DYNAMIC STABILITY
ON LATERAL DIRECTIONAL OF AN AIRCRAFT USING AILERON

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DECLARATION

I declare that this project report entitled "Dynamic Stability on Lateral Directional of An Aircraft Using Aileron" is the result of my own work except as cited in the references.

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Date : 6 JUNE 2018
....

APPROVAL

I hereby declare that I have read this project report and in my opinion this project report is sufficient in terms of scope and quality for the award of degree of Bachelor of Mechanical Engineering (with Honours).

Signature : ....

Name : PROF. MADYA AHMAD RIVAI

Date : 6 JUNE 2018

DEDICATION

Dedicated to my beloved father and mother,

my friends and family members.

For their encouragement and supports throughout the research.

ABSTRACT

The dynamic stability analysis of the aircraft can be evaluated in two dimensional modes: longitudinal stability analysis and lateral directional stability analysis. This present work focuses on the second mode which is lateral directional. The dynamic stability analysis is carried out by evaluating the behavior of three flight parameter due to aileron deflection. These three flight parameters are sideslip angle ß, roll angle Ø and yaw angle ψ. These three flight parameters describe the behavior of the aircraft in lateral directional and it can be obtained by solving the governing equation of lateral directional. In this present work, a computer code is developed in MATLAB software to solve the governing equation of flight motion using Laplace transformation. The validation was carried out by comparing the results for the lateral directional of aircraft model Learjet 24 with the results provided by Marcello R. Napolitano (2012). After that, the developed computer code in MATLAB is applied to all three types of aircraft models for flight dynamic analysis. These three types of aircraft models are Cessna 182, Cessna 310, and Cessna 620. The developed computer code in MATLAB provides four types of aileron deflection, namely single doublet impulse, multiple doublet impulse, single doublet and multiple doublet. The results show that each aircraft has different response due to the deflection of aileron and the developed computer code represents a useful tool for flight dynamic analysis.

ABSTRAK

Analisis kestabilan dinamik penerbangan dapat dilakukan melalui dua mod dimensi, iaitu analisis kestabilan arah bujur dan arah sisi. Kajian ini memberi tumpuan kepada mod yang kedua, iaitu analisis kestabilan arah sisi. Analisis kestabilan ini dilakukan untuk menilai kelakuan tiga parameter akibat daripada pesongan aileron. Ketiga-tiga parameter penerbangan ini adalah sudut sisi ß, sudut roll Ø dan sudut yaw ψ. Ketiga-tiga parameter penerbangan ini menggambarkan kelakuan sesebuah kapal terbang dari arah sisi dan ia dapat diperolehi dengan menyelesaikan persamaan bagi arah sisi. Dalam kajian ini, kod komputer dibangunkan dalam perisian MATLAB untuk menyelesaikan persamaan gerakan dengan penggunaan transformasi Laplace. Pengesahan telah dilakukan dengan membandingkan keputusan untuk arah model kapal terbang Learjet 24 dengan keputusan yang diperolehi daripada Marcello R. Napolitano (2012). Selepas itu, kod komputer yang dibangunkan di perisian MATLAB digunakan untuk membuat analisis kestabilan dinamik penerbangan bagi tiga jenis model kapal terbang. Ketiga-tiga jenis model kapal terbang ini adalah Cessna 182, Cessna 310, dan Cessna 620. Kod komputer di perisian MATLAB ini menyediakan empat jenis pesongan aileron, iaitu dorongan doublet tunggal, dorongan doublet berganda, doublet tunggal dan doublet berganda. Keputusan bagi kajian ini menunjukkan bahawa setiap kapal terbang mempunyai tindak balas yang berbeza terhadap pesongan aileron dan kod komputer yang dibangunkan merupakan alat yang amat berguna untuk analisis kestabilan dinamik penerbangan.

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LIST OF ABBREVIATIONS

D_1	Denominator
AOA	Angle of Attack
CG	Center of Gravity
FLC	Fuzzy Logic Controller
LQR	Linear Quadratic Regulator
Num	Numerator
STFLC	Self-Tuning Fuzzy Logic Controller

LIST OF SYMBOLS

a	=	Aileron
AR	=	Aspect Ratio
b	=	Wingspan
c	=	Chord
C_{l_p}	=	The Variation of Rolling Moment Coefficient with Roll Rate.
C_{l_r}	=	The Variation of Rolling Moment Coefficient with Yaw Rate.
C_{l_β}	=	The Variation of Rolling Moment Coefficient with Sideslip Angle.
$C_{l_{\delta_A}}$	=	The Variation of Rolling Moment Coefficient with Aileron Deflection.
$C_{l_{\delta_R}}$	=	The Variation of Rolling Moment Coefficient with Rudder Deflection.
C_{n_p}	=	The Variation of Yawing Moment Coefficient with Roll Rate.
C_{n_r}	=	The Variation of Yawing Moment Coefficient with Yaw Rate.
C_{nT_β}	=	The Variation of Yawing Moment Coefficient with Thrust
C_{n_β}	=	The Variation of Yawing Moment Coefficient with Sideslip Angle.
$C_{n_{\delta_A}}$	=	The Variation of Yawing Moment Coefficient with Aileron Deflection.
$C_{n_{\delta_R}}$	=	The Variation of Yawing Moment Coefficient with Rudder Deflection.
C_{Y_p}	=	The Variation of Side Force Coefficient with Roll Rate.

C_{Y_r} = The Variation of Side Force Coefficient with Yaw Rate.

C_{Y_β} = The Variation of Side Force Coefficient with Sideslip Angle.

$C_{Y_{\delta_A}}$ = The Variation of Side Force Coefficient with Aileron Deflection.

$C_{Y_{\delta_R}}$ = The Variation of Side Force Coefficient with Rudder Deflection.

g = Acceleration of Gravity

h = Altitude

I = Characteristic Length

I_{XXB} = Moment of Inertia x-axis

I_{XZB} = Product of Inertia x and z-axis

I_{YYB} = Moment of Inertia y-axis

I_{ZZB} = Moment of Inertia z-axis

L = Sum of the Component of Moment in x axes

L_p = Rolling Moment with Roll Rate.

L_r = Rolling Moment with Yaw Rate.

L_β = Rolling Moment with Sideslip Angle.

$L_{\delta A}$ = Rolling Moment with Aileron Deflection.

$L_{\delta R}$ = Rolling Moment with Rudder Deflection.

M = Sum of the Component of Moment in y axes

M = Mach Number

m = Mass of Aircraft

N = Sum of the Component of Moment in z axes

N_r = Yawing Moment with Yaw Rate.

$N_{T\beta}$ = Yawing Moment with Thrust

N_β = Yawing Moment with Sideslip Angle.

$N_{\delta A}$ = Yawing Moment with Aileron Deflection.

$N_{\delta R}$ = Yawing Moment with Rudder Deflection.

p = Component of Rotational Velocity about x axes

q = Component of Rotational Velocity about y axes

Q = Dynamic Pressure

q_1 = Dynamic Pressure

r = Component of Rotational Velocity about z axes

S = Reference Area

u = Instantaneous Linear Velocity in x axes

U = Axial Velocity

U_1 = Air Speed

v = Instantaneous Linear Velocity in y axes

v = Sideslip Velocity

V = Total Velocity Vector

w = Instantaneous Linear Velocity in z axes

X = Sum of the Component of Forces in x axes

x_{cg} = Location of CG-%MAC

Y = Sum of the Component of Forces in y axes

y = Length from Longitudinal Axis

Y_p = Side Force with Roll Rate.

Y_r = Side Force with Yaw Rate.

Y_β = Side Force with Sideslip Angle.

$Y_{\delta A}$	=	Side Force with Aileron Deflection.
$Y_{\delta R}$	=	Side Force with Rudder Deflection.
Z	=	Sum of the Component of Forces in z axes
β	=	Sideslip Angle
Γ	=	Dihedral Angle
C_l	=	Coefficient of Rolling Moment
C_{Law}	=	Coefficient of Lift due to Wing
Cm	=	Coefficient of Yawing Moment
Cn	=	Coefficient of Pitching Moment
Cx	=	Coefficient of Force in x axes
Cy	=	Coefficient of Force in y axes
Cz	=	Coefficient of Force in z axes
L_F	=	Lift Generated due to Fin
N_p	=	Yawing Moment with Roll Rate.
α	=	Angle of Attack
δ	=	Deflection
δ_A	=	Deflection of Aileron
τ	=	Taper Ratio
ψ	=	Yawing Angle
ϕ	=	Roll Angle

CHAPTER 1

INTRODUCTION

1.1 Background of Study

After the first flight made by Wilbur and Orville Wright in 1903, there was a rapid development in aeronautical and the progress and study made in the following decade was impressive. However, the flying qualities of their aircraft that time were always less than satisfactory due to the problems of stability and control. Many researchers like Bryan and Lanchester were studying the problems of stability and control at that time and they managed to come out with mathematical method to describe the flight dynamic and the general equations of motion of an aircraft with six degrees of freedom to describe the aircraft motion which it is in the same form as they are known today. (Anderson & Eberhardt, 2001)

Stability and control are study on how well an aircraft flies and how easily the aircraft can be controlled. Stability is the ability of an aircraft to return to a previous condition if it is upset by disturbance. The disturbance can be generated by the pilot' s action or atmospheric phenomena such as turbulence or a gust of air. An aircraft must have a good stability so that the pilot does not become tired by keep having to control the aircraft in order to make it stable. Whereas control is the ability to command the aircraft to perform a specific maneuver or to