Structural Analysis Toolbox Report

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1 Overview

The investigated system has

- 15 constraints $\mathcal{C} = [\ c_1,\ c_2,\ c_3,\ c_4,\ c_5,\ c_6,\ d_7,\ d_8,\ d_9,\ d_10,\ d_11,\ d_12,\ m_13,\ m_14,\ m_15\ ]$,
- 4 known variables $\mathcal{K} = [\ u,\ y_1,\ y_2,\ y_3\ ]$ and
- 13 unknown variables $\mathcal{X} = [\ \theta_1,\ \dot{\theta_1},\ \omega_1,\ \dot{\omega_1},\ \theta_2,\ \dot{\theta_2},\ \omega_2,\ \dot{\omega_2},\ \theta_3,\ \dot{\theta_3},\ \omega_3,\ \dot{\omega_3},\ d\ ]$.

The constraints of the system are as follows:

c_1	$0 = dtheta_1 - w_1$
c_2	$0 = d - u + J_1\, dw_1 + b_1\, w_1 + k_1\ (\theta_1 - \theta_2)$
c_3	$0 = dtheta_2 - w_2$
c_4	$0 = J_2\, dw_2 + b_2\, w_2 - k_1\ (\theta_1 - \theta_2) + k_2\ (\theta_2 - \theta_3)$
c_5	$0 = dtheta_3 - w_3$
c_6	$0 = J_3\, dw_3 + b_3\, w_3 - k_2\ (\theta_2 - \theta_3)$
d_7	$0 = dtheta_1 - \theta_1'$
d_8	$0 = dw_1 - w_1'$
d_9	$0 = dtheta_2 - \theta_2'$
d_10	$0 = dw_2 - w_2'$
d_11	$0 = dtheta_3 - \theta_3'$
d_12	$0 = dw_3 - w_3'$
m_13	$0 = y_1 - \theta_1$
m_14	$0 = y_2 - \theta_2$
m_15	$0 = y_3 - \theta_3$

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 $\mathcal{C}^+ = [\ c_3,\ c_4,\ c_5,\ c_6,\ d_9,\ d_10,\ d_11,\ d_12,\ m_13,\ m_14,\ m_15\ ]$ and $\mathcal{X}^+ = [\ \theta_1,\ \theta_2,\ \dot{\theta}_2,\ \omega_2,\ \dot{\omega}_2,\ \theta_3,\ \dot{\theta}_3,\ \omega_3,\ \dot{\omega}_3\ ]$,
- the just-determined subsystem $\mathcal{S}^0$ with $\mathcal{C}^0 = [\ c_1,\ c_2,\ d_7,\ d_8\ ]$ and $\mathcal{X}^+ = [\ \dot{\theta}_1,\ \omega_1,\ \dot{\omega}_1,\ d\ ]$ 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	y_1	y_2	y_3	θ_1	$\dot{\theta}_1$	ω_1	$\dot{\omega}_1$	θ_2	$\dot{\theta}_2$	ω_2	$\dot{\omega}_2$	θ_3	$\dot{\theta}_3$	ω_3	$\dot{\omega}_3$	d
c_1	0	0	0	0	0	1	1	0	0	0	0	0	0	0	0	0	0
c_2	1	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	1	1	0	0	0	0	0	0
c_4	0	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	1	1	0	0
c_6	0	0	0	0	0	0	0	0	1	0	0	0	1	0	1	1	0
m_13	0	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
m_14	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0
m_15	0	0	0	1	0	0	0	0	0	0	0	0	1	0	0	0	0
d_7	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	X	1	0	0	0	0	0	0	0	0	0
d_9	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	X	1	0	0	0	0	0
d_11	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	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	d_7	d_8	d_9	$d_1 0$	$d_1 1$	$d_1 2$	$m_1 3$	$m_1 4$	$m_1 5$
1	ω_1	d	ω_2	$\dot{\omega}_2$	ω_3	$\dot{\omega}_3$	$\dot{\theta}_1$	$\dot{\omega}_1$	$\dot{\theta}_2$	0	$\dot{\theta}_3$	0	θ_1	θ_2	θ_3

Table 3: Matchings of the investigated system.

5 Parity Equations

$$0 = -y_2'' - \frac{k_1\ (y_2 - y_1) + k_2\ (y_2 - y_3) + b_2\, y_2'}{J_2}$$
$$0 = -y_3'' - \frac{k_2\ (y_3 - y_2) + b_3\, y_3'}{J_3}$$

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	d_7	d_8	d_9	$d_1 0$	$d_1 1$	$d_1 2$	$m_1 3$	$m_1 4$	$m_1 5$
1			d	d	d	d	n	n	n	n	n	n	d	d	d
ALL			d	d	d	d	n	n	n	n	n	n	d	d	d

Table 4: Detectability and isolability of the investigated system.