Indian Institute of Technology Bombay

Flight Mechanics/Dynamics

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Tutorial 5

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Objectives

- To have a linear systems perspective in studying aircraft flight dynamics.

Problem 1. Consider the linearized unforced longitudinal dynamics of an aircraft

$$\begin{bmatrix} \delta\dot{u} \\ \dot{w} \\ \dot{q} \\ \delta\dot{\theta} \end{bmatrix} = \begin{bmatrix} -0.0212 & 0.0466 & 0 & -32.174 \\ -0.2229 & -0.5839 & 262.472 & 0 \\ 0.0001 & -0.0018 & -0.5015 & 0 \\ 0 & 0 & 1 & 0 \end{bmatrix} \begin{bmatrix} \delta u \\ w \\ q \\ \delta\theta \end{bmatrix}.$$

(a) Find the characteristic equation governing the longitudinal dynamic stability.

(b) Determine the damping coefficients and natural frequencies of phugoid and short-period modes.

Problem 2. Consider the linearized unforced lateral dynamics of an aircraft

$$\begin{bmatrix} \dot{v} \\ \dot{p} \\ \dot{\phi} \\ \dot{r} \end{bmatrix} = \begin{bmatrix} -0.0999 & 0 & 32.174 & -279.10 \\ -0.0057 & -1.0932 & 0 & 0.2850 \\ 0 & 1 & 0 & 0 \\ 0.0015 & -0.0395 & 0 & -0.2454 \end{bmatrix} \begin{bmatrix} v \\ p \\ \phi \\ r \end{bmatrix}.$$

(a) Find the characteristic equation governing the lateral dynamic stability.

(b) Determine the exponential decay rate for spiral and roll modes.

(c) Determine the damping coefficients and natural frequencies of dutch roll mode.

Problem 3. Consider a system defined by the following state and output equations

$$\begin{bmatrix} \dot{x}_1 \\ \dot{x}_2 \end{bmatrix} = \begin{bmatrix} 0 & 1 \\ -25 & -4 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 1 & 1 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$$
$$\begin{bmatrix} y_1 \\ y_2 \end{bmatrix} = \begin{bmatrix} 1 & 0 \\ 0 & 1 \end{bmatrix} \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} + \begin{bmatrix} 0 & 0 \\ 0 & 0 \end{bmatrix} \begin{bmatrix} u_1 \\ u_2 \end{bmatrix}$$

Note that this system involves two inputs and two outputs.

(a) How many input-output transfer functions can be realized?

(b) Compute all the input-output transfer functions.

Problem 4. The lateral-directional characteristic equation for the Douglas DC-8 aircraft in a low altitude cruise flight conditions is

$$\Delta(s) = s^4 + 1.326s^3 + 1.219s^2 + 1.09s - 0.015 = 0.$$

What can you say about the stability of the aeroplane?