Vibration protection drive control in small movement mode

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Abstract. Mathematical model of the stepper motor is considered. Features of “large” and “small” movements require implementation different approaches to solve stabilization problem. For large movements, is proposed to use an algorithm of active regulation according information from position sensor. Small movements, stabilization algorithm is proposed taking into account use elastic-dissipative properties of the creation and control stopping torque.

1. Introduction
With 1982, instrument was designed at the IBM Research Laboratory that could be used to examine individual atoms on electrically conductive surface (scanning tunneling microscope (STM)). In 1986, design of the device was proposed there, which made it possible to study surfaces with accuracy atom from any materials. The new device was called atomic force microscope, today these two devices are the greatest interest for use in modern laboratories, in intermediate control areas [1]. The main problem of using these devices is need to improve image quality by reducing external influences on measuring module. This requires creation fundamentally new vibration protection systems. Currently, all vibration protection systems for such systems are purchased abroad.

The task replacing foreign models equipment with domestic will increase the independence research and scientific-production work from foreign suppliers equipment. One of the ways to improve positioning accuracy is implementation elastic-dissipative vibration-isolating device based on electric motor. Modern possibilities processing algorithms in "real" time allow use changes in engine design parameters as sensor signals. Assessing change current in the motor winding allows you to determine inertial characteristics and dynamic parameters, providing more efficient mode operation [2]. In control systems, engine is generally regarded as actuator. The description of his work in most cases comes down to integrator model, but elastic dissipative characteristics are not taken into account in known models.

2. Structure
For figure 1 a 3D model proposed design solution is presented. This 3D model shows a parallel structure mechanism (3) with active control implemented by two stepper motors (1) and measuring system consisting of an accelerometer (4), rotation angle sensor (5), which provide positioning of installation. The first motor operates in active control mode, the second, connected through the reducer (6), provides active damping mode. Exciter (2) creates harmonic oscillations. Overall control of the system is carried out using a microcontroller (not specified on the 3D model).
Figure 1. 3D model of the facility.

The structural diagram of model shown in figure 2, consists of stepper motor (1) operating in modes damper or integrator, oscillation source (2), accelerometer (3), mechanical part (4), rotation angle sensor (5), control devices (6), power supply (7) and driver (8). Rotation angle sensor (5) based on potentiometer is used to determine deviations the installation. Signals from the sensor read and processed by control device. After processing, these signals transmitted to engine. The setup also uses accelerometer to plot external disturbances.

Figure 2. Block diagram.

3. Mathematical models
In mathematical models of engine [2,3] its elastic dissipative characteristics not taken into account. In this paper, it is proposed to take them into account and consider the operation of engine in active damping mode, which will reduce dimensions external elastic dissipative elements. The operation of stepper motor is reduced to changing direction motion rotor according algorithm selected by control system on microcontroller. The determining mode operation will be operation engine with small angles not exceeding 2°. This mode operation can be described using system nonlinear equations (1), consisting equation of moments, equations electric balance for voltage, also the equation electrical energy conversion.
\[
\begin{align}
\frac{d^2\theta}{dt^2} + D \frac{d\theta}{dt} + p\psi i_a \sin(p\theta) + p\psi i_b \sin(p(\theta - \lambda)) + M_0 &= 0 \\
U_\parallel - r i_a - L \frac{d i_a}{dt} - M \frac{d i_b}{dt} + \frac{d}{dt}(\psi \cdot \cos(p\theta)) &= 0 \\
U_\parallel - r i_b - L \frac{d i_b}{dt} - M \frac{d i_a}{dt} + \frac{d}{dt}(\psi \cdot \cos(p(\theta - \lambda))) &= 0
\end{align}
\]

Where \( J \) – rotor inertia moment, \( D \) – viscous friction coefficient, \( \lambda = \frac{\pi}{4} \) - intervals between windings, \( \theta = \frac{\lambda}{2} \) - equilibrium position, \( \delta\theta \) – deviation from equilibrium position, \( M_0 \) – moment applied to motor shaft, \( \tau_{a,b} \) – moments created by currents \( i_a, i_b \), \( U_\parallel \) – voltage of power source, \( L \) – self-inductance, \( M \) – mutual inductance, \( r \) – resistance of stator winding circuit, \( \psi \) – maximum value flux linkage maximum value flux linkage. It is assumed that \( L, M \) are independent \( \theta \). Based on mathematical model, block diagram was developed and transfer function (figure 3.) was obtained, which was used to obtain transient characteristics the engine taking into account nonlinearities.

**Figure 3.** Transient response model of a stepper motor taking into account nonlinearities.

Block I - model describing changes in current and voltage in the first stator winding;
Block II - voltage realization model in the second stator winding;
Block III - rotor motion model.

A two-phase voltage signal \( (U_\parallel) \) and two effects \( \frac{d}{dt}(\psi \cdot \cos(p\theta)), \frac{d}{dt}(\psi \cdot \cos(p(\theta - \lambda))) \), taking into account the design features stepper motor. Windings modeled by inertial blocks with transfer functions \( \frac{K_a}{T s+1}, \frac{K_b}{T s+1} \). At the output, stator phase currents \( i_a, i_b \) obtained transfer functions have form (2-3):

\[
i_a = \frac{k_a}{T s+1} \left( \frac{d}{dt}(\psi \cdot \cos(p\theta)) + U_\parallel \right),
\]

\[
i_b = \frac{k_b}{T s+1} \left( \frac{d}{dt}(\psi \cdot \cos(p(\theta - \lambda))) + U_\parallel \right).
\]

The stator phase currents \( i_a, i_b \) converted at corresponding moments by formulas (4-5):
\[
\tau_a = -p \psi_i_a \sin(p \theta),
\]
\[
\tau_b = -p \psi_i_b \sin(p(\theta - \lambda))
\]

(4) (5)

4. Researches

On the rotor, developed moments \( \tau_a \), \( \tau_b \) Added and summed with external moment applied to motor shaft. Signal passes through winding modeled in block diagram by transfer function \( \frac{K}{T_1 + 1} \), being converted to a value proportional to angular velocity the rotor \( \frac{D\theta}{Dt} \). Accounting for the operation engine made it possible to implement control algorithm physical model vibration protection system, taking into account the influence on control external torque. In the course of research, it was possible to reduce vibrational activity by 5 db in mode dynamic vibration suppression. Figures 4-6 show results obtained during the operation of installation with various vibration protection options.

![Figure 4](image4.png)

**Figure 4.** Operation schedule of the installation without vibration isolation devices.

![Figure 5](image5.png)

**Figure 5.** Schedule of the installation with a passive elastic element.

![Figure 6](image6.png)

**Figure 6.** Schedule of the installation in the mode of active elastic-dissipative absorption.

Experiments carried out clearly demonstrate possibility a significant increase in effectiveness vibration protection system. There is an effective decrease in amplitudes of the oscillations. Replacing active system with passive elastic system leads to additional oscillations. The created device is effective and can be used to solve problems of special engineering. When exciting pulses are applied, the rotor shifts from the equilibrium position, creating oscillations on the transition function. However, over time, again comes to a stable state due to damping in the engine (attenuation of the transition process, because the system is stable).

5. LTR-EU-2-5

To verify the assumptions, tests and schedules of the LTR-EU-2-5 installation were carried out using LTR210 (figure 7). Consider the operation of the installation. Modular data acquisition system LTR is
used in the creation of information management systems for research and development. Any LTR module is galvanically isolated from the crate housing (block frame, to accommodate electronic and electrical devices) and the computer, which allows you to improve the quality of measurements and external connections.

The LTR data acquisition system is built on a modular principle that allows flexible configuration changes and selection of the optimal set of modules for a particular task. LTR contains 2 crates. Blackfin ADSP-BF537 signal processor is used for data processing. The LTR communicates with the computer via USB 2.0 (high-speed mode) and Fast Ethernet (TCP/IP Protocol, 100 Mbps).

![Block diagram of the LTR-EU-2-5.](image)

**Figure 7.** Block diagram of the LTR-EU-2-5.

6. Test procedure

PowerGraph is used for visualization, storage, processing and analysis of measurement results. The signal on the charts is filtered from noise using Noise Filter (figure 8) in order to see the "clean" signal.

![Schedule of the pathogen.](image)

**Figure 8.** Schedule of the pathogen.

The amplitude of the oscillations created by the exciter is 4 mV (figure 9).
The amplitude of oscillations after the operation of the stepper motor decreased by 2 times and is equal to 2 mV.

To confirm the repeatability of the results of this installation, a series of 10 tests was carried out. According to the results of these tests, there is an effective reduction in the amplitude of oscillations in 1.5-2 times.

References

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