الآية

بسم الله الرحمن الرحيم

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صدق الله العظيم

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ABSTRACT

The design of an aircraft autopilot controller that provides a fast and stable response to pilot commands, and which maintains this performance throughout the entire flight envelope, provides a challenging problem to flight control engineers.

The main objective of this thesis is to design a longitudinal autopilot system for a business jet aircraft. To be more specific, the autopilot system that is designed is a pitch-attitude controller.

It is assumed that the aircraft under investigation is subjected to some degree changes in elevator angle, which in turn, causes an oscillatory motion of the airplane. In order to minimize the effect of these oscillations, a proportional (P) controller, proportional-integral (PI) controller and a proportional-integral-derivative (PID) controller are designed for both, the short and long periods of motions.

For the short period of motion, it is found that the P controller is the optimal controller. On the other hand, the PID controller is found to be the optimal controller for long period of motion.

مستخلص

إن تصميم متحكمة لنظام طيّار آلي، بحيث توفر استجابة سريعة ومستقرة لأوامر الطيّار، مع المحافظة على هذا الأداء طوال فترة الرحلة، يظل هو التحدى الذى يواجه مهندسى نظم التحكم فى الطيران.

ولذلك فإن الهدف الرئيسى لهذه الأطروحة هو تصميم نظام طيار آلى طولى لطائرة تجارية نفاثة، ولنكون أكثر دقة، تصميم نظام لمتحكمة تستجيب بسرعة ودقة حسب الظروف.

تم افتراض أن الطائرة قيد الدراسة قد أخضعت لبعض التغيرات فى زاوية الصعود مما أدى الى تذبذب فى حركة الطائرة. ومن أجل تقليل هذه التذبذبات تم تصميم بعض المتحكمات وهى: المتحكمة النسبية، المتحكمة النسبية التكاملية، المتحكمة النسبية التكاملية االتفاضلية، لكل من فترتى الحركة القصيرة والطويلة.

لفترات الحركة القصيرة وجُد أن النظام المثالى لها هو نظام المتحكمة النسبية. كما أن نظام المتحكمة النسبية التكاملية التفاضلية هو الأنسب للفترات الطويلة.

DEDICATION

To the soul of my great father who gave me the meaning of patience and wisdom

To my unique mother who taught me the meaning of faith and diligence

To my beloved husband who made my life bright and meaningful

To my dear daughters who brought the essence of perfect happiness to my life

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NOMENCLATURE

A	State matrix
B	Input matrix
C	Output matrix
cg	Center of gravity
C_D	Drag coefficient
C_L	Lift coefficient
D	Direct matrix
g	Gravity
I	Identity matrix
I_x	Moment of inertia in roll
I_y	Moment of inertia in pitch
I_z	Moment of inertia in yaw
I_{xy}	Product of inertia about *ox* and *oy* axes
I_{xz}	Product of inertia about *ox* and *oz* axes
I_{yz}	Product of inertia about *oy* and *oz* axes
k	General constant
k_q	Pitch rate transfer function gain constant
k_u	Axial velocity transfer function gain constant
k_w	Normal velocity transfer function gain constant
k_θ	Pitch attitude transfer function gain constant
K_{cr}	Critical gain

K_d	Derivative gain
K_i	Integral gain
K_p	Proportional gain
K_{pu}	Ultimate proportional gain
L	Rolling moment
m	Mass
M	Pitching moment
N	Yawing moment
$N_{\delta_e}^{\theta}$	A shorthand notation to denote a transfer function numerator polynomial relating the pitch attitude response θ (output) to elevator δ_e(input).
p	Roll rate
P	Proportional controller
PI	Proportional-Integral controller
PID	Proportional-Integral-Derivative controller
P_{cr}	Critical period
q	Pitch rate
r	Yaw rate
S	Wing area
T	Time constant
T_d	Derivative time constant
T_i	Integral time constant
T_s	Spiral mode time constant
T_u	Numerator zero in axial velocity transfer function
T_w	Numerator zero in normal velocity transfer function
T_θ	Numerator zero in pitch rate and attitude transfer function
T.F	Transfer Function
u	Axial velocity perturbation

U	Total axial velocity
U_e	Axial component of steady equilibrium velocity
v	Lateral velocity perturbation
V	Total lateral velocity
V_e	Lateral component of steady equilibrium velocity
V_0	Steady equilibrium velocity
w	Normal velocity perturbation
W	Total normal velocity
W_e	Normal component of steady equilibrium velocity
x	*ox* axis (longitudinal axis)
X	Axial force component
$\overset{o}{X}_u$	A shorthand notation to denote the dimensional derivative $\frac{\partial X}{\partial u}$.
X_u	A shorthand notation to denote the dimensionless derivative $\frac{\partial \hat{X}}{\partial \hat{u}}$.
y	*oy* axis (lateral axis)
Y	Lateral force component
z	oz axis (vertical axis)
Z	Normal force component
ρ	Air density
ζ	Rudder angle perturbation, Damping ratio
ζ_p	Long-period (Phugoid) damping ratio
ζ_s	Short-period pitching oscillation damping ratio
ω	Undamped natural frequency
ω_p	Long-period natural frequency
ω_s	Short-period pitching oscillation natural frequency

α	Angle of attack or incidence
α_e	Equilibrium incidence
Δ	Characteristic polynomial
δ_e	Elevator angle perturbation
δ_m	Mass increment
θ	Pitch angle perturbation
θ_e	Equilibrium pitch angle
ϕ	Roll angle perturbation
ψ	Yaw angle perturbation
ε	Throttle lever angle
ξ	Ailerons angle
τ	Engine thrust perturbation