CONTRIBUTION TO CONTROL OF AN ELASTIC TWO-MASS SYSTEM BY MEANS OF GENETIC ALGORITHM

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Summary Oscillations of an elastic two-mass system with all known parameters may be suppressed by suitable feedback signal. An observer enables to estimate this feedback without measurement of load mechanism speed. This article contains application of genetic algorithms for identification of elastic system parameters and determination of corresponding observer feedback coefficients. Design correctness is verified by simulation.

1. INTRODUCTION

Electrical drives with elastic connection are modeled as two-mass systems, where the first mass represents the motor, the second mass represents the load mechanism and the shaft is considered inertia free. The block scheme (Fig.1) was designed by normalized equations.
Mechanical part of the scheme is described by three equations in normalized (p.u.) form

$$\dot{\omega}_m = K_m(m_m - m_e) \quad (1)$$

$$\dot{m}_e = K_e(\omega_m - \omega_z) \quad (2)$$

$$\dot{\omega}_z = K_z(m_e - m_z) \quad (3)$$

where $K_m = 1/T_m$, $K_e = 1/T_e$, $K_z = 1/T_z$.

Current loop is expressed as

$$\dot{m}_m + m_m = u_{Iw} , \quad (4)$$

For the investigated 4.8 kW motor were chosen following basic (norm) values:

$$N_\omega = 200 s^{-1} ,\ N_U = K_T N_\omega ,\ N_M = \frac{K_{TD} N_\omega}{K_m K_I} , \quad (5)$$

where converter gain is noted K_T , speed sensor gain K_{TD}, current sensor gain K_I and $K_m = 1/c\Phi$.

Knowledge of all drive parameters enables to design current and speed controllers by usual methods, however elastic element excites speed oscillations (Fig.2). Their substantial suppression (Fig.3) may be reached by feedback signal created as difference of motor and driven mechanism speed $(\omega_m - \omega_z)$.

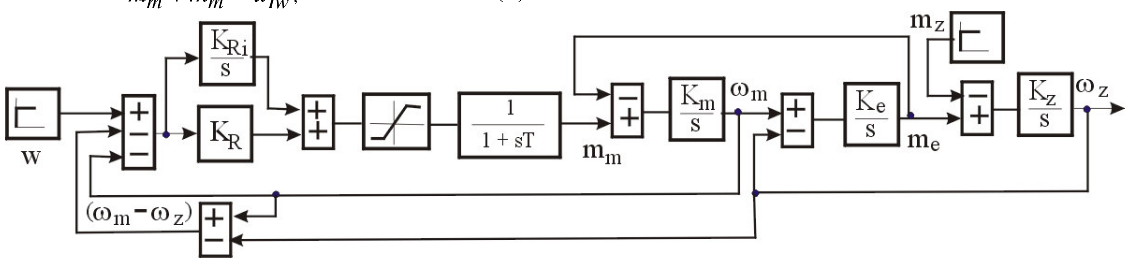

Fig. 1. Oscillation suppression by feedback

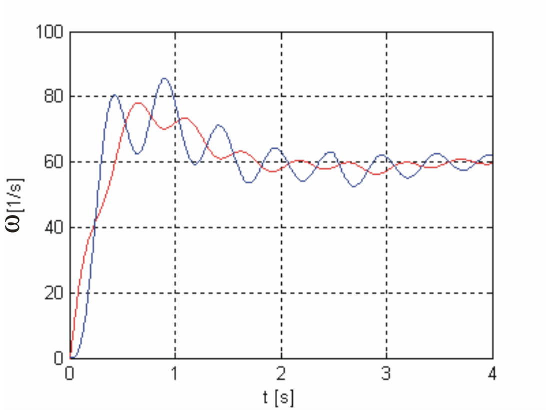

Fig. 2. Control of a two-mass drive without oscillation suppression

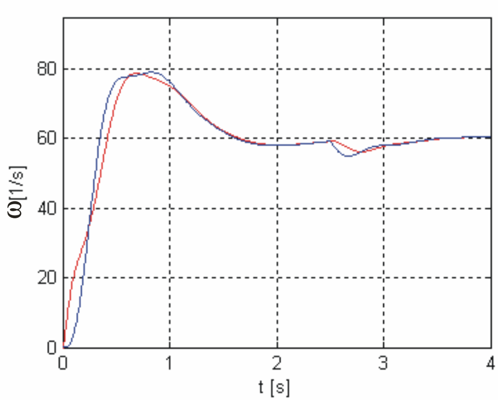

Fig. 3. Control of a two-mass drive with oscillation suppression

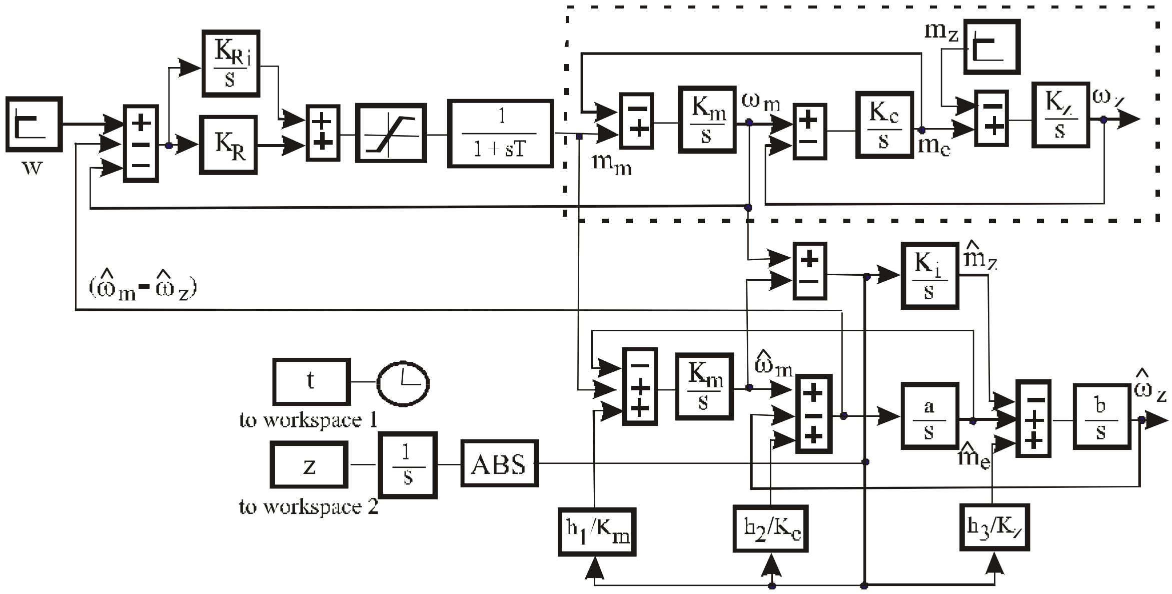

Fig. 4. Control of a two-mass drive by observer

Measurement of the load mechanism speed ω_z is not admissible in some tasks. Its value can be estimated by a state and disturbance observer [1], [2] (Fig.4) assuming knowledge of all system parameters ($a=K_e$, $b=K_z$). Obtained time responses ensure sufficient oscillations suppression and the identical result as that at load speed measurement (Fig.3).

Parameters of motor and controllers are usually known, but those of the elastic element and load mechanism (a, b) have to be identified. More methods suitable for identification are known, here genetic algorithm is applied for optimization of two parameters of the SIMULINK model. Then observer coefficients h_1, h_2, h_3, K_i are calculated by equations introduced below.

2. OBSERVER PARAMETERS AND GENETIC ALGORITHM

The observed part of the scheme (dashed line in Fig. 4) is described by the following state equation

$$\dot{x} = \begin{bmatrix} 0 & -K_m & 0 \\ K_e & 0 & -K_e \\ 0 & K_z & 0 \end{bmatrix} x + \begin{bmatrix} 0 \\ 0 \\ -K_z \end{bmatrix} u + \begin{bmatrix} 0 \\ 0 \\ -K_z \end{bmatrix} z = $$

$$= \boldsymbol{A}x + \boldsymbol{b}u + \boldsymbol{e}z$$

$$y = x_1 = \boldsymbol{c}^T \boldsymbol{x} \qquad (6)$$

Characteristic polynomial of the system matrix $\boldsymbol{A}$ is

$$P(\lambda) = det(\lambda \boldsymbol{I} - \boldsymbol{A}) = \lambda^3 + \lambda K_e (K_m + K_z) \qquad (7)$$

Its eigenvalues are

$$\lambda_1 = 0, \quad \lambda_{2,3} = \pm j \sqrt{K_e (K_m + K_z)} \qquad (8)$$

Observer eigenvalues are chosen more negative:

$$\lambda_{1,2} = -10, \ \lambda_{3,4} = -10 \pm j50 . \qquad (9)$$

The desired characteristic polynomial is then

$$P(s) = \prod_{1}^{4} (s - s_i) = \qquad (10)$$

$$= s^4 + 40s^3 + 3100s^2 + +54000s + 260000$$

Observer system matrix $\boldsymbol{F}$ [1] is written as

$$\boldsymbol{F} = \begin{bmatrix} \boldsymbol{A} - \boldsymbol{h}\boldsymbol{c}^T & -\boldsymbol{e} \\ K_i \boldsymbol{c}^T & 0 \end{bmatrix} =$$

$$= \begin{bmatrix} -h_1 & -K_m & 0 & 0 \\ -h_2 + K_e & 0 & -K_e & 0 \\ -h_3 & K_z & 0 & -K_z \\ K_i & 0 & 0 & 0 \end{bmatrix} \qquad (11)$$

Observer characteristic polynomial is derived

$$P(\lambda) = \lambda^4 + h_1 \lambda^3 + (K_e K_z + K_m K_e - K_m h_2) \lambda^2 + \\ + (K_e K_z h_1 + K_e K_m h_3) \lambda - K_e K_m K_z K_i \qquad (12)$$

Comparison of terms at equal order variables offers following expressions for the searched observer parameters (K_m of motor is known):

$$h_1 = 40, \ h_2 = \frac{K_e (K_m + K_z) - 3100}{K_m},$$

$$h_3 = \frac{54000 - 40K_z}{K_m K_e}, \quad K_i = \frac{260000}{K_m K_e K_z} \qquad (13)$$

Fitness function of genetic algorithm ensures minimal difference between motor and observer speed $\Delta = \int |\omega_m - \hat{\omega}_m| dt \rightarrow 0$. Precisely identified *a*, *b* values provide the desire speed (Fig.5) and load torque time responses (Fig.6). Small differences of identified parameters have not noticeable influence on speed response, but they cause a peak in the observed load torque curve at no-load (*a*, *b* parameter error 2.7 % in Fig.7). To avoid it, hybrid genetic algorithm program is recommended to apply.

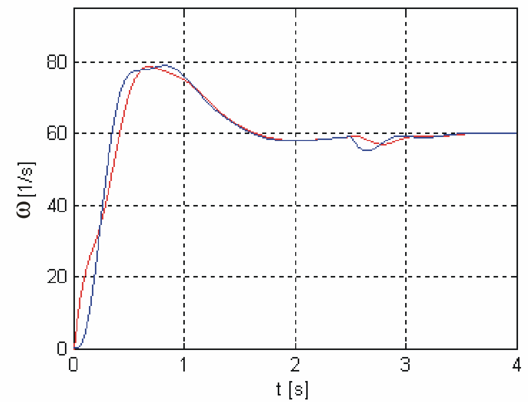

Fig. 5. Time responses of speed (hybrid parameter identification)

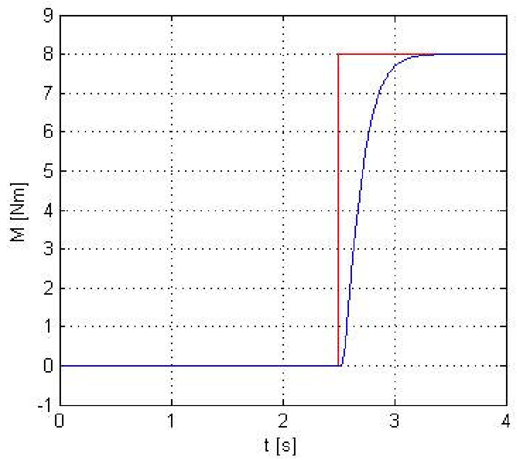

Fig. 6. Time responses of load torque (hybrid parameter identification)

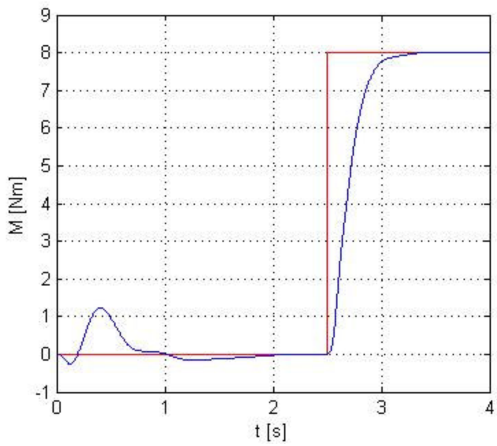

Fig. 7. Time responses of load torque (only GA parameter identification)

3. CONCLUSION

A two-mass elastic drive system with some unknown parameters may be successfully controlled applying suitable identification method. Genetic algorithm program was used in the introduced task. Unmeasured speed of the driven mechanical mechanism is estimated by an observer with coefficients calculated by means of identified parameters. Simulation results have proved feasibility of this approach.

Acknowledgement

This work was supported by the VEGA Project 1/2177/05 “Intelligent mechatronic systems”.

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