MECHATRONICS SYSTEM WITH FLEXIBLE COUPLING ANALYSIS BY SIMULATION TOOL SIMSCAPE™

Martin JUHÁS, Bohuslava JUHÁSOVÁ, Igor HALENÁR

Authors:	***Martin Juhás, MSc. Eng., Bohuslava Juhásová, MSc. Eng., Igor Halenár, MSc. Eng.***
Workplace:	***Slovak University of Technology in Bratislava*** ***Faculty of Materials Science and Technology in Trnava*** ***Institute of Applied Informatics, Automation and Mathematics***
Address:	***Hajdóczyho 1, 91724 Trnava, Slovak Republic***
Phone:	***+421 918 646 021***
Email:	***martin_juhas@stuba.sk, bohuslava.juhasova@stuba.sk, igor.halenar@stuba.sk***

Abstract

In this contribution is shown how to utilise simulation software tool Simscape™ for analysis of mechatronics system with flexible coupling. There is presented a classical principle of mechatronics system modeling in comparison with using of software modeling. Simulation tool Simscape™ is used for analyse of permanent magnet synchronous motor with flexible join with load.

Key words

mechatronics system, flexible coupling, Matlab®, Simscape™, Simulink®, variable compliance

Introduction

Mechatronics is the synergetic combination of precision mechanical engineering, electronic control and systems thinking in the design of products and processes. Process of mechatronics system analyse based on classical principle is conditioned by physical, mechanical and mathematical dependencies knowledge from this branch. The main advantage of simulation tools using is that mentioned knowledge is unnecessary. [1]

Classical method of modeling

Classical method of mechatronics system analyse consist firstly in mathematical model creation, which is represented by system of algebraic - differential equations in this case. A simulation model in the state space representation is consequently created. It's possible to use simulation software such as Simulink® for design of simulation model in graphic form.

As analysed mechatronics system we choose permanent magnet synchronous motors (PMSM) with flexible coupling. In practical applications, PMSM is usually linked to their loads by transmission mechanisms such as drive shafts, belts, gears, harmonic speed changer and so on. The mechanical stiffness of these mechanisms is limited. If the inertia of the transmission mechanisms is small compared to the motor and load, the flexible coupling between the motor and load can be treated as a two-mass motor/load system [2, 3], as shown in Fig. 1.

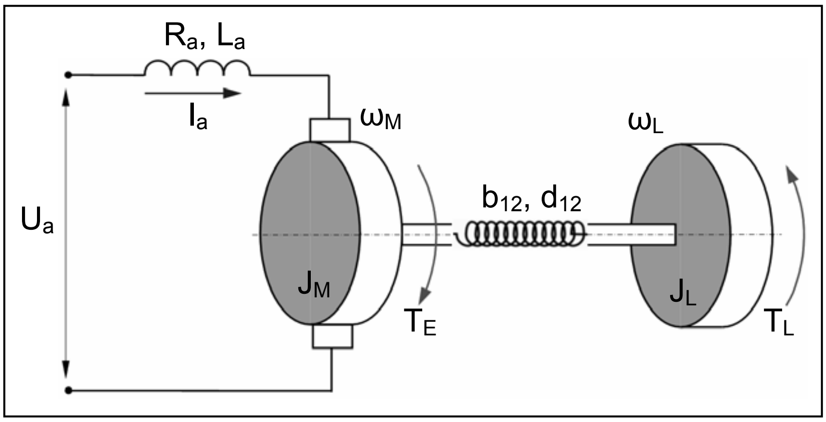

Fig. 1 *PMSM with flexible join*

PHYSICAL VALUES FOR PMSM WITH FLEXIBLE JOIN Table 1

Variable	Unit	Description
U_a	V	supply voltage
I_a	A	armature current
R_a, L_a	Ω, H	resistance and inductance of armature winding
J_M	kg m^2	inertia of the motor rotor
J_L	kg m^2	inertia of the load
T_E	Nm	electromagnetic torque
T_L	Nm	loading torque
d_{12}	Nm	spring constant of the transmission
b_{12}	Nm s	damping of the transmission
ω_M	rad/s	motor angular speed
ω_L	rad/s	load angular speed
cΦ	Nm/A	torque constant
T_{12}	Nm	torque passing through the transmission

The electric subsystem is represented by following equations [4]:

$$U_a = R_a I_a + L_a \frac{dI_a}{dt} + U_i$$

$$U_i = (c\Phi)\,\omega_M\,;\; T_E = (c\Phi)\,I_a$$

The mechanical subsystem is represented by following equations [4]:

$$J_M \frac{d\omega_M}{dt} + b_{12}(\omega_M - \omega_L) + T_{12} - T_E = 0$$

$$\frac{dT_{12}}{dt} - d_{12}(\omega_M - \omega_L) = 0$$

$$J_L \frac{d\omega_L}{dt} - b_{12}(\omega_M - \omega_L) - T_{12} + T_L = 0$$

The model stated in the vector form of the state equations:

$$\frac{d}{dt}\begin{bmatrix} I_a \\ \omega_M \\ \omega_L \\ T_{12} \end{bmatrix} = \begin{bmatrix} -\frac{R_a}{L_a} & -\frac{c\Phi}{L_a} & 0 & 0 \\ \frac{c\Phi}{J_M} & -\frac{b_{12}}{J_M} & \frac{b_{12}}{J_M} & -\frac{1}{J_M} \\ 0 & \frac{b_{12}}{J_L} & -\frac{b_{12}}{J_L} & \frac{1}{J_L} \\ 0 & d_{12} & -d_{12} & 0 \end{bmatrix} \begin{bmatrix} I_a \\ \omega_M \\ \omega_L \\ T_{12} \end{bmatrix} + \begin{bmatrix} \frac{1}{L_a} \\ 0 \\ 0 \\ 0 \end{bmatrix} U_a + \begin{bmatrix} 0 \\ 0 \\ -\frac{1}{J_L} \\ 0 \end{bmatrix} T_L$$

A graphical form of mathematical model – simulation model (Fig. 2), was designed in software tool Simulink® by transformation of algebraic - differential equations system.

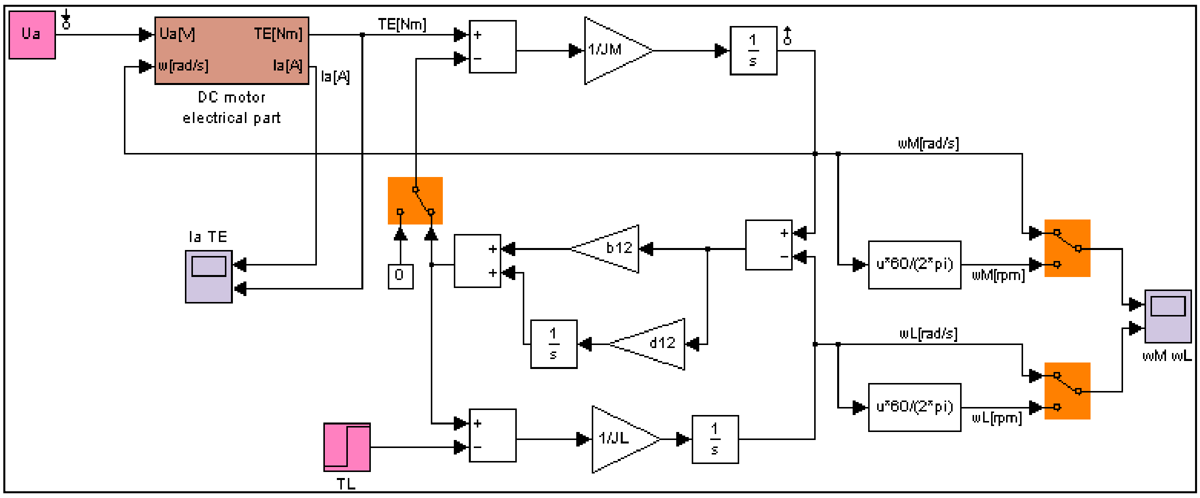

Fig. 2 *Simulink® model of PMSM with FJ*

We used real motor catalogue parameters for verification of simulation model. These parameters are shown below

CATALOGUE PARAMETERS Table 2

Parameter	**Unit**	**Value**
Motor Maxon EC 60 Ø60 mm, brushless, 400 Watt		
U_a	V	48
cΦ	mNm/A	147
R_a	Ω	1.03
L_a	mH	0.82
J_M	g cm^2	831
Flexible coupling		
b_{12}	Nm s	0.001
d_{12}	Nm	100
Load		
J_L	g cm^2	5*J_M
T_L	Nm	1
in time	s	0.2

The result of simulation process was graphical representation of angular velocity, armature current and motor torque dependency on time, shown in Fig. 3.

SIMULINK® MODEL VERIFICATION Table 3

Parameter	Unit	Catalogue output value	Simulation output value
ω_M no load	rpm	3100	3115
starting current	A	46.4	44
stall torque	mNm	6820	6460

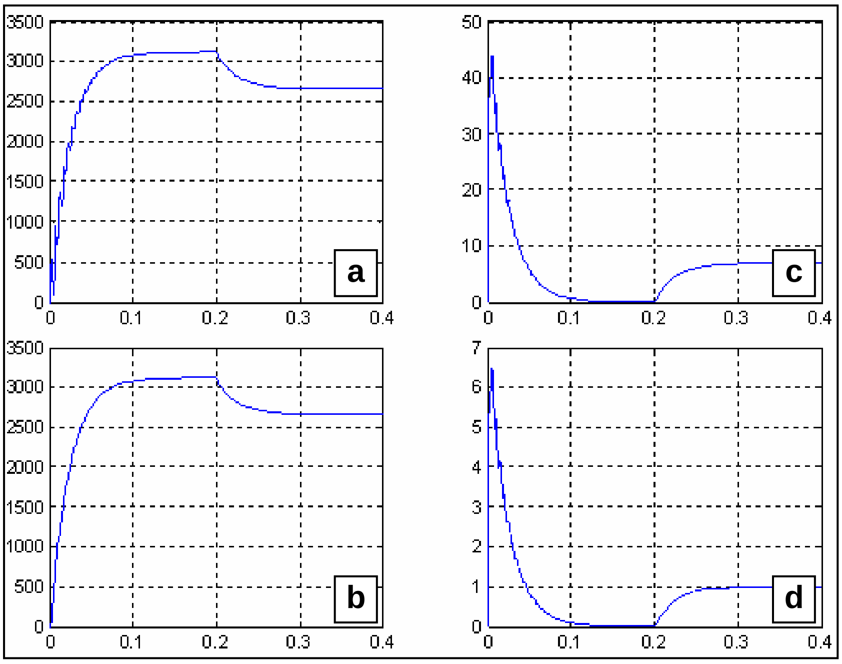

Fig. 3 *Simulation results a)ω_M b)ω_L c)I_a d)T_E*

Simulation method of modeling

Simulation tool Simscape™ makes it possible to design model of real mechatronics system without using mathematical acknowledgements. The simulation model consists of parts, which represent single electrical or mechanical parts of real system. Individual objects connection is based on block diagram of mechatronics system.

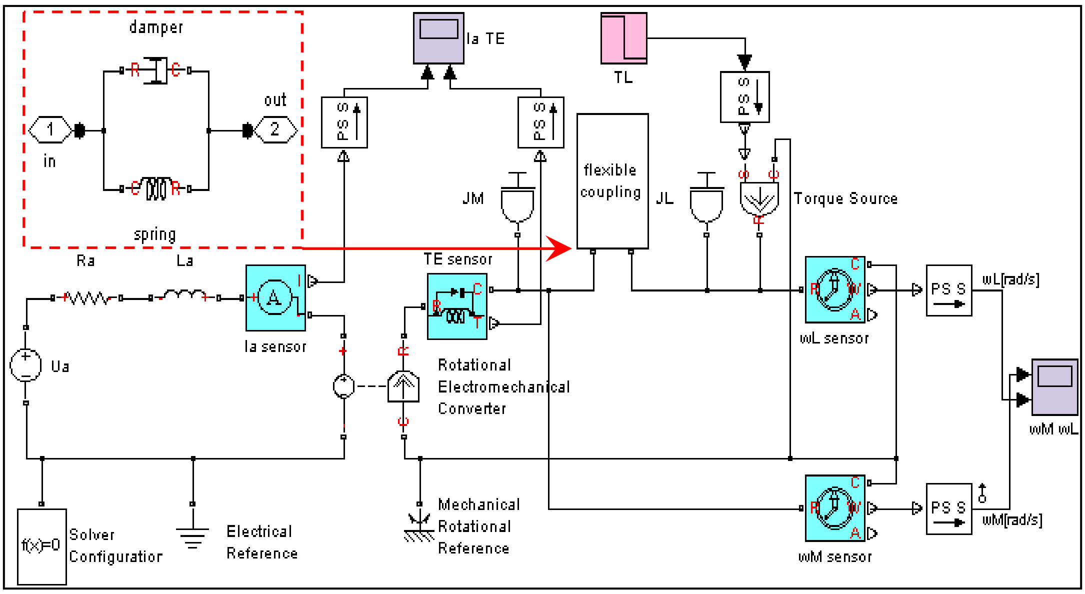

Fig. 4 *Simscape™ model of PMSM with FJ*

Observed parameters were same as parameters in Simulink® model - angular velocity, armature current and motor torque. Simulation results are shown in *Fig. 5*.

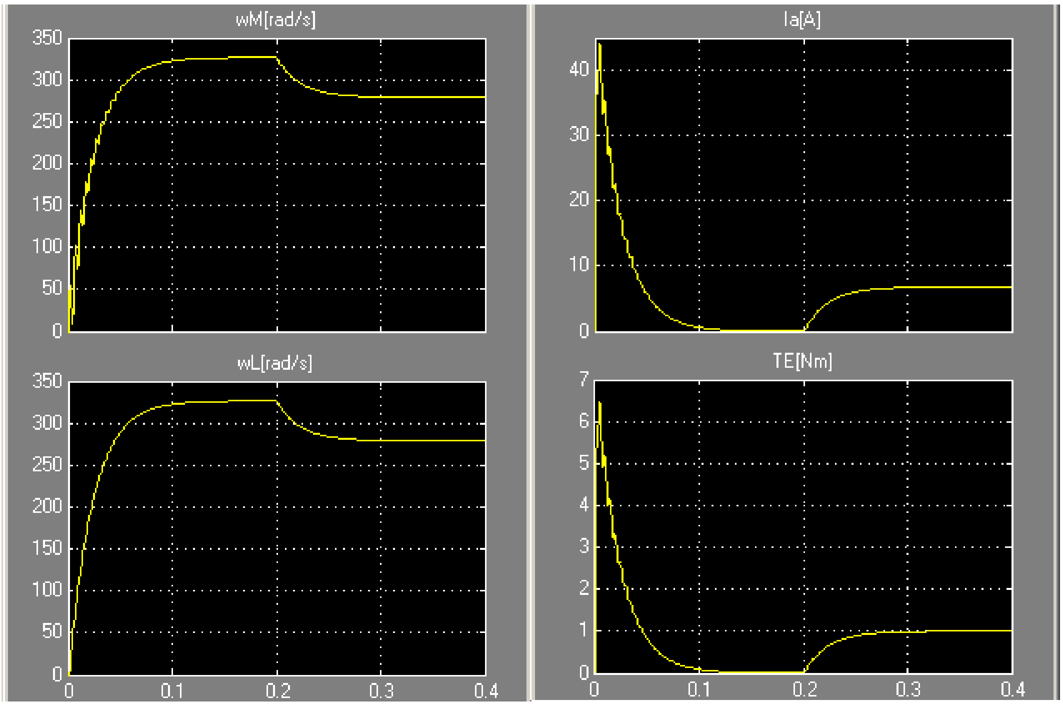

***Fig. 5** Simscape™ model simulation results*

Conclusion

Based on achieved results is obvious that using of simulation tool Simscape™ is possible to create mechatronics system simulation model. This model corresponds to simulation model that was created by classical method of mathematic-physical analysis.

References:

[1] BRADLEY, D.A., DAWSON, D., BURD, N.C., LOADER, A.J. *Mechatronics.* London: Chapman & Hall, 1991. ISBN 0-412-58290-2

[2] VUKOSAVIC, S., STOJIC, M. Suppression of Torsional Oscillations in a High-Performance Speed Servo Drive. In *IEEE Trans. on Industrial Electronics*, 1998, vol. 45, pp. 108-117.

[3] ELLIS, G., LORENZ, R.D. Resonant load control methods for industrial servo drives. In *IEEE Industry Applications Conference.* Rome, 2000, pp. 1438-1445.

[4] KALOUS J., KRATOCHVÍL C., HERIBAN P. *Dynamics of Rotary Electromechanical Drives.* Brno: ÚT AVČR – Centrum mechatroniky, 2007. ISBN: 80-214-3340-X

[5] Available on internet <http://www.mathworks.com/products/simscape/>, 2010-05-11