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AERODYNAMIC PERFORMANCE OF AIRCRAFT PROPELLER

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This report is presented in
partial fulfillment of the requirements for the
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I hereby declare that this report entitled "Aerodynamics Performance of Aircraft Propeller" is the result of my own research except as cited in the references.

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This thesis is dedicated to my parents, Siti Fatimah Binti Salleh and Mustafa Bin Ibrahim, my brothers, sisters, Noor Masnira Binti Muhammed Salleh and other family members who provide a loving, caring, encouraging, and supportive atmosphere. These are characteristic that contribute to the environment that is always needed to achieve the goals a heads.

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ABSTRACT

The objectives of the thesis are to determine the aerodynamics performance and aerodynamic load distribution of an aircraft propeller especially Lift and Drag forces. The propeller force provides thrust which is the force created aerodynamically to push the aircraft through the air. Thus, it is important to define the aerodynamics performance of the propeller. This project is carried out by two different approaches which are the Analytical approach and Computational Fluid Dynamic (CFD) simulation using Fluent 6.3 software. Analytical Method using Propeller Blade analysis is one of the most effective methodologies available for determining the Aerodynamic Performance especially Lift and Drag force of a propeller. While the Computational Fluid Dynamic simulation using Fluent CFD software is used to simulate and capturing the aerodynamics performance of the propeller. Through both methodologies, the aerodynamic performance of the propeller was analyzed and compared. Results obtained were tabulated and the corresponding graphs were plotted. Both methods suggest that the Lift and Drag force increase with the increasing of relative velocity. There are several factors that contribute to error between the Analytical method and CFD Simulation. In conclusion, the propeller has less efficiency since the ratio of lift to drag is smaller than recommended ratio which is more than 13 for optimal performance of the propeller.

ABSTRAK

Objektif tesis ini adalah untuk mengenalpasti prestasi aerodinamik dan agihan beban aerodinamik sebuah kipas pesawat terutama daya angkat dan daya seretan. Daya kipas menghasilkan daya tujahan yang terhasil secara aerodinamik untuk menolak pesawat melalui udara. Oleh itu, adalah penting untuk mengenalpasti prestasi aerodinamik sesebuah kipas. Projek ini dilaksanakan dengan menggunakan dua kaedah iaitu kaedah Analitik dan Kaedah Dinamik Bendalir (CFD) menggunakan perisian Fluent 6.3. Kaedah Analitik menggunakan Analisis Bilah Kipas merupakan pengkaedahan yang paling efektif bersesuaian untuk mengenalpasti prestasi aerodinamik terutama daya angkat dan daya seretan. Manakala simulasi Kaedah Dinamik Bendalir menggunakan perisian Fluent CFD digunakan untuk mensimulasi dan mendapatkan prestasi aerodinamik sebuah kipas. Melalui kedua-dua kaedah ini, prestasi aerodinamik kipas dianalisa dan dibandingkan. Keputusan yang diperolehi dijadualkan dan graf yang berkaitan dilukis. Kedua-dua kaedah ini mencadangkan daya angkat dan daya seretan meningkat apabila halaju relatif meningkat. Terdapat beberapa faktor yang menyumbang kepada perbezaan antara kaedah analisis dan Simulasi CFD. Sebagai kesimpulan, Kecekapan Kipas pesawat adalah kurang kerana nisbah Daya Angkat kepada Daya Seretan lebih kecil dari nisbah yang disarankan iaitu lebih dari 13 untuk prestasi optimum Kipas pesawat.

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LIST OF ABBREVIATIONS

A	-	Axial Force
CAD	-	Computer-aided Design
CAE		Computer-aided Engineering
CATIA	-	Computer Aided Three-Dimensional Interactive Application
CFD	-	Computational Fluid Dynamic
CMM	-	Coordinate Measuring Machine
CTRM	-	Composites Technology Research Malaysia
D	-	Drag Force
GUI	-	Graphical User Interface
k	-	Number of Blade
L	-	Lift Force
M	-	Moment
N	-	Normal Force
NACA	-	National Advisory Committee for Aeronautics
r	-	Radial Distance
R	-	Resultant Aerodynamic Force/Freestream Velocity
RANS	-	Reynolds-averaged Navier–Stokes Equations
TUAV	-	Tactical Unmanned Aerial Vehicle
SIM	-	Simulation
EXP	-	Experiment

LIST OF SYMBOLS

α	-	Angle of Attack
β	-	Aerodynamic Pitch Angle
ε_b	-	Total Downwash Angle
ε_∞	-	Propeller's Forward Motion
V_b	-	Total Relative Airspeed
V_∞	-	Relative Air Velocity
ω	-	Angular Velocity
c_b	-	Local Section Chord Length
C_d	-	Drag coefficient
C_l	-	Lift coefficient
Re	-	Reynolds Number
ρ	-	Density
μ	-	Viscosity
L_{max}	-	Maximum Lift Force

CHAPTER I

INTRODUCTION

1.1 Project Background

An Aircraft Propeller is one of the most common important parts in the aircraft. It is an airfoil section designed to generate an aerodynamic force. The propeller force provides thrust to push the aircraft through the air. Thrust is the component of the aerodynamic force that is parallel to the axis of rotation. A propeller achieves a specified level of thrust by giving a relatively small acceleration to a relatively large mass of air.

Maximizing thrust while minimizing the torque necessary to turn a propeller has becomes one of the most important aspects of good propeller design. The torque required to turn the propeller multiplied with the angular velocity is called the brake power. It is the power that must be supplied by the engine. The thrust developed by the propeller multiplied by the airspeed of the aircraft is called the propulsive power. This is the useful power that is provided to propel the aircraft forward against the airframe drag. The ratio of the propulsive power to the brake power for a propeller is called the propulsive efficiency which is one of important measure of propeller performance. The thrust developed by the propeller when the aircraft is not moving is called the static thrust. This thrust is important for a propeller to produces high static thrust in order to accelerate the aircraft during takeoff.

In order to analyze the aerodynamic performance of the propeller, Computational Fluid Dynamic (CFD) software is used to simulate the fluid flow over a body to solve and analyze the aerodynamic properties of a body. While, analytical approach will be used to compare the result gather from CFD simulation.

1.2 Problem Statement

Aircraft propeller evaluation in terms of aerodynamic performance is a critical aspect in designing an aircraft propeller. Propeller used to generate thrust that pushes the aircraft through the air. Thus, it is important to determine the aerodynamic performance and the aerodynamic load distribution over the propeller body. Since the airframe of an aircraft is induced by the drag on the air, the propeller needs to provide enough thrust to overcome the drag. There are several tools and method that can be used to analyze the aerodynamic performance of an aircraft propeller such as the Computational Fluid Dynamic simulation.

1.3 Objectives

The objectives of this thesis are:

a) To determine aerodynamic performance of an aircraft propeller especially Lift and Drag forces using analytical and CFD approaches.
b) To determine aerodynamic load distribution of an aircraft propeller.

1.4 Scope of Project

The scope of the project is focused on the aerodynamic performance of aircraft propeller. Research is made to understand the aircraft propeller in general. Computational Fluid Dynamics (CFD) software is used to analyze and simulate the propeller in terms of aerodynamic performance and aerodynamic load distribution. The result of manual calculation and CFD software is compared.

1.5 Summary

This chapter is introducing the project background and the objective of the project. In addition, the problem statement and scope of study also being clarify in order to limit the range of this project conduct.

CHAPTER II

LITERATURE REVIEW

2.1 Introduction

This literature review explores the dominant themes includes study and research of published materials like journals, thesis, case study, technical document, and online library. Generally, the purpose of a review is to analyze critical segment of a published body of knowledge through summary, classification and comparison of prior research studies, reviews of literature, and theoretical articles.

This chapter describes topics that related to propeller aerodynamics such as propeller theory, propeller geometry and parameters, aerodynamics forces and Computational Fluid Dynamic. Emphasize is more on aerodynamics force on the propeller blade and also the computational fluid dynamic approach and simulation.

Propeller is focused more on the definition of that phase, the historical development of propeller, the parameter governing propeller design, and the available propeller airfoil. Moreover, the Aerodynamic force will describe about the forces acting on the propeller and its analytical approach.

2.2 Introduction to Propeller

The airplane propeller consists of two or more blades and a central hub to which the blades are attached. Each blade of an airplane propeller is essentially a rotating wing. As a result of their construction, the propeller blades are like airfoils and produce forces that create the thrust to pull, or push, the airplane through the air.

The power needed is supplied by the engine to rotate the propeller blades. The engine rotates the airfoils of the blades through the air at high speeds, and the propeller transforms the rotary power of the engine into forward thrust. As the air flows past the propeller, the pressure on one side of propeller is less than that on the other. As in a wing, this produces a reaction force in the direction of the lesser pressure. Propeller is mounted in a vertical plane, the area of lower pressure is in front of the propeller. Thus the thrust force is created in a forward direction.

Drag force that oppose the forward motion of an aircraft will be created as it moving through the air. Consequently, if an aircraft fly, there must be a force applied to it that is equal to the drag force, but acting in opposite direction. This force is called as the "thrust."

2.2.1 Historical Development of Propeller Theory

Development of a rational propeller theory begins with the work of Rankine and Froude with their interest in moving propulsion, but the fundamental principle is the same for water and air. They developed the fundamental momentum relation governing a propulsive device in fluid medium. (Wald Q. R, 2006)

Dvzewiercki (1892) develop the theory of propeller action where blade element were considered as individual lifting surface moving through medium on a helical path. In this