Mechatronics Skripsie Proposal

Mechatronic Project 478
Final Report

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Executive summary

Title of Project
...
Objectives
...
What is current practice and what are its limitations?
...
What is new in this project?
...
If the project is successful, how will it make a difference?
...
What are the risks to the project being a success? Why is it expected to be successful?
...
What contributions have/will other students made/make?
...
Which aspects of the project will carry on after completion and why?
...
What arrangements have been/will be made to expedite continuation?
...

Acknowledgements

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Constants

$L_0 =$ 300 mm

Variables

Re_{D}	Reynolds number (diameter)	[ ]
x	Coordinate	[m]
$\ddot{x}$	Acceleration	[m/s^2]
θ	Rotation angle	[rad]
τ	Moment	[N·m]

Vectors and Tensors

$\vec{\boldsymbol{v}}$ Physical vector, see equation ...

Subscripts

a Adiabatic

a Coordinate

Abreviations

DEM Discrete Element Method

FEA Finite Element Analysis

Chapter 1

Introduction

1.1 Background

Helicopters are said to be the only aircraft that, since its conception, has saved more lives than they have taken. Their high level of mobility, vertical take off and landings and their ability to hover give helicopters great versatility. Helicopters are the most common example of a rotary aircraft and are used in environments ranging from rocky, mountainous to stormy seas. With such high stakes it is vital to minimize points of potential failure. One of these failure points is the helicopter's tail rotor. It is required to counter the toque produced by the engine which rotates the main rotor to produce lift. If the tail rotor were to stop working, the helicopter would lose its controllability and would have to land immediately. A jet-tipped rotary aircraft places the propulsion on the tips of the aircraft's rotor and thus does not produce any toque that needs to be canceled, eliminating the need of a tail rotor. As the tail rotor is connected to the same engine that operates the rotor, transmission of the rotation to the tail rotor increases complexity of the helicopter.

This project will research, design, construct and test a jet-tipped rotary aircraft which will actuate the pitch of the rotor the use of propulsion situated at the tip of the blades. Traditional rotary wing aircraft change the rotor's pitch for portions of its rotation, this creates an unbalanced, causing the aircraft to move in the desired direction. Different methods for directional thrust will investigate varying from traditional methods to using the propulsion force itself to control the direction of the aircraft.

This project, which is prepared for Mechanical Project 448 and prepared by Mr RA Krüger, was proposed by the student after devising the concept with Dr A Gill. The research and results from this project hopes to further the development of tip-propelled rotary aircraft, which currently is a relatively unresearched field. Stated below include the projects scope, objectives, literature review, motivation and planning of the project are outlined.

1.2 Objectives

The objectives of the project (in some cases the objectives of the report). If necessary describe limitations to the scope.

1.3 Motivation

Why this specific project/report is worth while.

Chapter 2

Objectives

2.1 Scope and limitations

As previously mentioned this project aims to research, design, build and test a tip-propelled rotary aircraft. The tip-propulsion should vary the pitch of the rotor such that at lower propulsion, the pitch will have a higher pitch, there by increasing the lift generated. As propulsion is increased, the pitch lessens, decreasing the lift produced, but also decreasing the drag generated by the rotor. The final design should prove controllability, but does not need to achieve sustained flight, and thus showing that the aircraft can produce lift in the desired direction will suffice. While a basic understanding of rotor design can be applied to the aircraft's main rotor, it is not the focus of the project and thus no computational fluid dynamics are required either.

2.2 Objectives

The objectives of this project are as follows:

1. Construct a working prototype of the created design
2. Implement a method to produce directional thrust
3. Implement a control system for the tip-propulsion
4. Test and analyse the prototype

2.3 Research questions

2.3.1 Can the aircraft be fully controlled using the tip propulsion alone?

2.3.2 What is the efficiency of the aircraft?

2.3.3 How much thrust can the aircraft produce?

2.3.4 Which control system method works best?

2.3.5 How stable is the system?

2.4 Motivation

As previously mentioned, tip-propelled rotary aircraft remove the need for a tail rotor as they do not produce a torque which needs to be canceled. Traditional shaft-drive helicopters need an engine-to-rotor power transmission to the main rotor and tail rotor. The output shaft goes into a high rpm/ low torque gearbox and converts the input to low rpm/ high torque output to drive the rotor.

Chapter 3

Literature Review

3.1 Historical development

The advantage of the [[Jet-Tipped Helicopter]] is the omission of the transmission and [[tail rotor]], thus making it more simple and cheaper to produce. The decreased weight allows it to have a larger payload. No need for a high-speed gear boxes, clutches, transmission shafts, oil system w/ tanks .

3.2 Rotary wing control system and stability

The objectives of the project (in some cases the objectives of the report). If necessary describe limitations to the scope.

3.3 Current state of the art

Why this specific project/report is worthwhile.

Appendix A

Mathematical proofs

A.1 Euler's equation

Euler's equation gives the relationship between the trigonometric functions and the complex exponential function.

$$e^{i\theta} = \cos\theta + i\sin\theta \tag{A.1}$$

Inserting $\theta = \pi$ in (A.1) results in Euler's identity

$$e^{i\pi} + 1 = 0 \tag{A.2}$$

A.2 Navier Stokes equation

The Navier–Stokes equations mathematically express momentum balance and conservation of mass for Newtonian fluids. Navier-Stokes equations using tensor notation:

$$\frac{\partial \rho}{\partial t} + \frac{\partial}{\partial x_j}\left[\rho u_j\right] = 0 \tag{A.3a}$$

$$\frac{\partial}{\partial t}\left(\rho u_i\right) + \frac{\partial}{\partial x_j}\left[\rho u_i u_j + p\delta_{ij} - \tau_{ji}\right] = 0, \quad i = 1, 2, 3 \tag{A.3b}$$

$$\frac{\partial}{\partial t}\left(\rho e_0\right) + \frac{\partial}{\partial x_j}\left[\rho u_j e_0 + u_j p + q_j - u_i\tau_{ij}\right] = 0 \tag{A.3c}$$

Appendix B

Experimental results

List of references