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Mini Review

Structural Diagram of Electromagnetoelastic Actuator for Nanobiotechnology and Medicine

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Abstract

The structural diagram and the matrix transfer function, the characteristics of the electromagnetoelastic actuator for nanobiotechnology and medicine are determined. The aim of this work is to build the structural diagram of the electromagnetoelastic actuator for nanobiotechnology and medicine and control systems for nano and micromotion. The method of mathematical physics with the Laplace transform is used in the work for solve the wave equation. In result the structural diagram and the matrix transfer function of the electromagnetoelastic actuator for nanobiotechnology and medicine are obtained. The generalized structural diagram, the generalized matrix transfer function for the electromagnetoelastic actuator nanodisplacement are obtained from its structural-parametric model.

Keywords: *Structural Diagram; Electromagnetoelastic Actuator; Piezoactuator; Matrix Transfer Function*

Introduction

The electromagnetoelastic actuator with the piezoelectric, piezomagnetic, electrostriction, magnetostriction effects is used in the control system for nanobiotechnology and medicine in the scanning tunneling microscopy [1-25].

For control system of the deformation of the electromagnetoelastic actuator its structural diagram, matrix transfer function, the characteristics are calculated [9-18].

The structural diagram and matrix transfer function the electromagnetoelastic actuator based on the electromagnetoelasticity make it possible to describe the dynamic and static properties of the electromagnetoelastic actuator for nanobiotechnology and medicine with regard to its physical parameters and external load [14-24].

Aim of the Study

The aim of the work is to build the structural diagram of the electromagnetoelastic actuator for nanobiotechnology and medicine and for control systems of nano and micromotion in the scanning tunneling microscopy.

Methods

The method of mathematical physics with the Laplace transform is used to solve the wave equation and obtain the structural diagram and matrix transfer function of the electromagnetoelastic actuator.

Results

The structural diagram and the matrix transfer function of the electromagnetoelastic actuator for nanobiotechnology and medicine are constructed. The structural diagram of the electromagnetoelastic actuator is difference from Cady and Mason electrical equivalent circuits. The method of the mathematical physics with Laplace transform we used for the determination the structural diagram of the electromagnetoelastic actuator for nanobiotechnology and medicine [1-18].

The generalized equation [8, 11] of the electromagnetoelasticity has the form

$$S_i = \nu_{mi}\Psi_m(t) + s_{ij}^{\Psi}T_j(x,t) \qquad (1)$$

where $S_i = \partial\xi(x,t)/\partial x$ is the relative displacement along axis *i* of the cross section of the actuator, $\Psi_m = \{E_m, D_m, H_m$ is the control parameter, E_m is the electric field strength for the voltage control along axis *m*, D_m is the electric induction for the current control along axis *m*, H_m for magnetic field strength control along axis *m*, T_j is the mechanical stress along axis *j*, ν_{mi} is the electromagnetoelastic coefficient or the electromagnetoelastic module, s_{ij}^{Ψ} is the elastic compliance for the control parameter $\Psi = \text{const}$, the indexes *i*= 1, 2, ... , 6; *j* = 1, 2, ... , 6; *m* = 1, 2, 3.

The main size of the actuator is determined us the working *l = δ, h, b* length for the piezoactuator in the form the thickness, the height and the width for the longitudinal, transverse and shift piezoeffect.

In the foundation 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. With Laplace transform is obtained the linear ordinary second-order differential equation with the parameter p. Then the original problem for the partial differential equation of hyperbolic type using the Laplace transform is reduced to the simpler problem [8,14,18] for the linear ordinary differential equation

$$\frac{d^2\Xi(x,p)}{dx^2} - \gamma^2\Xi(x,p) = 0 \qquad (2)$$

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

The generalized structural-parametric model and the generalized structural diagram [7,8,14] of the actuator on figure 1 are determined, using the method of the mathematical physics with Laplace transform for the solution of the wave equation, the equation of the electromagnetoelasticity, the boundary conditions in the form

$$\Xi_1(p) = \left[1/\left(M_1p^2\right)\right] \times$$
$$\times\left\{-F_1(p) + \left(1/\chi_{ij}^{\Psi}\right)\left[\nu_{mi}\Psi_m(p) - \left[\gamma/\text{sh}(l\gamma)\right]\left[\text{ch}(l\gamma)\Xi_1(p) - \Xi_2(p)\right]\right]\right\}$$

(3)

$$\Xi_2(p) = \left[1/\left(M_2p^2\right)\right] \times$$
$$\times\left\{-F_2(p) + \left(1/\chi_{ij}^{\Psi}\right)\left[\nu_{mi}\Psi_m(p) - \left[\gamma/\text{sh}(l\gamma)\right]\left[\text{ch}(l\gamma)\Xi_2(p) - \Xi_1(p)\right]\right]\right\}$$

$$\nu_{mi} = \begin{cases} d_{33}, d_{31}, d_{15} \\ g_{33}, g_{31}, g_{15} \\ d_{33}, d_{31}, d_{15} \end{cases}, \quad \Psi_m = \begin{cases} E_3, E_1 \\ D_3, D_1 \\ H_3, H_1 \end{cases}, \quad s_{ij}^{\Psi} = \begin{cases} s_{33}^{E}, s_{11}^{E}, s_{55}^{E} \\ s_{33}^{D}, s_{11}^{D}, s_{55}^{D} \\ s_{33}^{H}, s_{11}^{H}, s_{55}^{H} \end{cases},$$

$$c^{\Psi} = \begin{cases} c^{E} \\ c^{D} \\ c^{H} \end{cases}, \quad \gamma = \begin{cases} \gamma^{E} \\ \gamma^{D} \\ \gamma^{H} \end{cases}, \quad l = \begin{cases} \delta \\ h \\ b \end{cases}, \quad \chi_{ij}^{\Psi} = s_{ij}^{\Psi}/S_0,$$

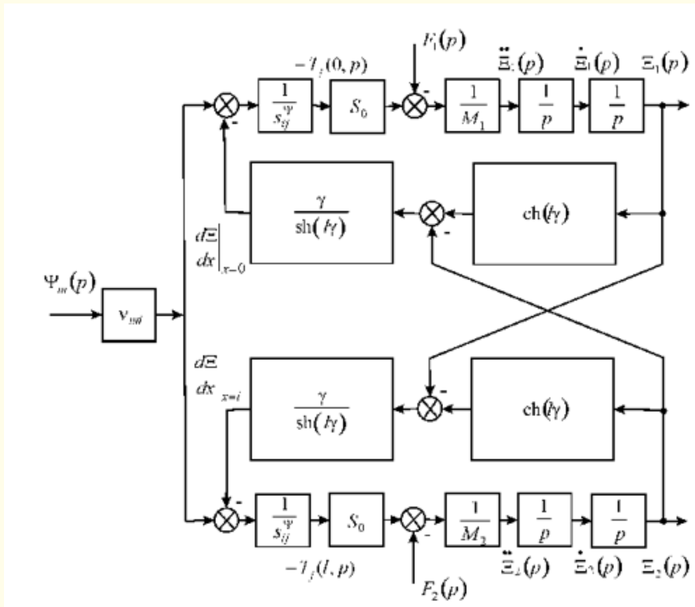

Figure 1: *Generalized structural diagram of electromagnetoelastic actuator.*

where ν_{mi} is the electromagnetoelastic coefficient, d_{mi} is the piezomodule at the voltage-controlled piezoactuator or the magnetostrictive coefficient for the magnetostrictive actuator, g_{mi} is the piezomodule at the current-controlled piezoactuator, s_{ij}^{Ψ} is the elastic compliance, S_0 is the cross section area, M_1, M_2 are the mass on two faces of the actuator, $\Xi_1(p)$, $\Xi_2(p)$and $F_1(p)$, $F_2(p)$ are the Laplace transforms of the appropriate displacements and the forces on two faces.

The structural diagrams of the voltage-controlled or current-controlled piezoactuator are determined from the generalized structural diagram of the electromagnetoelastic actuator.

Let us consider the matrix transfer function of the electromagnetoelastic actuator [8,18] obtained from the structural-parametric model (3) in the form

$$(\Xi(p)) = (W(p))(P(p)) \qquad (4)$$

$$(\Xi(p)) = \begin{pmatrix} \Xi_1(p) \\ \Xi_2(p) \end{pmatrix}, \ (W(p)) = \begin{pmatrix} W_{11}(p) & W_{12}(p) & W_{13}(p) \\ W_{21}(p) & W_{22}(p) & W_{23}(p) \end{pmatrix},$$

$$(P(p)) = \begin{pmatrix} \Psi_m(p) \\ F_1(p) \\ F_2(p) \end{pmatrix}$$

where $(\Xi(p))$ is the column-matrix of the Laplace transforms of the displacements for the faces of the electromagnetoelastic actuator, $(W(p))$ is the matrix transfer function, $(P(p))$ the column-matrix of the Laplace transforms of the control parameter and the forces.

The transfer function of the voltage-controlled transverse piezoactuator is obtained from (4) for the elastic-inertial load at $M_1 \to \infty$, $m < M_2$ and the approximation the hyperbolic cotangent by two terms of the power series in the form

$$W(p) = \Xi_2(p)/U(p) = k_t/\left(T_t^2 p^2 + 2T_t\xi_t p + 1\right) \qquad (5)$$

$$k_t = (d_{31} h/\delta)/\left(1 + C_e/C_{11}^E\right), \quad T_t = \sqrt{M_2/\left(C_e + C_{11}^E\right)},$$

$$\xi_t = \alpha h^2 C_{11}^E \Big/ \left(3c^E \sqrt{M_2\left(C_e + C_{11}^E\right)}\right)$$

where $U(p)$ is the Laplace transform of the voltage on the plates of the piezoactuator, k_t is the transfer coefficient, T_t is the time constant. ξ_t is the damping coefficient of the piezoactuator.

For the transverse piezoactuator with the elastic-inertial load at d_{31} = 2·10^{-10} m/V, h/δ = 20, M_2 = 1 kg, C_{11}^E = 2·10^7 N/m, C_e = 0.5·10^7 N/m we obtain values the transfer coefficient k_t = 3.2 nm/V and the time constant of the piezoactuator T_t = 0.2·10^{-3} s.

The matrix transfer function of the electromagnetoelastic actuator are calculated for control system of the deformation the electromagnetoelastic actuator in nanobiotechnology and medicine.

Summary

The structural diagram and the matrix transfer function of the electromagnetoelastic actuator are obtained for nanobiotechnology and medicine and control systems for nano and micromotion.

Conclusion

For nanobiotechnology and medicine and for control systems of nano and micromotion the generalized structural diagram of the electromagnetoelastic actuator are constructed with the mechanical parameters the displacement and the force in the difference from Cady and Mason electrical equivalent circuits.

The generalized structural diagram, the matrix transfer function and the characteristics of the electromagnetoelastic actuator are determined. This structural diagram and transfer functions of the electromagnetoelastic actuator make it possible to describe the dynamic and static characteristics of the actuator with regard to its physical parameters and external load.

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