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DEVELOPMENT OF DATABASE ACQUISITION SYSTEM FOR EXTERNAL BALANCE DEVICE IN LOW-SPEED WIND TUNNEL

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By

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

April 2011

DEDICATION

I dedicate this thesis to my wife Rossilawati binti Abu Bakar and my kids Nur Dania and Ahmad Daniel.

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Abstract of thesis presented to Senate of the Universiti Putra Malaysia in Fulfillment of the requirement for the degree of Master Science

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April 2011

Chairman: Prof. Shamsuddin Sulaiman, PhD

Faculty: Engineering

Wind tunnel is an essential tool for aerodynamic testing. To keep them operating in good condition, it is required a balance device. Unfortunately, not all wind tunnels that available in market are equipped with the balance unit. With availability of high technology manufacturing equipment such as Computer Aided Drawing (CAD) / Computer Aided Manufacturing (CAM) machine there is possibility to build and fabricate the balance device by the user themselves. However, a lack of knowledge on calibration and validation of balance device could be a potential obstacle to a success on balance device development. Moreover the knowledge on design and fabrication of balance device is limited to be a published to public due to its commercial matters.

The purpose of this study is to develop a database acquisition system for external balance device for low speed wind tunnel. To calibrate and validate the external balance with database acquisition system a known weight is used.

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Then the external balance with database acquisition system is tested at low speed wind tunnel in order to investigate the aerodynamic characteristic on circular cylinder model and NACA0012 aerofoil model.

The studied was done by developing the external balance device with database acquisition system. The database acquisition system was fabricated and tested on the external balance using a simulation fault test on control panel. After that, the fabricated external balance with database acquisition system is calibrated and validated using known weights. The tests were carried out by comparing against the reading from the external balance database acquisition system with apply loads on lift and drag axis using calibration arms. To measure the accuracy of external balance database acquisition system, an aerodynamic experiment on the circular cylinder model and NACA0012 aerofoil model is performed at a low speed wind tunnel. The aerodynamic experiments on a circular cylinder model and NACA0012 aerofoil model are used to determine the aerodynamic force of drag coefficient and lift coefficient and then it is compared with other existing test data.

The results showing that the accuracy of the external balance database acquisition system on lift force and drag force at 99.9% and 100% of each respectively. The drag coefficient of circular cylinder at Reynolds number 2.05 x 10^4, 2.20 x 10^4, 2.36 x 10^4, 2.51 x 10^4, 2.59 x 10^4 and 2.75 x 10^4 were recorded at 1.02, 1.02, 1.00, 0.99, 1.06 and 1.06 respectively. For NACA0012 aerofoil, the lift coefficient and drag coefficient is recorded at Reynolds number 1.036 x 10^5. For C_L/ C_D ratio at angle of attack range from 0° - 12° the

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recorded value is smaller than the published data due to low Reynolds number effects. However for angle of attacks 14°, 16° and 18° the data for Reynolds number at 3.6×10^6 and 1.036×10^5 is given the value 3.08, 2.60, 2.31 and 2.5, 2.6, 2.1 respectively which showing the balance reading is nearly same with published data. From the results, we conclude that the external balance database acquisition system has been successfully developed.

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Abstrak tesis yang dikemukan kepada Senat Universiti Putra Malaysia sebagai memenuhi sebahagian keperluan untuk ijazah Master Sains

MEMBANGUNKAN SISTEM PEROLEHAN PANGKALAN DATA UNTUK PENGIMBANG LUARAN BAGI TEROWONG ANGIN HALAJU RENDAH

Oleh

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April 2011

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Terowong angin adalah satu alat yang penting bagi ujian aerodinamik. Untuk memastikan mereka beroperasi dalam keadaan yang baik, ia memerlukan peranti pengimbang. Malangnya, tidak semua terowong angin yang terdapat di pasaran dilengkapi dengan unit pengimbang. Dengan adanya peralatan teknologi tinggi pembuatan seperti Computer Aided Drawing (CAD)/ Computer Aided Manufacturing (CAM) mesin ada kemungkinan untuk membina dan membuat peranti pengimbang oleh pengguna sendiri. Walau bagaimanapun, kekurangan pengetahuan mengenai penentukuran dan pengesahan peranti pengimbang boleh menjadi penghalang potensi untuk kejayaan kepada pembangunan peranti pengimbang. Lebih-lebih lagi pengetahuan mengenai reka bentuk dan fabrikasi peranti pengimbang adalah terhad untuk disiarkan kepada orang ramai kerana mempunyai nilai komersial.

Tujuan kajian ini adalah membangunkan sistem perolehan pangkalan data pengimbang luar bagi terowong angin halaju rendah. Untuk menentukur dan

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mengesahkan pengimbang luar dengan sistem perolehan pangkalan data ia menggunakan pemberat. Kemudian pengimbang luar dengan sistem perolehan pangkalan data diuji pada terowong angin kelajuan rendah untuk menyiasat ciri-ciri aerodinamik pada model silinder bulat dan model aerofoil NACA0012.

Kajian telah dilakukan dengan membangunkan peranti pengimbang luar dengan sistem perolehan pangkalan data. Sistem perolehan pangkalan data yang direka dan diuji ke atas pengimbang luar yang menggunakan ujian simulasi kerosakan pada panel kawalan. Selepas itu, pengimbang luar yang direka dengan sistem perolehan pangkalan data ditentukur dan disahkan menggunakan pemberat diketahui. Ujian telah dijalankan dengan membandingkan terhadap bacaan dari sistem perolehan pangkalan data pengimbang luar dengan nilai beban pada paksi angkatan dan seretan menggunakan alatan penentukuran. Untuk mengukur ketepatan sistem perolehan pangkalan data pengimbang luar, eksperimen aerodinamik pada model silinder yang bulat dan model aerofoil NACA0012 dilakukan pada terowong angin kelajuan rendah. Eksperimen aerodinamik pada model silinder bulat dan model aerofoil NACA0012 digunakan untuk menentukan daya aerodinamik pekali seretan dan pekali daya angkat dan kemudian dibandingkan dengan data ujian lain yang sedia ada.

Keputusan menunjukkan bahawa ketepatan data dari sistem perolehan pangkalan data pengimbang luar berdasarkan daya angkatan dan daya seretan masing-masing pada 99.9% dan 100%. Pekali seretan silinder bulat di

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nombor Reynolds 2.05 x 10^4, 2.20 x 10^4, 2.36 x 10^4, 2.51 x 10^4, 2.59 x 10^4 and 2.75 x 10^4 masing-masing mencatatkan nilai pada 1.02, 1.02, 1.00, 0.99, 1.06 dan 1.06. Bagi model aerofoil NACA0012, pekali daya angkat dan pekali daya seret direkodkan pada nombor Reynolds 1.036 x 10^5. Bagi nisbah C_L/ C_D pada sudut pelbagai serangan dari 0 ° - 12 ° nilai yang dicatatkan adalah lebih kecil daripada data yang diterbitkan kerana kesan nombor Reynolds yang rendah. Walau bagaimanapun, bagi sudut serangan 14°, 16° dan 18° data pada nombor Reynolds 3.6 x 10^6 dan 1.036 x 10^5 menunjukkan bacaan kira-kira hampir sama dengan data yang diterbitkan iaitu masing – masing mencatatkan bacaan pada 3.08, 2.60, 2.31 and 2.5, 2.6, 2.1. Daripada keputusan, kita membuat kesimpulan bahawa sistem perolehan pangkalan data pengimbang luar telah berjaya dibangunkan.

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Above all, without the support and relentless encouragement of my wonderful and long-suffering wife Rossilawati bte Abu Bakar and our two children, this enterprise could neither have been started nor certainly completed.

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NOMENCLATURE

LIST OF ABBREVIATIONS

LSWT	Low Speed Wind Tunnel
OLWT	Open Loop Wind Tunnel
CLWT	Close Loop Wind Tunnel
SWT	Supersonic Wind Tunnel
CFD	Computer Fluid Dynamic
UAV	Unmanned Aerial Vehicle
KARI	Korea Aerospace Research Institute

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LIST OF SYMBOLS

b	Wing span
c	Chord length
α	Angle of attack
D	Drag force
D_i	Induced drag
L	Lift force
M	Pitching moment
N	Newton
Nm	Newton Meter
ρ_∞	Air density
S	Plan surface or reference area
AR	Aspect ratio
δ	Constant
μ_∞	Viscosity of air
T	Ambient temperature
K	Kelvin
V_∞	Free stream velocity
Re	Reynolds number
M_∞	Mach number
a_∞	Speed of sound
R	Gas constant
q_∞	Dynamic pressure
C_D	Drag coefficient

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Wind tunnel is an essential tools for aerodynamic research and developments. Until now there are many Research and Development (R&D) institutions are still using wind tunnel for testing, analysis and predicting the aerodynamic performance of the test model.

The accuracy of the measurements is one of important factor in wind tunnel testing. Wind tunnel using several important instruments such as balances, flow sensor, temperature sensor. All those instruments are needs to be calibrated and validated for each wind tunnel testing and etc. Some of this equipment has been upgraded with automatic reading systems that are able to monitor, storing and analyzing the data using computer system. Those improvements have enhanced the apparatus performance and saving a lot of time.

Due to wind tunnel demands are still increasing though out the years and this support a future growth and enhancement in wind tunnel design. There are many wind tunnel manufacturers are competing to each other to give the best offer in term of functionality in wind tunnel performance and control. Whether a series of computational simulation software have been developed, most of

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engineer still prefers to use wind tunnel as validation tools in their research studies.

1.2 Problem statements

Generally, there are a concerned due to inaccessible of balance device on the wind tunnel. Each wind tunnel is required at least one balance device to perform an aerodynamic testing. Due to a limited of funding to buy a balance device there are needed to develop a balance device in house using available resources.

Typical of low-speed wind tunnel type owned by the Department of Mechanical and Manufacturing, Faculty of Engineering, Universiti Putra Malaysia as shown in Figure 1.1. It is shown that the wind tunnel has not being equipped with any balance device since it being bought few years ago. Therefore there are needed to equip this wind tunnel with the balance device to able the engineers to perform an aerodynamic test.

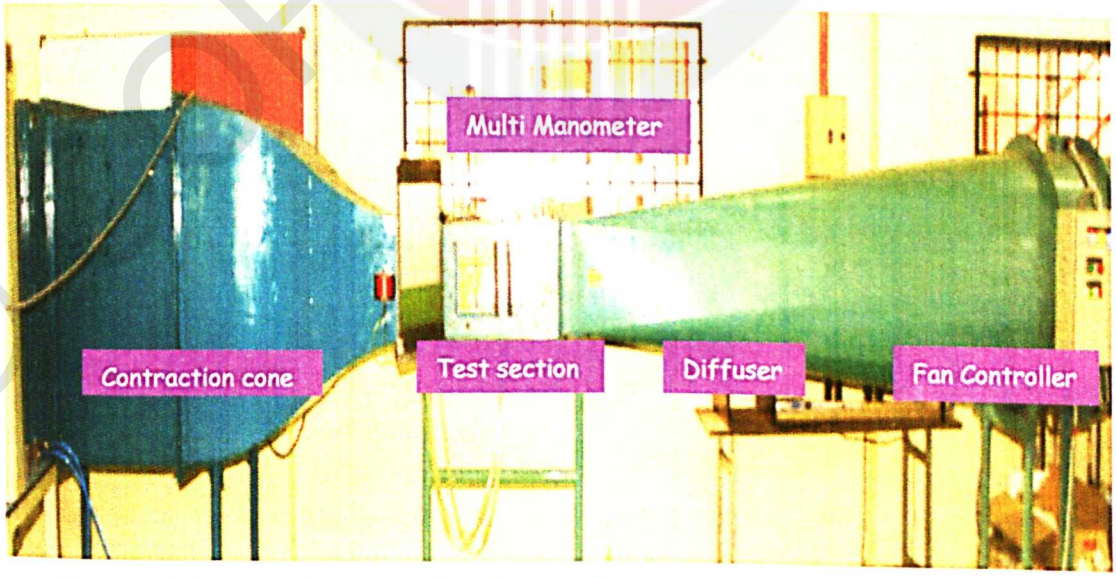

Figure 1.1. Low-Speed Wind Tunnel of Department of Mechanical Faculty of Engineering University Putra Malaysia

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This project is focusing on the development of database acquisition system for external balance device and to calibrate and validate the external balance that can be used for low speed wind tunnel application. Therefore, a completed data base acquisition system is designed and installed on the external balance as read out system that able to read the signal and store data on the computer hard disk. The balance with database acquisition system will be calibrated using a known weight especially at lift force and drag force. Finally, an aerodynamic experiment is set for Circular Cylinder and NACA0012 Aerofoil model to validate the balance accuracy on low speed wind tunnel.

1.3 Objectives of the study

The objectives of this study are:

1. To improve an external balance with development of database acquisition system for wind tunnel testing.
2. To calibrate and validate the unit.
3. To investigate the accuracy of the developed balance in predicting the aerodynamic forces act on circular cylinder and NACA0012 aerofoil Model.

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1.4 Scope of the study

The scope of this study is to develop data base acquisition system for external balance. The study is limited to measure, calibrate and validate for lift force and drag force at load magnitude 10N and 5N relatively. The test model will be tested in the low speed wind tunnel at maximum velocity 10.6m/sec with test section size is 200 (H) mm x 200 (W) mm.

1.5 Layout of the thesis

This thesis consists of five chapters included:

The first chapter introduces the background, objectives and the scope of the research. Chapter 2 elaborates the critical review of literature related to the overview of wind tunnel and balance device. Chapter 3 describes the methodology of the developing device process and test used. Chapter 4 explains the results and analysis and discussion. It consists of simulation test, calibration test and validation test and aerodynamic test and discussion. Chapter 5 concludes the comparison result in relation to the objective of the research, and presents the conclusion and future work in this field of research.

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REFERENCES

Arief Suhariyono, Jong Hyun Kim, Nam Seo Goo, Hoon Cheol Park, Kwang Joon Yoon (2005). *Design of Precision Balance and Aerodynamic Characteristic Measurement System for Micro Aerial Vehicles.* Jurnal of Aerospace Science and Technology.

Bardowicks H. (1984). *A New Six–Component Balance and Applications on Wind Tunnel Models of Slender Structures.* Journal of Wind Engineering and Industrial Aerodynamics.

Chung Jindeog, Lee Jangyeon, Sung Bongzoo and Koo Samok (2003). *Wind Tunnel Test of an Unmanned Aerial Vehicle*. KSME International Journal.

Evans R.A. and Lee B.E. (1983). *The Determination of The Modal Forces Acting On Three Buldings Using Wind Tunnel Methods*. Journal of Wind Engineering and Industrial Aerodynamics.

Govinda Raju S.P. (2003). *Role of Wind Tunnels in Aircraft Design.* Aerospace Engineering Department Indian InsBangalorebile Industry and the Defence Establishment.

Hafizal Abu Bakar (2001). *Design and Construction of Three Component Balance for Low Speed Wind Tunnel*. Bachelor dissertation. Universiti Putra Malaysia, Serdang Selangor.

Houghton E.L. and Carpenter P.W. (2003). *Aerodynamics for Engineering Students*. 5th Edition, Butterworth–Heinemann, London.

Plint and partners engineers (1993). *Instruction Manual–TE.81/E. Three Component Balance*. University Malaya, Kuala Lumpur.

Jewel B. Barlow, William H. Rae, JR Alan Pope (1999). *Low Speed Wind Tunnel Testing*. Third Edition, John Wiley & Son.

Joarder R., Jagadeesh G. (2004). *A new free floating accelerometer balance system for force measurements in shock tunnels*" Journal of Shock Waves.

Julian Allen H. and Edward W. Perkins (1955). *Characteristics of Flow Over Inclined Bodies of Revolution*. National Advisory Committee For Aeronautics.

Knut Fristedt (1993). *A Calibration Model of a Six Component Internal Wind-Tunnel Balance of the Bending-Beam Type*. Elsevier Science Publishers B.V.

Maurice Dubois (1981). *Six Component Strain-Gage Balances For Large Wind Tunnels*. SESA International Congress on Experiment Mechanic.

M Sapuan Salit (1999). *Design of a Wind Tunnel For The Study of Turbulent Flow in a Circular Pipe*. Rencana Jurutera Malaysia.

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Niranjan Sahoo, Mahapatra D.R., Jagadeesh G., Gopalakrishnan S., Reddy K.P.J. (2006). *Design and analysis of a flat accelerometer-based force balance system for shock tunnel testing*. Science Direct.

Saravanan S., Jagadeesh G., Reddy K.P.J. (2008). *Aerodynamic Force Measurement using 3-component Accelerometer Force Balance System in a Hypersonic Shock Tunnel*. Springer-Verlag.

Smith A.L., Mee D.J., Danielc W.J.T., Shimoda T. (2000). *Design, modelling and analysis of a six component force balance for hypervelocity wind tunnel testing*. Journal of computers and structures, Elsevier Science Ltd.

Portman V., Sandler B.Z., Chapsky V. and Zilberman I. (2009). *A 6-DOF Isotropic Measuring System for Force and Torque Components of Drag for Use in Wind Tunnels*. Journal of Springer Science.

Xie J., Irwin P.A. (1998). *Application of The Force Balance Technique to a Building Complex*. Journal of Wind Engineering and Industrial Aerodynamics.

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