Project #4

MAE 598: ACFD
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12/5/2019

Task 0:

Name of Collaborator: Ronnie Ramirez	
Task 1	Ronnie set up the geometry and mesh. We discussed the setup. Jeff ran the simulation and generated the figures.
Task 2	We discussed the set up together and helped each other troubleshoot. Independent results developed.
Task 3	We discussed the set up together and helped each other troubleshoot. Independent results developed.
Task 4	Ronnie set up the geometry and mesh. We discussed the setup. Jeff ran the simulation and generated the figures.

Task 1:

Task 1 is a 2-D transient simulation of incompressible flow passing a cylinder. In part a, the cylinder is circular with a radius of 5 cm. In part b, 2 runs are performed with an elliptical cylinder. In the first run, the major axis is perpendicular to the flow while in the second run, the major axis is parallel to the flow. In both runs, the major axis is 12 cm and the minor axis is 8 cm.

The computational domain is a 50cm x 100cm rectangle. The left side of the domain is a velocity inlet with a constant x-velocity of 3.5 cm/s. The right side of the domain is a pressure outlet with zero-gauge pressure. All other boundaries are walls. The mesh is formed with 0.25 cm elements and the capture curvature function is left on. The total number of nodes in the mesh is just under 80k.

The transient simulation was run to 5 minutes with a time step of 0.1s. The maximum number of iterations per time step is set to 10. The last 3 minutes of the simulation are used to estimate the amplitude and period of the lift force.

Task 1a Deliverables:

(i)

$$Re = \frac{\rho V D}{\mu}$$

$$\rho = 998.2\,\frac{kg}{m^3}$$

$$V = 0.035\,\frac{m}{s}$$

$$D = 0.1\ m$$

$$\mu = 0.001003\,\frac{kg}{m\ s}$$

$$Re = \frac{(998.2)(0.035)(0.1)}{0.001003} = 3483.3$$

(ii)

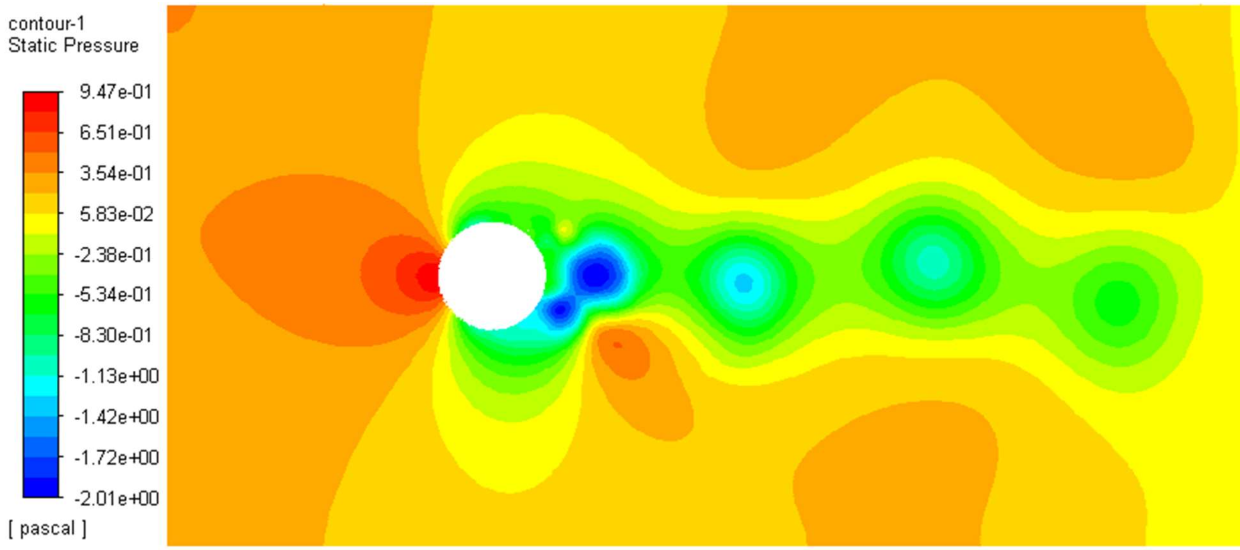

Figure 1. Contour plot of the static pressure at t = 5 min.

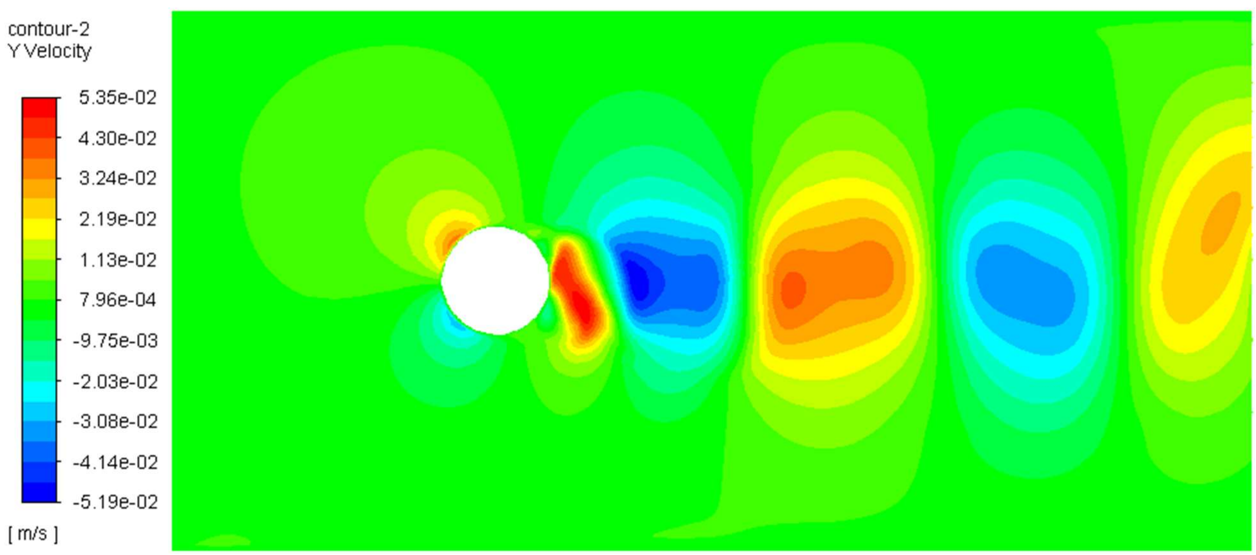

Figure 2. Contour plot of the y-velocity at t = 5 min.

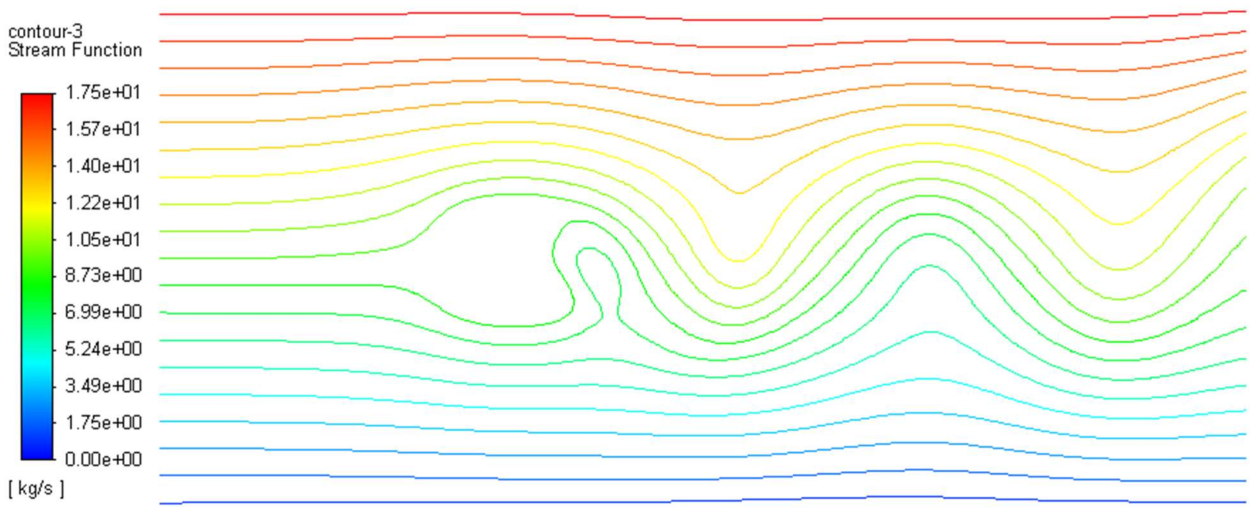

Figure 3. Contour plot of the stream function at t = 5 min.

(iii)

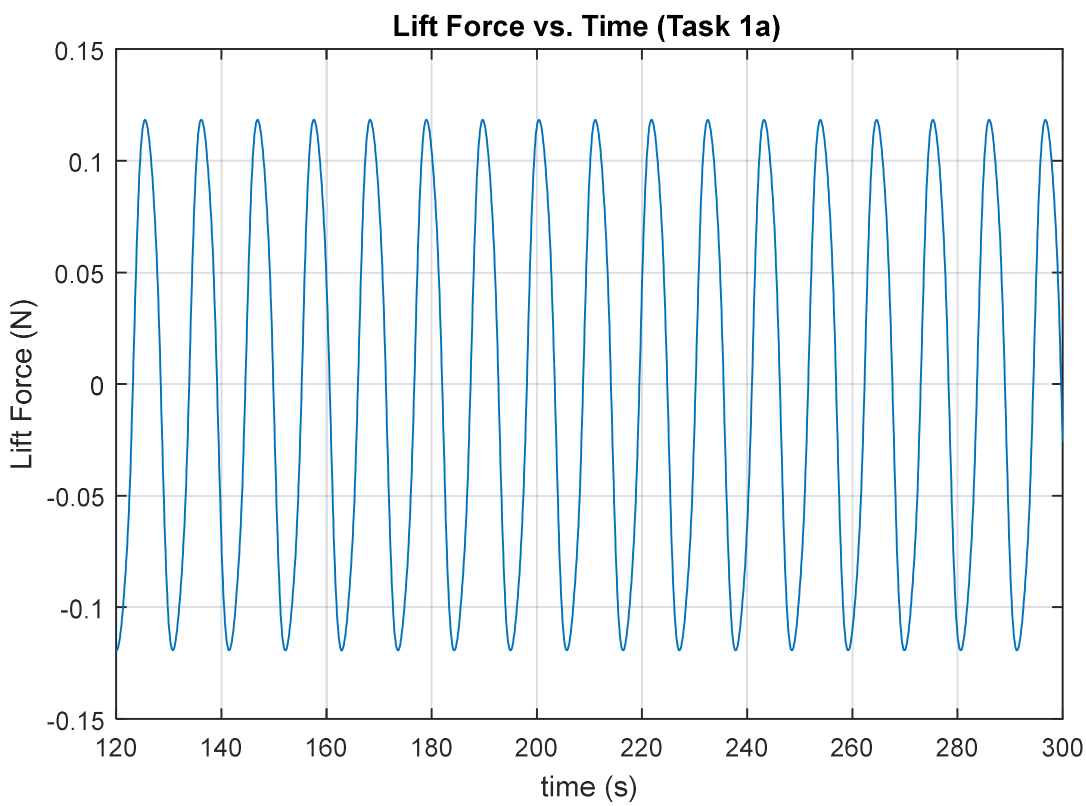

Figure 4. Line plot of the lift force as a function of time for the last 3 minutes of the Task 1a simulation.

By taking the mean value of the difference between the maximum and minimum values in Figure 4, the amplitude is estimated to be 0.1189 N. The period is estimated to be 10.7 s by counting the time between peaks.

Task 1b Deliverables:

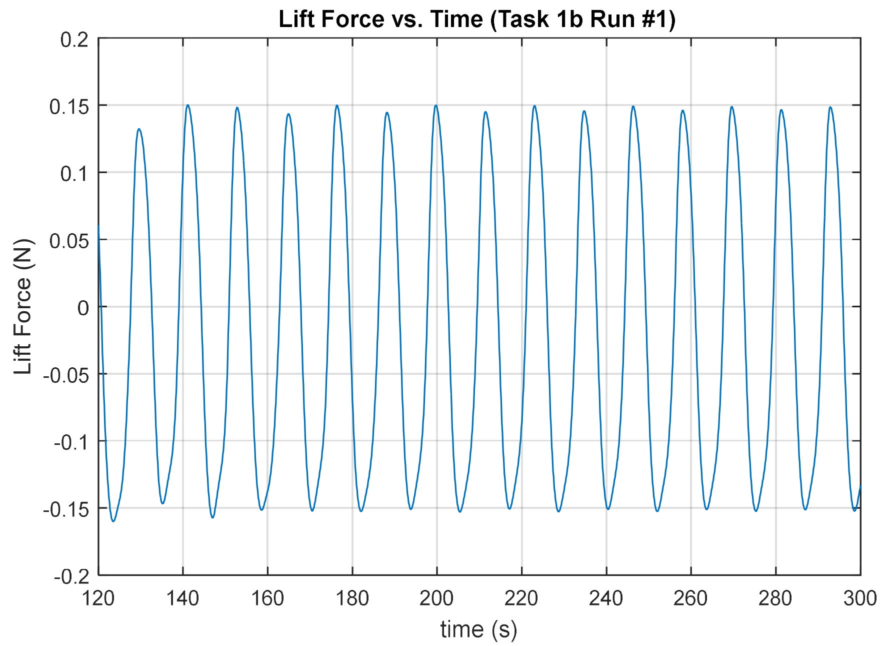

Figure 5. Line plot of the lift force vs. time for the last 3 minutes of Task 1b Run#1.

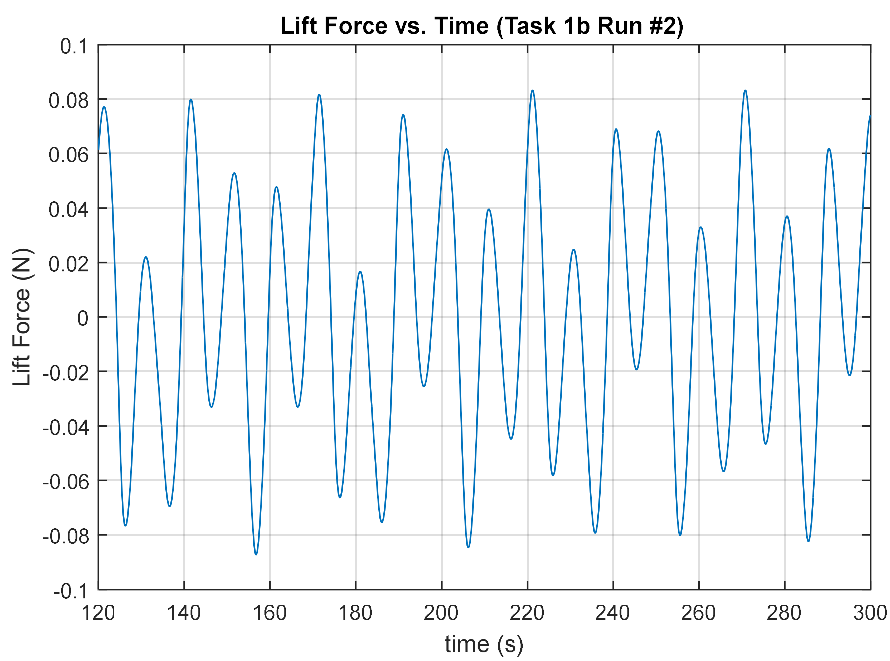

Figure 6. Line plot of the lift force vs. time for the last 3 minutes of Task 1b Run#2.

For run #1, the last 5 peaks and the last 5 valleys were averaged to estimate an amplitude of 0.1499N. The period between successive peaks and successive valleys alternates between 11.6s and 11.7s so a period of 11.65s is estimated.

For run #2, the last 5 peaks and the last 6 valleys were average to estimate an amplitude of 0.0539N. In the data sampled, there is no clear pattern to the period. The nine possible periods from the data sampled were averaged to estimate a period of 9.93s.

Run	Lift Force Amplitude (N)	Lift Force Period (s)
Task 1a	0.1189	10.7
Task 1b Run#1	0.1499	11.65
Task 1b Run#2	0.0539	9.93

Figure 7. Table of results for all Task 1 runs for comparison.

From comparing the results, it is possible to conclude that a larger cross-sectional area perpendicular to the flow results in a larger lift force amplitude and a longer time period.

Task 2:

Task 2 is a 3-D simulation that models a flying saucer in a cylindrical wind tunnel. The properties of air are set to a constant density of 0.4 kg/m^3 and a constant velocity of 1.45(10^{-5}) N s m^{-2} which approximately models the cruising altitude of a commercial airliner. Four different runs of this simulation were completed using varying tilt angles of the saucer about the z-axis. These angles are 0, 15, 30 and 45 degrees. The following table shows the element size and the number of elements in each of the 4 simulations. It is interesting to note that as the angle of tilt increased, the element size needed to be increased in order to keep the maximum number of elements under 512k.

Tilt Angle (deg)	Element Size (cm)	# of Elements in Mesh (10^3)
0	3.75	511.5
15	3.8	510
30	3.85	509.2
45	3.85	508.9

Figure 1. Element size and number of elements in the mesh for each run in Task 2.

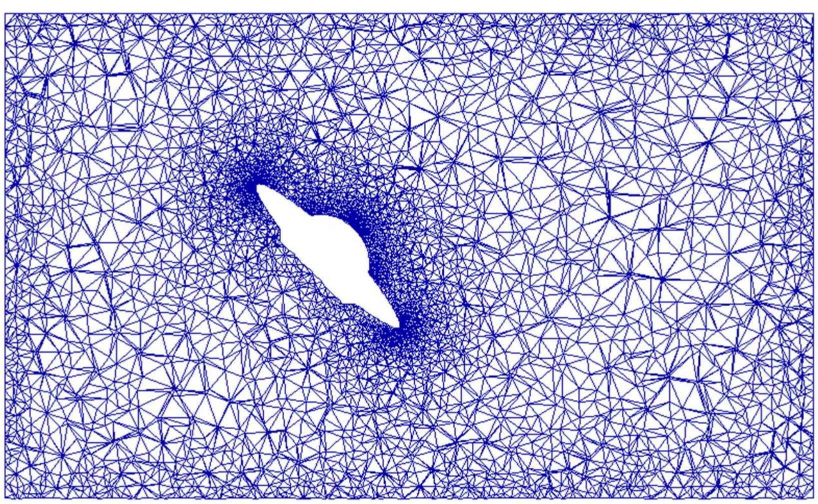

Figure 2. Mesh on the vertical plane of symmetry used during the 45-degree tilt angle run.

Task 2 Deliverables:

(i)

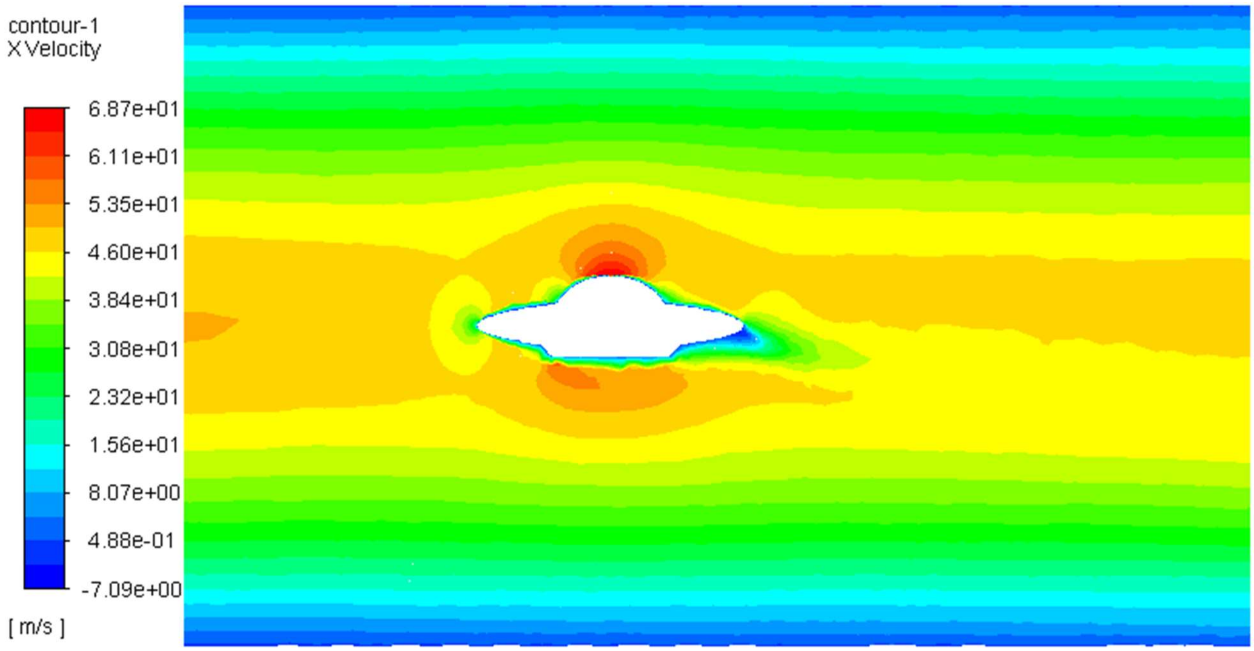

Figure 3. Contour plot of the x-velocity on the plane of symmetry when tilt angle is 0 degrees.

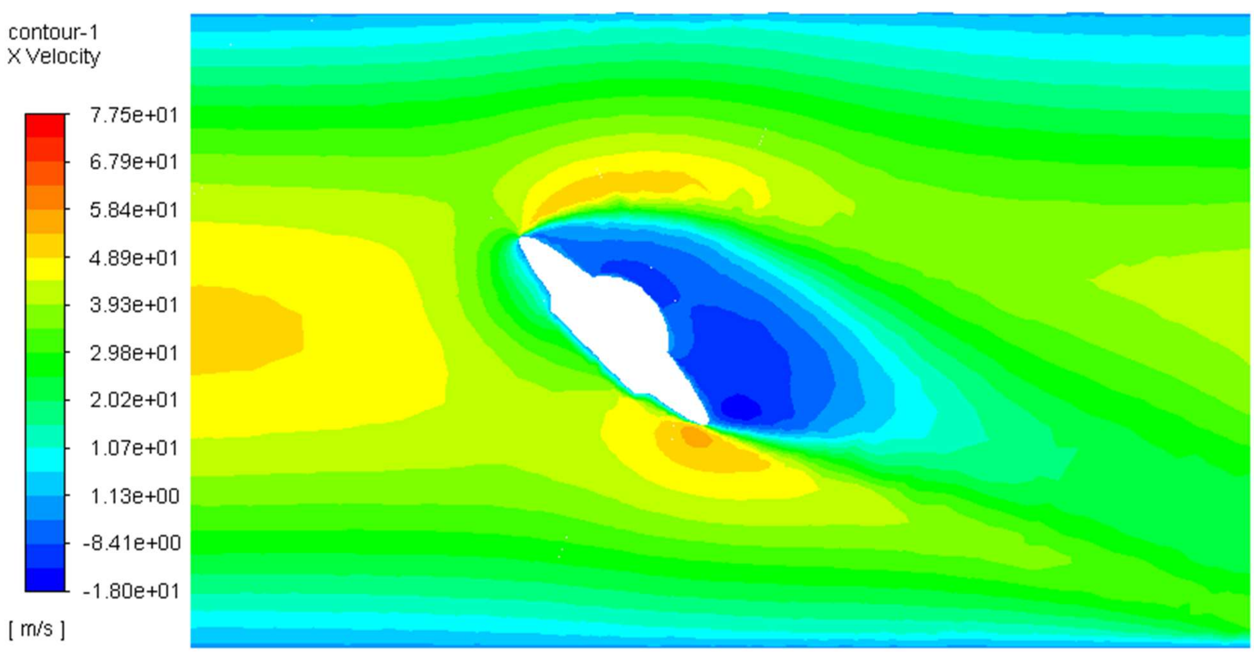

Figure 4. Contour plot of the x-velocity on the plane of symmetry when tilt angle is 45 degrees.

(ii)

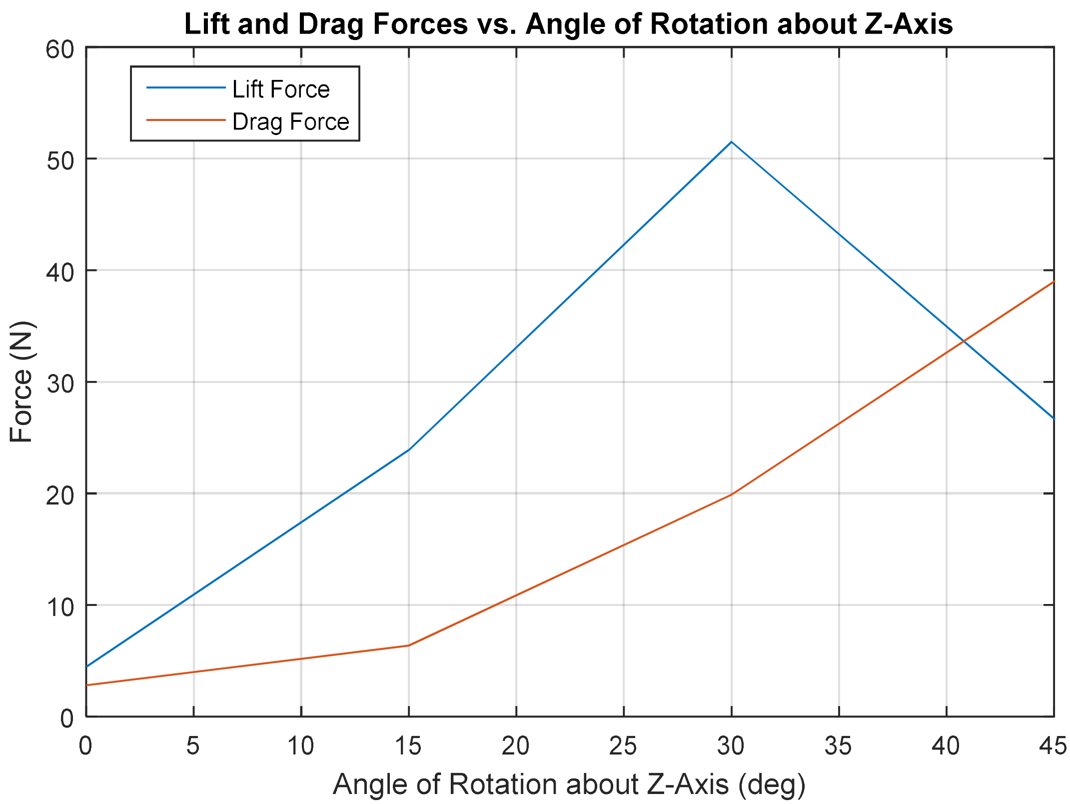

Figure 5. Plot of the lift force and drag force as a function of the tilt angle.

Tilt Angle (deg)	Lift Force (N)	Drag Force (N)
0	4.4474	2.8203
15	23.8846	6.3636
30	51.5067	19.8798
45	26.6779	38.9797

Figure 6. Numerical values of points in Figure 5.

Task 3:

Task 3 simulates the flow of air over a pentagonal building in a rectangular virtual wind tunnel. The building is 2 m tall and each side of the pentagon is 1 m long. The computational domain is 8 x 12 x 10 m and the building is positioned centrally on the base of the wind tunnel. The left and right openings are set to either a velocity inlet or a pressure outlet depending on the direction of the flow being simulated. Two different runs are performed for flow in each direction. The goal of the task 3 runs is to explore the effects of the upwind geometry on the drag force exerted onto the building. The simulation uses the standard k-epsilon model and seeks the steady solution. The inlet velocity is set to a constant 50 m/s and the default properties of air are used. The computation domain was meshed with 0.175 m elements and contains about 459k elements.

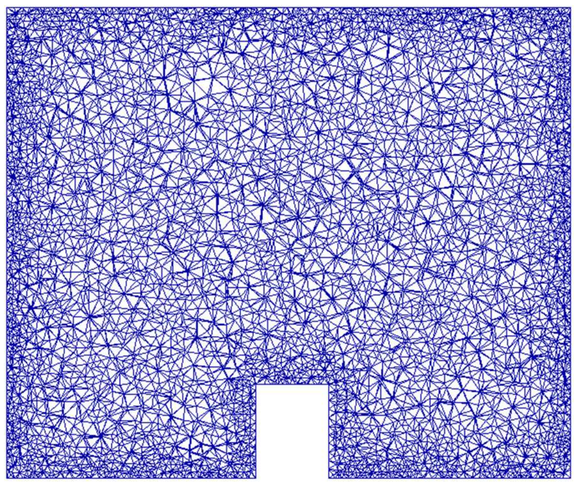

Figure 1. Mesh displayed on the vertical plane of symmetry running along the wind tunnel.

The results presented in the following deliverables sections allow for interesting observations with respect to the structures of pressure and velocity and their effect on the drag force acting on the building. It is important to note that the largest cross-sectional area perpendicular to the flow is the same in both simulations; however, in part a, the largest cross-sectional area is behind the center of the pentagon while in part b, this area is in front of the center of the pentagon. As a result, in part a, the flow hits the flat side of the pentagon then runs against the 2 sides with a large portion of their direction parallel to the flow. With the flat side encountering the flow first, the velocity running along the sides of the building is faster allowing for a greater contribution from the viscosity to the drag force. Also, in part a, the position of the largest cross-sectional area behind the center of the pentagon results in a lower pressure acting on the building. Since the pressure is the largest contributor to the drag force, the drag force is lower in part a as a result.

In part b, the flow encounters the largest cross-sectional area in front of the center of the pentagon and the two sides preceding this area have the largest part of their direction perpendicular to the flow. As a result, the contribution of viscosity to the drag force is very low in part b, especially since the flow is pushed away from the building and the remaining 3 sides are shielded from the flow. Furthermore, encountering the large cross-sectional area before the center of the pentagon results in a larger pressure force acting on the building. As a result, the overall drag force is much larger in part b.

Task 3a Deliverables:

(i)

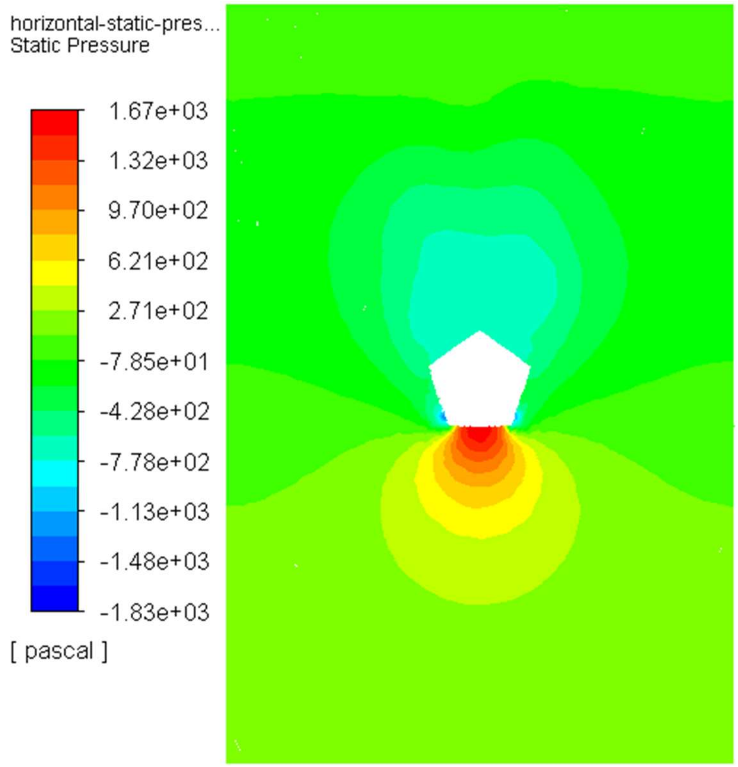

Figure 2. Contour plot of static pressure on the horizontal plane, z = 1.

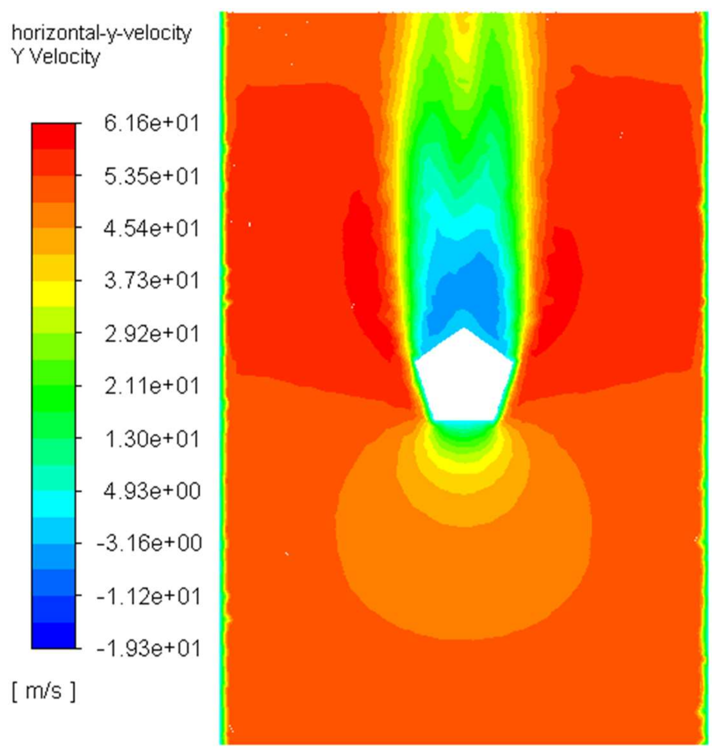

Figure 3. Contour plot of y-velocity on the horizontal plane, z = 1.

(ii)

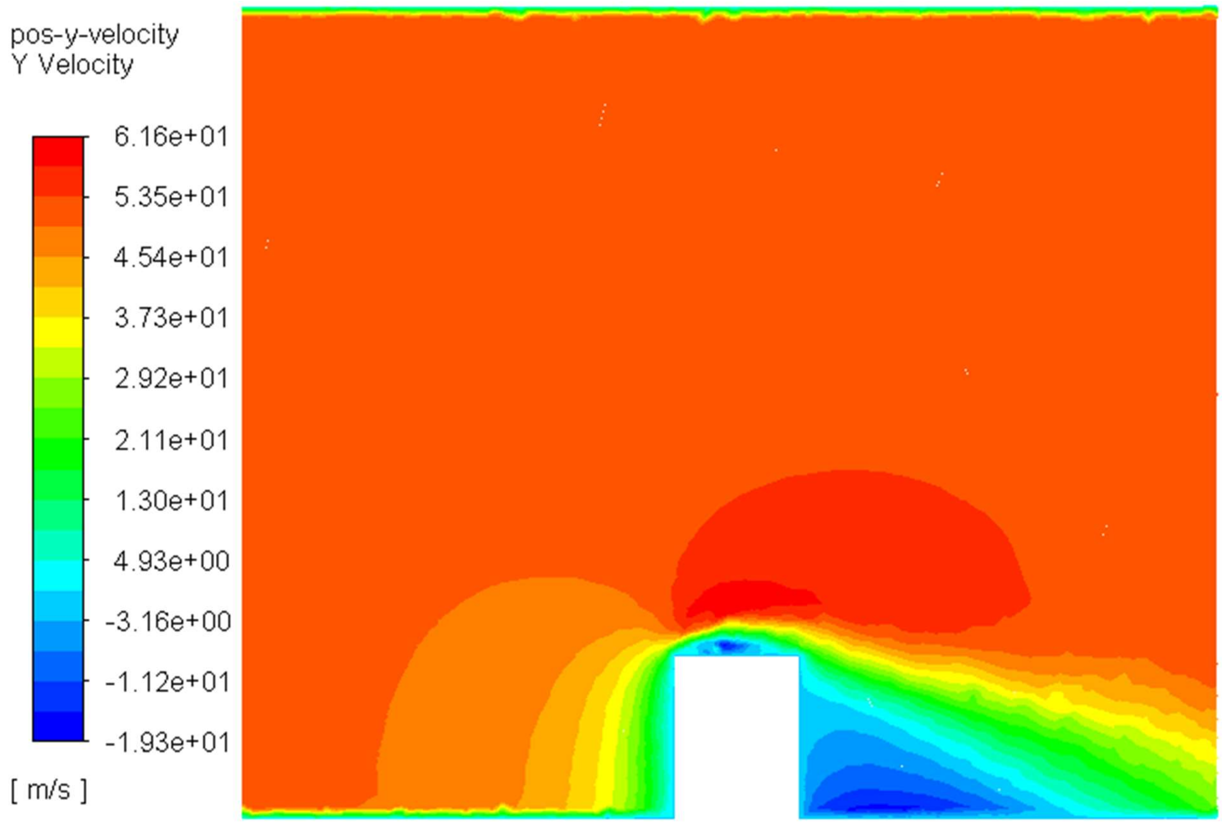

Figure 4. Contour plot of y-velocity on the plane of symmetry.

(iii)

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Forces - Direction Vector (0 1 0)
                          Forces (n)
Zone                      Pressure        Viscous         Total
wall-building             3567.885        10.843987       3578.729
------------------------- --------------- --------------- ---------------
Net                       3567.885        10.843987       3578.729
```

Task 3b Deliverables:

(i)

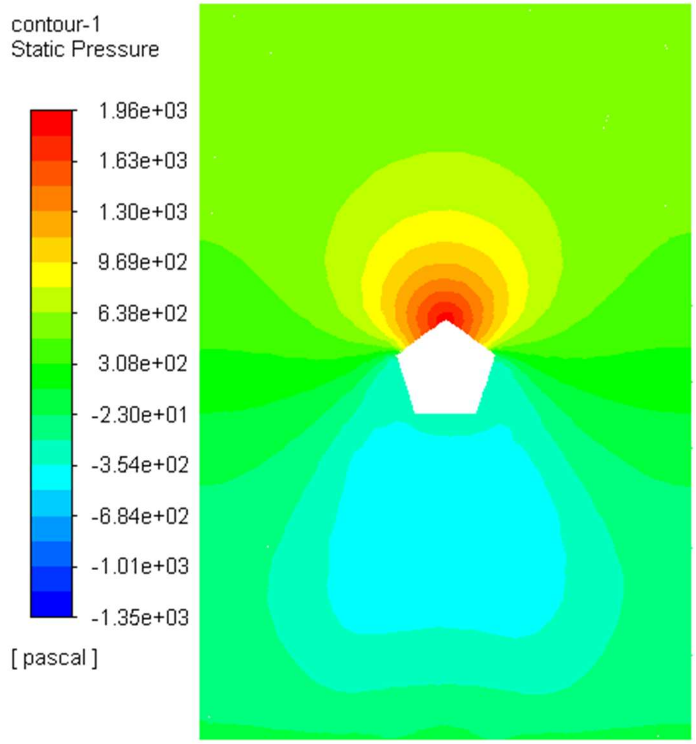

Figure 5. Contour plot of static pressure on the horizontal plane, z = 1.

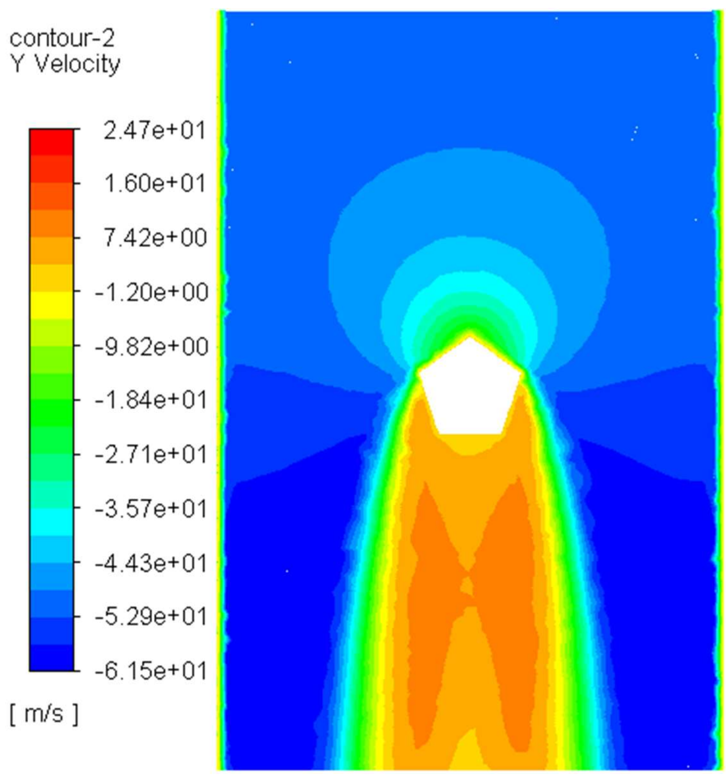

Figure 6. Contour plot of y-velocity on the horizontal plane, z = 1.

(ii)

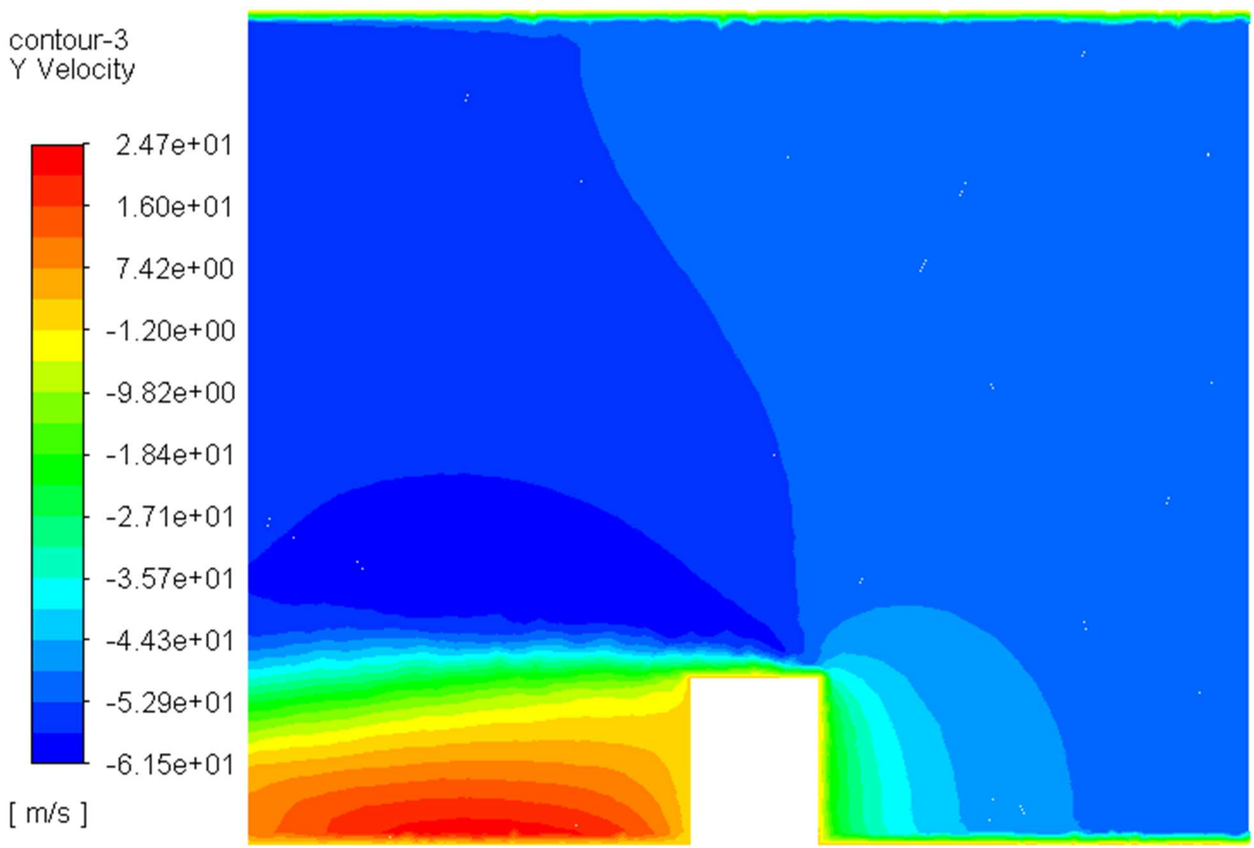

Figure 7. Contour plot of y-velocity on the plane of symmetry.

(iii)

Forces - Direction Vector (0 -1 0)

	Forces (n)		
Zone	Pressure	Viscous	Total
wall-building	5107.8857	1.3522233	5109.238
Net	5107.8857	1.3522233	5109.238

Task 4:

Task 4 is a repeat of the Task 1 simulation and uses the same mesh and set up as Task 1. The goal of Task 4 is to explore the possibility of an asymmetric cylinder producing a large amplitude response in a numerical simulation. Using video 3 from lecture 24 as inspiration, a semi-circular cylinder was selected with the flat surface facing the flow. The radius of the cylinder was derived using the following expression,

$$\frac{1}{2}\pi R^2 = \pi r^2$$

Where r is the known radius of the circle in Task 1 and R is the radius of the semi-circular cylinder used in Task 4. Simplifying the relationship results in:

$$R = \sqrt{2}r$$

The relationship yields a radius of 7.0711 cm for the semi-circular cylinder used in Task 4.

Task 4 Deliverables:

(i)

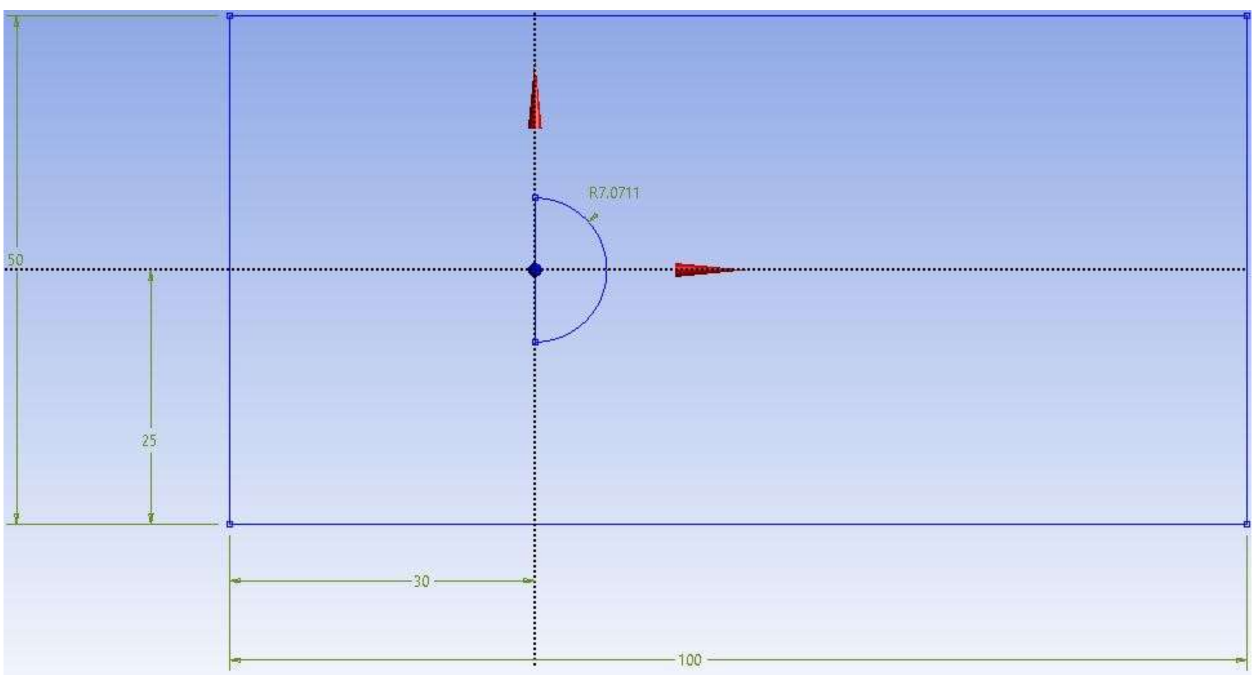

Figure 1. Geometry of the cylinder and its position in the computational domain. All numbers are in centimeters.

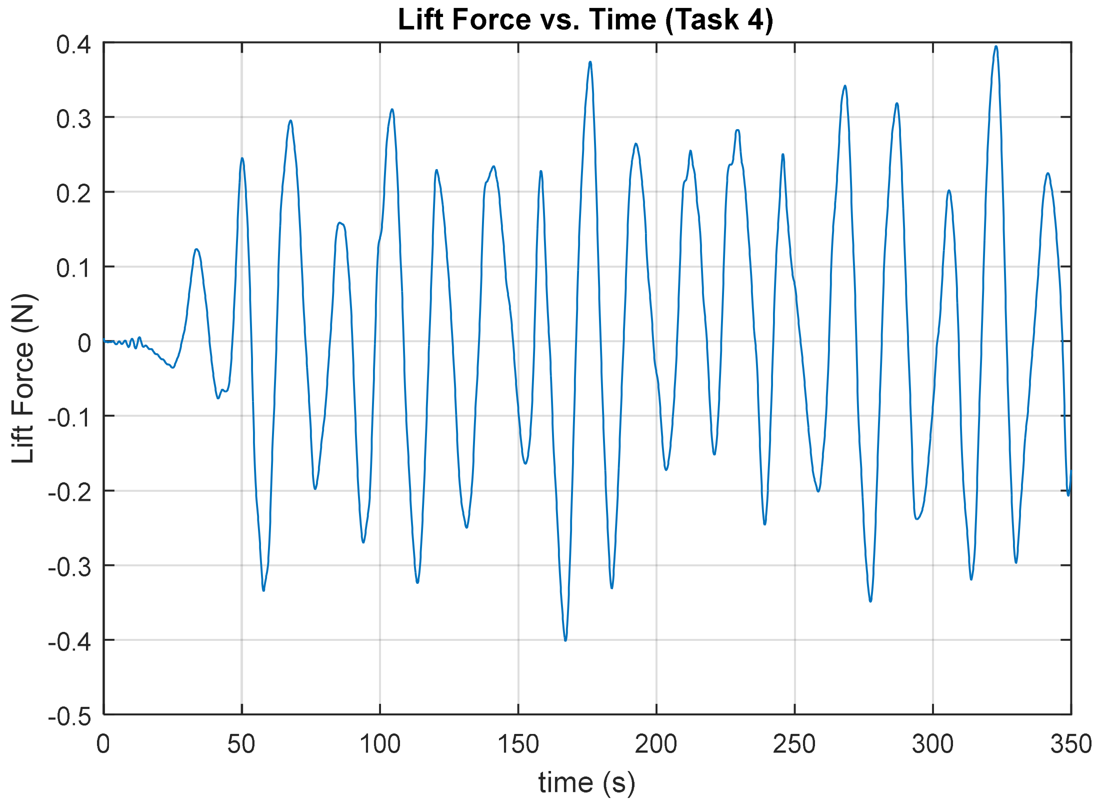

Figure 2. Line plot of lift force vs. time.

From the line plot in Figure 2, a large amplitude response can be generated in a numerical simulation using an asymmetric cylinder of similar area. The response is over 2.5 times greater than the largest response in Task 1. If the cylinder were not fixed in the simulation, then the integrity of the structure could be threatened given the unstable nature of the response that appears to be growing in amplitude.