THE DEVELOPMENT OF A FIXED WING AIRCRAFT ANALYSIS AND DESIGN FLIGHT DYNAMIC SOFTWARE

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ABSTRACT

The present work focused on the development of computer software for flight dynamic analysis and controlling the behavior of a fixed-wing aircraft. For a given aircraft geometry, mass and inertia properties, and flight conditions, the software was designed in such a way to start the estimation of aerodynamic characteristics, trimmed flight, stability analysis through linearized approach as well as non-linearized, and finally the control design of the flying behavior by using PID controller method. The estimation of aerodynamic characteristics used the semi-empirical aerodynamic method as used by Roskam. The trimmed flight conditions were solved through trimmed flight equations iteratively. The linearized form of flight dynamic equations in longitudinal as well as in lateral direction were solved using the transfer function approach and state-space method. Whilst, non-linear flight dynamic equations were solved using the Simulink. Three different PID controller designs were developed to control the aircraft to follow a particular flight behavior. The developed computer code was written in MATLAB programming language and grouped into several modules. The validation results were carried out by comparing the results of each module to other results available in the literature. The developed computer code was applied to the case of five aircraft. They were named Cessna 182, Cessna 310, Piper Cherokee PA 28-162, Learjet 24, and Cessna 620. The first three aircraft were propeller piston engine aircraft. The fourth aircraft was a jet engine aircraft while the fifth aircraft represented a turboprop aircraft. The flight dynamics behavior motion which consisted of 22 flight variables were obtained by solving the governing equation of flight after the aerodynamic characteristics data were established and the trimmed fight conditions were solved. A particular flight variable can be set up to have a particular behavior that follows the movement of the control surface operations. Various control surface movements were simulated to ensure the

designed PID controller was really providing a particular flight behavior. Through the implementation of five types of aircraft models, the developed computer code represents a useful tool for flight dynamic analysis and control design for a fixed-wing aircraft.

ABSTRAK

Kajian ini memfokuskan pembangunan perisian komputer untuk menganalisis dinamik penerbangan dan kawalan tingkah laku pesawat bersayap tetap. Perisian bagi sesuatu pesawat direka berdasarkan geometri, sifat seperti jisim dan inersia, dan keadaan penerbangan. Perisian tersebut digunakan untuk membuat anggaran awal bagi ciri-ciri aerodinamik, potongan sayap pesawat, analisis kestabilan melalui pendekatan linear dan juga tak linear, disusuli dengan kawalan reka bentuk perilaku penerbangan dengan menggunakan kaedah pengawal PID. Penganggaran ciri aerodinamik dibuat dengan menggunakan kaedah aerodinamik separa empirikal sebagaimana yang diguna pakai oleh Roskam. Keadaan potongan sayap pesawat diselesaikan melalui persamaan potongan sayap pesawat secara lelaran. Persamaan dinamik penerbangan berbentuk linear dalam arah membujur dan juga sisi diselesaikan dengan menggunakan pendekatan fungsi pemindahan dan kaedah ruang keadaan. Seterusnya, persamaan dinamik penerbangan tak linear diselesaikan dengan menggunakan Simulink. Tiga buah reka bentuk pengawal PID yang berbeza dibangunkan untuk mengawal pesawat supaya mengikut tingkah laku penerbangan tertentu. Kod komputer yang dibangunkan ditulis dalam bahasa pengaturcaraan MATLAB dan dikumpulkan dalam beberapa modul. Keputusan pengesahan dijalankan dengan membandingkan keputusan setiap modul dengan keputusan yang terdapat dalam kajian terdahulu. Kod komputer yang dibangunkan kemudiannya diaplikasikan pada lima kes pesawat. Model pesawat tersebut dikenali sebagai Cessna 182, Cessna 310, Piper Cherokee PA 28-162 , Learjet 24 dan Cessna 620. Tiga pesawat pertama yang disenaraikan merupakan pesawat berenjin omboh bebaling. Pesawat keempat merupakan pesawat berenjin jet, manakala pesawat kelima mewakili pesawat berenjin turboprop. Tingkah laku gerakan dinamik penerbangan yang terdiri daripada 22 pemboleh ubah penerbangan diperoleh dengan

menyelesaikan persamaan penentu penerbangan setelah data berkenaan ciri aerodinamik dibangunkan dan keadaan potongan sayap pesawat diselesaikan. Pemboleh ubah penerbangan tertentu boleh ditetapkan dengan tingkah laku tertentu mengikut pergerakan operasi permukaan kawalan. Pelbagai pergerakan permukaan kawalan disimulasikan untuk memastikan pengawal PID yang direka benar-benar menepati tingkah laku penerbangan tertentu. Melalui pelaksanaan lima jenis model pesawat, kod komputer yang dibangunkan menjadi alat yang berguna untuk menganalisis dinamik penerbangan dan reka bentuk kawalan bagi pesawat bersayap tetap.

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LIST OF SYMBOLS

U	-	X-direction trim velocity
V	-	Y-direction trim velocity
W	-	Z-direction trim velocity
u	-	Velocity in X-direction
v	-	Velocity in Y-direction
V_t	-	Total velocity
w	-	Velocity in Z-direction
θ	-	Pitch angle
Ψ	-	Yaw angle
ϕ	-	Roll angle
α	-	Angle of attack
β	-	Side slip angle
γ	-	Flight path angle.
p	-	Roll rate
q	-	Pitch rate
r	-	Yaw rate
L	-	Rolling moment
M	-	Pitching moment
N	-	Yawing moment
I_{xx}	-	Moment of inertia about X-axis
I_{yy}	-	Moment of inertia about Y-axis
I_{zz}	-	Moment of inertia about Z-axis
T	-	Thrust
C_x	-	The aircraft axial force coefficient
C_Y	-	The aircraft side force coefficient

C_z	-	The aircraft normal force coefficient
C_ι	-	The aircraft rolling moment coefficient
C_m	-	The aircraft pitching moment coefficient
C_n	-	The aircraft yawing moment coefficient
N	-	The engine rotational speed in radian
I_{xe}	-	The engine moment of inertia of the rotating mass
$\bar{q}$	-	The dynamic pressure is equal to $\frac{1}{2}\rho(\vec{V})^2$
C.G	-	Aircraft's center of gravity
S	-	The wing area reference
S_H	-	Horizontal tail area
i_w	-	Wing incidence angle
b	-	The wing span.
ρ	-	The air density
C_L	-	Aircraft lift coefficient
C_D	-	Aircraft drag coefficient
m	-	Aircraft mass
C_Y	-	Aircraft side force coefficient
V_t	-	Total velocity
δ_e	-	Elevator deflection angle
δ_a	-	Aileron deflection angle
δ_r	-	Rudder deflection angle
δ_{th}	-	Aircraft engine thrust
t	-	Time
C_A	-	Axial force coefficient
C_N	-	Normal force coefficient
Θ	-	Wing twist angle
x_E	-	Distance in X-direction
y_E	-	Distance in y-direction
h	-	Flight altitude
d_f	-	Aircraft fuselage average width
M	-	Mach number

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