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Structural Scheme Actuator for Nano Research

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Abstract

We obtained the structural scheme of the electro elastic actuator in the control system for nano research. The transfer functions of the electro elastic actuator are used for the decision of the characteristics of the actuator for nano research.

Keywords: Structural scheme; Electro elastic actuator; Piezo actuator; Transfer function

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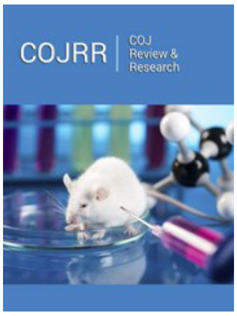

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Introduction

The application of the electro elastic actuator on the piezoelectric or electrostriction effects is promising in the control system for nano research. The electro elastic actuator is applied for nano research, adaptive optics, micro surgery, nano manipulator. The electro elastic actuator for the control system in nano research is used in scanning microscopy, nano injector, focus system, image stabilization [1-14]. The electro elastic actuator for nano research have the displacement 1nm-10μm, fast response 1-10ms, force 100-1000N [15-31]. The structural scheme and transfer functions of the electro elastic actuator are calculated for the decision of the dynamic and static characteristics of the actuator in the control system for nano research [4-14].

Structural Scheme and Transfer Function of Actuator

We used the method of mathematical physics with Laplace transform for the decision the wave equation. The structural scheme of the electro elastic actuator for the control system for nano research is changed from Cady and Mason electrical equivalent circuits [7,8]. We have the equation of the electro elasticity [5, 6,8,12,14] in the form

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

Where S_i is the relative displacement along axis i, $\Psi_m = \{E_m, D_m$ is the control parameter in the form of the electric field strength or the electric induction along axis m, T_j is the mechanical stress along axis j, ν_{mi} is the electro elastic module, s_{ij}^{Ψ} is the elastic compliance for $\Psi = \text{const}$, and the indexes i= 1, 2, ... , 6; j=1, 2, ... , 6; m=1, 2, 3.

We obtained the linear ordinary second-order differential equation by using Laplace transform.

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

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

The structural scheme is received by using the linear ordinary second-order differential equation, the boundary conditions, the equation of the electro elasticity in the form

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

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

Where

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

$$c^{\Psi} = \begin{cases} c^E \\ c^D \end{cases}, \ \gamma = \begin{cases} \gamma^E \\ \gamma^D \end{cases}, \ \chi_{ij}^{\Psi} = s_{ij}^{\Psi} / S_0,$$

ν_{mi} is the electro elastic module, d_{mi}, g_{mi} are the piezo module for the voltage-controlled actuator or the current-controlled actuator, l is the main size along axis i, S_0 is the cross section area, M_1, M_2 are the mass of the load, $\Xi_1(p)$, $\Xi_2(p)$ and $F_1(p)$, $F_2(p)$ are the Laplace transforms of the displacements and the forces on the faces 1, 2 (Figure 1).

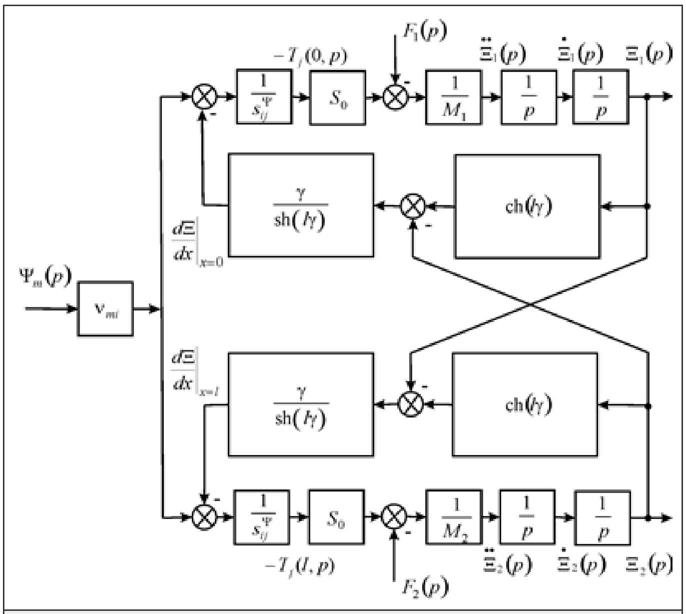

Figure 1: Structural scheme of electro elastic actuator for nano research.

We obtained the structural scheme of the voltage-controlled or current-controlled piezo actuator for nano research from its mathematical model. The matrix transfer function [6,17,18,21,22-31] of the electro elastic actuator for nano research is received in the form

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

where $(\Xi(p))$, $(W(p))$, $(P(p))$ are the column-matrix of the Laplace transforms of the displacements for the faces 1, 2 of the actuator, the matrix transfer function, the column-matrix of the Laplace transforms of the control parameter, the forces.

Conclusion

We received the structural scheme by using the linear ordinary second-order differential equation, the boundary conditions, the equation of the electro elasticity for the actuator in nano research. We determined the structural scheme, the transfer functions of the electro elastic actuator in nano research for the decision of the characteristics of the actuator in the control system.

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