Characteristics Actuator for Nanomedical Sciences

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***Abstract*—We obtained the mechanical and regulation characteristics the piezo actuator of the nanomechatronics system for nanomedical sciences. We considered the characteristics of the electro magneto elastic actuator for nanomedicine. We found mechanical and regulation characteristics of the electro magneto elastic actuator for nanomedical sciences.**

Keywords—Electro magneto elastic actuator, Piezo actuator, Mechanical and regulation characteristics, Nanomedical sciences.

Introduction

The electro magneto elastic actuator with the piezoelectric or electrostriction effect is applied for nanomoving in nanomedical sciences, scanning microscopy, nanomanipulator, nanopump. It is used in the nanomechatronics systems of nanomedicine. The electro magneto elastic actuator is the device for actuating and controlling mechanisms, systems with the transformation electrical signals into mechanical displacements and forces [1-9]. The electro magneto elastic actuator is used for nanomoving in interferometry, adaptive optics, laser systems, micromanipulation in cells, stabilization systems. It is also have range of movement from nanometers to tens microns, load 10N-1000 N, response 0.1-10 ms [5-31].

Characteristics of actuator

Let us consider the mechanical and regulation characteristics of the piezo actuator for the calculation of the nanomechatronics system for nanomedical sciences. The equation [2, 6, 8-30] for relative deformation S_1 of the actuator with the transverse piezo effect has the form

$$S_1 = d_{31}E_3 + s_{11}^E T_1$$

where d_{31}, E_3, s_{11}^E, T_1 are the transverse piezo module, the electro field strength on axis 3 the elastic compliance for $E = \text{const}$ on axis 1, the mechanical stress on axis 1. The mechanical characteristic of the actuator with the transverse piezo effect has the form

$$\Delta h = \Delta h_{\max}\left(1 - F/F_{\max}\right)$$

where h is the height, $\Delta h_{\max}$ is the maximum displacement for $F = 0$ and $F_{\max}$ is the maximum force for $\Delta h = 0$. For the actuator with the transverse piezo effect the maximum displacement and the maximum force have the form

$$\Delta h_{\max} = d_{31}E_3 h$$

$$F_{\max} = d_{31}E_3 S_0 / s_{11}^E$$

where S_0 is the cross sectional area of the actuator. At d_{31} = 2·10^{-10} m/V, E_3 = 3·10^5 V/m, h = 1.5·10^{-2} m, S_0 = 1·10^{-5} m^2, s_{11}^E = 15·10^{-12} m^2/N for the actuator from ceramic PZT with the transverse piezo effect are found the maximum displacement $\Delta h_{\max}$ = 900 nm and the maximum force $F_{\max}$ = 40 N on Figure 1.

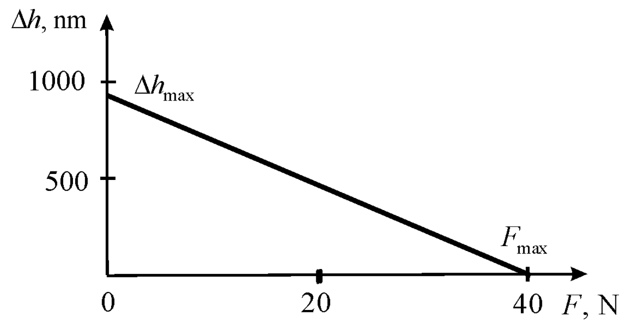

Figure 1: Mechanical characteristic of actuator with transverse piezo effect for nanomedical sciences.

The equation [2, 8-30] for relative deformation S_3 of the actuator with the longitudinal piezo effect has the form

$$S_3 = d_{33}E_3 + s_{33}^E T_3$$

where d_{33}, s_{33}^E, T_3 are the t longitudinal piezo module, the elastic compliance for $E = \text{const}$ on axis 3, the mechanical stress on axis 3.

For the calculation the regulation characteristic of the multilayer actuator with the longitudinal piezo effect and elastic force $F = C_e \Delta l$ we have equation

$$\frac{\Delta l}{l} = d_{33}E_3 - \frac{s_{33}^E C_e}{S_0}\Delta l$$

$$l = n\delta\text{, } U = E_3\delta\text{, } C_{33}^E = S_0 / \left(s_{33}^E l\right)$$

where l is the length of the actuator, δ is the thickness of the layer, U is the voltage, C_{33}^{E} is stiffness of the actuator at $E = \text{const}$.

Therefore, the regulation characteristic of the multilayer actuator with the longitudinal piezo effect has the following form

$$\Delta l = \frac{d_{33} n U}{1 + C_e / C_{33}^{E}} = k_{33}^{U} U$$

$$k_{33}^{U} = \frac{d_{33} n}{1 + C_e / C_{33}^{E}}$$

where k_{33}^{U} is the transfer coefficient. At d_{33} = 4·10^{-10} m/V, n = 12, C_{33}^{E} = 2.5·10^{7} N/m, C_e = 0.4·10^{7} N/m, U = 50 V for the multilayer actuator with the longitudinal piezo effect from ceramic PZT the transfer coefficient k_{33}^{U} = 4.14 nm/V and the displacement Δl = 207 nm are found on Figure 2. The discrepancy between the experimental data and the calculation results for the actuator is 10%.

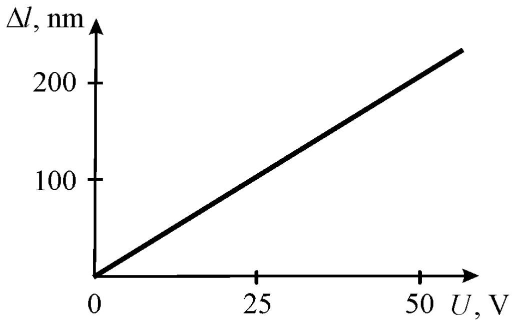

Figure 2: Regulation characteristic of multilayer actuator with longitudinal piezo effect for nanomedical sciences.

The equation of the electro magneto elasticity [2, 8-30] for relative deformation S_i on axis i of the 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 E_m or magneto H_m field strength on axis m, the elastic compliance, the mechanical stress on axis j.

From the equation of the the electro magneto elasticity [6, 7, 11-30] the mechanical characteristic of the actuator has the form $S_i(T_j)$ or $\Delta l(F)$. We have the mechanical characteristic in the following form

$$S_i\big|_{E=\text{const}} = d_{mi} E_m\big|_{E=\text{const}} + s_{ij}^{E} T_j \,.$$

The regulation characteristic of the actuator has the form $S_i(E_m)$ or $\Delta l(U)$. We have the control characteristic in the form

$$S_i\big|_{T=\text{const}} = d_{mi} E_m + s_{ij}^{E} T_j\big|_{T=\text{const}}$$

The mechanical characteristic of the actuator has the following equation

$$\Delta l = \Delta l_{\max} \left(1 - F / F_{\max}\right)$$

where $\Delta l_{\max}$ is the maximum displacement for $F = 0$ and $F_{\max}$ is the maximum force for $\Delta l = 0$.

The maximum displacement of the actuator has the form

$$\Delta l_{\max} = d_{mi} E_m l$$

where l is the length of the actuator.

The maximum mechanical stress of the actuator has the form

$$T_{j\max} = d_{mi} E_m / s_{ij}^{E}$$

The maximum force of the actuator is written as the expression

$$F_{\max} = T_{j\max} S_0 = d_{mi} E_m S_0 / s_{ij}^{E}$$

For the regulation characteristic of the actuator with elastic force we have equation

$$\frac{\Delta l}{l} = d_{mi} E_m - \frac{s_{ij}^{E} C_e}{S_0} \Delta l$$

Therefore, for elastic load the regulation characteristic of the actuator has the form

$$\Delta l = \frac{(d_{mi}\, l/\delta) U}{1 + C_e / C_{ij}^{E}}$$

$$U = E_m \delta \,, \;\; C_{ij}^{E} = S_0 / \left(s_{ij}^{E} l\right)$$

where C_{ij}^{E} is stiffness of the actuator at $E = \text{const}$. We received the mechanical and regulation characteristics of the electro magneto elastic actuator for nanomedical sciences.

Conclusions

The mechanical and regulation characteristics of the electro magneto elastic actuator are used for the calculation of the nanomechatronics systems of nanomedicine. The mechanical characteristic of the actuator is received with used the maximum displacement and the maximum force of the actuator.

The regulation characteristic of the multilayer actuator with the longitudinal piezo effect is obtained for the elastic load in the nanomechatronics system for nanomedical sciences.

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