AERODYNAMIC STUDY ON AN AIRCRAFT

MOHD AMERRULL B ISMAIL

UNIVERSITI TEKNIKAL MALAYSIA MELAKA

© Universiti Teknikal Malaysia Melaka

AERODYNAMIC STUDY ON AN AIRCRAFT

MOHD AMERRULL B ISMAIL

This dissertation is submitted as partial fulfillment of the requirement for the degree of Bachelor of Mechanical Engineering (Thermal Fluid)

Faculty of Mechanical Engineering
Universiti Teknikal Malaysia Melaka

APRIL 2009

© Universiti Teknikal Malaysia Melaka

APPROVAL OF SUPERVISOR

"I hereby declared that I have read through this report and I found that it has comply the partial fulfilment for awarding the degree in Bachelor of Mechanical Engineering (Thermal Fluid)"

Signature : ……………………….................
Supervisor 1: Mr. Nazri B Md Daud
Date : ....

© Universiti Teknikal Malaysia Melaka

"I declare that this report is done by my own exclude the citation with the mentioned references for each"

Signature: ………………………..................
Author : Mohd Amerrull B Ismail
Date : 10th April 2009

© Universiti Teknikal Malaysia Melaka

ACKNOWLEDGEMENT

All praises be to God. My deepest appreciation to my first supervisor Mr. Nazri Md Daud and second supervisor who have been very patient and committed in giving me the knowledge and guidance in completing this report this whole time.

Another gratitude for other lecturer that keep helping and involved in my dissertation and others.

Lastly, my family and my fellow friends that always give me courage, a few advice and knowledge to fulfill this report.

© Universiti Teknikal Malaysia Melaka

ABSTRACT

Aerodynamic is one of the most important factors for a steady and balance aircraft with an economical fuel usage. Nowadays, many ways or methods were designed to simplify the complicated research in aerodynamic field, especially in vehicle dynamic subject. There are new methods that use simulation study to obtain aerodynamic data for any vehicle design. In this dissertation, the preferred aircraft for the simulation is the stable and unique maneuvering MIG-29 Fulcrum aircraft. This kind of research can give several simulation results data such as drag coefficient, C_L and lift coefficient, C_D for future research. The first procedure is by designing a model using design software, SolidWorks. Next, transfer the model design to modeler software, COSMOSFloWorks to generate a mesh web for aircraft geometrical volume. Then the solver will solve the problems to get a result connected to certain aerodynamic forces on aircraft that is drag coefficient, C_D and lift coefficient, C_L. Wind Tunnel Test then performed on the real model, also to get both drag and lift coefficient from the test section. The value of C_D and C_L obtained for simulation using COSMOSFlowork is **0.087** and **0.019**, while C_D and C_L for Wind Tunnel Test is **0.0102** and **0.0207** respectively. Lastly, compared both methods' results to find the relationship and differences for the drag coefficient, C_D and lift coefficient, C_L between COSMOSFloWorks simulation and Wind tunnel Test.

© Universiti Teknikal Malaysia Melaka

ABSTRAK

Aerodinamik merupakan salah satu faktor yang penting untuk menentukan keseimbangan dan kestabilan pesawat bagi meningkatkan kadar penggunaan bahan api supaya lebih menjimatkan. Sejajar dengan perkembangan teknologi dalam bidang aerodinamik, berbagai kaedah telah direka untuk memudahkan kajian di dalam bidang aerodinamik, lebih-lebih lagi dalam cabang dinamik kenderaan. Terdapat kaedah yang terkini yang menggunakan kajian simulasi untuk mendapatkan data aerodinamik sesuatu rekabentuk kenderaan. Model rujukan pesawat yang dipilih untuk simulasi ini adalah jet pejuang MIG-29 Fulcrum yang mempunyai kestabilan dan pemanduan yang unik. Kajian ini akan memberikan keputusan simulasi bagi pekali seretan,C_D dan pekali daya angkat, C_L pesawat ini untuk kegunaan kajian di masa hadapan. Prosedur yang digunakan bermula dengan melukis semula model di dalam perisian rekabentuk, SolidWorks. Diikuti dengan menjalankan simulasi rekabentuk model tersebut di dalam perisian model, COSMOSFloWorks untuk menjana jaringan isipadu pada geometri pesawat dan diselesaikan di dalam COSMOSFloWorks juga untuk memperolehi keputusan dan data berkenaan daya-daya aerodinamik yang bertindak ke atas pesawat. Nilai C_D dan C_L juga akan dicari menggunakan satu lagi kaedah iaitu dengan menjalankan Ujian Terowong Angin. Nilai C_D dan C_L bagi simulasi menggunakan COSMOSFloWorks adalah **0.087** and **0.019** manakala bagi Ujian Terowong Angin pula adalah **0.0102** and **0.0207**. Akhir sekali, nilai C_D dan C_L antara simulasi COSMOSFloWorks dan Ujian Terowong Angin akan dianalisis untuk mencari sebarang perbezaan dan juga hubungkait antara keputusann dua kaedah ini.

© Universiti Teknikal Malaysia Melaka

CONTENTS

© Universiti Teknikal Malaysia Melaka

© Universiti Teknikal Malaysia Melaka

CHAPTER	TITLE	PAGE

© Universiti Teknikal Malaysia Melaka

LIST OF TABLES

© Universiti Teknikal Malaysia Melaka

LIST OF FIGURES

© Universiti Teknikal Malaysia Melaka

© Universiti Teknikal Malaysia Melaka

© Universiti Teknikal Malaysia Melaka

LIST OF APPENDICES

© Universiti Teknikal Malaysia Melaka

CHAPTER I

INTRODUCTION

1.1 Background

In this chapter, the introduction to the fundamental characteristic of aerodynamics will be discussed in order to get the basic idea of aerodynamic itself.

1.1.1 Aerodynamics

Aerodynamics is a branch of dynamics concerned with studying the motion of air, particularly when it interacts with a moving object. Aerodynamics is closely related to fluid dynamics and gas dynamics, with much theory shared between them. Aerodynamics is often used synonymously with gas dynamics, with the difference being that gas dynamics applies to all gases. Understanding the motion of air (often called a flow field) around an object enables the calculation of forces and moments acting on the object. Typical properties calculated for a flow field include velocity, pressure, density and temperature as a function of position and time. By defining a control volume around the flow field, equations for the conservation of mass, momentum, and energy can be defined and used to solve for the properties. The use of aerodynamics through mathematical analysis, empirical approximation and wind tunnel experimentation form the scientific basis for heavier-than-air flight.

© Universiti Teknikal Malaysia Melaka

Aerodynamic problems can be identified in a number of ways. The flow environment defines the first classification criterion. External aerodynamics is the study of flow around solid objects of various shapes. Evaluating the lift and drag on an airplane, the shock waves that form in front of the nose of a rocket or the flow of air over a hard drive head are examples of external aerodynamics. Internal aerodynamics is the study of flow through passages in solid objects. For instance, internal aerodynamics encompasses the study of the airflow through a jet engine or through an air conditioning pipe.

The ratio of the problem's characteristic flow speed to the speed of sound comprises a second classification of aerodynamic problems. A problem is called subsonic if all the speeds in the problem are less than the speed of sound, transonic if speeds both below and above the speed of sound are present (normally when the characteristic speed is approximately the speed of sound), supersonic when the characteristic flow speed is greater than the speed of sound, and hypersonic when the flow speed is much greater than the speed of sound. Aerodynamicists disagree over the precise definition of hypersonic flow; minimum Mach numbers for hypersonic flow range from 3 to 12. Most aerodynamicists use numbers between5 and 8.

The influence of viscosity in the flow dictates a third classification. Some problems involve only negligible viscous effects on the solution, in which case viscosity can be considered to be non existent. The approximations to these problems are called inviscid flows. Flows for which viscosity cannot be neglected are called viscous flows.

© Universiti Teknikal Malaysia Melaka

1.2 Problem Statement

The study of the flow around an aircraft is very important. In this project aircraft studied in terms of aerodynamic shape in order to get steady and balance aircraft. The problem will be examined by using **SolidWorks COSMOSFloWorks** software and Wind Tunnel Test to determine the relationship and differences between lift coefficient C_L and drag coefficient C_D for both methods.

1.3 Objective

This project objective is as below:

I. Find C_D and C_L of an aircraft using simulation and experimental
II. Compare results between simulation and experimental

1.4 Scopes

Scopes of this project is as below:

I. Redraw MIG-29 Fulcrum aircraft model using SolidWorks
II. Find C_D and C_L using COSMOSFloWorks and Wind Tunnel Test
III. Compared C_D and C_L value between Wind Tunnel and COSMOSFloWorks

© Universiti Teknikal Malaysia Melaka

CHAPTER 2

LITERATURE REVIEW

2.1 Aerodynamics Spin Phenomenon Aircraft

Raghavendra et al (2005) stated that spin has been and continues to be one of phenomena in encountered flight. By the early 1980s.the most complex and dangerous approximate methods based on reduced-order models had been developed for equilibrium spin prediction. For definitions of various spin types or modes (equilibrium or steady vs. oscillatory, erect vs. inverted, flat vs. steep, etc.) the reader is referred to standard books. The introduction of bifurcation methods around that period, however, brought about a major advancement spin prediction capabilities. It became possible to work with the complete equations of aircraft motion with no approximation and to numerically compute not just equilibrium spin states but also oscillatory spin solutions. Jumps from a non spin state to a spin state, or between two different spin states, hysteresis, and other nonlinear phenomena observed in post stall flight could also be predicted.

One strategy for spin prevention is to avoid the jump phenomenon leading to spin entry by suitably scheduling the control surfaces in either a feed forward or a feedback manner. Control scheduling effectively changes the topology of the equilibrium spin solutions at high angles of attack, either eliminating the stable spin solutions or deleting the bifurcation points at which departure to spin occurs. Piloting strategies for spin recovery have undergone drastic changes over the years.

© Universiti Teknikal Malaysia Melaka

The first strategy uses an indirect, two-step recovery procedure in which the airplane is first recovered to a high- or moderate-angle-of-attack level flight trim condition. Followed by a second step where the airplane is then transitioned to the desired low-angle-of-attack trim. The second strategy involves the use of thrust-vectoring controls in addition to the standard aerodynamic control surfaces to directly recover the aircraft from high-angle-of-attack oscillatory spin to a low-angle-of-attack level-flight trim state. Our studies reveal that both the strategies, the first involving a two step angle-of-attack command along with an increase in static thrust to trim at an intermediate high/moderate-angle-of-attack level trim state and the second employing pitch and yaw thrust vectoring, are successful spin recovery to a low-angle-of-attack in level-flight trim condition. These results highlight the importance of effective thrust management conjunction with suitable use of all of the aerodynamic control surfaces in for successful spin recovery strategies. They summarized the research that has been conducted to attain that ultimate goal and a continuance of previous studies of two-dimensional drag prediction.

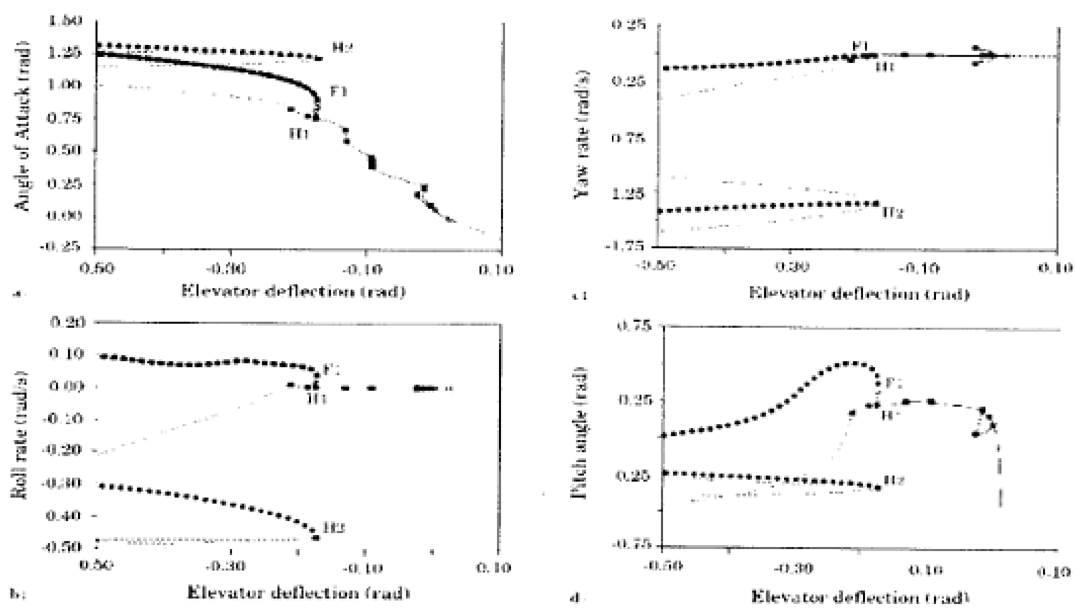

Figure 2.1: Bifurcation diagram of :a) angle of attack α, b) roll rate p, c) yaw rate r, and d) pitch angle θ, with elevator deflection δe as the continuation parameter

(Source: JOURNAL OF AIRCRAFT, Vol.42, No.6,November-December 2005)

© Universiti Teknikal Malaysia Melaka

2.2 Spin Phenomena Recovery Method

The problem of recovering an aircraft from a flat, oscillatory spin has been posed as an inverse dynamics problem of computing the control inputs required to transition the airplane from the spin state to a symmetric, level-flight trim condition. The use of bifurcation analysis, in conjunction with the nonlinear dynamic inversion method, has been critical as it provided both the start point (oscillatory spin solution) as well the endpoint (stable, level flight trim solution) for the inversion algorithm. Three different level-flight trims have been examined, which represent high-, moderate-, and low-angle-of-attack α trims for the aircraft model under consideration. Spin recovery, using only aerodynamic control surfaces, seen to be successful case of the high- and moderate- α trims, but leaves airplane in a wing rock-like limit cycle oscillation about the low-the o trim state. Two alternate strategies, one involving a two-step recovery procedure using only aerodynamic controls and the other using additional thrust vector control effectors are both seen to be successful in recovering the airplane to the low- α trim state. Some interesting observations can be made as a result of these simulations, as follows:

Recovery to high- α trim is not necessarily faster as the poor aerodynamic damping under these conditions implies that residual oscillations do not decay rapidly. Even the control surfaces, under full deflection conditions, are unable to provide sufficient damping augmentation. As a result, the airplane takes nearly twice as long to recover to high- α trim A as to the moderate- α, trim B. Hence, stabilization at a high- α trim might not always be recommended.

Direct recovery from a flat spin to a low- α trim, such as trim C, is not to be expected because of control surface rate and deflection limits. One can consider switching off the dynamic inversion controller or switching to an alternate control strategy at a particular point in time to try avoiding the rate-limiter-induced limit cycle in case of trim C. This needs further exploration, however.

The two-step spin recovery strategy is a practical possibility for aircraft not equipped with thrust vectoring. The intermediate trim state, such as trim B, can be chosen to have good stability and damping characteristics and adequate control effectiveness, especially in the lateral-directional dynamics. The use of increased thrust,

© Universiti Teknikal Malaysia Melaka

something that used to be practiced in the early days of aviation, is seen to be an important factor in the success of the two-step recovery procedure. However, the use of throttle input during spin recovery, in general, needs to be carefully evaluated.

Further simulations using pitch and yaw thrust vectoring have shown that airplanes equipped with thrust vectoring have a distinct advantage in being able to recover from flat spin directly to a low-o trim. In the example considered here, spin recovery time was reduced by a factor of nearly 60% for a thrust-vectored airplane, as against the same airplane without thrust vectoring undergoing a two-step spin recovery procedure. More extensive simulations should be able to better quantify the precise advantage gained in spin recovery by incorporating thrust vectoring when additional factors such as thrust/weight penalty caused by addition of thrust-vectoring nozzles are considered.

Finally, all of the simulations show that the initial sense of application of recovery controls is very much along expected lines-aileron with the roll, rudder/yaw thrust vectoring against the turn, and elevator/pitch thrust vectoring to pitch the nose down to a lower angle of attack.

© Universiti Teknikal Malaysia Melaka

2.3 Aerodynamic Drag Forces

According to Chao and van Dam (2006), the aerodynamic drag of an aircraft can be separated in to viscous (or profile) drag, induced drag, and wave drag. Viscous drag Consists of skin friction and form drag and is generated through the action of viscosity within the boundary layer. Induced drag is the result of the shedding of vorticity that accompanies the production of lift. Wave drag arises from the radiation of energy away from the aircraft in the form of pressure waves. Accurate prediction of drag during the various stages of the development process of an aircraft is of importance to the efficiency of this process and to the prediction of scale effects on aircraft drag. The most common technique to calculate the drag of an airfoil, wing, or complete configuration is based on the integration of the pressure and the shear stress acting on the surface of the configuration. An alternative to calculating aerodynamic forces by means of surface integration is to compute the forces around a far-field surface enclosing the body, a technique known as far-field integration. A second alternative drag-prediction method is the wake integration technique, which is based on the principle that the aerodynamic drag of a configuration can be obtained from pressure and momentum information in the wake at some distance downstream of the configuration.

Both the far-field and wake integration techniques are closely related to the surface integration technique and all three techniques are derived from momentum integral theory. One of the earliest studies on the subject of computational fluid dynamics (CFD)-based drag prediction was by Yu et al, who explored the three different drag prediction techniques for several two and three dimensional configurations. Van der Vooren et al, also have published several insightful papers on CFD-based drag prediction.

Recently the wake integration technique was successfully applied to the prediction of lift, induced drag, and wave drag of three-dimensional wings in subsonic and transonic flows based on CFD solutions. However, most of these studies have been limited to flows governed by the Euler equations. On the experimental side, a good example illustrating the usefulness of wake integration to determine the effect of configuration modifications on drag and its physical components as part of a wind-

© Universiti Teknikal Malaysia Melaka

tunnel experiment is presented by Kusunose et al. The present goal is to apply the wake integration technique to numerical solutions of the three-dimensional Reynolds averaged Navier-Stokes (RANS) equations for complex configurations. They summarized the research that has been conducted to attain that ultimate goal and a continuance of previous studies of two-dimensional drag prediction.

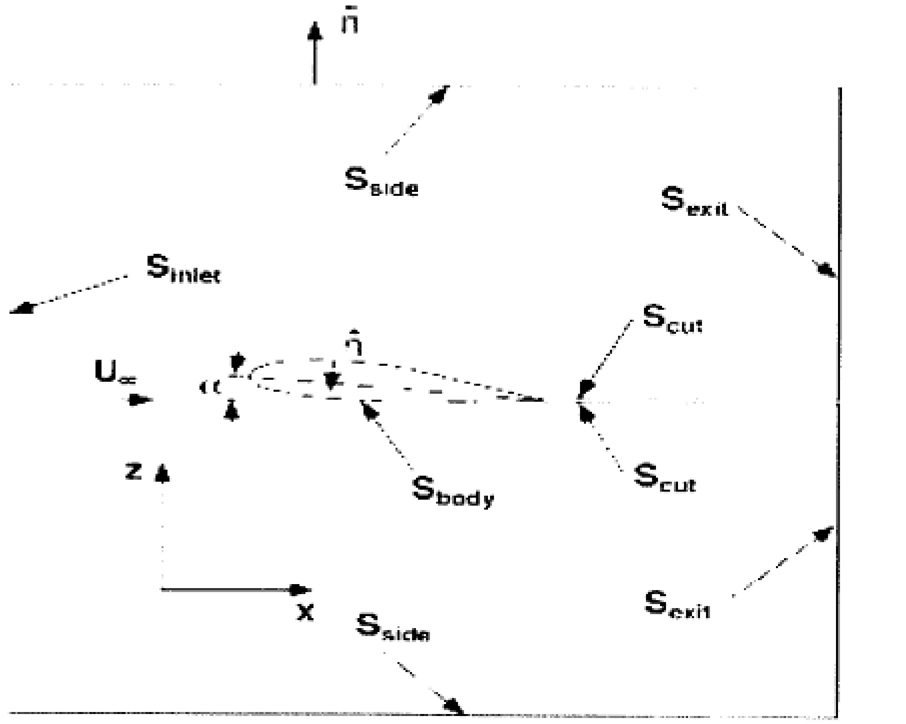

Figure 2.2: Control Volume used in derivation of aerodynamic forces.
(Source: JOURNAL OF AIRCRAFT, Vol.43, No.1, January-February 2005)

© Universiti Teknikal Malaysia Melaka