Electro Magneto Elastic Actuator for Nanomedical Research

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Received: August 14, 2019
Published: August 23, 2019

Introduction

The electro magneto elastic actuator with the piezoelectric, piezomagnetic, electrostriction, magnetostriction effects is used for nanomedical research in the scanning tunneling microscopy [1-9]. For control system of the deformation of the electro magneto elastic actuator its structural diagram, transfer function, characteristics are calculated [9-18]. The structural diagram and matrix transfer function the electro magneto elastic actuator is applied to describe the dynamic and static characteristics of the electro magneto elastic actuator for nanomedical research with regard to its physical parameters and external load [14-28].

Aim

The aim of this work is to construct the structural diagram and the matrix transfer function of the electro magneto elastic actuator for control systems of nanomedical research.

Method

The method of mathematical physics is used to solve the wave equation with the Laplace transform for obtain the structural diagram, the matrix transfer function, the characteristics of the electro magneto elastic actuator for nanomedical research.

Results

We constructed the structural diagram and the matrix transfer function of the electro magneto elastic actuator. The structural diagram of the electro magneto elastic actuator is difference from Cady and Mason electrical equivalent circuits. The method of the mathematical physics we used for the determination the structural diagram actuator is used decision with Laplace transform the wave equation for the wave propagation in the long line with damping but without distortions. We obtained with using Laplace transform the linear ordinary second-order differential equation with the parameter $p$ [8,14,18].

$$
\frac{d^2 \Xi(x,p)}{dx^2} + \left( \gamma^2 \Xi(x,p) - \alpha \right) = 0
$$

where $\Xi(x,p)$ is the Laplace transform of the displacement of section of the actuator, $\gamma = p/c^* + \alpha$ is the propagation coefficient, $c^*$ is the sound speed for the control parameter $\Psi = \text{const}$, $\alpha$ is the damping coefficient.

Figure 1: Generalized structural diagram of electro magneto elastic actuator for nanomedical research.
We determined the generalized structural-parametric model, the generalized structural diagram [7,8,14] of the actuator on (Figure 1) by the method of the mathematical physics with using the equation of the electro magneto elasticity and the boundary conditions in the following form

\[ \xi(p) = [1/(M_\xi p^2) + E(p)](1/\gamma_s) \left\{ [\xi(p) - \xi(p) - \xi(p)] \left\{ \gamma + \delta_{\gamma}(p) \right\} \right\} \]

\[ \xi(p) = [1/(M_\xi p^2) + E(p)](1/\gamma_s) \left\{ [\xi(p) - \xi(p) - \xi(p)] \left\{ \gamma + \delta_{\gamma}(p) \right\} \right\} \quad (3) \]

where \( \xi = \xi(p) = \xi(p) = \xi(p) = \xi(p) \) is the piezomodule or the magnetostrictive coefficient, \( \xi = \xi(p) = \xi(p) = \xi(p) = \xi(p) \) is the piezomodule, \( S_{\xi}^{2} \) is the elastic compliance, \( S_{\xi}^{2} \) is the elastic compliance, \( S_{\xi}^{2} \) is the Laplace transforms of the displacements and the forces on two faces. The structural diagrams of the magnetostrictive actuator or piezoelement are determined from the generalized structural diagram of the electro magneto elastic actuator. We obtained the matrix transfer function of the electro magneto elastic actuator \[ \Theta(p) \] from the structural-parametric model (3) in the form

\[ (\Theta(p)) = (W(p))(P(p)) \]

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where \( \Theta(p) \) is the matrix of the Laplace transforms of the displacements for the faces of the actuator. \( (W(p)) \) is the matrix transfer function, \( (P(p)) \) the matrix of the Laplace transforms of the control parameter and the forces. We calculated the matrix transfer function of the electro magneto elastic actuator for control system of nanomedical research. We obtained the transfer function of the transverse piezoelement with one fixed face for the elastic-inertial load from (4) at \( M \rightarrow \infty, m \ll M_\xi \), in the form

\[ W(p) = \Pi(p)/U(p) = K_p/(T_p^2 p^2 + 2T_p \xi p + 1) \]

\[ K_p = (d_\xi h/\delta)(1+C_{\xi}/C_{\xi}^2), \quad T_p = \sqrt{M_p/(1+C_{\xi}/C_{\xi}^2)} \]

\[ \xi = \alpha hC_{\xi}/C_{\xi}^2 \sqrt{M_p}(c_{\xi} + c_{\xi}^2) \]

where \( U(p) \) is the Laplace transform of the voltage on the piezoelement, \( k_\xi \) is the transfer coefficient, \( T_p \) is the time constant. \( \xi \) is the damping coefficient of the piezoelement. For the transverse piezoelement with one fixed face for the elastic-inertial load at \( d_\xi = 2.4 \times 10^{-5} N/V, \delta = 0 \), \( M_\xi = 1 kg, C_{\xi} = 3.10^{10} N/m \), \( C_{\xi} = 0.6 \times 10^7 N/m \) we obtain values the transfer coefficient \( K_p \approx 2 nm/V \) and the time constant of the piezoelement \( T_p \approx 1.7 \times 10^{-5} s \).

**Summary**

We obtained the structural diagram and the matrix transfer function of the electro magneto elastic actuator for control systems of nanomedical research.

**Conclusion**

We constructed the generalized structural diagram of the electro magneto elastic actuator for nanomedical research with the mechanical parameters the displacement and the force in the difference from Cady and Mason electrical equivalent circuits. The generalized structural diagram, the transfer function and the characteristics of the electro magneto elastic actuator are determined for describe the dynamic and static characteristics of the actuator in control systems.

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DOI: 10.32474/GJAPM.2019.02.000128

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Citation: Afonin SM. Electro Magneto Elastic Actuator for Nanomedical Research. Glob J Anes & Pain Med 2(1)-2019. GJAPM.MS.ID.000128.
DOI: 10.32474/GJAPM.2019.02.000128.