A COMPARISON OF NEURAL NETWORK AND CONVENTIONAL CALIBRATION MAPS FOR PNEUMATIC PROBE MEASUREMENTS

Dr Chris Clark
Whittle Laboratory
University of Cambridge

Dr Sam Grimshaw
Whittle Laboratory
University of Cambridge

ABSTRACT

Neural networks are used to map the time-averaged pressures measured with a pneumatic multi-hole probe to flow angle, stagnation pressure and static pressure. When compared with conventional interpolated calibration maps, neural network calibrations are found to have several advantages. The individual non-dimensionalised hole pressures are used as inputs so that the neural network can use combinations that provide the best indicator at different flow conditions, rather than using pre-defined coefficients which may be unsuitable over regions of the map. This avoids an issue encountered with conventional calibration maps where at high angles the map "folds" and produces a one-to-two mapping; this folding limits the useable range of conventional probe coefficients. By using the best local indicators, regions where coefficients are ill-conditioned are avoided and errors are reduced.

Previous solutions to these problems involve complicated and slow heuristics that govern the use of sectored maps. The new method using neural networks is simpler to implement, faster and relies on a single, multi-dimensional, continuous map. This type of mapping means that iteration across maps for Mach Number and Reynolds Numbers sensitivity, used with conventional calibration coefficients, is no longer necessary, speeding the analysis and reducing cumulative errors from interpolation. Generating an independent mapping for each flow property based on the non-dimensional hole pressures reduces cumulative errors due to repeated interpolation from one flow property to another. Error analyses of sectored and non-sectored calibration methods, and the neural network calibration, show that the new method is more accurate over a wider range of flow angles.

INTRODUCTION

The use of pneumatic multi-hole probes for time-averaged aerodynamic measurements remains commonplace due to their low cost and robust measurements. The method of their use has not changed significantly in the last few decades. Measurement accuracy is improved through the use of higher fidelity calibrations which incorporate an increased number of flow quantities, such as Mach and Reynolds Numbers. As the number of calibration dimensions rise new mapping methods become of increased interest.

RESULTS AND DISCUSSION

Calibrations were performed at five Reynolds Numbers for yaw angle of +/- 60º and pitch angle of +/- 25º. A conventional calibration coefficient maps is shown to fold at yaw angles of between 35º and 40º, depending on the pitch. The useable range of the map can be extended to 60º in yaw using sectoring. The new method, which uses a trained neural network, is also shown to produce a useable calibration map which extends to +/-60 to 60º in yaw. An error analysis using a Monte-Carlo method shows that the new approach is as accurate as existing methods close to the center of the map (+/-20º in yaw and pitch), but reduces error at the edges of the conventional coefficient map and at the edges of the sectors used in the sectoring. This results in a more robust measurement technique. The probe is used to traverse an IGV in an experimental compressor facility, with errors again compared between existing techniques and the new neural network-based method.

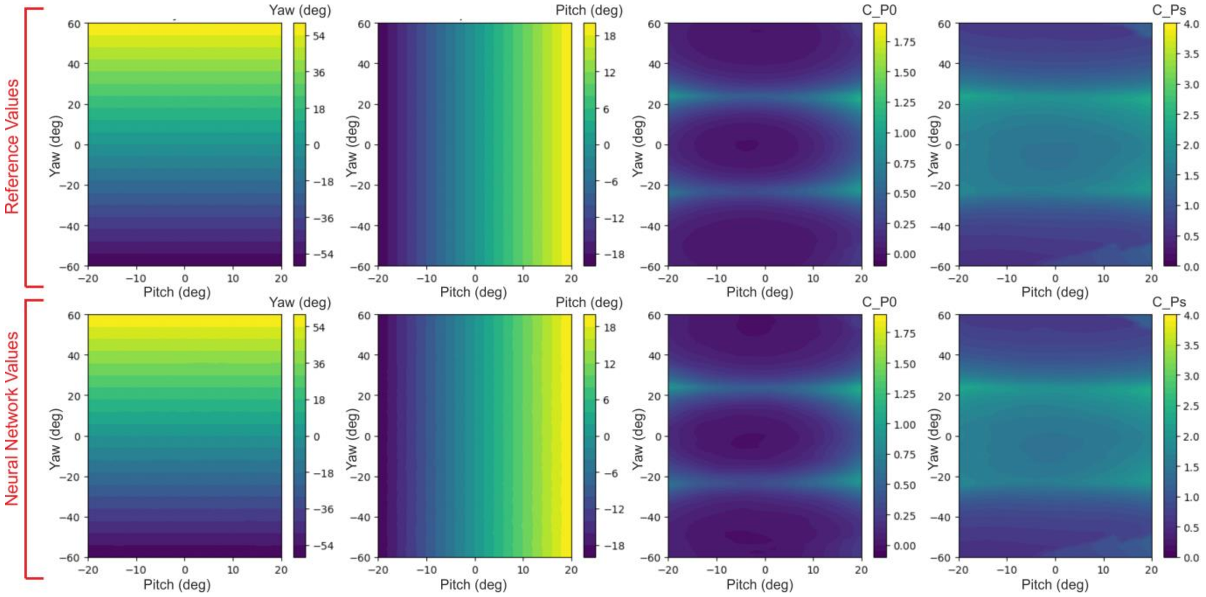

Figure 1: Yaw, Pitch, Stagnation Pressure Coefficient and Static Pressure Coefficient against Yaw and Pitch for reference measurement values and Neural Network calculated values.

REFERENCES

Put references here should it be required.