

New Methodology for Wind Tunnel Calibration Using Neural Networks - EGD Approach

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ABSTRACT

One of the hardest tasks involving wind tunnel characterization is to determine the air-flow condition inside the test section. The Log-Tchebycheff method and the Equal Area method allow calculation of local velocities from measured differential pressures on rectangular and circular ducts. However, these two standard methods for air flow measurement are limited by the number of accurate pressure readings by the Pitot tube. In this paper, a new approach is presented for wind tunnel calibrations. This approach is based on a limited number of dynamic pressure measurements and a predictive technique using Neural Network (NN). To optimize the NN, the extended great deluge (EGD) algorithm is used. Wind tunnel testing involves a large number of variables such as wind direction, velocity, rate flow, turbulence characteristics, temperature variation and pressure distribution on airfoils. NN has the advantage that multilayer perceptron neural networks can describe a 3D flow area with a small amount of experimental data, fewer numbers of iterations and less computation time per iteration. The Fluent results are used to train and optimize the proposed NN approach. The validation of this new approach is achieved by experimental tests using the wind tunnel Price-Paidoussis of LARCASE laboratory. This wind tunnel has two test chambers; a first chamber with a section equal to 0.3×0.6 meter that provides a speed ranging from 0 to 60 m/s and a second chamber test with a section equal to 0.6×0.9 meter that provides a speed from 0 to 30 m/s.

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INTRODUCTION

In recent years, the Research Laboratory in Active Controls, Avionics and Aeroservoelasticity (LARCASE) has acquired two pieces of equipment, making it a total of three State-of-the-art research apparatus: A Research Flight Simulator Cessna Citation X, an Open Return Subsonic Wind Tunnel and a Flight Autonomous System (UAV). LARCASE is one of the few multidisciplinary research laboratories in Canada with a wide range of equipment with the capabilities of simulating aircraft models, especially airfoils, and validating the models with experimental data collected on the ground (Wind Tunnel) and in-flight (UAV).

The Open Return Subsonic Wind Tunnel will be described and its calibration will be shown in details with the method developed by the authors. From the way to keep the Prandtl tube parallel to the fluid stream reducing this way induced errors by yaw and pitch angle effect to the Log-Tchebycheff method variation used with the 0.6×0.9 meter test section.

The main purpose of this article is developing a new approach for wind tunnel calibrations using a limited number of dynamic pressure measurements and a predictive technique based on Artificial Neural Network (ANN). Linear interpolation is simple to use but not suited for multivariate nonlinear modeling; Regression Polynomial is a very common method to obtain an empirical equation that predicts observed results in a fluid dynamics applications. Wind tunnel testing involves a large number of variables such as wind direction, velocity, rate flow, turbulence characteristics, temperature variation and pressure distribution on airfoils. It is very time-consuming and difficult to develop an empirical generalization to fit the experimental data by means of Regression Polynomial. Complementing the development of an ANN model, a further objective of the research was to investigate an optimal method for determining local flow characteristics by means of X, Y and Z coordinates. Using a minimum of data collected from the wind tunnel calibration for training, the ANN model would generate the proper pressure for any given 3D coordinate inside the test section.

The neural networks were created using the Matlab neural network toolbox and trained using EGD back propagation algorithm. The application of ANN to solve wind engineering problems has received increasing interest in recent years by its ability to learn and generalize a complex, multivariate, multidimensional and nonlinear relationships by training with sample data containing noisy or incomplete information. ANN has the advantage that a multilayer perceptron neural network can describe a 3D flow area with a small amount of experimental data, fewer numbers of iterations and less computation time per iteration.

SUBSONIC WIND TUNNEL

The Price-Paidoussis Twelve Meter Open Return Subsonic Wind Tunnel is a research apparatus used to test airfoils and validate Computational Fluid Dynamics (CFD) models. The wind tunnel allows for a safe control of the flow conditions and makes measurements of pressure distribution on a wing shape possible [1]. At the beginning, the air pressure rises through the Centrifugal Fan creating lateral mixing of fluid layers, then the turbulent particles are straightened by the filters producing a laminar flow [2]. The wind tunnel in [Figure 1](#) consists of a centrifugal fan, a diffusing section, a settling chamber, a contraction section and a working section. The dimensions of the different sections are showed in [Figure 2](#). The centrifugal fan is powered by a 40 HP 67 Amps electrical engine from NorthWestern Electric Co. This DC engine possesses a Silicon-Controlled-Rectifier (SCR) therefore it can be powered by any conventional 120 VAC outlet.

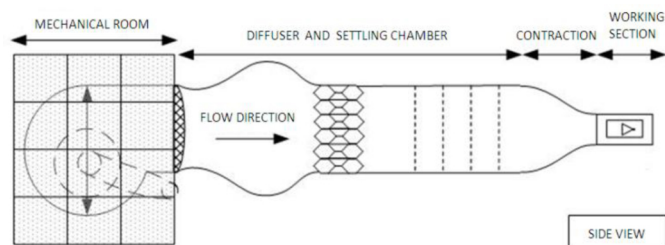


Figure 1. Wind Tunnel Sections

The flow develops a 0.18 Mach maximum speed due to the engine and the double impeller centrifugal fan. The 2 inlets at the opposite side of the rotor allows the air supply to increase the pressure flow and the use of the 24 small propellers by impeller allows the fan to turn at a much higher speed than normal fans with large blades [3] [Figure 3](#). The engine and the centrifugal fan are located inside the soundproof mechanical room protected from debris and dust.

The diffusing section consists of a wide angle diffuser, a large settling chamber, a contraction section and a test section. From the static pressure buildup the flow is projected to an oval shaped circular pattern flow Straightener. Then the flow goes through a series of 5 filters, the first is a Honeycombs shaped filter and the other 4 are Nylon squared shape filters positioned 0.5 meter from each other [Figure 4](#).

The settling section allows the flow to go from a turbulent state to a laminar flow.

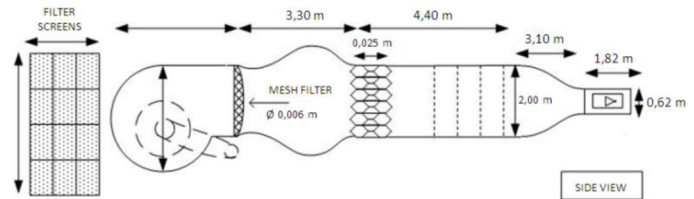


Figure 2. Wind Tunnel Measurement



Figure 3. Double Impeller Centrifugal Fan

The LARCASE's Wind Tunnel has 2 test sections, the main one is 0.6 by 0.9 meter made in wood with Plexiglass removable doors able to reach 0.12 Mach. The second test section, half the volume of the first one, is able to reach 0.18 Mach.

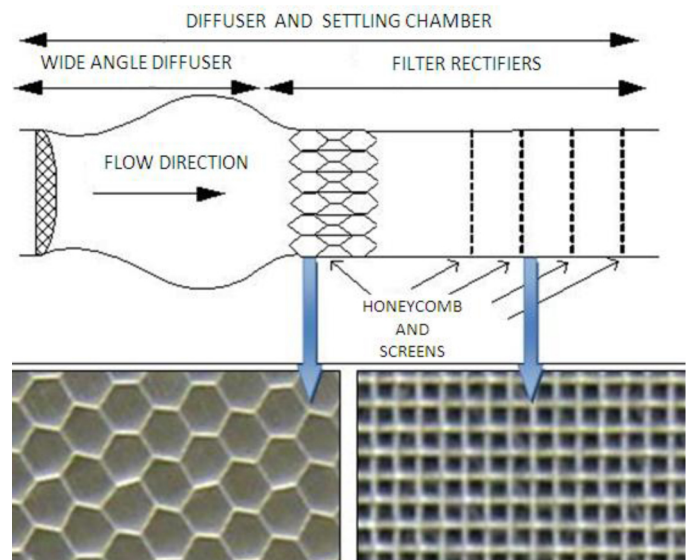


Figure 4. Settling Sections