Uncertainty Quantification for a Seven Hole Pressure Probe

Leigh Honzatko | Graduate Mentor: Brent Pomeroy | Advisor: Michael S. Selig

Department of Aerospace Engineering, College of Engineering, University of Illinois at Urbana-Champaign

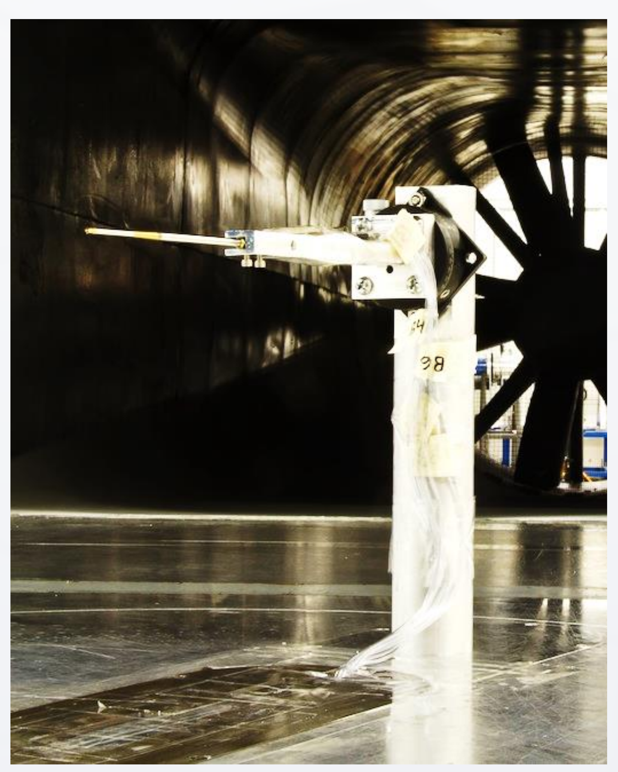
Introduction

Motivation

Flaps are one of the heaviest portions of an aircraft wing. It is necessary to generate as much lift as possible with as small and light of flap as possible. A flow field phenomena called wake-bursting decrease lift. This research focuses on gaining an understanding of burst-wakes by conducting experiments in the University of Illinois low-speed subsonic wind tunnel.

Project Goals

A device called a seven-hole pressure probe collects pressure readings from the wind tunnel. This project focuses on formulating uncertainty quantifications for a seven-hole pressure probe.



Seven–hole pressure probe mounted in the UIUC wind tunnel

There are three sources of uncertainty for a seven-hole pressure probe:

- uncertainty in the measurements
- uncertainty in the calibration plots
- uncertainty in the interpolations

Focus on quantifying uncertainty in the measurements from the seven-hole pressure probe.

These uncertainty quantifications will be added to an already existing MATLAB code that was written by Brent Pomeroy.

Why is Uncertainty Analysis Important?

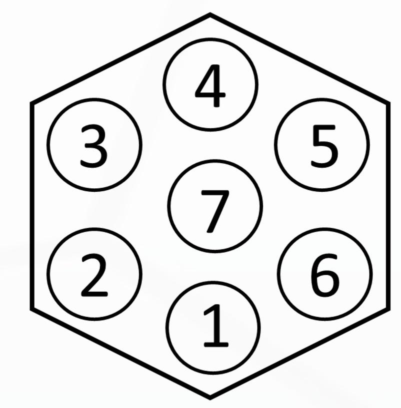
It is important to know how accurate the results are. Uncertainty analysis provides a means for quantifying the accuracy of the measured data.

Method

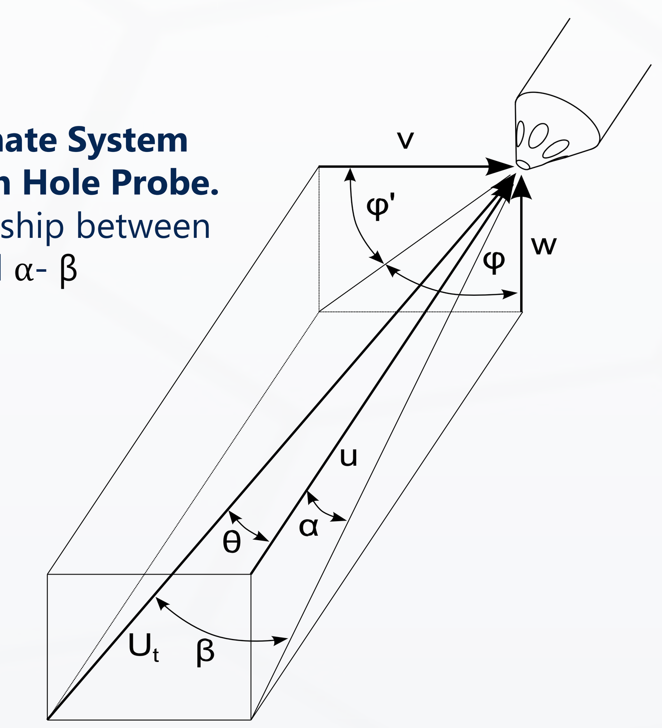
Understanding Calibration Techniques

Sectoring

1. Measure pressure from each hole of the probe and determine which hole has the highest pressure.
2. Calculate roll angle (φ) and cone angle (θ) from measured pressures
3. Determine calibration coefficients from roll angle and cone angle
4. Generate contour plots from calibration coefficients
5. Interpolate the angle of attack (α), sideslip angle (β) and total pressure and static pressure from plots.
6. Use Bernoulli's Equation to find velocity ($\vec{v}$) from the total and static pressure



Pressure Probe Tip. Numbering for each of the holes at the tip of the seven-hole pressure probe.



Coordinate System of seven Hole Probe. Relationship between φ- θ and α- β

Implementing Uncertainty Analysis

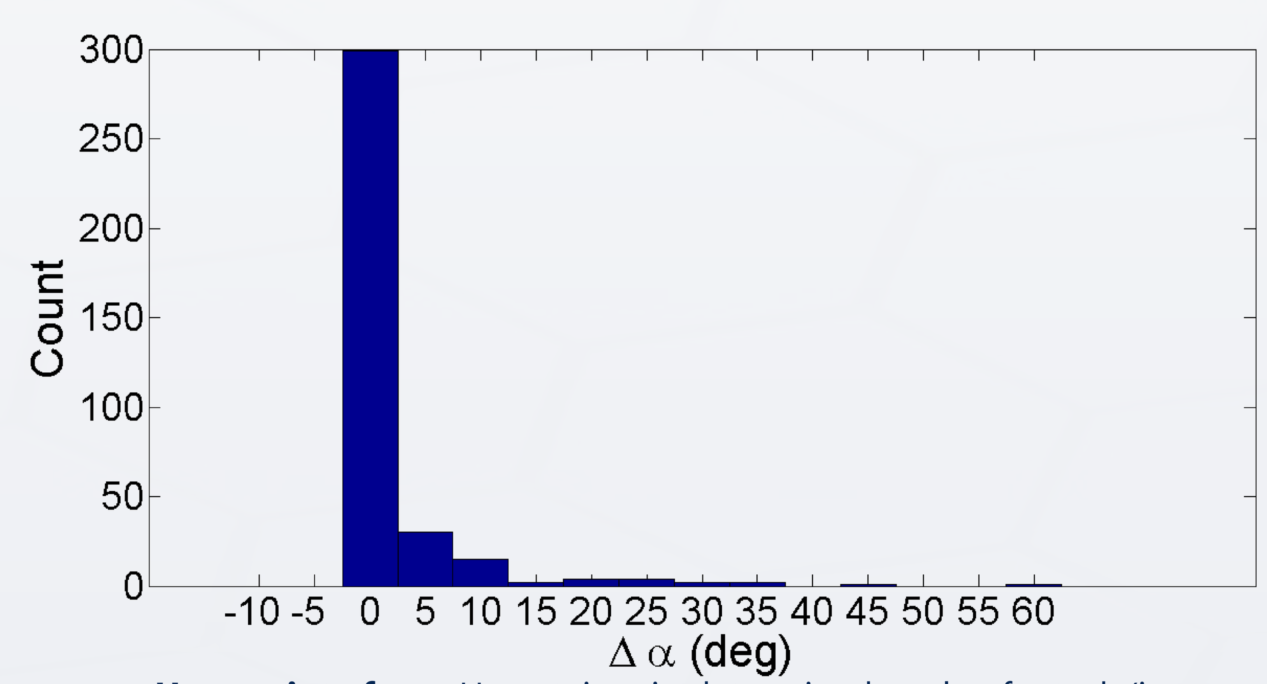
- The probe used in lab has an uncertainty of ± 0.00036 psi
- Uncertainty of α, β, and $\vec{v}$ need to be accounted for

Jitter Method

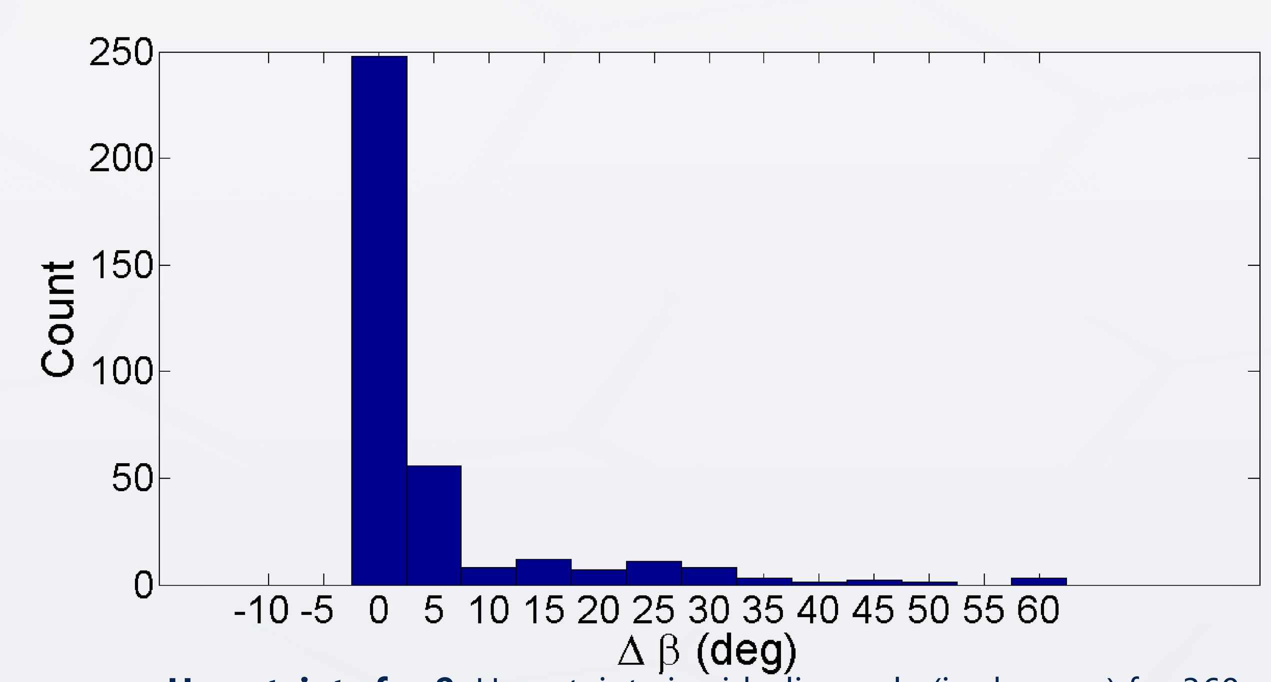
1. Overall uncertainty of the measurement from the hole (0.00036 Psi) → δP_n
2. $\frac{\partial R}{\partial P_1}$ is the sensitivity in R due to the perturbed pressure differences found from the central difference formula:
$$\frac{\partial R}{\partial x_i} = \frac{R_{x_i+\Delta x_i} - R_{x_i-\Delta x_i}}{2\Delta x_i}$$
3. Calculate uncertainty for R using the general formula of uncertainty:
$$\delta R = \sqrt{\sum_{n=1}^{n=7}\left(\frac{\partial R}{\partial U_n}\delta U_n\right)^2}$$

Uncertainty quantification was implemented into MATLAB by imbedding the method into a data reduction code that looped through each of the selected independent variables and estimated the partial derivatives.

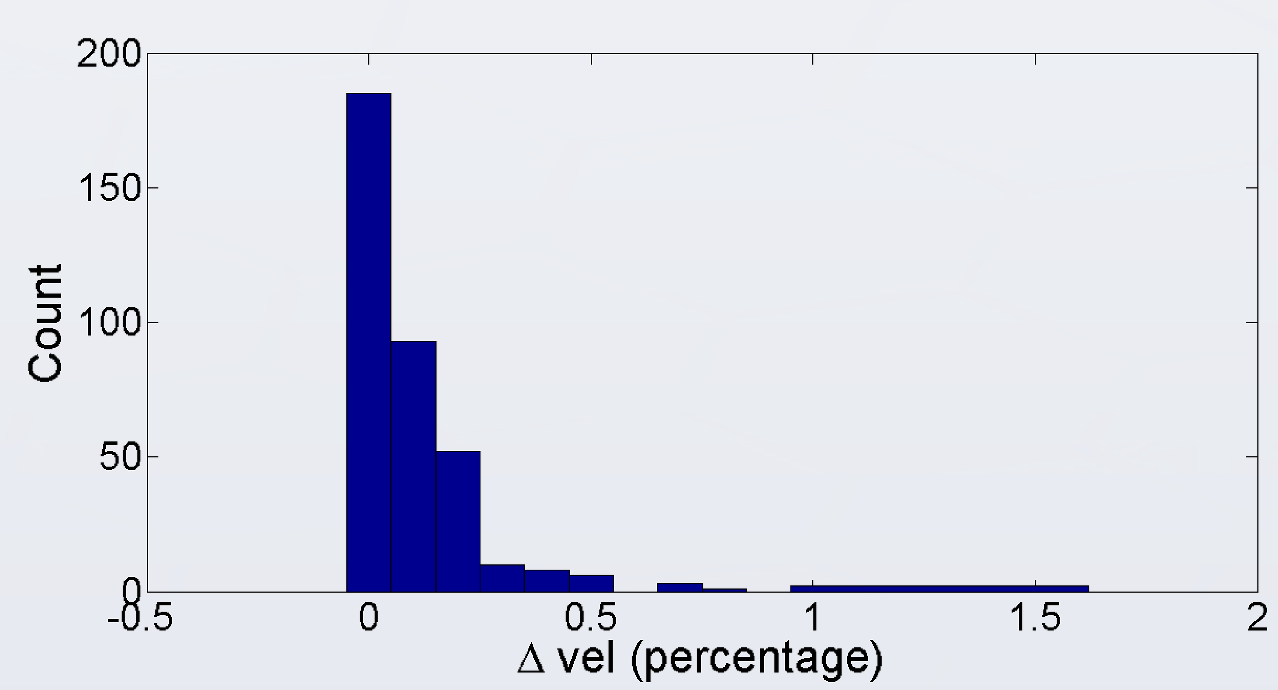
Results



Uncertainty for α. Uncertainty in determined angle of attack (in degrees) for 360-point data set



Uncertainty for β. Uncertainty in sideslip angle (in degrees) for 360-point data set



Uncertainty in $\vec{v}$. Uncertainty in determined velocity (as a percentage) for 360-point data set

The MATLAB code produces three histograms displaying the occurrences of uncertainties and calculates the median uncertainty values for α, β, and $\vec{v}$.

Median Uncertainty Values	
α	0.2857
β	1.2032
$\vec{v}$	0.0481

Conclusions

From the histogram plots, β has a larger uncertainty than α. This is Potentially due to how pressure probe is calibrated.

- α has less variation because it is less sensitive to calibrations and interpolations. (Only affected by hole 1 and 4)
- β has more variation because it's more sensitive to calibrations and interpolations. (Affected by holes 2, 3, 5 and 6)

Acknowledgments

Special thanks to Brent Pomeroy, Jeff Diebold and the Department of Aerospace Engineering

ILLINOIS
UNIVERSITY OF ILLINOIS AT URBANA-CHAMPAIGN

Leigh Honzatko | Aerospace Engineering | Class of 2017
honzatk2@Illinois.edu