NACA 0012 Airfoil Testing at Low Reynolds Numbers

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Introduction

Research in aerospace engineering has been primarily focused on developing more fuel efficient fighter jets and commercial airplanes that yield better performances. In recent years, more interest has been placed in the development of Unmanned-Aerial-Vehicles (UAVs) with low Reynolds numbers. These UAVs have significantly different flight mechanics than large scale planes. In order to gather more information on UAV flight mechanics, Professor Geoffrey Spedding at the University of Southern California has been conducting research in the Dryden Wind Tunnel to find out more about the behaviors of airfoils at low Reynolds numbers.

Objectives and Future Impact

Dr. Spedding's research targets the question "how do airfoils behave at low Reynolds numbers?" Since there is a lack of information on flight mechanics at low Reynolds numbers, the objectives are as follows:

1. Gather Data
   The main objective is to gather results through repeatable experiments. Experiments are done on a 3D printed NACA 0012 airfoil at Reynolds numbers of 50k and 100k in the Dryden Wind Tunnel. The force balance, an instrument for testing that converts applied forces to volts, is calibrated each day by applying forces to each component. Since there are only two pulleys on the current system, the base must be calibrated by applying known forces to each component. This rotation is a possible source of error that could be validated through comparisons with existing data. The data will also be compared with existing computational results and experimental results from other research groups. Particle Image Velocimetry tests may be done in the future to validate the results of our experiments.

2. Compare Results
   By creating graphical representations of airfoil behavior, the results can be validated through comparisons with existing data. The data gathered are presented in three graphs (lift vs AOA, drag vs AOA, lift vs drag).

Reynolds Numbers

Reynolds number is the ratio of inertial forces to viscous forces. Due to the way Reynolds Numbers are calculated, this dimensionless number greatly reduces the number of variables in testing. As long as the Reynolds numbers for two airfoils of the same model number are identical, the results will be identical. As a result, it is possible to compare data without concern of multiple aspects about the testing conditions.

\[ Re = \frac{\rho \times V \times L}{\mu} \]

Re = Reynolds Number
V = velocity of fluid
P = density of fluid
\( \mu \) = viscosity of fluid
L = length of contact surface

Matlab

Learning the basics of this coding language is fairly simple once the right tools are found. Since detailed explanations of every Matlab command could be found online, it is possible to write complex programs without prior experience. Using this programming language, I created a virtual instrument that output the exact coordinates of any point on a graph, which facilitated data comparisons.

Skills Learned

- Programming in Matlab
- Coding basic programs
- Learning the basics of this software and help with research
- Creating a virtual instrument
- Using this software

How This Relates to My STEM Coursework

The skills that I learned in this program allowed me to gain a better understanding in the field of Aerospace Engineering. This program gave me the formal lab experience that was not available in high school. Furthermore, this experience revealed to me how different STEM subjects are integrated into engineering. For example, when I signed up for aerospace engineering, I was not expecting to be working with new programming languages or learning how to correctly interpret statistics. By participating in this program, I now know what to expect when studying engineering in the future.

Next Steps in Research

After conducting tests for both rough and smooth airfoils, the results will be compared to see the effect of surface texture on lift and drag coefficients. The data will also be compared with existing computational results and experimental results from other research groups. Particle Image Velocimetry tests may be done in the future to validate the results of our experiments.

Acknowledgements

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(1) Turbulent flows past airfoils,
   http://home.illinois.edu/~smittal/res_act/turbu_flo_pas_airfo.html

(2) Separation Control by Acoustic Excitation at Low Reynolds Numbers
   (poster source), By: Shanling Yang, Dr. Geoff Spedding

Graphs are a courtesy of Joe Tank, who is a PhD student conducting research in the Dryden Wind Tunnel.