Universiti Teknologi Malaysia

BORANG PENGESAHAN STATUS TESIS*

JUDUL: **WING-EXTERNAL STORE AERODYNAMIC INTERFERENCES OF A SUBSONIC AIRCRAFT**

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WING-EXTERNAL STORE AERODYNAMIC INTERFERENCES OF A SUBSONIC AIRCRAFT

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Dedicated to my parents,

my wife and

my children

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ABSTRACT

Modern fighter aircraft are mostly designed to carry its store externally. Installing store to an aircraft wing externally would have much engineering implication especially through the change in the aerodynamic characteristic. This research was carried out to study the application of the Computational Fluid Dynamics (CFD) method along with experimental methods in predicting the aerodynamic interference caused by these installations. Commercial CFD code, Fluent 5.3 had been validated using experimental results reported in the literature for two dimensional, subsonic and transonic flow over the NACA 0012 and the RAE 2822 airfoil. Subsequently, low speed wind tunnel experiments were carried out over a wing model installed with an external store. The wing model was fabricated based on a digitized BAe Hawk 208 fighter wing. For further CFD code validation, the wind tunnel configurations were again simulated using the CFD method and its results were validated with the experimental results. Finally, a simplified full scale Hawk 208 aircraft model carrying an external store was simulated at various attitudes and flow speeds. In the two-dimensional subsonic flow, pressure distribution predicted by CFD was in good agreement and comparable to the experimental results. For the transonic two-dimensional flow validation, pressure distribution predicted by various flow models were slightly different from the experimental results (9% to -22.2% in term of C_L). For wind tunnel configuration, an average of about 12% deviation in pressure distribution between the results predicted by the CFD method and measured in the wind tunnel. The results of the full scale Hawk 208 simulation show that the aerodynamic interference caused by the store installation were mostly evidence on the lower wing surface and negligible on the upper surface at low angle of attack. This trend was reversed as the angle of attack was increased. The area of influence on the wing surface by store interference increased in line with the increased in airspeed.

ABSTRAK

Kebanyakan pesawat pejuang modern adalah direka untuk membawa "store" di bahagian luar seperti di bawah sayap. Memasang "store" di bawah sayap pesawat mempunyai banyak implikasi terutamanya yang disebabkan oleh perubahan dalam ciri-ciri aerodinamik. Projek kajian ini mengkaji penggunaan kaedah CFD dalam meramal ganguan aerodinamik seiring dengan ujikaji terowong angin. Pengaturcaraan CFD komersial iaitu Fluent 5.3 telah digunakan untuk meramal aliran dua dimensi ke atas aerofoil NACA 0012 dan RAE 2822 dalam lingkungan aliran subsonik dan juga transonik. Ini diikuti dengan satu ujikaji terowong angin ke atas satu model yang terdiri daripada sebahagian sayap pesawat yang dipasang dengan pelancar roket, ia merupakan model yang diringkaskan daripada pesawat pejuang Hawk 208. Keputusan ujikaji terowong angin akan digunakan untuk menilai ketepatan ramalan oleh kaedah CFD dalam aliran 3 dimensi dan memantau perubahan aerodinamik yang disebabkan oleh Pelancar Roket. Akhir sekali, kaedah CFD digunakan untuk meramal aliran angin dan gangguan angin yang disebabkan oleh pemasangan Pelancar Roket keatas satu model pesawat Hawk 208 bersaiz penuh pada pelbagai kelajuan dan sudut tuju. Keputusan simulasi dengan kaedah CFD untuk aliran dua dimensi, mendapati ramalan tekanan bagi aliran subsonik adalah sangat baik jika dibandingkan dengan keputusan ujikaji yang dilaporkan. Walaubagaimanapun ramalan CFD bagi aliran transonik memperolehi perbezaan antara 9% ke –22.2% dalam C_L dibanding dengan keputusan ujikaji. Perbezaan sebanyak 12% dalam tekanan udara didapati antara ramalan CFD dengan keputusan ujikaji terowong angin yang dijalankan dalam kajian ini. Dalam kes simulasi pesawat berukuran penuh, ramalan CFD menunjukan bahawa, gangguan aliran angin tertumpu pada bahagian bawah sayap dan hampir tiada kesan pada bahagian atas pada sudut serang yang rendah, trend ini terbalik apabila sudut serang meningkat. Keluasan kawasan yang dipengaruhi oleh gangguan Pelancar roket meningkat seiring dengan kelajuan pesawat.

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NOMENCLATURE

E	Energy
i	Internal energy
K	Kinetic energy
M	Mach number
m	Molar mass
p	Pressure
R	Universal gas constant
s	Entropy
T	Temperature
t	Time
U	Velocity vector
u	Velocity component in x direction
v	Velocity component in y direction
w	Velocity component in z direction
C_v	Constant volume
C_p	Constant pressure
Re	Reynold number
Pr	Prandtl number
$S_{Mx/y/z}$	Source in x, y and z direction
div	Divergence
grad	Gradient
u'	Fluctuating velocity in x direction
v'	Fluctuating velocity in x direction
w'	Fluctuating velocity in x direction
T_o	Total temperature
α	Incidence angle
ε	Dissipation
ϕ	Scalar
Φ	Mean scalar
φ	Fluctuating scalar
φ'	Time varying scalar
γ	Specific heat ratio
ψ	Stream function
μ	Viscosity coefficient
ν	Kinematics viscosity
ρ	Density

ρ_o	Stagnation density
τ	Stress
δ	Del
ω	Vorticity
l	Characteristic length
λ	Second viscosity

CHAPTER I

INTRODUCTION

1.1 Introduction

Modern fighter aircraft are mostly designed to carry store externally. When a store is installed externally, for example under the wing, the flowfield on its surrounding components such as the wing, the engine and the control surfaces will change considerably. The flow phenomena that may be induced or introduced could include local shock waves, flow separation and turbulence. These phenomena may extend downstream and affect other aircraft components such as the horizontal and vertical stabilizer and hence the controllability and the stability of the aircraft.

Before a store can be certified for aircraft carriage, a comprehensive store clearance program needs to be conducted. The aim of the store clearance program is to ensure that the store is safe to be carried and/or released without causing any stability and controllability difficulties to the aircraft and the store besides achieving its objective of release.

Store clearance studies may include many areas such as aerodynamic, structure, flutter, physical integration, trajectory prediction, aircraft performance and stability analysis. The overall scope is wide and involves multiple engineering disciplines. Ability to identify the changes in aerodynamic characteristics are perhaps the most critical and important. It is a prerequisite for other analysis, i.e. the aerodynamic loads data are required for subsequent aircraft structural, stability and performance analysis and the store trajectory prediction.

Aerodynamic change investigation in the external store clearance studies usually involved complex geometry (multi components with mutual interference) and complex flow field (two or more dominant flow phenomenon in a single flow). Traditionally, flow of such nature was investigated through wind tunnel testing beside empirical methods.

In recent year, Computational Fluid Dynamics (CFD) simulation has come into practice in various aerodynamics study including store clearance. CFD is basically a theoretical method using computational procedure to solve the universal conservation laws those govern the fluid flow. Latest development in this field had seen the CFD been integrated with computational structural analysis code for inter-disciplinary analysis [1]. References [2,3] presented methods of integrating CFD and six degrees of freedom (6 DOF) dynamics simulation in store trajectory analysis.

1.2 Research Objective

(i) To identify the aerodynamic interference effect to the present of external store using theoretical method, which are suitable in environment where the wind tunnel facilities and empirical data are not available.

(ii) To investigate the feasibility of using commercially available general purpose CFD code to identify the aerodynamic forces and characteristics as a result of the mutual aerodynamics interference between the external store and wing.

1.3 Research Scopes

(i) To carry out literature review on methods in determining aircraft wing and external store aerodynamics interference.

(ii) To determine the suitability of applying a commercial CFD code for predicting aerodynamic interference involving store-wing configuration at subsonic flight.

(iii) To explore the use of a 3 Dimensional measurement software to extract measurement from photographs, i.e. Photomodeler for Hawk 208 wing geometry digitization.

(iv) To construct a pressure model of an aircraft wing installed with external store and pylon and carried out wind tunnel testing.

(v) To identify the aerodynamic interference effect when a Rocket Launcher pod LAU 5003, installed externally to a simplified HAWK 208-support fighter model.

1.4 Research Methodology

This research includes comprehensive literature review on progresses in CFD application especially in complex aerodynamic interference study. Followed with validation on a commercial CFD code, i.e. Fluent 5.3 by Fluent Inc. The validation begins with simulations of a simple two dimensional, subsonic and transonic flow over NACA 0012 and RAE 2822 airfoil, respectively. Simulated results were validated with the reported data in literature.

Subsequently, wind tunnel experiments on a pressure model built based on a section of Hawk 208, support fighter's wing installed with external store were carried out. These experimental configurations were then numerically simulated using the CFD method. The results obtained from experiment and simulation were compared and formed second stage of CFD code validation.

Finally, a simplified full-scale Hawk 208 installed with LAU 5003 Rocket Launcher Pod was simulated at different flight condition. This would help to identify the effect of the external store aerodynamic interference on flowfield around the wing specifically and overall system generally.

1.5 Expected Results

It is expected that, the simulation results will be satisfactory for preliminary investigation involving aerodynamic interference at subsonic flight. The simulation results, supplemented with the experimental results, will reveal some facts on the nature of aerodynamic interference for wing-store configuration under present study.

1.6 Outline of Thesis

Chapter one generally introduces the outline of the research. Followed by literature review in chapter two, review was emphasized on the nature of problem, application of CFD method in aerodynamic interference study and the development in CFD especially in aerodynamic application.

Chapter three outlined the general research methodology and the Hawk 208 wing geometry digitization processes utilizing computer program.

Chapter four presents a validation case in which a subsonic flow over NACA 0012 airfoil was simulated. The simulation results were validated with the experimental results reported in literature.

Chapter five extends the two dimensional validation into the transonic flow regime where a transonic flow over RAE 2822 airfoil was simulated. The simulation results were again validated with the experimental results.

Chapter six outlines wind tunnel experiment of low speed flow over a wing-store configuration model. The model was built based on digitized Hawk wing section complete with external store. These wing-store configurations were then simulated using CFD method.

Chapter seven presents the final simulation study in which simplified full scales Hawk 208 aircraft flies at various angle of attack and speed were simulated. Aerodynamic interference arise from external store installation were analyzed extensively. The thesis ends with conclusion and recommendation in chapter eight.

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