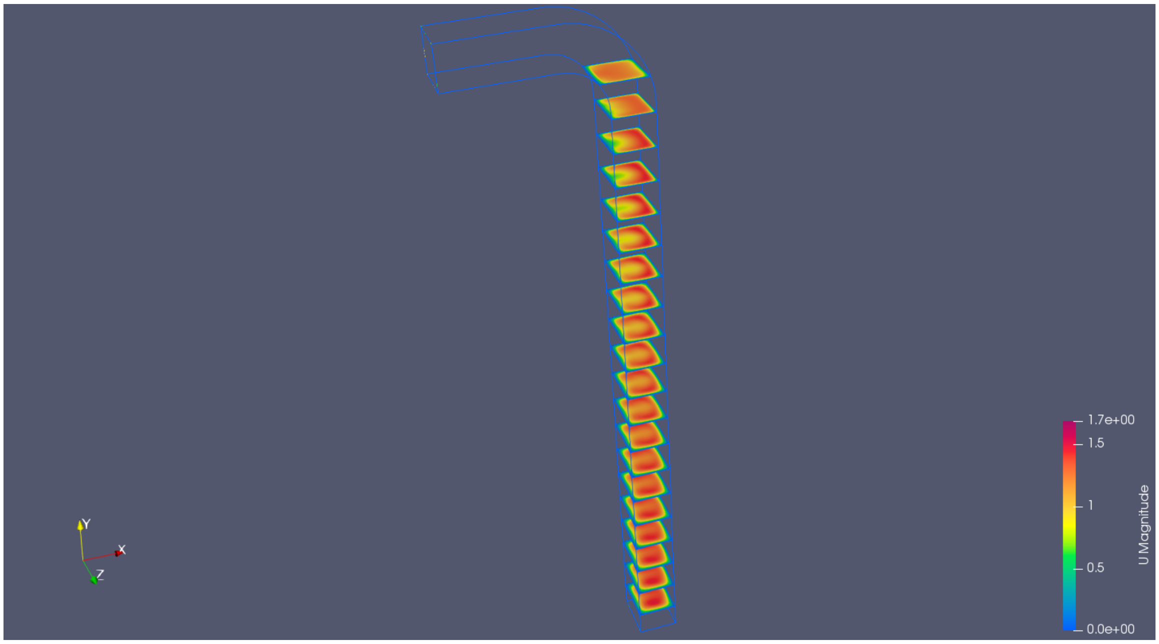
The refined grid was run twice, using a upwind and linear solvers. The linear solver ran off a solution from a linear-upwind solver. We found that the second order solution defined the various velocity gradients much better than the first order solution. The second order solution captured the main re-circulation zone , while the first order solution failed to capture it (see Figure 7). The second order solution, therefore, gives a much more accurate and realistic representation of the flow through this duct than the first order.



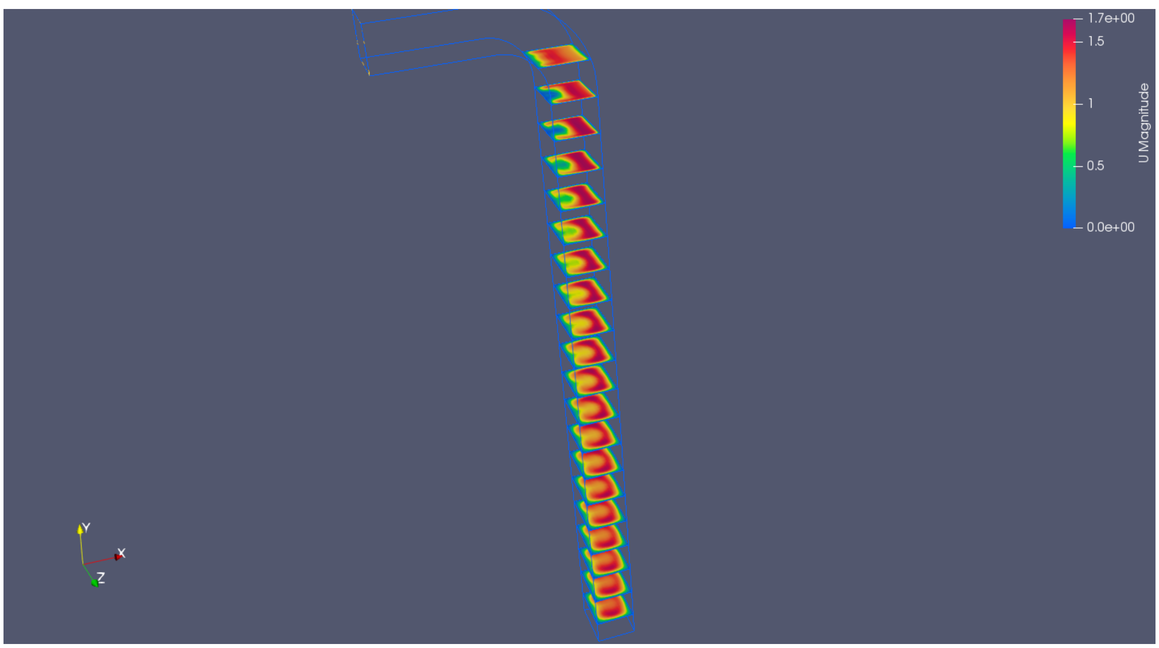
(a) Upwind Solver

(b) Linear Solver

Figure 5: Convergence plots for both solvers.

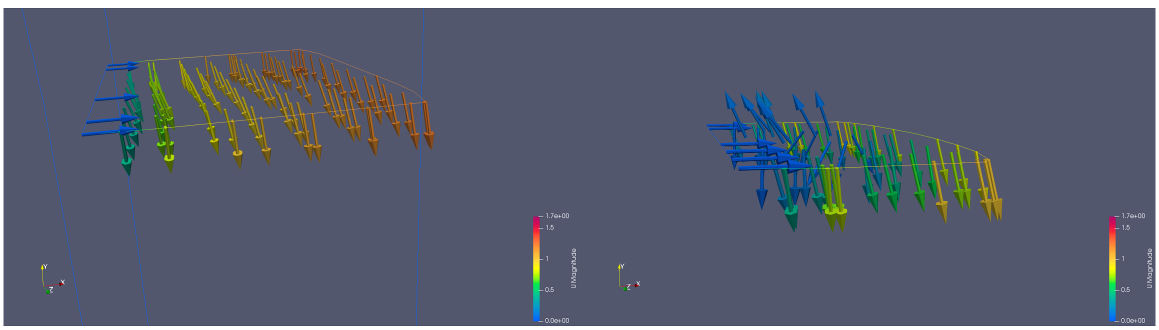


(a) Upwind Solver



(b) Linear Solver

Figure 6: Slices of the flood plot of the U magnitude at regular intervals after the bend in the duct from both solvers.



(a) Upwind Solver (b) Linear Solver

Figure 7: Glyphs taken $9cm$ below the y axis closest to the inner wall of the duct. Figure 7a shows no recirculation zone while Figure 7b shows a recirculation zone.

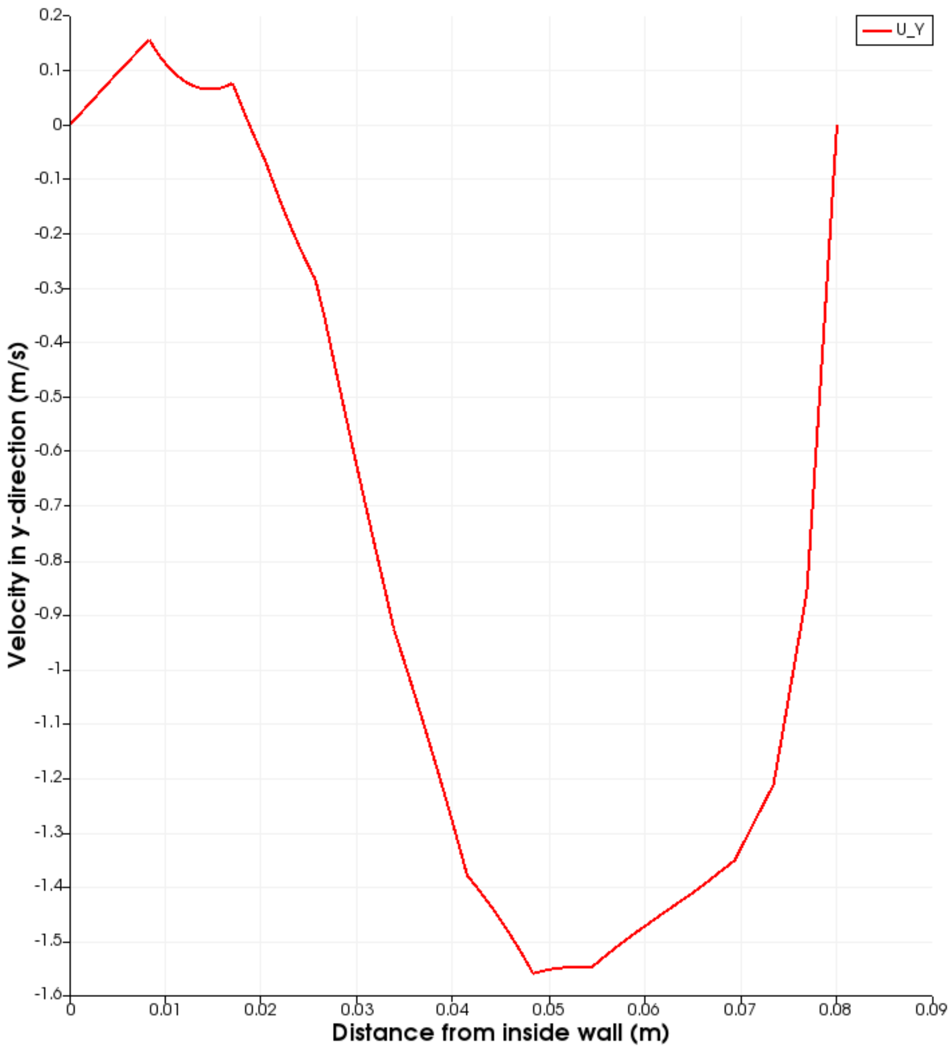


Figure 8: Graph of the y-component of the velocity as a function of the distance from the innermost duct wall as seen in 7b.

3 Some Cool Stuff

One thing we noticed was the flow curling occurred in different places based on the different solvers being used (see Figure 9). The the flow in the first order solver began to curl in on itself more quickly, but the curling was more defined and tighter with the second order solution. We found it really interesting that the first order completely failed to capture any back-flow at all.

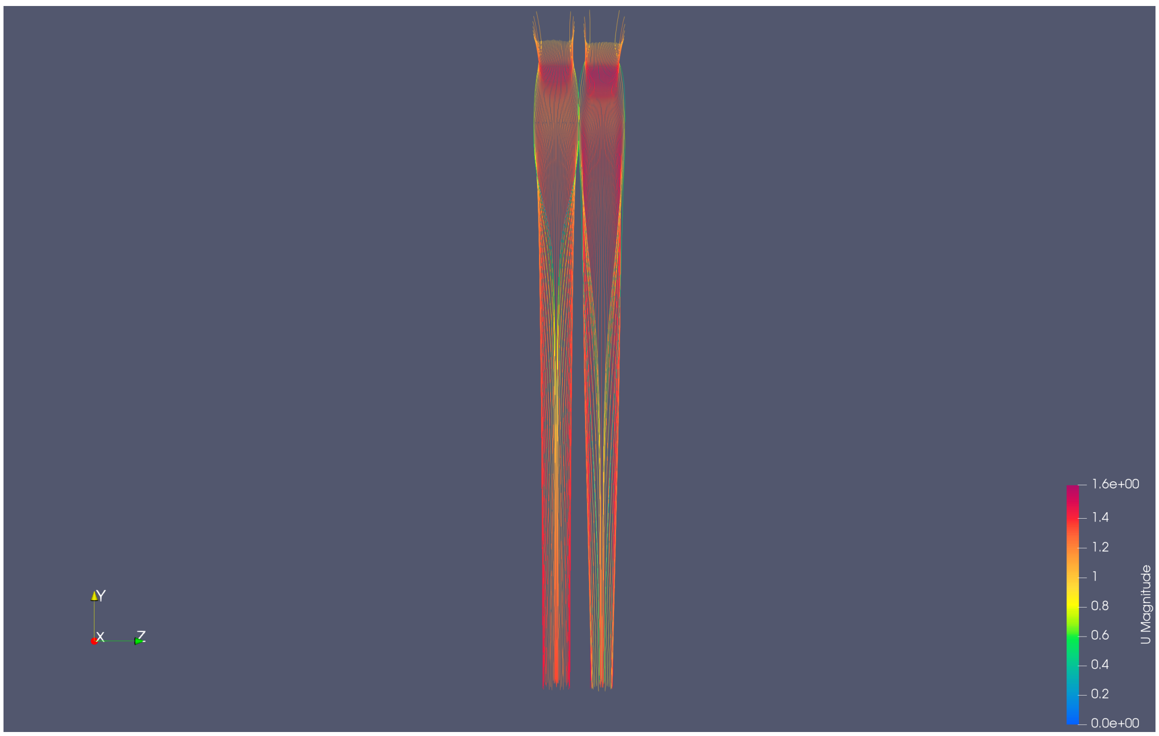


Figure 9: Streamline comparisons between the different solvers (1st Order on the left, 2nd Order on the right)