Structural Analysis Toolbox Report

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1 Overview

The investigated system has

- 15 constraints $\mathcal{C} = [\ c_1,\ c_2,\ c_3,\ c_4,\ c_5,\ c_6,\ m_{13},\ m_{14},\ m_{15},\ d_7,\ d_8,\ d_9,\ d_{10},\ d_{11},\ d_{12}\ ]$,
- 5 known variables $\mathcal{K} = [\ u_1,\ u_2,\ y_1,\ y_2,\ y_3\ ]$ and
- 13 unknown variables $\mathcal{X} = [\ theta_1,\ dtheta_1,\ omega_1,\ domega_1,\ theta_2,\ dtheta_2,\ omega_2,\ domega_2,\ theta_3,\ dtheta_3,\ omega_3,\ domega_3,\ d\ ]$.

The constraints of the system are as follows:

c_1	$0 = dtheta_1 - omega_1$
c_2	$0 = d - u_1(t) + k_1 \cdot (theta_1 - theta_2) + J_1 \cdot domega_1 + b_1 \cdot omega_1$
c_3	$0 = dtheta_2 - omega_2$
c_4	$0 = k_2 \cdot (theta_2 - theta_3) - k_1 \cdot (theta_1 - theta_2) - u_2(t) + J_2 \cdot domega_2 + b_2 \cdot omega_2$
c_5	$0 = dtheta_3 - omega_3$
c_6	$0 = J_3 \cdot domega_3 - k_2 \cdot (theta_2 - theta_3) + b_3 \cdot omega_3$
m_{13}	$0 = y_1(t) - theta_1$
m_{14}	$0 = y_2(t) - theta_2$
m_{15}	$0 = y_3(t) - theta_3$
d_7	$0 = dtheta_1 - \frac{\partial}{\partial t} theta_1$
d_8	$0 = domega_1 - \frac{\partial}{\partial t} omega_1$
d_9	$0 = dtheta_2 - \frac{\partial}{\partial t} theta_2$
d_{10}	$0 = domega_2 - \frac{\partial}{\partial t} omega_2$
d_{11}	$0 = dtheta_3 - \frac{\partial}{\partial t} theta_3$
d_{12}	$0 = domega_3 - \frac{\partial}{\partial t} omega_3$

The analysis obtained 1 matchings that yield in total 2 parity equations.

2 Canonical Decomposition

The system consists of

- the over-determined subsystem $\mathcal{S}^+$ with $\mathcal{C}^+ = [\ c_3,\ c_4,\ c_5,\ c_6,\ m_{13},\ m_{14},\ m_{15},\ d_9,\ d_{10},\ d_{11},\ d_{12}\ ]$ and $\mathcal{X}^+ = [\ theta_1,\ theta_2,\ dtheta_2,\ omega_2,\ domega_2,\ theta_3,\ dtheta_3,\ omega_3,\ domega_3\ ]$,
- the just-determined subsystem $\mathcal{S}^0$ with $\mathcal{C}^0 = [\ c_1,\ c_2,\ d_7,\ d_8\ ]$ and $\mathcal{X}^+ = [\ dtheta_1,\ omega_1,\ domega_1,\ d\ ]$ and
- the under-determined subsystem $\mathcal{S}^-$ with $\mathcal{C}^- = [\ ]$ and $\mathcal{X}^+ = [\ ]$.

3 Incidence Matrix

Table 2 presents the incidence matrix of the investigated system.

	$\mathcal{K}$					$\mathcal{X}$												
#	u_1	u_2	y_1	y_2	y_3	$theta_1$	$dtheta_1$	$omega_1$	$domega_1$	$theta_2$	$dtheta_2$	$omega_2$	$domega_2$	$theta_3$	$dtheta_3$	$omega_3$	$domega_3$	d
c_1	0	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
c_2	1	0	0	0	0	1	0	1	1	1	0	0	0	0	0	0	0	1
c_3	0	0	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	0
c_4	0	1	0	0	0	1	0	0	0	1	0	1	1	1	0	0	0	0
c_5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0
c_6	0	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	0
m_{13}	0	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
m_{14}	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
m_{15}	0	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
d_7	0	0	0	0	0	X	1	0	0	0	0	0	0	0	0	0	0	0
d_8	0	0	0	0	0	0	0	X	1	0	0	0	0	0	0	0	0	0
d_9	0	0	0	0	0	0	0	0	0	X	1	0	0	0	0	0	0	0
d_{10}	0	0	0	0	0	0	0	0	0	0	0	X	1	0	0	0	0	0
d_{11}	0	0	0	0	0	0	0	0	0	0	0	0	0	X	1	0	0	0
d_{12}	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	X	1	0

Table 2: Incidence matrix of the investigated system.

4 Matchings

Table 3 lists the obtained matchings. The fields either contain the matched unknown variables, zeros to indicate an unmatched constraints or nothing if constraints are not used in a matching.

	c_1	c_2	c_3	c_4	c_5	c_6	m_{13}	m_{14}	m_{15}	d_7	d_8	d_9	d_{10}
1	$omega_1$	d	$omega_2$	$domega_2$	$omega_3$	$domega_3$	$theta_1$	$theta_2$	$theta_3$	$dtheta_1$	$domega_1$	$dtheta_2$	0

Table 3: Matchings of the investigated system.

5 Parity Equations

$$0 = \frac{u_2(t) - b_2 \cdot \frac{\partial}{\partial t} y_2(t) + k_1 \cdot y_1(t) - k_1 \cdot y_2(t) - k_2 \cdot y_2(t) + k_2 \cdot y_3(t)}{J_2} - \frac{\partial^2}{\partial t^2} y_2(t)$$

$$0 = \frac{k_2 \cdot (y_2(t) - y_3(t)) - b_3 \cdot \frac{\partial}{\partial t} y_3(t)}{J_3} - \frac{\partial^2}{\partial t^2} y_3(t)$$

6 Detectability and isolability analysis

Table 4 lists the detectability and isolability properties of the parity equations separately and over all combined. Detectable (d), isolable (i) and non-failable constraints (n) are marked accordingly.

	c_1	c_2	c_3	c_4	c_5	c_6	m_{13}	m_{14}	m_{15}	d_7	d_8	d_9	d_{10}	d_{11}	d_{12}
1			d	d	d	d	d	d	d	n	n	n	n	n	n
ALL			d	d	d	d	d	d	d	n	n	n	n	n	n

Table 4: Detectability and isolability of the investigated system.