UNIVERSITI PUTRA MALAYSIA

AERODYNAMIC CHARACTERISTIC ASSESSMENT OF AN AIRFOIL USING OPEN CIRCUIT WIND TUNNEL AND COMPUTATIONAL FLUID DYNAMICS

TABREJ KHAN

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By

TABREJ KHAN

Thesis Submitted to the School of Graduate Studies, Univesiti Putra Malaysia, in Fulfillment of the Requirements for the Degree of Master of Science

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Abstract of thesis presented to the Senate of Univesiti Putra Malaysia in fulfillment of the requirement for the Degree of Master of Science

AERODYNAMIC CHARACTERISTIC ASSESSMENT OF AN AIRFOIL USING OPEN CIRCUIT WIND TUNNEL AND COMPUTATIONAL FLUID DYNAMICS

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TABREJ KHAN

September 2015

Chairman : Associate Professor Surjatin Wiriadidjaja, PhD
Faculty : Engineering

This work is an attempt to investigate the airflow characteristics around an airfoil by using the existing wind tunnel of the University Putra Malaysia (UPM) and Computational Fluid Dynamics (CFD) methods. These results are compared to the available trusted experimental result of the University of Illinois at Urbana-Champaign UIUC (UIUC wind tunnel) for validity and assessment. A Clark Y airfoil was available at the laboratory and used therefore as the airfoil to be investigated. This airfoil was subjected to tests in the low-speed, open-circuit wind tunnel at different test-section velocities (7 m/s – 14 m/s). In order to be able to verify the investigation, the same airfoil definition with the same flow conditions as used in the wind tunnel test was also used for CFD's calculation by using the PHOENICS software, which was available as supplementary joint work elaborated in a companion thesis work as listed in the references. The results of the above two methods were compared and analyzed. The data obtained were further verified by comparing it to the standard data of the UIUC wind tunnel, yielding to an impression that the UPM wind tunnel test results and CFD data exhibited considerable differences. However, both methods shared characteristics that are almost similar to UIUC wind tunnel. Further, the CFD data were found to have more similarity with the UIUC wind tunnel data if compared to those of the UPM wind tunnel data. Some differences that are exhibited by the wind tunnel results are assessed in view of uncertainties and accuracy. Overall, a systematic procedure has been followed that can be used as a basis for further.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk Ijazah Master Sains

PENILAIAN CIRI-CIRI AERODINAMIK KE ATAS AIRFOIL DENGAN MENGGUNAKAN TEROWONG ANGIN LITAR TERBUKA DAN PENGIRAAN CFD.

Oleh

TABREJ KHAN

September 2015

Pengerusi : Profesor Madya Surjatin Wiriadidjaja, PhD
Fakulti : Kejuruteraan

Kerja ini cuba menyiasat sifat aliran udara di sekeliling aerofoil dengan menggunakan terowong angin sedia ada di Universiti Putra Malaysia (UPM) dan kaedah pengiraan dinamik bendalir (CFD). Keputusan tersebut dibandingkan dengan keputusan ujikaji daripada University of Illinois at Urbana-Champaign UIUC (terowong angin UIUC) yang boleh dipercayai, untuk pengesahan dan penilaian. Satu aerofoil Clark Y yang terdapat di makmal digunakan sebagai aerofoil untuk dikaji. Aerofoil ini digunakan di dalam ujian terowong angin litar terbuka pada halaju rendah, di pelbagai bahagian ujian halaju (7 m/s – 14 m/s). Untuk mengesahkan siasatan, aerofoil yang sama dengan keadaan aliran seperti di dalam ujikaji terowong angin digunakan di dalam pengiraan CFD melalui perisian PHOENICS yang terdapat di dalam kerjsama tambahan yang diulas lanjut di dalam tesis seperti di dalam senarai rujukan. Keputusan daripada kedua-dua kaedah dibanding dan dianalisa. Data yang diperolehi disahkan melalui perbandingan dengan data piawai dari terowong angin UIUC, yang memberi gambaran bahawa keputusan terowong angin UPM dan CFD sangat berbeza. Tetapi, kedua-dua kaedah mempunyai sifat yang sama dengan terowong angin UIUC. Dalam pada itu, data CFD didapati hampir sama dangan data terowong angin UIUC berbanding data terowong angin UPM. Beberapa perbezaan yang ditunjukkan oleh keputusan terowong angin dinilai dari segi ketidakpastian dan ketepatan. Pada keseluruhan, satu prosedur yang sistematik telah diikuti sebagai asas.

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I certify that a Thesis Examination Committee has met on 11 September 2015 to conduct the final examination of Tabrej Khan on his thesis entitled "Aerodynamic Characteristic Assessment of an Airfoil Using Open Circuit Wind Tunnel and Computational Fluid Dynamics" in accordance with the Universities and University Colleges Act 1971 and the Constitution of the Universiti Putra Malaysia [P.U.(A) 106] 15 March 1998. The Committee recommends that the student be awarded the Master of Science.

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This thesis was submitted to the Senate of the Universiti Putra Malaysia and has been accepted as fulfillment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Declaration by graduate student

I hereby confirm that:

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LIST OF ABBREVIATIONS

C	chord
H	Test Section Height
S	Platform Area
t	Time
T	Temperature
AOA	Angle of Attack
C_d	Coefficient of Drag
C_l	Coefficient of lift
Re	Reynolds Number
C_m	Moment Coefficient for an Airfoil
N	Normal Force
A	Axial Force
C_P	Pressure Coefficient
Q	Dynamic Pressure
P_t	Total Pressure
P	Pressure
P_s	Static Pressure
P	Free stream Pressure
P	Density
V	Velocity
B	Tunnel Width
B	Wing Span
C	Test Section Cross-sectional Area
Δ	Boundary Layer Thickness

CFD	Computational fluid dynamics
UIUC	University of Illinois at Urbana- Champaign

CHAPTER 1

INTRODUCTION

1.1 Overview

Successful aircraft are developed by selecting appropriate wing design and airfoil design.

Nowadays, the aircraft industries have their own way to design aircraft by developing by using computational fluid dynamics codes, and validated in a wind tunnel. There is another analytical method, which can be used only for special simple case but not for arbitrary.

This work is an attempt to study the airfoil and to investigate the appropriate flow mechanism at UPM (Universiti Putra Malaysia) open circuit wind tunnel and computational fluid dynamics.

Limitation in this work is some of the wind tunnel flow qualities are not known, such as turbulence etc. the available Clark Y model (chord ± 0.50) is about too big related to wind tunnel test section (1×1 m). 2D airfoil should relay on balance to avoid too many interference. (Actually C <25% wind tunnel width).

However, by looking into those limitations, it is hoped that by combining experimental efforts supported computational fluid dynamics calculation would still give sufficient evidence for making conclusions about the airfoil characteristics.

This research strongly support by comparison with other available wind tunnel test data (UIUC wind tunnel) which are trustworthy. Thus this investigation results in an acceptable conclusion, conducted results on this airfoil may be considered as a proof of "calibration" of the wind tunnel.

This work is therefore composed of literature reviews (theory), methodology, experimental reports, and computational fluid dynamics work. Which is all together lead to discussion and conclusion.

1.2 Problem Statement

There are several variable that can be used in this research. The problem which would be face in this research related to the model, wind tunnel, measuring equipment and computational fluid dynamic (CFD). Wind tunnel experiment has constraints by mean of model accuracy in terms of material and size, wind tunnel flow qualities (Uniformity and turbulence), measuring equipment (rack and balance). Computational technique also has some constraints by means of insufficient computational power of computers, time limitation and incorrect selection of flow models and boundary conditions (mesh density and turbulence model). We cannot say that every output result is always true as the simulation can generate the result whatever input we enter. It would lead to sufficient acceptable results for understanding.

1.3 Objective

The main objective of this research is to:

1. To investigate flow mechanism around an airfoil.
2. To use the available facilities, for testing an airfoil in,
   a) An open circuit wind tunnel experiment of UPM open-circuit and using available model (Clark Y).
   b) Conducting Computational fluid dynamics calculation by using Phoenics software.
3. To analyze and compare the experimental and the computational fluid dynamic and to validate by using the UIUC wind tunnel.

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