MODELLING OF ASYNCHRONOUS MOTOR DRIVEN MACHINES

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Abstract

The article presents the solution of model of machine with a static non-linear moment characteristic of asynchronous motor. Parameters of model, loading forces or moments, elasticity, damping and unbalances of mechanical parts, clearances, friction, etc. have influence on the behavior of machine systems. Also the driving motor plays a decisive role. One solution is the computer software, which describes mechanical model of mechanical systems with asynchronous motor drive. The designed SW with help Matlab uses a numerical solution in order to solve the mathematical model, i.e. the system of non-linear differential equations of the second order. The simulation of operating behavior of the machine makes it possible to design the parameters of the machinery. The construction of mechanical and mathematical models of non-linear dynamical systems and numerical solution will be illustrated by example.

1 Introduction

The machine systems, which are mostly system with more degrees of freedom, are usually compiled with a driving asynchronous motor, gearbox, mechanisms, kinematics bonds, control elements and a driven machine. It is necessary to consider all fundamental influences such as elasticity, damping, friction, clearance, unbalances, etc.

The moment characteristic in mechanical systems with asynchronous motor drive is usually substituted with Kloss´s function. The example indicates a solution of motion of machine with 2 Degrees of Freedom φ_1, φ_2 (Fig. 1). The parameters of a machine system and driving asynchronous motor, the physical features and initial conditions have an influence on the final solution.

2 Model of the machine with rack and pinion

The mathematical model of this machine system is compiled by the equations of motion based on the second Lagrange equation.

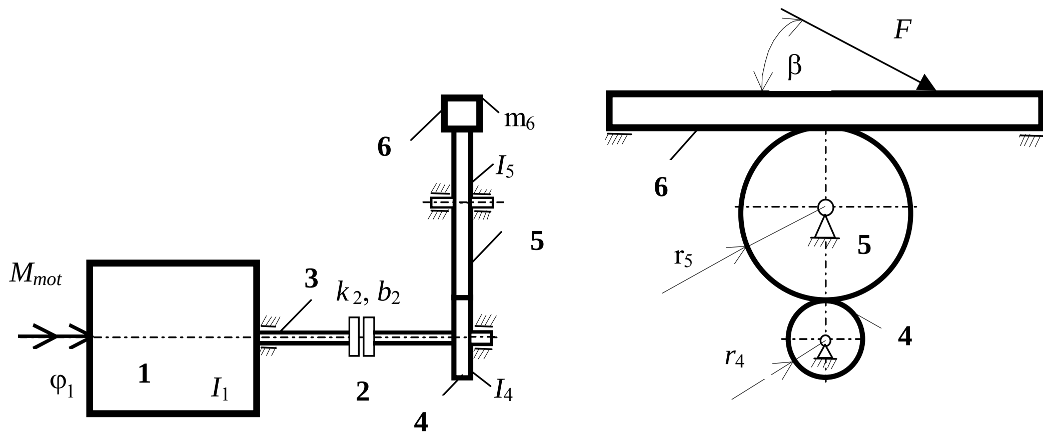

Figure 1: Model of an asynchronous motor powered machine

A model with a moment of load acting in periodical time interval t_{INT} on the mass 2 (Fig. 3) is two-mass torsion system (Fig. 2).

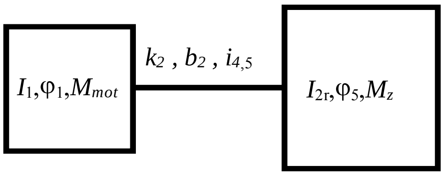

Figure 2: Model of the machine system with two degrees of freedom φ_1, φ_5

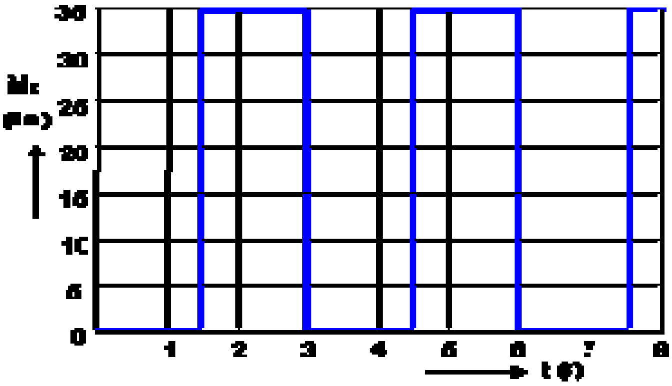

Figure3: Moment of load

The equations of motions are systems of non-linear differential equations. The parameters of a machine system and driving asynchronous motor, the physical features and initial conditions have an influence on the final solution. The mathematical model describing the behaviour of the machine system:

$$I_1\ddot{\varphi}_1 + k_2(\varphi_1 - i_{4,5}\varphi_5) + b_2(\dot{\varphi}_1 - i_{4,5}\dot{\varphi}_5) = M_{mot},$$
$$I_{2r}\ddot{\varphi}_5 - i_{4,5}k_2(\varphi_1 - i_{45}\varphi_5) - i_{4,5}b_2(\dot{\varphi}_1 - i_{4,5}\dot{\varphi}_5) = -M_Z, \tag{1}$$

where $I_{2r} = I_4 + I_5 \dfrac{1}{i_{4,5}^2} + m_6 r_4^2$, $i_{4,5} = r_5/r_4$, $M_{mot} = M_0 \dfrac{2s_z s}{s_z^2 + s^2}$, $M_{Z\max} = F_6 r_4 \cos\beta$.

The moment characteristic in mechanical systems with asynchronous motor drive is usually substituted with Kloss´s function:

$$M_{mot} = M_0 \frac{2s_z s}{s_z^2 + s^2}, \tag{2}$$

where $s = 1 - \omega/\omega_{syn}$ is slip of angular velocity ω respect to synchronous angular velocity ω_{syn}, and s_z is a parameter, which gives the slip value for the moment maximum M_0.

Example of this characteristic for value $s_z = 0{,}25$ (the maximum of moment is by angular velocity $\omega_M = (1 - s_z)\omega_{syn} = 0{,}75\omega_{syn}$) is on the Fig.4.

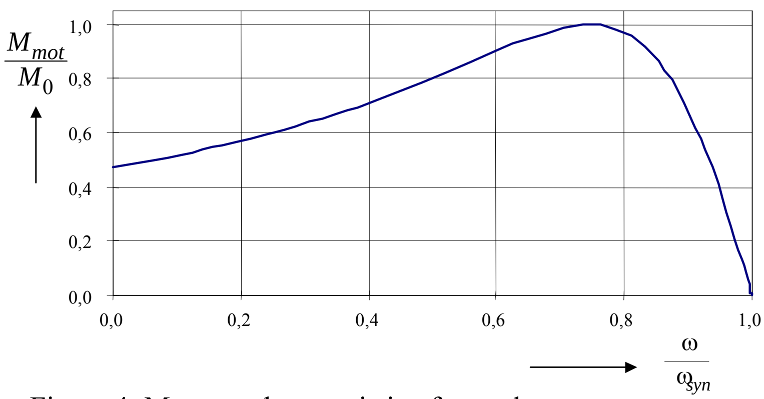

Figure 4: Moment characteristic of asynchronous motor

The parameters of the machine system are:

$I_1 = 0{,}025$ kg.m^2	$r_4 = 40$ mm	$M_0 = 10$ Nm	$\beta = 30^o$
$I_4 = 0{,}025$ kg.m^2	$r_5 = 160$ mm	$t_{INT} = 1{,}5$ s	$\omega = \dot{\varphi}_1$
$I_5 = 0{,}0768$ kg.m^2	$k_2 = 348$ Nm.rad^{-1}	$\omega_{syn} = 314$ s^{-1}	$s_z = 0{,}25$
$m_{6c} = 3$ kg	$b_2 = 0{,}005$ Nm^{-1}.s	$F_6 = 1000$ N	

3 Results and conclusion

The numerical solution was provided with SW MATLAB (filename RH_STMdKloss2). The dependences of angular velocity $\dot{\varphi}_1$ and $\dot{\varphi}_5$ are shown on the Fig.5 and Fig.6. On Fig.7 is the plot of moment M_{coup} on the coupling and on Fig.8 is the total driving moment M_{tot} with respect loading moment M_z (Fig.3).

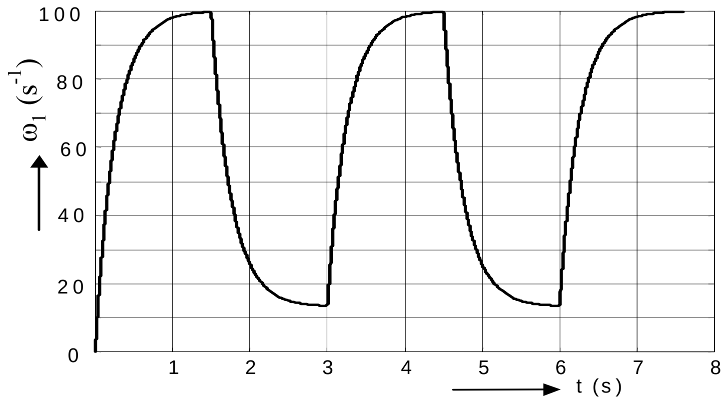

Figure 5: Plot of the angular velocity $\omega_1 = \dot{\varphi}_1$, versus time

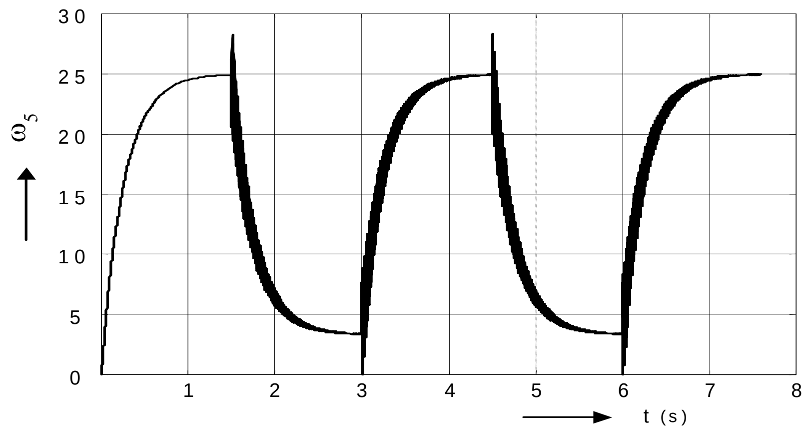

Figure 6: Plot of the angular velocity $\omega_5 = \dot{\varphi}_5$ versus time

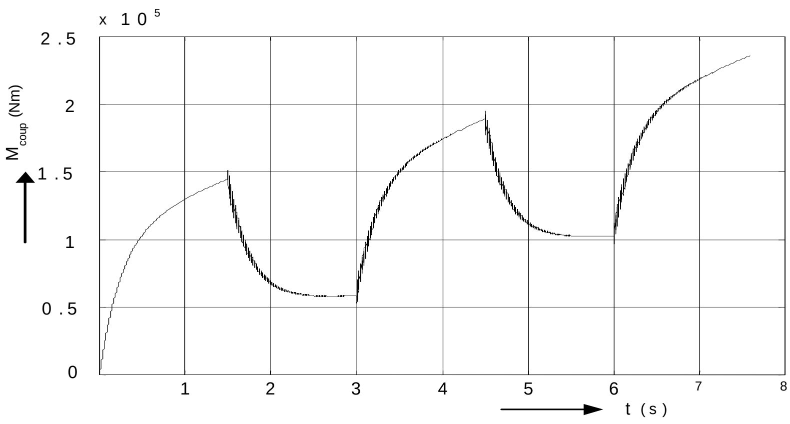

Figure 7: Moment of the coupling M_{coup}

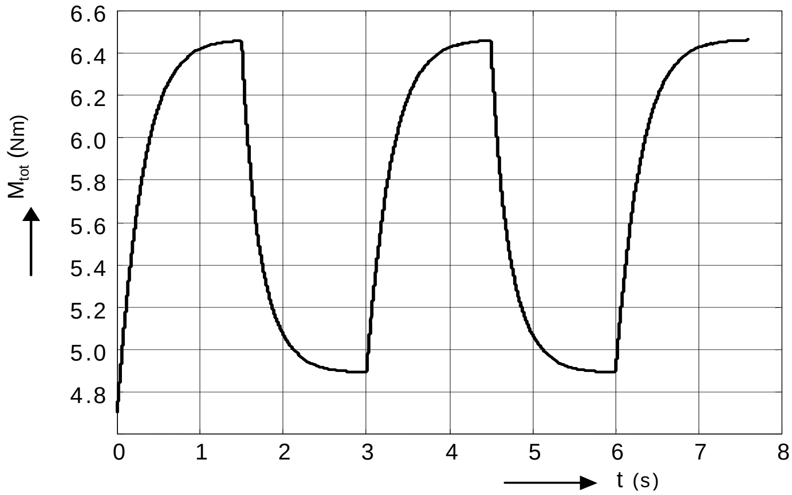

Figure 8: Total driving moment M_{tot} with respect loading moment M_z

The parameters of the elastic coupling have considerable influence on the behavior of machine parts. For example for the parameters k_2 = 5 Nm.rad^{-1} and b_2=50 Nm^{-1}.s machine parts do not oscillate and the moment of the coupling is constant with maximal value $M_{coup} = 12.10^5 \mathrm{Nm.}$.

References

[1] J. Vondřich, S. Jirků *Applications of Modelling of Machine Systems and Simulations of their Operating Behaviour*, Proceedings of the Nineteenth IASTED International Conference Modelling, Identification and Control, pp. 615-619, Innsbruck, 2000.

[2] R. Havlicek *Problem of Design of Non-cascade Control of a Electromechanical System,* Proceeding of XVIII. International Symposium of Electric Machinery, Prague, 2010.

[3] P. Kocarnik, S. Jirků *The Pulley System with Tree Degrees of Freedom,* Journal of Machine Engineering, Editorial Institution of the Wroclaw Board of Scientific Technical Societies Federation NOT, Wroclaw, 2008.

[4] R. Havlicek *Design of Non-cascade Control of an Electromechanical System,* Proceeding of 50. International Conference of Departments of Machines and Mechanisms, Terchova, 21009.

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