Development Multiprocessing Mathematical Model of Electromagnetic AC Drive

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Abstract: The study describes the development of multiprocessing mathematical model to take account of the mechanical, electrical and magnetic parameters electromagnetic AC drives. The resulting model is a system of three equations each of which is responsible for a separate proceeding process. The developed model is relevant for the assessment of electromagnetic drivers, using the method of natural-model tests. The method of natural-model tests combines measurement known quantities on the physical object and measure the required variables in the model.

Key words: Electromagnetic AC drive, electromagnetic drive model, the method of natural-model tests, multiprocessing mathematical model, object

INTRODUCTION

It is proposed to use natural-model approach (Bakhvalov *et al.*, 2015; Gorbatenko, 2001; Gorbatenko and Lankin, 2004b) for the construction of the automatic regulation of the electromagnetic AC drive. This requires multiprocessing mathematical model reflecting the magnetic, electrical and mechanical processes occurring in the electromagnetic drive (Gorbatenko *et al.*, 2015a).

As in real electromagnetic drive moving part can be considered as a rigid body, the dynamic equations for it have the form of homogeneous differential equations of motion. In automatic control systems operation of the electromagnetic drivers is mainly through the formation of the necessary electrical interference (voltage or current) for given characteristics of the electromagnet (Borovoi *et al.*, 2015; Gorbatenko *et al.*, 2011a, b, 2015a, b; Gorbatenko and Lankin, 2004a). The aim of electromagnetic calculation should be the definition of the parameters of the system in which the magnetic field of the latter would create the necessary power for a given movement interaction. Thus the problem can be formulated as follows: characterization of electromagnetic system to ensure specified parameters of movement.

MATERIALS AND METHODS

Electrical processes electromagnetic AC drive in the most general form of the equation describes a circuit that reflects the relationship between voltage, current and magnetic flux (Lankin *et al.*, 2015):

$$\frac{d\psi}{dt} + Ri = u$$

Where:
u = Voltage on working coil
R = Resistance of working coil
I = Current in the working coil
ψ = Thread coupling of working coil

Given the sinusoidal current provided in the form of a Fourier series:

$$i(t) = \sum_{m=1}^{n} I_{(2m-1)} \operatorname{sign}((2m-1)\omega t) \qquad (1)$$

Where:
$I_{(2m-1)}$ = Amplitude of $(2m-1)$ harmonic of current
ω = Angular frequency
t = Time and sinusoidal electromagnetic coil attached to the AC drive voltage amplitude U_a

$$u(t) = U_a \sin(\omega t) \qquad (2)$$

Rewrite circuit based on the known laws of variation of the current (Eq. 1) and tension (Eq. 2):

$$U_a \sin \omega t = R\left(\sum_{m=1}^{n} I_{(2m-1)} \sin((2m-1)\omega t)\right) + \frac{d\psi}{dt}$$

Electrical steel magnetic magnetic drive characterized by nonlinearity with a pronounced saturation. This process describes the basic magnetization curve that is the dependence of the induction (flux) of the magnetic

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field from its voltage (current) which can be described by a power polynomial. Moving the moving part of the magnetic core determines the slope of the magnetization curve:

$$\psi = k_1 xi + \sum_{2}^{n} k_{2m-1} i^{2m-1}$$

Where:

k_1, k_{2m-1} = Approximation coefficients weber-ampere characteristic

x = Moving the movable part

This model reflects the magnetic processes occurring in the cells of the electromagnetic drivers. To reflect the mechanical processes in electromagnetic drivers should be considered force acting on the movable portion of the electromagnetic drive (Fig. 1):

$$F_g = F_{em}(G, \psi) - F_f(k_f, V) - F_e(k_e, x)$$

Where:

F_g = Force of the movable part of the magnetic circuit
F_{em} = Electromagnetic force
F_f = Friction force
F_e = Reaction force mechanism
k_f = Friction coefficient
k_e = Coefficient of elasticity counteracting mechanism

The total force applied to the the movable part of the magnetic circuit in turn depends can be expressed as the product of the mass the movable part of the magnetic
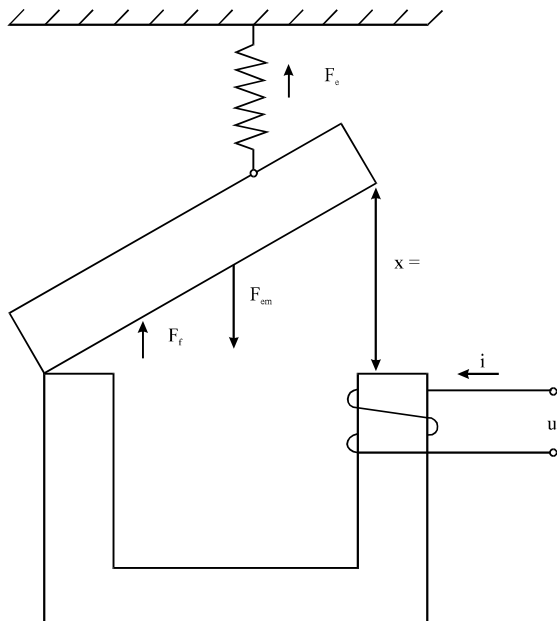

Fig. 1: Mechanical processes occurring in the electromagnetic drives

circuit on the acceleration of the mass of the movable part of the magnetic circuit and accelerate its movement (the second derivative of displacement with respect to time):

$$F_g = \frac{m d^2 x}{dt^2}$$

where, m is mass of the movable part magnetic circuit. The magnitude of the electromagnetic force depends on the size and configuration of the magnetic magnetic circuit electromagnetic drive:

$$F_{em} = f(\psi, G)$$

where, G is index of the magnetic configuration. In general expression for the electromagnetic forces produced on the basis of the Maxwell equations is:

$$\overline{F}_{em} = \varepsilon_0 \int_s \left(\overline{E}(\overline{n}\overline{E}) - \frac{1}{2} E^2 \overline{n} \right) ds + \frac{1}{\mu_0} \int_s \left(\overline{B}(\overline{n}\overline{B}) - \frac{1}{2} B^2 \overline{n} \right) ds$$

Where:

$\overline{E}$ = Electric field vector
ε_0 = Permittivity of free space
μ_0 = Permeability of free space
$\overline{B}$ = Vector magnetic field
$\overline{n}$ = Vector normal to the surface of integration S

The integration is performed on the surface S, the female body considered. The first integral in the expression characterizes the force generated by the electric field and the second-magnetic.

The friction force the movable part magnetic circuit depends on the coefficient of friction and the normal pressure:

$$F_f = F_n[x, B_{mp}(H), B_{sp}(H), G] k_f \, \text{sign}\left(\frac{dx}{dt} \right)$$

Where:

B_{mp} = Induction of the movable part magnetic circuit
B_{sp} = Induction of a stationary part magnetic circuit

The friction force is discontinuous in nature and it varies in magnitude and in sign when the value and sign of the velocity of the test sample.

The counter force mechanism the movable part magnetic circuit (special case of a counteracting spring) depends on the coefficient of elasticity and counteracting mechanism of the movable part magnetic circuit:

$$F_e = k_e x$$

The resulting equation of motion (Newton's second law) is as follows:

$$\frac{mdx^2}{d^2t} = \varepsilon_0 \int_s \left(E(nE) - \frac{1}{2}E^2 n \right) ds + \frac{1}{\mu_0} \int_s \left(B(nB) - \frac{1}{2}B^2 n \right) ds -$$

$$F_n[y, B_{mp}(H), B_{sp}(H), G]k_f \, \text{sign}\left(\frac{dy}{dt} \right) - k_e x$$

RESULTS

The resulting model is a system of equations, it reflects the processes occurring in the electromagnetic drive; Mechanical processes:

$$\frac{mdx^2}{d^2t} = \varepsilon_0 \int_s \left(E(nE) - \frac{1}{2}E^2 n \right) ds + \frac{1}{\mu_0} \int_s \left(B(nB) - \frac{1}{2}B^2 n \right) ds -$$

$$F_n[x, B_{mp}(H), B_{sp}(H), G]k_f \, \text{sign}\left(\frac{dx}{dt} \right) - k_e x$$

Electrical processes:

$$U_a \sin \omega t = R\left(\sum_{m=1}^{n} I_{(2m-1)} \sin((2m-1)\omega t) \right) + \frac{d\psi}{dt}$$

Magnetic processes:

$$\psi = k_1 x i + \sum_{2}^{n} k_{2m-1} i^{2m-1} a$$

DISCUSSION

During the study, it was composed of equations, which is a multi-process model. The proposed system of equations can form the basis of a virtual model of a software package for implementing LabView natural-model tests. Resulting in LabViewmodel allows for natural-method model tests in order to obtain magnetic, electrical and mechanical parameters of electromagnetic actuators

CONCLUSION

The resulting multiprocessing model allows us to describe the magnetic, electrical, and mechanical processes occurring in the course of electro-magnetic AC drive. This model can be used for later use with the method of natural-model tests (Grayr *et al.*, 2014; Lankin *et al.*, 2015) to determine the weber-ampere characteristics and the gap of the magnetic circuit of the electromagnetic AC drive.

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