University of New Hampshire

Magnus Effect on Cylindrical Airfoils

Zhangxi Feng, Simon Popecki, James Skinner

ME 646

Professor Todd Gross

5/9/2017

# Table of Contents

Abstract………………………………………………………………………………………… 2

Introduction………………………………………………………………………………………. 3

Methods……………………………………………………………………………………...…… 4

Results and Discussion……………………………………………………...……………….…... 5

Summary and Conclusion……………………………………….……………………………… 6

List of References……………………………………………………………….…….…………7

Appendix…………………………………………………………………………………………..8

# Table of Figures

Figure 1……………………………………………………………………………………………2

Figure 2…………………………………………………………………………………………....3

Figure 3……………………………………………………………………………………...…….4

Figure 4…………………………………………………………………………………………....3

Figure 5…………………………………………………………………………………………....3

Figure 6…………………………………………………………………………………………....3

Figure 7…………………………………………………………………………………………....3

# Table of Equations

Equation 1…………………………………………………………………………………………2

Equation 2…………………………………………………………………………………………3

Equation 3…………………………………………………………………………………………4

Equation 4…………………………………………………………………………………………5

Equation 5…………………………………………………………………………………………6

Equation 6…………………………………………………………………………………………7

Equation 7…………………………………………………………………………………………8

# Abstract

Our goal was to evaluate the Magnus Effect around cylindrical airfoils at high rates of rotation (RPM). Using the University of New Hampshire wind tunnel we tested rotating cylinders at different mean wind velocity and RPM. By keeping the velocity in the wind tunnel constant and changing the RPM of the cylinder we were able to track the trend of the lift force. This test was completed for four different wind speeds at approximately: 12 m/s, 16 m/s, 20 m/s, 24 m/s; and three different cylinder radiuses at: 0.0290 m, 0.0419 m, and 0.0641 m. We ran an additional test on the smallest cylinder radius at constant RPM and for a range of wind speeds from approximately 11 m/s to 30 m/s to more closely see the effect of just the wind speed on lift. Theoretically, we expected to see a linear increase in lift as we increased wind speed or RPM, and quadratic growth when increasing the cylinder radius. What actually occurred was an apparent plateau at our range of tested RPM and wind speeds with our size of cylinders. Despite seeing the expected increase in lift with radius, the total magnitude of lift was not nearly as close to our theoretical values. For our smallest cylinder we reach a Reynolds number as high as 1.128x105, which is well above an appropriate Reynolds number and are now creating vortex shedding behind our cylinder which reduced the experimental lift force.

# Introduction

A spinning ball will drag more air to one side and create a force from the resulting pressure difference. For example, top spin drags more air to flow below the ball. According to Bernoulli’s principle, faster air flow results in lower pressure, which causes the ball to curve downwards [1]. This is known as the Magnus effect. For cylinders, the Magnus lift force is found using the Kutta-Joukowski equation:

(1)

Where is the Magnus lift force for a cylinder of length in a fluid of density flowing at a velocity . The spin of the cylinder will create the vortex strength found using the radius of the cylinder and angular velocity in rad/s [2]:

(2)

Combining equations 1 and 2 gives equation 3:

(3)

Equation 3 predicts a linear relationship between the angular velocity and the force, a linear relationship between the freestream velocity and the force, and a quadratic relationship between the cylinder radius and the force. This experiment aims to verify the accuracy of the Kutta-Joukouski equation at high rotational speeds by measuring the resulting lift forces on cylindrical airfoils at various radii and wind speeds.

<http://students.iitk.ac.in/projects/wiki/lib/exe/fetch.php?media=2014:seifert_flettner_apps.pdf>

# Methods

# Results and Discussion

# Summary and Conclusion

To test the validity Kutta-Joukouski lift equation (equation 1) at high rotational speeds we tested three different sized cylinders at different wind speeds and high rotational speeds. Based on this equation, you could theoretically produce an enormous amount of lift if you kept increasing any one of the factors from equation 1. Theoretically, we expected to see a linear increase in lift as we increased wind speed or RPM, and quadratic growth when increasing the cylinder radius.

Our experiment shows that at high rates of RPM and wind speed the difference between the theoretical and the obtained values are significant. After research we found that the wind speeds we were placing our model cylinders in was producing large Reynolds numbers that was producing a turbulence vortex behind the cylinder which disrupted the flow behind the cylinder. This disrupts the low pressure region above the cylinder and the high pressure region below the cylinder, because of this we assume the magnitude of pressure on the top and bottom are both increasing due to the alternating flow path beyond the cylinder as a result of the vortex.

# References

|  |  |
| --- | --- |
| [1] | R. K. G. Kobes, "Bernoulli's Principle," 29 September 1999. [Online]. Available: http://theory.uwinnipeg.ca/mod\_tech/node68.html. [Accessed 6 May 2017]. |
| [2] | N. Hall, "Lift of Rotating Cylinder," NASA, 5 May 2015. [Online]. Available: https://www.grc.nasa.gov/www/k-12/airplane/cyl.html. [Accessed 30 4 2017]. |

# Appendix

Table A

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Stella |  |  |  |  |  |  |
| P1 (inH2O) | P2 (inH2O) | Delta h (m) | Wind Speed (m/s) | RPM | Lift (N) | Test |
| 1.65 | 1.3 | 0.00889 | 12.00973309 | 3100 | 0.5 | **TRIAL 1** |
|  |  |  |  | 4060 | 1.45 |  |
|  |  |  |  | 6000 | 1.96 |  |
| 2 | 1.35 | 0.01651 | 16.36650742 | 3024 | 1.25 | **TRIAL 2** |
|  |  |  |  | 4130 | 1.48 |  |
|  |  |  |  | 5960 | 2.28 |  |
| 2.45 | 1.5 | 0.02413 | 19.78614266 | 2950 | 1.35 | **TRIAL 3** |
|  |  |  |  | 3930 | 1.27 |  |
|  |  |  |  | 5950 | 2.31 |  |
| 3 | 1.6 | 0.03556 | 24.01946618 | 2800 | 1.43 | **TRIAL 4** |
|  |  |  |  | 4000 | 1.17 |  |
|  |  |  |  | 5870 | 2.11 |  |

Table B

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Budweiser |  |  |  |  |  |  |
| P1 (inH2O) | P2 (inH2O) | Delta h (m) | Wind Speed (m/s) | RPM | Lift (N) |  |
| 1.65 | 1.3 | 0.00889 | 12.00973309 | 3200 | 2.3 | **TRIAL 1** |
|  |  |  |  | 4940 | 3.17 |  |
|  |  |  |  | 5800 | 1.65 |  |
| 2 | 1.35 | 0.01651 | 16.36650742 | \* | \* | **TRIAL 2\*** |
|  |  |  |  | \* | \* |  |
|  |  |  |  | \* | \* |  |
| 2.45 | 1.5 | 0.02413 | 19.78614266 | 3291 | 10.13 | **TRIAL 3** |
|  |  |  |  | 4700 | 21.92 |  |
|  |  |  |  | 5844 | 13.91 |  |
| 3 | 1.6 | 0.03556 | 24.01946618 | 3100 | 10.25 | **TRIAL 4** |
|  |  |  |  | 4860 | 13.11 |  |
|  |  |  |  | 5916 | 8.97 |  |

Table C

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Oats |  |  |  |  |  |  |
| P1 (inH2O) | P2 (inH2O) | Delta h (m) | Wind Speed (m/s) | RPM | Lift (N) |  |
| 1.65 | 1.3 | 0.00889 | 12.00973309 | 3720 | 3.72 | **TRIAL 1** |
|  |  |  |  | 4560 | 3.14 |  |
|  |  |  |  | 5560 | 4.35 |  |
| 2 | 1.35 | 0.01651 | 16.36650742 | 3660 | 6 | **TRIAL 2** |
|  |  |  |  | 4470 | 4.97 |  |
|  |  |  |  | 5630 | 5.26 |  |
| 2.45 | 1.5 | 0.02413 | 19.78614266 | 3675 | 8.42 | **TRIAL 3** |
|  |  |  |  | 4050 | 7.25 |  |
|  |  |  |  | 5500 | 7.67 |  |
| 3 | 1.6 | 0.03556 | 24.01946618 | 3000 | 10.6 | **TRIAL 4** |
|  |  |  |  | 3160 | 15.5 |  |
|  |  |  |  | 5200 | 10.43 |  |

Table D

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| P1 (inH2O) | P2 (inH2O) | Delta h (m) | Wind Speed (m/s) | Lift (N) | RPM |
| 1.5 | 1.2 | 0.00762 | 11.11885229 | 0.67 | 3760 |
| 2 | 1.35 | 0.01651 | 16.36650742 | 0.61 | - |
| 2.5 | 1.5 | 0.0254 | 20.30015404 | 0.5 | - |
| 3 | 1.65 | 0.03429 | 23.58664756 | 0.4 | - |
| 3.5 | 1.8 | 0.04318 | 26.46816261 | 0.36 | - |
| 4 | 1.9 | 0.05334 | 29.41771802 | 0.47 | 3760 |