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Understanding Pilot Biodynamical Feedthrough Coupling in Helicopter Adverse Roll Axis Instability via Lateral Cyclic Feedback Control

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The paper reassesses the mechanism of biodynamical feedthrough coupling to helicopter body motion in lateral-roll helicopter tasks. An analytical bio-aeroelastic pilot-vehicle model is first developed and tested for various pilot's neuromuscular adaptions in the lateral/roll axis helicopter tasks. The results demonstrate that pilot can destabilize the low-frequency regressing lead-lag rotor mode; however he/she is destabilizing also the high-frequency advancing lag rotor mode. The mechanism of pilot destabilization involves three vicious energy circles, i.e. lateral - roll, flap - roll and flap – lag motions, in a very similar manner as in the air resonance phenomenon. For both modes, the destabilization is very sensitive to an increase of the steady state rotor coning angle that increases the energy transfers from flap to lag motion through Coriolis forces. The analytical linear time-invariant model developed in this paper can be also used to investigate designs proneness to lateral/roll aeroelastic rotorcraft-pilot couplings.

Nomenclature

x	=	airframe lateral translation (m)
a_x	=	airframe lateral acceleration (m/s²)
z	=	airframe vertical translation (m)
α_y	=	airframe roll angle (rad)
$\beta_i, \delta_i, \theta_i$	=	individual blade flap, lag and pitch angles (rad)
$\beta_0, \beta_{1c}, \beta_{1s}$	=	collective and cyclic blades flap angles (rad)
$\delta_0, \delta_{1c}, \delta_{1s}$	=	collective and cyclic blades lag angles (rad)
$\theta_0, \theta_{1c}, \theta_{1s}$	=	collective and cyclic blades pitch angles (rad)
b	=	main rotor number of blades
R	=	rotor radius (m)
e	=	blade root eccentricity (m)
γ	=	lock number
Ω	=	main rotor angular velocity (rad/s)
β_{0ss}	=	steady-state coning angle (rad)
m_s	=	individual blade static moment at blade root (m.kg)
I_{bl}	=	individual blade inertia at blade root (m².kg)
M_{bl}	=	individual blade mass (kg)
k_δ	=	individual blade equivalent angular lag damper stiffness (N.m/rad)
c_δ	=	individual blade equivalent angular lag damper damping (N.m.s/rad)
M_f	=	helicopter mass (kg)
I_{yy}	=	airframe roll inertia around its center of mass (m².kg)

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