Abstract

This research includes the design of a multivariable control system for aircraft wings. Two objectives are desired. The first is to control the vibrational problem for low-speed flight by applying a feedback control strategy. The second goal is to demonstrate that the controller for this wing assembly dissipates the least energy by comparing an alternative controller design technique. Simple procedures using established methods relating the wing vibrational problems, are outlined. The control strategies invoked using a simplified flutter dynamic model. A compensator designed to provide enhanced flutter suppression was employed. The transient performance of the system was computed for various flight velocities. Comparison of the energy dissipation for the gain ratios investigated was obtained. Numerical simulation was used to demonstrate the effectiveness of the approach advocated.

DEDICATION

I dedicate this dissertation to the three pillars of my life:

God and my parents.

Without you, my life would fall apart.

I might not know where the life's road will take me, but walking with You, God, through this journey has given me strength.

Mom, you have given me so much, thanks for your faith in me, and for teaching me that I should never surrender.

Daddy, you are everything for me, without your love, understanding and support, I would not be able to make it.

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Notations and Abbreviations

$A(s)$	numerator of $G(s)$
$A_n(s)$	invariant impedance model of degree n relating leading and trailing edge acceleration, velocity and displacements to applied forces
A_0	inertia or mass matrix (2×2)
A_1	damping or frictional matrix (2×2)
A_2	stiffness matrix (2×2)
$A_2(s)$	polynomial impedance matrix of degree 2 (2×2)
a_1	coefficient of compensator
a_2	coefficient of compensator
B	velocity-dependant damping matrix (2×2)
$b(s)$	Polynomial
$b_\circ$	controller gain
b_1	coefficient of compensator
b_2	coefficient of compensator
C	velocity-squared-dependant stiffness matrix (2×2)
$C(s)$	Laplace transformed compensator transfer function

C_1	capacitor
C_2	capacitor
$E(t)$	control energy
E_1	input voltage
E_2	output voltage
F	outer loop feedback gain matrix (2×2)
f_1	outer loop feedback gain
f_2	outer loop feedback gain
$f(t)$	input vector (1×2)
$f(s)$	transformed leading and trailing edge force vector (1×2)
$f_l(s)$	leading edge force
$f_t(s)$	trailing edge force
$\delta(s)$	force disturbance vector (1×2)
$\delta_1(s)$	disturbance
$\delta_2(s)$	disturbance
$G(s)$	Laplace transformed system transfer function matrix
$G_0(s)$	Laplace transformed system transfer function matrix at zero velocity

$g_{11}(s)$	transfer function
$g_{12}(s)$	transfer function
$g_{21}(s)$	transfer function
$g_{22}(s)$	transfer function
$h(s)$	forward path inner loop compensator
h_1	forward path inner loop gain
h_2	forward path inner loop gain
$H(s)$	feedback path controller gain
H_∞	optimal control
$J(n)$	performance index
$k(s)$	feedback path inner loop compensator
k_1	feedback path inner loop gain
k_2	feedback path inner loop gain
$K(s)$	forward path controller
n, n_1, n_2	gain ratio
P	outer loop feedback gain
$q(s)$	output vector (1×2)

$q_1(s)$	leading edge deflection
$q_2(s)$	trailing edge deflection
$Q(n)$	coefficient matrix
$r(s)$	reference input
$\bar{r}(s)$	reference input
R_1	resistance
R_2	resistance
R_3	resistance
R_4	resistance
R_5	resistance
R_6	resistance
R_7	resistance
R_8	resistance
R_9	resistance
s	Laplace variable
S_s	steady-state matrix
$u(s)$	open loop input vector (1×2)

v	air speed
$v_{\max}$	maximum air speed for wing model
v_a	node voltage
v_b	node voltage
v_c	node voltage
v_d	node voltage
x	closed loop generated zero
$y(s)$	output vector (1×2)
Z_1	impedance
$\Delta(s)$	denominator of $G(s)$
$\Delta_0(s)$	denominator of $G_0(s)$

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