Model description for the implementation of System Identification methodologies on the rotorcraft SH09

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1 Introduction

Bibliography: [?], [?], [?], [?]

2 Model description

2.1 F-16 model

This section aims to present the reduced equations for the dynamics of the F-16 fixed-wing aircraft which simulated in a non-linear manner using SIDPAC software.

2.1.1 Mathematical models of aircrafts

The notation for the aircraft is the one shown in Figure 1.

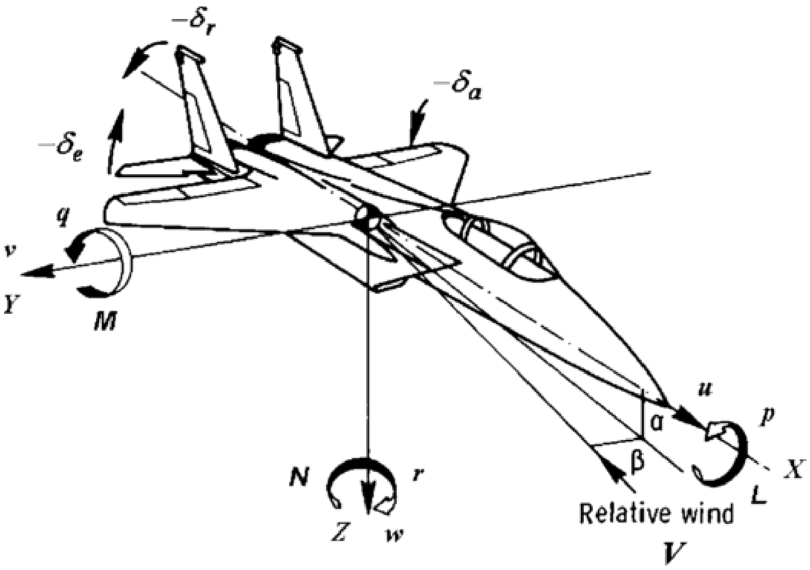

Figure 1: Airplane notation and sign conventions: u, v, w 5 body-axis components of aircraft velocity relative to Earth axes; p, q, r 5 body-axis components of aircraft angular velocity; X, Y, Z 5 body-axis components of aerodynamic force acting on the aircraft; and L, M, N 5 body-axis components of aerodynamic moment acting on the aircraft.

The components of the aerodynamic forces and moments, are the following:
Forces:

$$\text{Body} \quad \text{axes} \qquad \text{Stability} \quad \text{axes} \tag{1}$$

$$X = \bar{q}SC_X \qquad D = \bar{q}SC_D \tag{2}$$

$$Z = \bar{q}SC_Z \qquad L = \bar{q}SC_L \tag{3}$$

$$Y = \bar{q}SC_Y \qquad Y = \bar{q}SC_Y \tag{4}$$

Moments:

$$L = \bar{q}bSC_l \tag{5}$$

$$M = \bar{q}\bar{c}SC_m \tag{6}$$

$$N = \bar{q}bSC_n \tag{7}$$

where $\bar{q} = 1/2\rho V^2$ is the dynamic pressure, ρ is the air density, V is the airspeed, S is the wing reference area, b is the wing span and $\bar{c}$ is the mean aerodynamic chord (MAC).

The forces expressed in the wind axis systems as shown in set Equations 8.

$$
\begin{aligned}
C_{\mathrm{L}} &= -C_{\mathrm{Z}} \cos\alpha + C_{\mathrm{X}} \sin\alpha \\
C_{\mathrm{D}} &= -C_{\mathrm{X}} \cos\alpha - C_{\mathrm{Z}} \sin\alpha
\end{aligned} \tag{8}
$$

The Taylor expansion for the longitudinal motion of the aircraft are expressed in set of Equations 9. Hola Eva

$$
\begin{aligned}
C_D &= C_{D_0} + C_{D_V}\frac{\Delta V}{V_0} + C_{D_\alpha}\Delta\alpha + C_{D_q}\frac{q\bar{c}}{2V_0} + C_{D_{\delta_\mathrm{e}}}\Delta\delta_\mathrm{e} \\
C_L &= C_{L_0} + C_{L_V}\frac{\Delta V}{V_0} + C_{L_\alpha}\Delta\alpha + C_{L_{\dot\alpha}}\frac{\dot\alpha\bar{c}}{2V_0} + C_{L_q}\frac{q\bar{c}}{2V_0} + C_{L_{\delta_\mathrm{e}}}\delta_\mathrm{e} \\
C_m &= C_{m_0} + C_{m_V}\frac{\Delta V}{V_0} + C_{m_\alpha}\Delta\alpha + C_{m_{\dot\alpha}}\frac{\dot\alpha\bar{c}}{2V_0} + C_{m_q}\frac{q\bar{c}}{2V_0} + C_{m_{\delta_\mathrm{e}}}\delta_\mathrm{e}
\end{aligned} \tag{9}
$$

The set of equations that describe the motion of the aircraft, obtained from the Taylor series expansion is the one represented in Equation 10.

$$
\begin{aligned}
C_Y &= C_{Y_0} + C_{Y_\beta}\Delta\beta + C_{Y_p}\frac{pb}{2V_0} + C_{Y_r}\frac{rb}{2V_0} + C_{Y_{\delta_\mathrm{a}}}\Delta\delta_\mathrm{a} + C_{Y_{\delta_\mathrm{r}}}\Delta\delta_\mathrm{r} \\
C_l &= C_{l_0} + C_{l_\beta}\Delta\beta + C_{l_p}\frac{pb}{2V_0} + C_{l_r}\frac{rb}{2V_0} + C_{l_{\delta_\mathrm{a}}}\Delta\delta_\mathrm{a} \qquad (C_{l_{\delta_\mathrm{r}}} \ll 1) \\
C_n &= C_{n_0} + C_{n_\beta}\Delta\beta + C_{n_p}\frac{pb}{2V_0} + C_{n_r}\frac{rb}{2V_0} + C_{n_{\delta_\mathrm{r}}}\Delta\delta_\mathrm{r} \qquad (C_{l_{\delta_\mathrm{a}}} \ll 1)
\end{aligned} \tag{10}
$$

2.2 Model forces and moments coefficients

F matrix Forces:

$$X_u, X_v, X_w, X_p, X_q, X_r Y_u, Y_v, Y_w, Y_p, Y_q, Y_r Z_u, Z_v, Z_w, Z_p, Z_q, Z_r$$

Moments:

$$L_u, L_v, L_w, L_p, L_q, L_r M_u, M_v, M_w, M_p, M_q, M_r N_u, N_v, N_w, N_p, N_q, N_r$$

Controllability, **G** matrix: Forces

$$X_{\delta_\mathrm{lon}}, X_{\delta_\mathrm{lat}}, X_{\delta_\mathrm{ped}}, X_{\delta_\mathrm{col}} Y_{\delta_\mathrm{lon}}, Y_{\delta_\mathrm{lat}}, Y_{\delta_\mathrm{ped}}, Y_{\delta_\mathrm{col}} Z_{\delta_\mathrm{lon}}, Z_{\delta_\mathrm{lat}}, Z_{\delta_\mathrm{ped}}, Z_{\delta_\mathrm{col}}$$

Moments

$$M_{\delta_\mathrm{lon}}, M_{\delta_\mathrm{lat}}, M_{\delta_\mathrm{ped}}, M_{\delta_\mathrm{col}} N_{\delta_\mathrm{lon}}, N_{\delta_\mathrm{lat}}, N_{\delta_\mathrm{ped}}, N_{\delta_\mathrm{col}} N_{\delta_\mathrm{lon}}, N_{\delta_\mathrm{lat}}, N_{\delta_\mathrm{ped}}, N_{\delta_\mathrm{col}}$$

Time delays

$$\tau_\mathrm{lon}, \tau_\mathrm{lat}, \tau_\mathrm{ped}, \tau_\mathrm{col}$$