Seven-Hole Probe Calibration in a Low-Speed Wind Tunnel

En Yen Justin Chu | Dr. Zheng Zhang | Dr. J. Gordon Leishman
Department of Aerospace Engineering, Embry-Riddle Aeronautical University, Daytona Beach, FL

Introduction

The project is to calibrate a miniature seven-hole pressure probe designed to be utilized in the new wind tunnel of the Embry-Riddle Research Park.

The seven-hole pressure probe is designed to measure flow angularity, which has better senility than five-hole pressure probe. However, the seven-hole probe requires finer calibration due to manufacturing tolerance and its small dimensions.

Experimental Setup

Subsonic Boundary Layer Wind Tunnel

- A new facility built in 2017
- 22 inches by 22 inches cross section
- Test location: 4 feet from inlet

Figure 1: ERAU Boundary Layer Wind Tunnel

64-Channel Miniature Pressure Transducer

- Accuracy: ±0.0003 psi
- Maximum measurement range: 1 psi

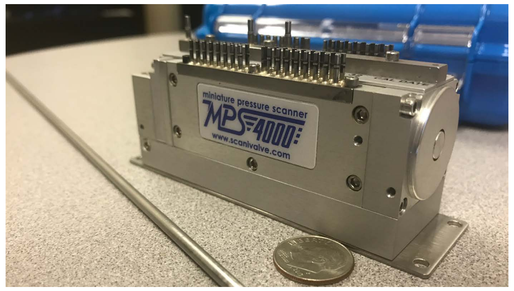

Figure 2: Scanivalve MPS 4000 Pressure Transducer

Motorized Rotary Tables (Fig. 4)

- 2-degree of freedom: pitching and yaw
- Accuracy: 100 acr-second (0.0278 deg)
- Automated for multiple pressure reading

Seven-Hole Pressure Probe

- Consists of seven small diameter holes (Fig. 3)
- OD of probe: 1/8 in; ID of hole: 0.012 in
- 64-Channel pressure transducer for measuring seven pressure taps simultaneously
- Calibrated from -10 to 10° at an interval of 0.5°, resulting in a test matrix of 41-by-41 measurement points

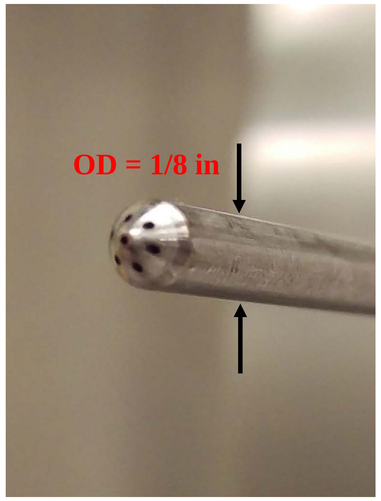

Figure 3: Seven-hole pressure probe

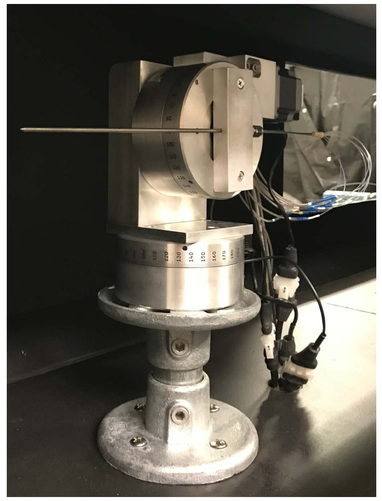

Figure 4: Probe mounted on a motorized rotary tables

Theory

- Pressure Coefficient: Based on Differences of Opposite Ports

$$C_{\alpha 1} = \frac{P_4 - P_1}{P_7 - \bar{P}_{1-6}} \qquad C_{\alpha 2} = \frac{P_3 - P_6}{P_7 - \bar{P}_{1-6}} \qquad C_{\alpha 3} = \frac{P_2 - P_5}{P_7 - \bar{P}_{1-6}}$$

- Angular Pressure Coefficients

$$C_\alpha = \frac{1}{3}(2C_{\alpha 1} + C_{\alpha 2} - C_{\alpha 3}) \qquad C_\beta = \frac{1}{\sqrt{3}}(C_{\alpha 2} + C_{\alpha 3})$$

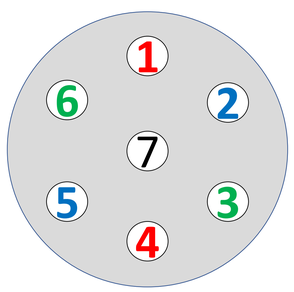

Figure 5: Front view of Seven-hole pressure probe

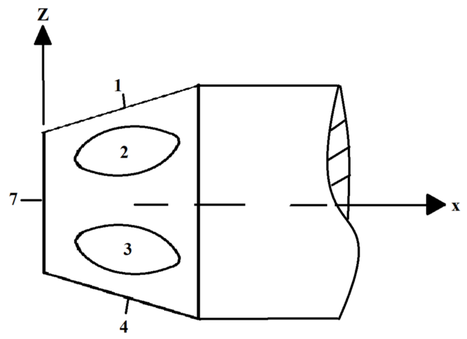

Figure 6: Side view of Seven-hole pressure probe

Calibration Results

- Converging Test to optimize testing time for 21-by-21 Test Matrix

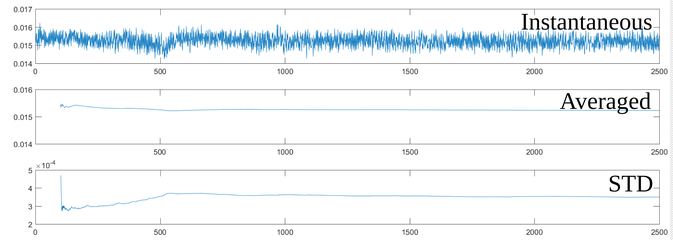

Figure 7: Converging test results

- Calibration coefficients varying with pitching and yaw

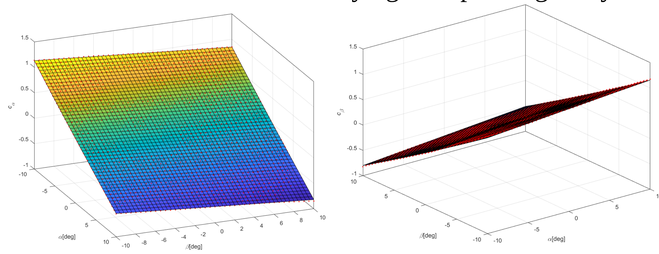

Figure 8: Calibration coefficients

- Isoline plot

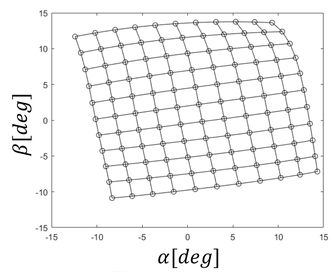

Figure 9: Isoline

Conclusion & Future Plan

- A high-precision calibration stand was designed and built
- A calibration was performed in BL wind tunnel
- Advance to multiple seven-hole probe rake for new subsonic wind tunnel flow qualification

References

Gerner, A., and C. Maurer. "Calibration of Seven-Hole Probes Suitable for High Angles in Subsonic Compressible Flows." *20th Aerospace Sciences Meeting*, Nov. 1982.

Acknowledgements

The seven-hole probe was manufactured by William Russo at College of Engineering machine shop