Review Article

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Electromagnetoelastic Actuator for Nanobiomedical Research

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Abstract
In this work the structural diagram and the transfer functions, the characteristics of the electromagnetoelastic actuator for nanobiomedical research are obtained. The generalized structural diagram, the matrix transfer functions of the electromagnetoelastic actuator make it possible to describe the characteristics of the actuator with regard to its physical parameters, external load.

Keywords: Electromagnetoelastic actuator, Piezoactuator, Electromagnetoelasticity, Structural diagram, Transfer function

Introduction
The electromagnetoelastic actuator for nanodisplacement on the piezoelectric, piezomagnetic, electrostriction, magnetostriction effects is used in the electromechanics systems for the nanobiomedical research in the scanning sensing microscopy [1-8].

When designing the nanotechnology equipment, the static and dynamic characteristics, the mathematical model, the structural diagram and transfer functions of the electromagnetoelastic actuator are calculated [9-18].

The mathematical model, the structural diagram and transfer functions the electromagnetoelastic actuator based on the electromagnetoelasticity make it possible to describe the dynamic and static properties of the electromagnetoelastic actuator for the nanomedicine research with regard to its physical parameters and external load [19-22].

Structural Diagram of Electromagnetoelastic Actuator
Let us consider the structural diagram of the electromagnetoelastic actuator for the nanobiomedical research in contrast Cady and Mason electrical equivalent circuits. The method of mathematical physics is applied for the solution the wave equation and for the determination the structural diagram of the electromagnetoelastic actuator for nanomedicine research [1-18].

For the electromagnetoelastic actuator let us consider the generalized equation of the electromagnetoelasticity in the form [8,11,18]

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

where $S_i = \partial\xi(x,t)/\partial x$ is the relative displacement along axis i of the cross section of the piezoactuator or the piezoplate, $\Psi_m = \{E_m, D_m, H_m$ 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, for example, the piezoelectric module, s_{ij}^{Ψ} is the elastic compliance for the control parameter Ψ=const, and the indexes i= 1, 2, … , 6; j = 1, 2, … , 6; m = 1, 2, 3.

The main size of the electromagnetoelastic actuator is determined us the working length $l=\{\delta,h,b$ for the actuator or for the piezoactuator in following form the thickness, the height and the width for the longitudinal, transverse and shift piezoeffect.

The mathematical model and the generalized structural diagram of the electromagnetoelastic actuator on Figure 1 are determined, using method of the mathematical physics for the solution of the wave equation, the boundary conditions and the equation of the electromagnetoelasticity, in the following form [7,14]

$$\Xi_1(p) = \left[1/\left(M_1 p^2\right)\right] \times$$
$$\times\left\{-F_1(p) + \left(1/\chi_{ij}^{\Psi}\right)\left[\nu_{mi}\Psi_m(p) - [\gamma/\mathrm{sh}(l\gamma)]\left[\mathrm{ch}(l\gamma)\Xi_1(p) - \Xi_2(p)\right]\right]\right\}$$

$$(2)$$

$$\Xi_2(p) = \left[1/\left(M_2 p^2\right)\right] \times$$
$$\times\left\{-F_2(p) + \left(1/\chi_{ij}^{\Psi}\right)\left[\nu_{mi}\Psi_m(p) - [\gamma/\mathrm{sh}(l\gamma)]\left[\mathrm{ch}(l\gamma)\Xi_2(p) - \Xi_1(p)\right]\right]\right\}$$

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

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

v_{mi} is the electromagnetoelastic coefficient, $\Psi_m = \{E_m, D_m, H_m$ 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, s_{ij}^{Ψ} is the elastic compliance, 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 pΨiezoactuator, S_0 is the cross section area, M_1, M_2 are the mass on the 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 the faces 1, 2.

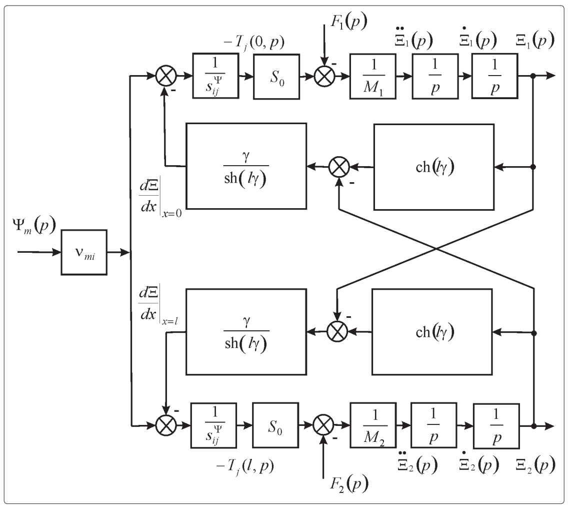

Figure 1: Generalized structural diagram of electromagnetoelastic actuator for the nanobiomedical research

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

Matrix Transfer Function of Electromagnetoelastic Actuator

The matrix transfer function of the actuator is deduced from its mathematical model (4) in the following form [8,14,18]

$$(\Xi(p)) = (W(p))(P(p)) \tag{3}$$

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

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

where $(\Xi_1(p))$ 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, $(P(p))$ is the column-matrix of the Laplace transforms of the control parameter and the forces.

Conclusion

The characteristics, the mathematical model, the structural diagram and transfer functions of the electromagnetoelastic actuator for the nanobiomedical research are obtained.

The generalized structural diagram, the transfer functions of the electromagnetoelastic actuator make it possible to describe the dynamic and static properties of the actuator with regard to its physical parameters, external load.

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