Actuator For Nanomedical Research

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***Abstract*—In this work, the mathematical model and the transfer functions of the actuator for nanomedical research with the piezoelectric or magnetostrictive effect are received. The static and dynamic characteristics of the actuator for nanomedical research are obtained.**

Keywords—actuator; nanomedical research; parameter; characteristic; piezoelectric actuator; magnetostrictive actuator; electromechanics.

Introduction

At present the actuator on the piezoelectric or magnetostrictive effect is used for nanomedical research in the nanolitre pump, the nanomanipulator, the cell penetration tool, the scanning microscope, the microsurgery [1−16]. We receive the transfer functions, static and dynamic the characteristics of the actuator on the piezoelectric and magnetostrictive effect for control system in nanomedical research [17−30].

Transfer function

The actuator on the piezoelectric and magnetostrictive effect is used in nanomedical research for nano adjustment and nano displacement. We use the equation of electromechanics [9, 11] with relative deformation S_i of the piezoelectric or magnetostrictive actuator in 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, the elastic compliance and the mechanical stress, and i, j, m are the indexes.

For nanomedical research we have the second order differential equation [8, 12, 14] of the actuator in the form

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

where p, γ, x are the conversion parameter, the propagation coefficient, the coordinate.

Therefore, the transfer function $W(p)$ of the actuator has the following form

$$W(p) = \Xi(p)/\Psi(p)$$

where $\Xi(p)$, $\Psi(p)$ are transforms of Laplace the displacement and the control parameter.

Let us consider the mathematical model for the actuator on the piezoelectric and magnetostrictive effect for control system in nanomedical research.

We drew the mathematical model of the actuator from decision the equation of electromechanics and the second order differential equation [12−20]. Therefore, we have the mathematical model and the scheme of the actuator for nanomedical research on Figure 1 with the piezoelectric or magnetostrictive effect in the form

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

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

where $\Xi_1(p)$, $\Xi_2(p)$, $F_1(p)$, $F_2(p)$ are transforms of the displacements and the forces of the faces, M_1, M_2, l are the mass of loads on the faces and the length of the actuator.

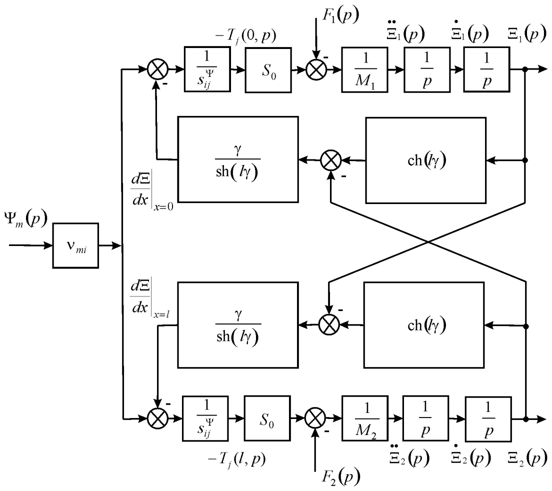

Figure 1: Structural scheme of actuator for nanomedical research.

Let us consider the static characteristics for the displacements of the faces of the transverse piezoelectric actuator at $m << M_1$, $m << M_2$ in the form

$$\xi_1(\infty) = d_{31}(h/\delta)U_0 M_2/(M_1 + M_2)$$

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where m is the mass of the actuator, d_{31} is the piezomodule, h, δ are the height and the thickness, U_0 is the voltage amplitude. For the piezoactuator at d_{31} = 2.5·10^{-10} m/V, h/δ = 20, U_0 = 25 V, M_1 = 0.5 kg, M_2 = 2 kg we obtain the static displacement of the faces of the piezoactuator $\xi_1(\infty)$ = 100 nm, $\xi_2(\infty)$ = 25 nm, $\xi_1(\infty) + \xi_2(\infty)$ = 125 nm.

Let us consider the transfer function of the transverse piezoelectric actuator with one fixed face for the elasticinertial load in the form

$$W(p)=\frac{\Xi_2(p)}{U(p)}=\frac{k_t}{T_t^2 p^2+2T_t\xi_t p+1}$$

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

Therefore, dynamic characteristic of the transverse piezoelectric actuator has the form

$$\xi_2(t)=\xi_{20}\left(1-\frac{e^{-(\xi_t t/T_t)}}{\sqrt{1-\xi_t^2}}\sin(\omega_t t+\varphi_t)\right)$$

$$\xi_{20}=\left(d_{31}U_0 h/\delta\right)/\left(1+C_e/C_{11}^E\right),\ \omega_t=\sqrt{1-\xi_t^2}\Big/T_t$$

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

where ξ_{20} is the steady-state value of displacement of the piezoactuator.

At d_{31} = 2.5·10^{-10} m/V, h/δ = 20, U_0 = 25 V, M_2 = 1 kg, C_{11}^E = 2·10^7 N/m, C_e = 0.5·10^7 N/m we obtain the parameters of piezoactuator k_t = 4 nm/V, ξ_0 = 100 nm, T_t = 0.2·10^{-3} s. The discrepancy between the experimental data and calculation results is 5%.

Conclusions

In work, we obtained the transfer functions and the static and dynamic parameters of the actuator for the control system for nanomedical research.

We received the mathematical model of the actuator for nanomedical research from decision the equation of electromechanics and the second order differential equation for describe the deformation of the actuator.

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