Task 1

The system in Task 1a (with kerosene) has Reynolds number ≈ 480. At this intermediate value of *Re*, the flow oscillates in time and the wake downstream of the cylinder has a wavy structure that resembles the von Karman "vortext street". See reference solutions for detail.

The system in Task 1b (with air) has Reynolds number ≈ 100. At this relatively low Reynolds number, the system is near the boundary of "steady" and "oscillatory" regimes. Most of the submitted reports show an oscillation in lift and drag but with very small amplitudes. The flow pattern is more symmetric (but not perfectly symmetric) compared to the case in Task 1a. The wake only meanders slightly.

Comparing the three cases in Task 1a and Task 1c, the case with an elliptic cylinder elongated in y-direction shows the strongest oscillation. This is followed by the case with a circular cylinder. The case with an elliptic cylinder elongated in x-direction shows only very weak oscillation or nearly steady behavior in lift and drag. Qualitatively, the results from numerical simulation are consistent with the lab experiment in the video that we showed in Lecture 21.

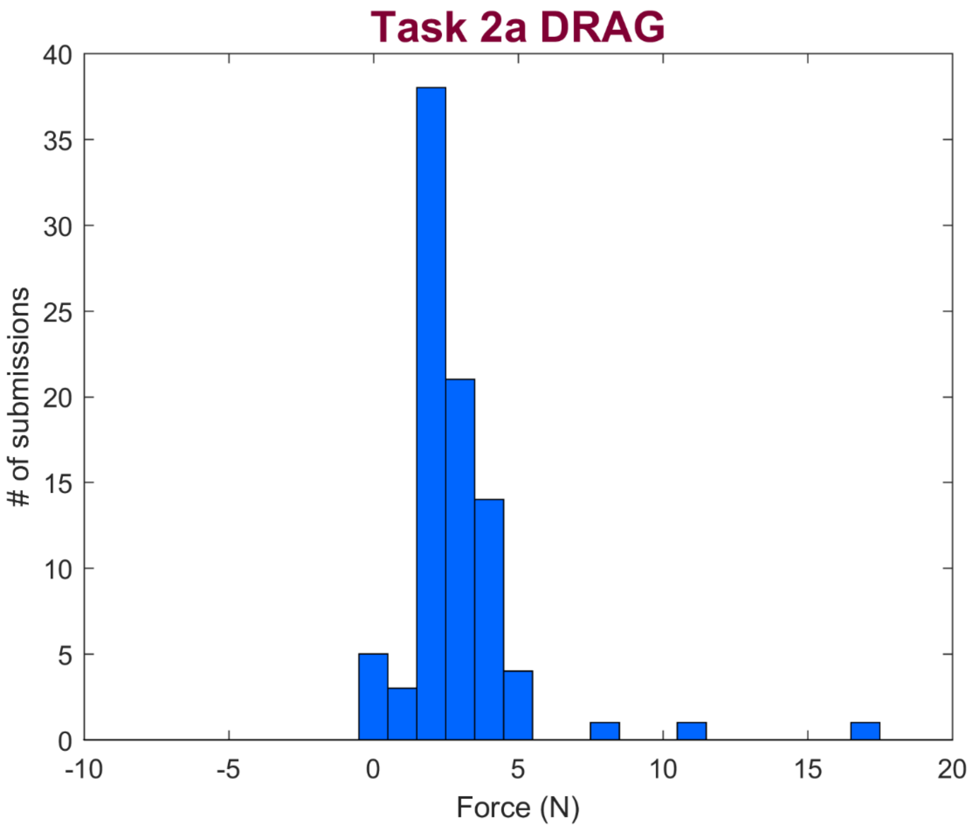
From the results of Task 1, it is clear that for this type of external flow simulation one cannot use only "half geometry" and assume symmetry. Unless Reynolds number is extremely low, the flow is expected to be asymmetric even though the geometry of the system appears to be symmetric.

Task 2

As clarified in the Addendum to the original problem statement, the two cases in Task 2a and 2b still exhibit some oscillatory behaviors. (The oscillation might not be entirely regular, which is an indication that the flow regime is not too far from the next transition to the turbulent/chaotic regime.) As such, we expect a somewhat wide range of lift and drag for the simulations. The general guideline of what's acceptable was explained in the Addendum.

We performed some quick statistics of the drag force and lift force for Task 2a and 2b from the submitted reports, as summarized in the following four charts. Since some students switched to transient simulation, for those cases we only took a rough estimate of the average (if it was not stated in the report) for the statistics. The reported values of lift and drag are somewhat sensitive to the detailed setting (mesh resolution, time step size, number of iteration, etc.) We will further discuss this point in class.

The values of lift and drag forces in the 2D case appear to be greater than those in the 3D case in Task 3. This is partly because, for a 2D simulation, Ansys internally assumes that the "depth" of the system in the 3rd dimension is 1 m. As such, the "2D saucer" actually has a much larger surface area than the more realistic 3D saucer. (Note that, unlike drag/lift coefficient, drag/lift force is not normalized or nondimensionalized. A bigger object is associated with a bigger force.)


Task 2a DRAG
# of submissions
Force (N)
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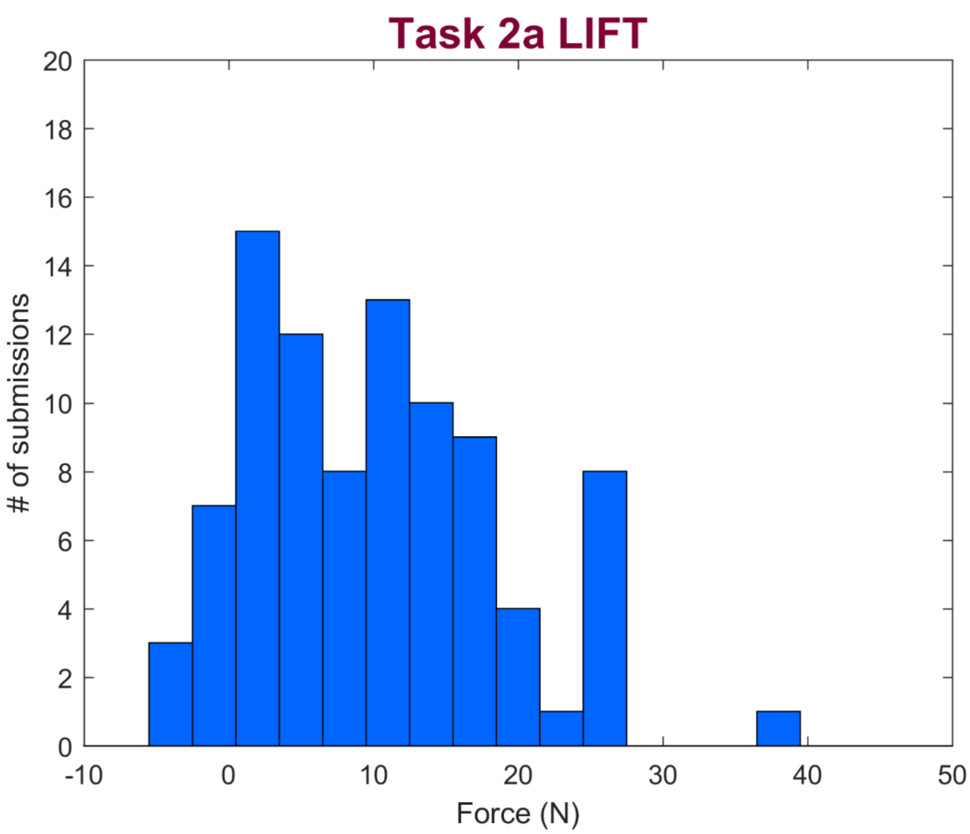
35
30
25
20
15
10
5
0
-10
-5
0
5
10
15
20


Task 2a LIFT
# of submissions
Force (N)
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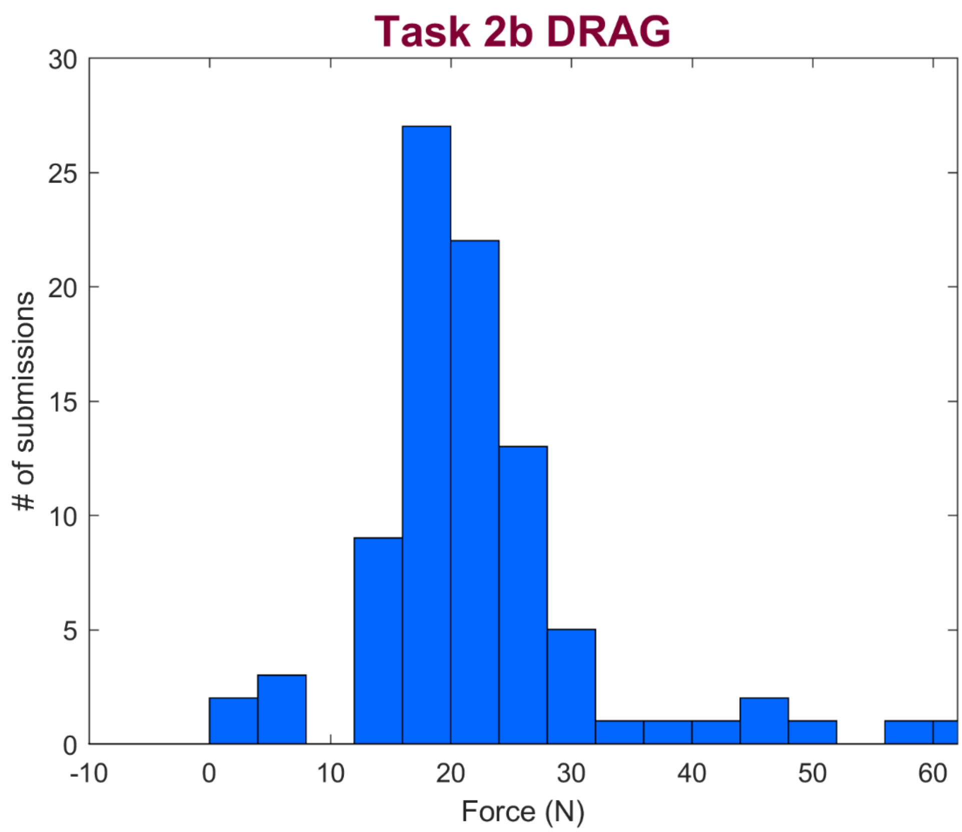
18
16
14
12
10
8
6
4
2
0
-10
0
10
20
30
40
50


Task 2b DRAG
# of submissions
Force (N)
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10
5
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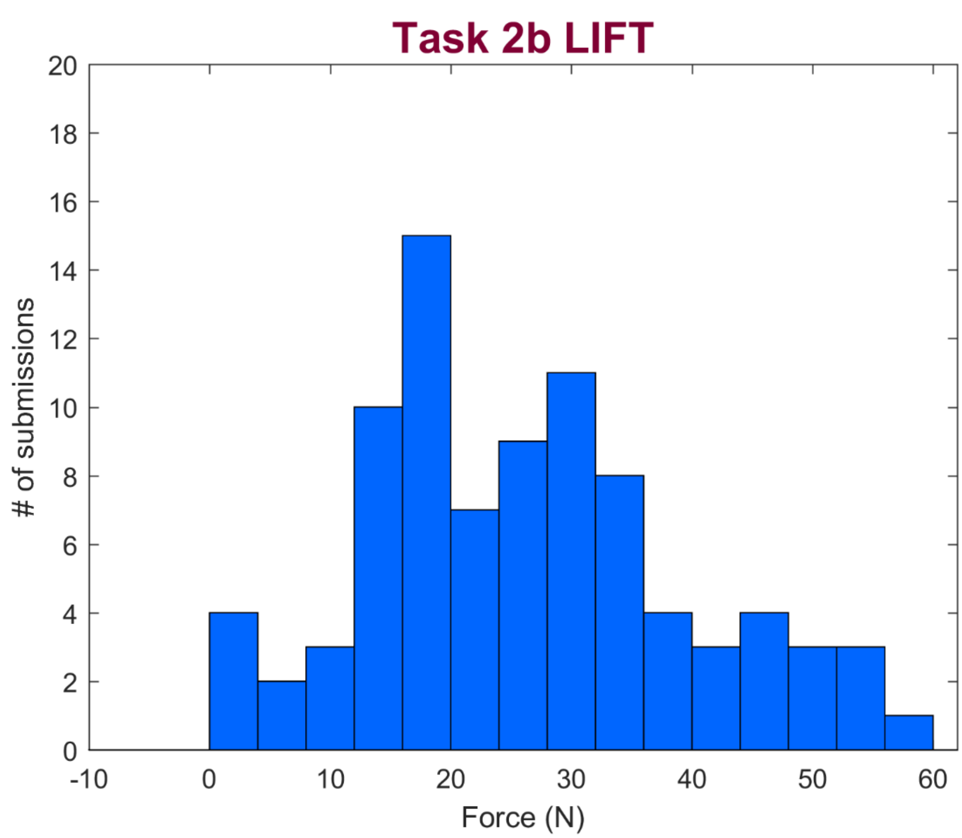
-10
0
10
20
30
40
50
60


Task 2b LIFT
# of submissions
Force (N)
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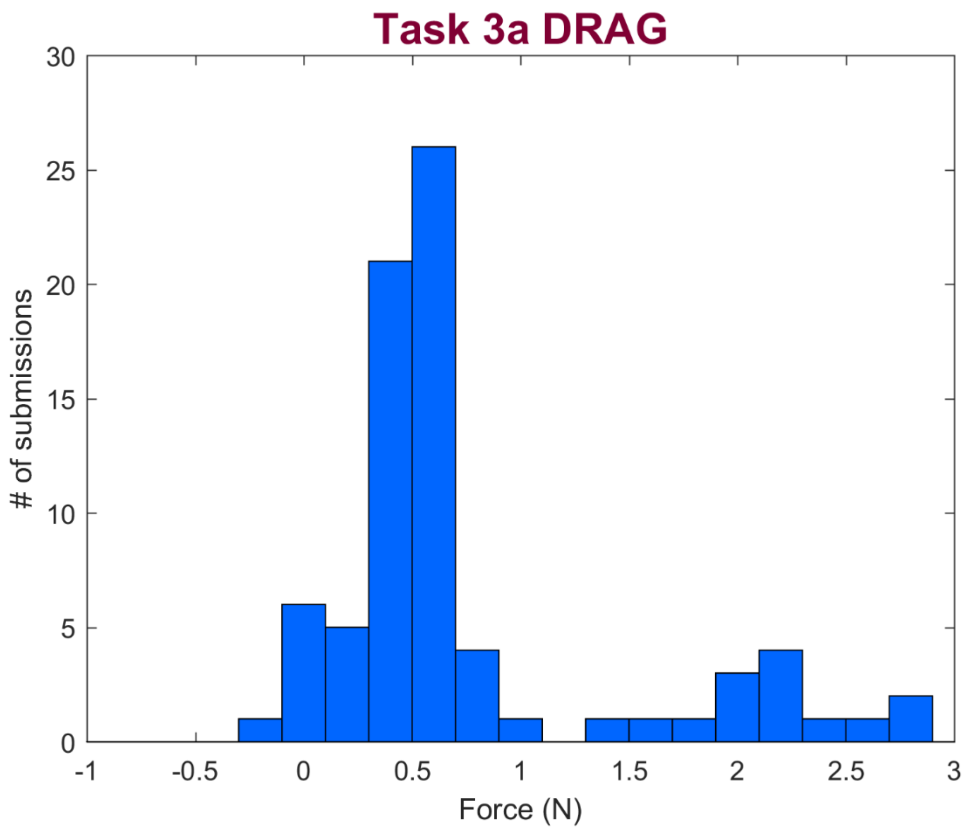
18
16
14
12
10
8
6
4
2
0
-10
0
10
20
30
40
50
60

Task 3

Compared to the 2D case in Task 2, the 3D case produces relatively more robust results in lift and drag. The statistics of drag force and lift force for Task 3a (with no tilt of the saucer) from the submitted reports are shown in the two charts in the next page. (See remakes in the discussion for Task 2 on how the lift and drag are sampled when the flow is not steady.)

As noted in the discussion for Task 1, it is recommended that full geometry be used for this type of external flow simulation. The spread in the distribution of lift and drag in the two charts shown in the next page is due in part to the fact that a group of students ran the simulation using half geometry by invoking symmetry.

In Task 3b, both lift and drag exhibit an initial tendency to increase with an increasing tilt angle. For the lift force, this trend saturates beyond a 30° tilt. In fact, from the submitted reports, we have not been able to firmly establish whether the lift force for 30° tilt is greater or less than that for 45° tilt. The potential difficulties with these simulations will be discussed in class.



Task 3a DRAG
# of submissions
Force (N)
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20
15
10
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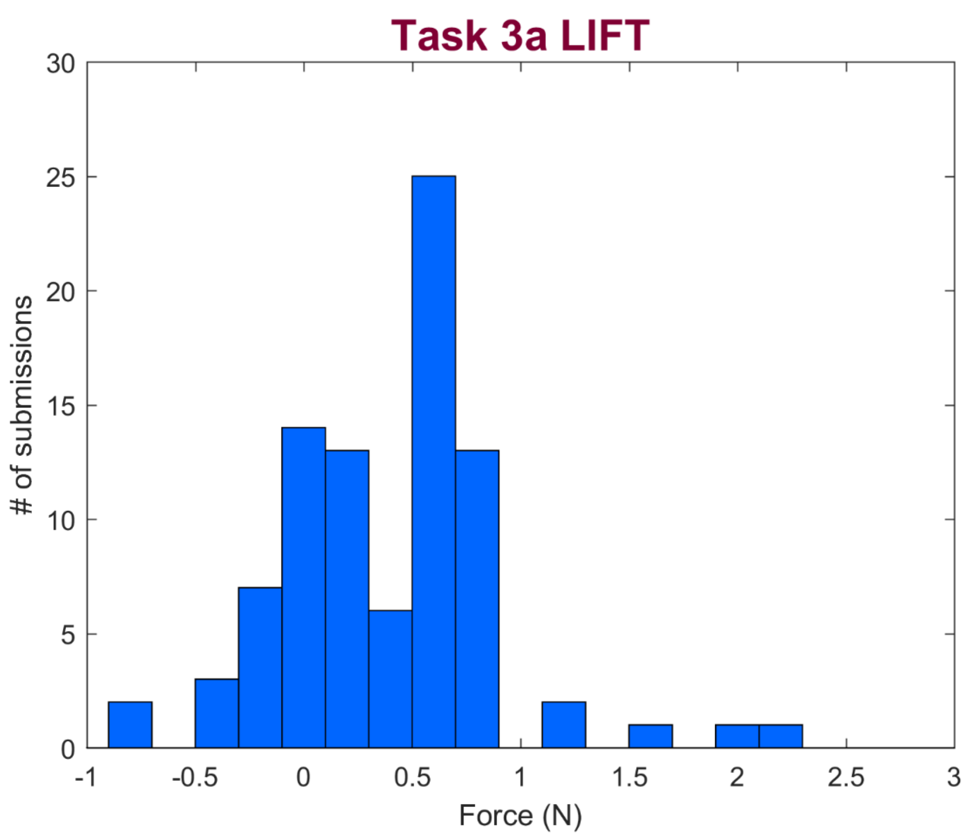
0
-1
-0.5
0
0.5
1
1.5
2
2.5
3



Task 3a LIFT
# of submissions
Force (N)
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25
20
15
10
5
0
-1
-0.5
0
0.5
1
1.5
2
2.5
3