Multilayer Actuator For Nanomedical Sciences

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***Abstract*—We obtained the mathematical model and the transfer functions of the multilayer actuator for nanomedical sciences.. We received the static and dynamic characteristics of the multilayer actuator.**

Keywords—Multilayer actuator, Electro magneto elasticity, Nanomedical sciences, Transfer function, Characteristic, Multilayer piezo actuator.

Introduction

The multilayer actuator on the piezoelectric or magnetostrictive effect is widely applied for nanomedical sciences in adaptive optics, micro surgery, nano pump, cell penetration tool, scanning microscopy, nano manipulate, focus system, image stabilization [1−16]. We obtained the structural scheme and the transfer functions, static and dynamic the characteristics of the multilayer electro magneto elastic actuator for control system in nanomedical sciences [7−35].

Structural scheme and transfer function

The multilayer electro magneto elastic actuator is used in nanomedical sciences for nano displacement. The multilayer electro magneto elastic actuator have the displacement 1 nm - 10 μm, fast response 1-10 ms, force 100-1000 N [23−37].

The equation of the electro magneto elasticity [8, 9, 13, 35, 36] for relative deformation S_i of the multilayer actuator has the form

$$S_i = \nu_{mi}\Psi_m + s_{ij}^{\Psi}T_j$$

where ν_{mi}, Ψ_m, s_{ij}^{Ψ}, T_j are the module, the control parameter in the form of electro or magneto field strength, the elastic compliance for $\Psi = \text{const}$, the mechanical stress and i, j, m are the indexes.

We have the matrix the quadripole for the multilayer actuator [7, 20, 24, 26, 32, 34] in the form

$$[M]^n = \begin{bmatrix} \text{ch}(l\gamma) & Z_0\text{sh}(l\gamma) \\ \dfrac{\text{sh}(l\gamma)}{Z_0} & \text{ch}(l\gamma) \end{bmatrix}$$

where *l* is the length of the multilayer actuator and γ is the coefficient propagation.

We received the mathematical model and the structural scheme of the multilayer actuator on Figure 1 for control system in nanomedical sciences with using the equation of the electro magneto elasticity and the matrix the quadripole in the form

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

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

where $\Psi_m(p)$, $\Xi_1(p)$, $\Xi_2(p)$, $F_1(p)$, $F_2(p)$ are transforms of the control parameter, the displacements and the forces for its faces 1 and 2, and M_1, M_2, l are the mass on the faces and the length of the multilayer actuator.

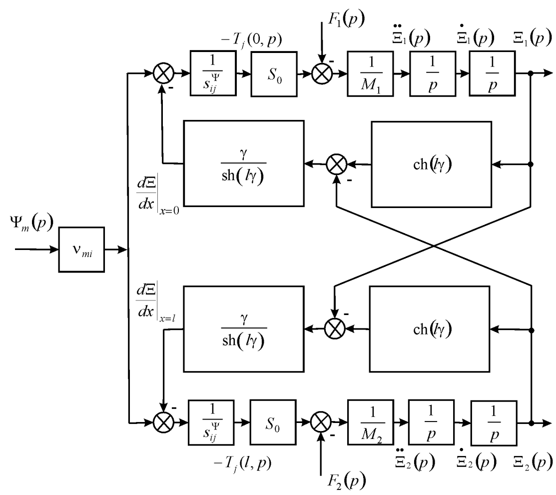

Figure 1: Structural scheme of multilayer actuator for nanomedical sciences.

For lumped parameters of the multilayer actuator we have the transfer function at longitudinal piezoeffect and one fixed face is obtained in the form

$$W(p) = \frac{\Xi_2(p)}{U(p)} = \frac{d_{33}n}{\left(1 + C_e/C_{33}^E\right)\left(T_t^2p^2 + 2T_t\xi_t p + 1\right)}$$

$$T_t = \sqrt{M_2/\left(C_e + C_{33}^E\right)},\ \ \xi_t = \alpha l^2 C_{33}^E \Big/ \left[3c^E\sqrt{M_2\left(C_e + C_{33}^E\right)}\right]$$

where $\Xi_2(p)$, $U(p)$ are transforms the displacement face of the multilayer piezo actuator and the voltage, T_t, ξ_t are the time constant and the damping coefficient, C_{33}^E is the is rigidity of the multilayer piezo actuator for electro field strength $E = \text{const}$. We get the expression for the transient response of the voltage-controlled the multilayer piezo actuator in the form

$$\xi(t)=\xi_m\left(1-\frac{e^{-\frac{\xi_t t}{T_t}}}{\sqrt{1-\xi_t^2}}\sin(\omega_t t+\varphi_t)\right)$$

$$\xi_m=\frac{d_{33}nU_m}{1+C_e/C_{33}^E},\ \omega_t=\sqrt{1-\xi_t^2}\Big/T_t$$

$$\varphi_t=\mathrm{arctg}\left(\sqrt{1-\xi_t^2}\Big/\xi_t\right)$$

where ξ_m is the static displacement and U_m is the amplitude of the voltage. We have for the multilayer piezo actuator at U_m = 200 V, d_{33} = 4·10^{-10} m/V, n = 10, M = 1 kg, C_{33}^E = 6·10^7 N/m, C_e = 0.4·10^7 N/m the static displacement ξ_m = 750 nm, the time constant T_t = 0.125·10^{-3} s. The discrepancy between the experimental data and calculation results is 5%.

Conclusions

We received the mathematical model and the structural scheme of the multilayer actuator for nanomedical sciences with using the equation of the electro magneto elasticity and the matrix the quadripole.

We received the static and dynamic characteristics of the multilayer actuator for control system in nanomedical sciences.

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