Experimental Lab 1

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I. Introduction

This experimental lab was conducted to study the shape of the wake behind aerodynamic bodies in a qualitative and quantitative form. In addition, this lab included an analysis of using the wake characteristics to find the sectional coefficient of drag on an aerodynamic body. In order to study these concepts multiple experiments using a wind tunnel were performed with changes in velocity shape. These results were then taken into MATLAB and used to perform analysis. The analysis included finding the velocity deficit at a given horizontal and vertical position and analysing the variations due to horizontal position, velocity, and shape. Finally using the velocity deficit the sectional coefficient of drag can be found.

II. Methodology

A. Experimental Setup

The experiments were conducted using four configurations: a Clark Y-14 airfoil at a velocity of 25m/s and 15 m/s, and a Cylinder at a velocity of 25 m/s and 15 m/s. These four configurations were tested at differing locations behind the aerodynamic body, 13-43mm for the airfoil and 60-240mm for the cylinder. The results of each experiment were then used in the following analysis.

B. Analysis

Analyzing the data required some cleaning and removing of bad data sets, which produces less accurate results. In order to calculate the velocity deficit the data was separated into up and down stream data. The velocity was calculated using the dynamic pressure and the air density for both up and down stream data. Then the velocity deficit can be found using the following equation: $\triangle u(x,y) = u_\infty - u(x,y)$, where the upstream velocity is u_∞ and the downstream velocity is $u(x,y)$. The velocity deficit is then used to find the wake half width using the equations: $\triangle u(x, y^{+-}_{1/2}(x)) = \frac{1}{2} \triangle u_{max}(x)$ and $\delta_{1/2} = \frac{1}{2}(y^{+}_{1/2} - y^{-}_{1/2})$ where $\delta_{1/2}$ is the wake half width and $y^{+-}_{1/2}(x)$ is the vertical positions where the velocity deficit is halved. Then the non-dimensional velocity deficit versus the non-dimensional vertical position can be found by dividing a given velocity deficit by the maximum velocity deficit, and dividing the vertical position by the wake half width. Finally, the sectional coefficient of drag is found using equation 2.83 from Anderson's textbook, $D' = \int_h^b \rho_2 u_2(u_2 - u_1)dy$, and the definition of sectional coefficient of drag, $c_D = \frac{D'}{q_\infty c}$.

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III. Results

A. Velocity Deficit

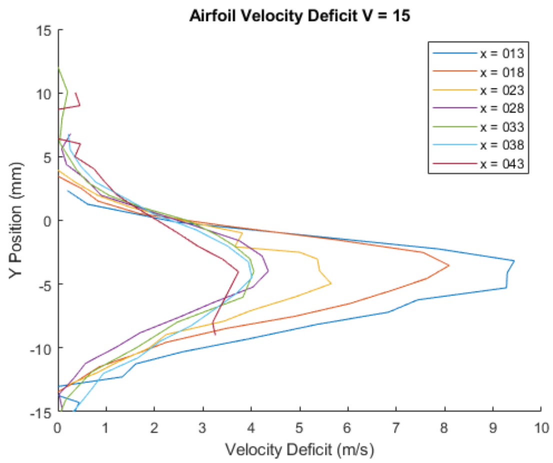

Figure 1: Airfoil V=15m/s

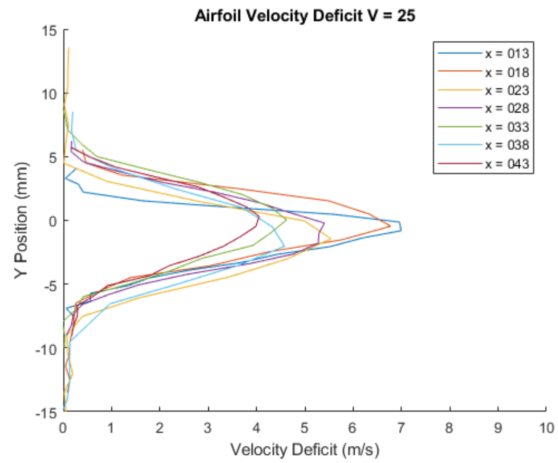

Figure 2: Airfoil V=25m/s

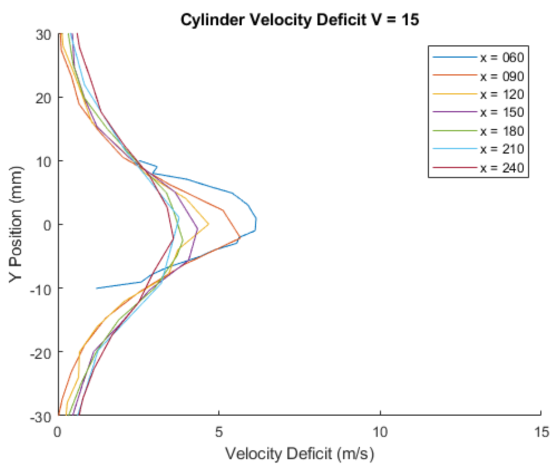

Figure 3: Cylinder V=15m/s

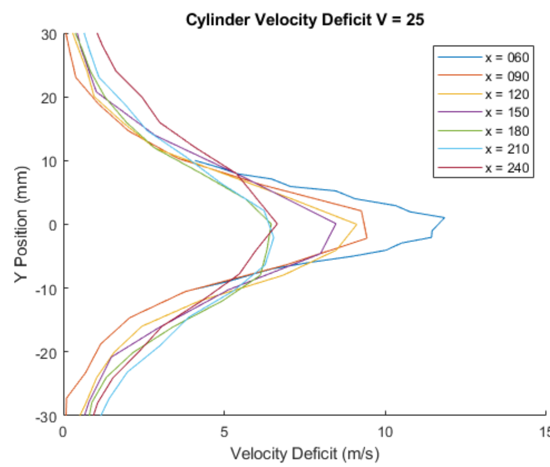

Figure 4: Cylinder V=25m/s

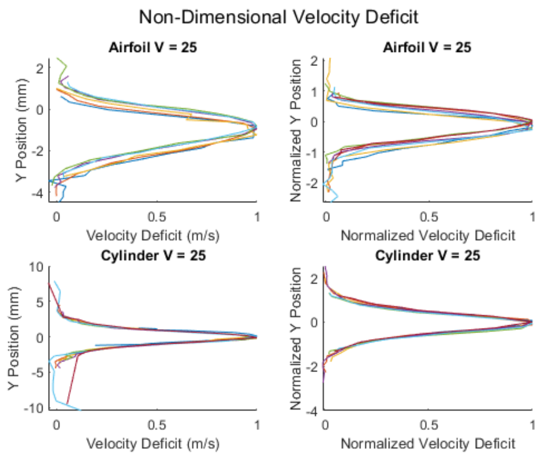

Figure 5: Non-dimensional Velocity Deficit

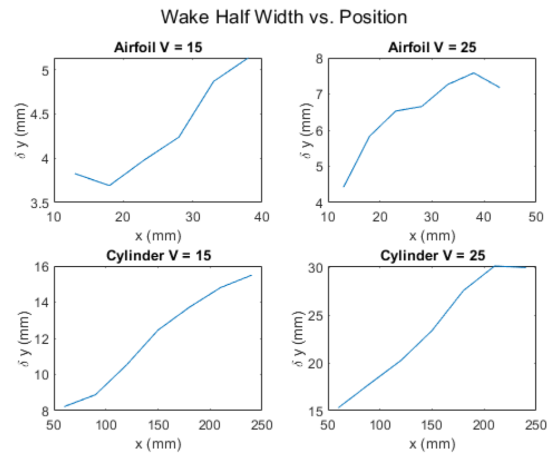

Figure 6: Wake Half Width

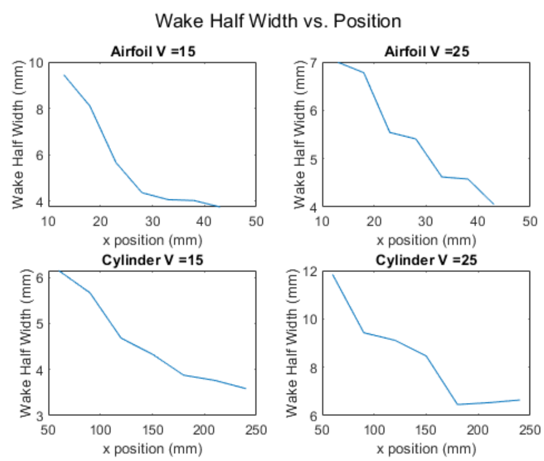

Figure 7: Wake Half Width Vs. Position

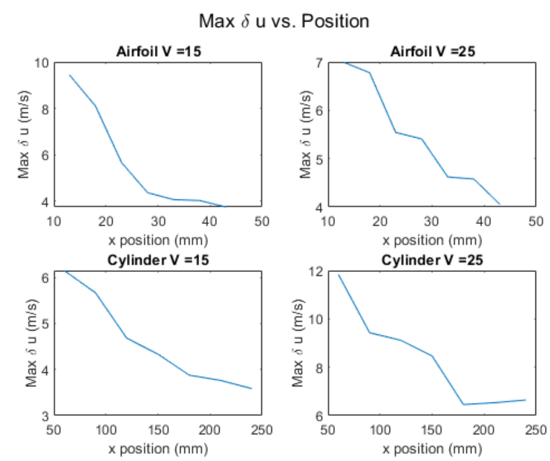

Figure 8: Max δu Vs. Position

Freestream	13 mm	18 mm	23 mm	28 mm	33 mm	38 mm	48 mm	Average
V=15m/s	0.0611	0.0574	0.0529	0.0467	0.0503	0.0536	0.0416	0.052
V=25m/s	0.0232	0.0295	0.0286	0.0280	0.0262	0.0294	0.0232	0.027

Table 1: Airfoil Sectional Coefficients of Drag

Freestream	60 mm	90 mm	120 mm	150 mm	180 mm	210 mm	240 mm	Average
V=15m/s	0.6411	0.9427	0.9556	1.1045	1.0640	1.0987	1.4603	1.038
V=25m/s	0.6736	0.9205	1.0391	1.0925	1.0383	1.1402	1.1791	1.012

Table 2: Cylinder Sectional Coefficients of Drag

IV. Conclusion

It can be seen from the velocity deficit plots that as the position moves further from the body the velocity deficit decreases. This would be due to the mixing of air behind the airfoil with the freestream air. The velocity deficit for the airfoil at V=15m/s seems to have an incorrect trend, since the air behind the airfoil should mix with the freestream air quicker therefore having a smaller deficit. But this seems to not be the case in our experiment.

The downward trending for the velocity deficit and wake half width as x increases is as expected. Since the mixing of the air increases as the distance from the body increases the velocity deficit would be expected to decrease.

The non-dimensional velocity deficit is not self-similar for the airfoil and is self-similar for the cylinder as can be seen in Figure 5. The reason for this is that the airfoil is not symmetrical and causes a shift in the profile downward as the distance increases.

The sectional coefficients of drag seem a little off for the airfoil at 15m/s. The reason is that looking at other airfoil plots for c_d the values at these Reynolds's numbers come out to be a bit lower. But the increase in c_D for the lower velocities was expected. The accuracy of the coefficient of drag for the airfoil seems to match closely to analytical results from airfoiltools.com for the Clark Y-15 airfoil since there was no Clark Y-14. But the results are relative and they were only used to see the trend in the coefficient of drag. The cylinder however has the same coefficient of drag for both the 15 and 25 m/s cases. This also follows what Weisstein found for the coefficients of drag of a cylinder which was approximately 1.

References

[1] Farnsworth ASEN 3111 Exp Lab University of Colorado Boulder, 2019. Web.

[2] John D. Anderson, Jr. Fundamentals of Aerodynamics, 6th Edition, McGraw-Hill Aerospace Engineering Series 2011.

[3] CLARK YM-15 AIRFOIL (clarym15-il). (2019). [image] Available at: http://airfoiltools.com/airfoil/details?airfoil=clarym15-il [Accessed 25 Oct. 2019].

[4] Weisstein, E. (2019). Cylinder Drag. [image] Available at: http://scienceworld.wolfram.com/physics/CylinderDrag.html [Accessed 25 Oct. 2019].