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Review Article

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Actuator for Nano Engineering Research and Development

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Abstract

We obtained the parameters of the actuator for nano engineering research and development. The structural diagram and the parameters of the actuator at the piezoelectric or magnetostrictive effect for nano engineering are determined.

Keywords: Actuator, Nano Engineering, Piezo Actuator, Characteristic, Parameter.

Introduction

Actuator for nano engineering research and development is used to nano manipulations in the scanning microscope, the nano pump, the gene manipulator, the cell penetration tool, the micro surgery [1-16].

We obtain the transfer functions and the characteristics of the actuators on the piezoelectric and magnetostrictive effect for control system of the nano deformation for nano engineering research and development [17-32].

Structural Diagram

The equation of electro magneto mechanics for relative deformation S_i of the piezoelectric or magnetostrictive actuator has the form [8, 11].

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

where ν_{mi}, Ψ_m, s_{ij}^{Ψ}, T_j are the module, the control parameter, the elastic compliance, the mechanical stress, and *i, j, m* are the indexes.

The second order differential equation for the actuator has the form [8, 12, 14].

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

where $\Xi(x,p)$ is the Laplace transform of the displacement, x, p, γ are the coordinate, the operator, the propagation coefficient. The matrix equation is obtained with using the equation of electro magneto mechanics, the differential equation and its boundary conditions in the form

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

where $(\Xi(p))$ is the matrix of the transforms of the displacements for its two faces of the actuator, $(W(p))$ is the matrix transfer function, $(P(p))$ is the matrix of the transforms of the control parameter of the actuator and the forces for two faces.

The mathematical model and the structural diagram on Figure 1 of the actuator are obtained from decision the equation of electro magneto mechanics and its differential equation [12-16]. In result the mathematical model of the actuator for nano engineering research and development has the form

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

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

$$\chi_{ij}^{\Psi} = s_{ij}^{\Psi}/S_0 \ , \quad \nu_{mi} = \begin{cases} d_{33}, d_{31}, d_{15} \\ d_{33}, d_{31}, d_{15}\end{cases} \ , \quad \Psi_m = \begin{cases} E_3, E_1 \\ H_3, H_1\end{cases} \ ,$$

$s_{ij}^{\Psi} = \begin{cases} s_{33}^{E}, s_{11}^{E}, s_{55}^{E} \\ s_{33}^{H}, s_{11}^{H}, s_{55}^{H} \end{cases}$, *E, H* are the electric and magnetic fields strengths, $\Xi_1(p)$, $\Xi_2(p)$, $F_1(p), F_2(p)$ are the transforms of the displacements and the forces of the faces for its two faces, M_1, M_2, l are the mass and the length.

The transfer function of the transverse piezo actuator with fixed one face has the form

$$W(p) = \frac{\Xi_2(p)}{U(p)} = \frac{k_{31}^{U}}{T_t^2 p^2 + 2T_t \xi_t p + 1}$$

$$k_{31}^{U} = (d_{31}\, l/\delta)/(1 + C_e/C_{11}^{E}),\ T_t = \sqrt{M_2/(C_e + C_{11}^{E})}$$

where k_{31}^{U} is the transfer coefficient for voltage, T_t, ξ_t are the time constant and the damping coefficient of the actuator. At d_{31}=2·10^{-10} m/V, h/δ = 16, U = 50 V, M_2 = 4 kg, C_{11}^{E} = 3·10^{7} N/m, C_e = 0.3·10^{7} N/m the parameters of the actuator from ceramic PZT are obtained in the form k_{31}^{U} = 2.91 nm/V, $\xi_2(\infty)$ = 145.5 nm, T_t = 0.35·10^{-3} s.

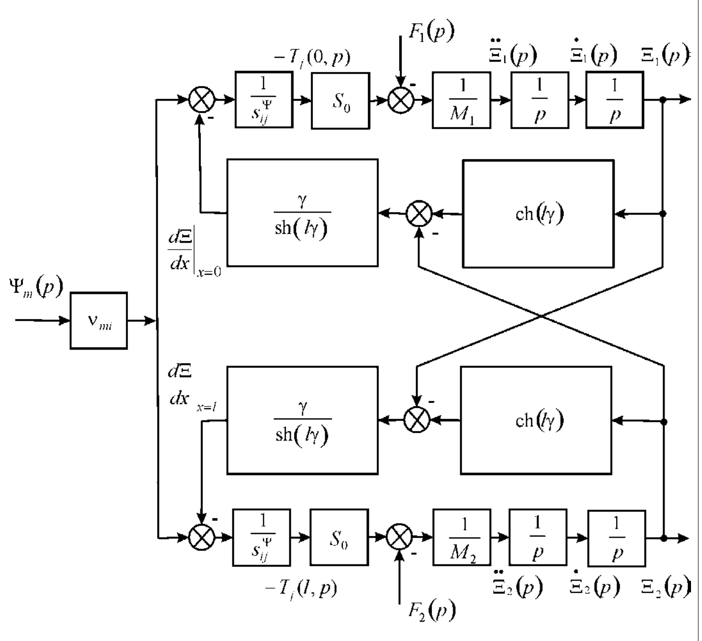

Figure 1: Structural diagram of actuator for nano engineering research and development research.

The characteristics of actuator are used in the calculation of nano mechatronics control systems for nano engineering research and development The relative deformation of actuator at elastic force has the form [7, 10-17, 20-31]

$$\frac{\Delta l}{l} = \nu_{mi}\Psi_m - \frac{s_{ij}^{\Psi} C_e}{S_0}\Delta l$$

$$F = C_e \Delta l$$

where l, Δl, C_e, S_0 are the length, the displacement of the actuator, the stiffness of the load, the area of the actuator. The regulation characteristic of the actuator at elastic force has the form

$$\Delta l = \frac{\nu_{mi} l \Psi_m}{1 + C_e/C_{ij}^{\Psi}}$$

$$C_{ij}^{\Psi} = S_0/(s_{ij}^{\Psi} l)$$

where C_{ij}^{Ψ}, is stiffness of the actuator at $\Psi = \text{const}$.

Therefore, the regulation characteristic for the transverse piezo actuator for the elastic load has the form

$$\Delta l = \frac{(d_{31}\, l/\delta)U}{1 + C_e/C_{11}^{E}} = k_{31}^{U} U$$

$$k_{31}^{U} = (d_{31}\, l/\delta)/(1 + C_e/C_{11}^{E})$$

where k_{31}^{U} is the transfer coefficient for voltage. For the piezo actuator from ceramic PZT at d_{31}= 2·10^{-10} m/V, l/δ = 16, C_{11}^{E} = 3·10^{7} N/m, C_e = 0.3·10^{7} N/m, U = 100 V the parameters of actuator are obtained in the form k_{31}^{U} = 2.91 nm/V, Δl = 291 nm.

The mechanical characteristic of the actuator has the form

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

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

where $\Delta l_{\max}$ is the maximum displacement for F = 0 and $F_{\max}$ is the maximum force for $\Delta l = 0$. At d_{31} = 2·10^{-10} m/V, $E_3 = U/\delta$ = 3·10^{5} V/m, l = 2·10^{-2} m, S_0 = 1·10^{-5} m^2, s_{11}^{E} = 15·10^{-12} m^2/N the parameters are received in the form $\Delta l_{\max}$ = 1200 nm and $F_{\max}$ = 40 N for the mechanical characteristic of the actuator from ceramic PZT.

Conclusions

The structural diagram and the parameters of the actuator are obtained for the control system in nano engineering research and development.

The mathematical model of the actuator is written from decision the equation of electro magneto mechanics and the differential equation and its boundary conditions.

References

1. Schultz J, Ueda J, Asada H (2017) Cellular Actuators. Butterworth-Heinemann Publisher, Oxford, 382.

2. Afonin SM (2006) Absolute stability conditions for a system controlling the deformation of an elecromagnetoelastic transduser. Doklady Mathematics 74: 943-948.

3. Zhou S, Yao Z (2014) Design and optimization of a modal-independent linear ultrasonic motor. IEEE Transaction on Uultrasonics, Ferroelectrics, and Frequency Control 61: 535-546.

4. Przybylski J (2015) Static and dynamic analysis of a flextensional transducer with an axial piezoelectric actuation, Engineering Structures 84: 140-151.

5. Ueda J, Secord T, Asada HH (2010) Large effective-strain piezoelectric actuators using nested cellular architecture with exponential strain amplification mechanisms. IEEE/ASME Transactions on Mechatronics 15: 770-782.

6. Karpelson M, Wei G-Y, Wood RJ (2012) Driving high voltage piezoelectric actuators in microrobotic applications. Sensors and Actuators A: Physical 176: 78-89.

7. Afonin SM (2015) Block diagrams of a multilayer piezoelectric motor for nano- and micro displacements based on the transverse piezo effect. Journal of Computer and Systems Sciences International 54: 424-439.

8. Afonin SM (2008) Structural parametric model of a piezoelectric nanodisplacement transduser. Doklady Physics 53: 137-143.

9. Afonin SM (2006) Solution of the wave equation for the control of an elecromagnetoelastic transduser. Doklady Mathematics 73: 307-313.

10. Cady WG (1946) Piezoelectricity: An introduction to the theory and applications of electromechancial phenomena in crystals. McGraw-Hill Book Company 806.

11. Mason W (1964) Physical Acoustics: Principles and Methods. Vol. 1. Part A. Methods and Devices. Academic Press 515.

12. Zwillinger D (1989) Handbook of Differential Equations. Academic Press 673.

13. Afonin SM (2015) Structural-parametric model and transfer functions of electroelastic actuator for nano- and microdisplacement. Chapter 9 in Piezoelectrics and Nanomaterials: Fundamentals, Developments and Applications. Ed Parinov IA. Nova Science 225-242.

14. Afonin SM (2017) A structural-parametric model of electroelastic actuator for nano- and microdisplacement of mechatronic system. Advances in Nanotechnology 19: 259-284.

15. Afonin SM (2009) Static and dynamic characteristics of a multi-layer electroelastic solid. Mechanics of Solids 44: 935-95.

16. Afonin SM (2010) Static and dynamic characteristics of multilayered electromagnetoelastic transducer of nano- and micrometric movements. Journal of Computer and Systems Sciences International 49: 73-85.

17. Afonin SM (2012) Nano- and micro-scale piezomotors. Russian Engineering Research 32: 519-522.

18. Afonin SM (2007) Elastic compliances and mechanical and adjusting characteristics of composite piezoelectric transducers. Mechanics of Solids 42: 43-49.

19. Afonin SM (2014) Stability of strain control systems of nano-and microdisplacement piezotransducers. Mechanics of Solids 49: 196-207.

20. Afonin SM (2017) Structural-parametric model electromagnetoelastic actuator nanodisplacement for mechatronics. International Journal of Physics 5: 9-15.

21. Afonin SM (2019) Structural-parametric model multilayer electromagnetoelastic actuator for nanomechatronics. International Journal of Physics 7: 50-57.

22. Afonin SM (2018) Structural-parametric model of electro-magnetoelastic actuator for nanomechanics. Actuators 7: 1-9.

23. Afonin SM (2019) Structural-parametric model and diagram of a multilayer electromagnetoelastic actuator for nanomechanics. Actuators 8: 1-14.

24. Afonin SM (2017) Parametric block diagrams of a multi-layer piezoelectric transducer of nano- and microdisplacements under transverse piezoelectric effect. Mechanics of Solids 52: 81-94.

25. Afonin SM (2018) Multilayer electromagnetoelastic actuator for robotics systems of nanotechnology, Proceedings of the 2018 IEEE Conference EIConRus 1698-1701.

26. Afonin SM (2018) Electromagnetoelastic nano- and microactuators for mechatronic systems. Russian Engineering Research 38: 938-944.

27. Afonin SM (2018) Structural-parametric model of electro elastic actuator for nanotechnology and biotechnology. Journal of Pharmacy and Pharmaceutics 5: 8-12.

28. Afonin SM (2018) Electromagnetoelastic actuator for nanomechanics. Global Journal of Research in Engineering: A Mechanical and Mechanics Engineering 18: 19-23.

29. Afonin SM (2019) Multilayer electro magneto elastic actuator for nano science and engineering. Journal of Applied Material Science & Engineering Research 3: 1-3.

30. Afonin SM (2018) A block diagram of electromagnetoelastic actuator nanodisplacement for communications systems. Transactions on Networks and Communications 6: 1-9.

31. Afonin SM (2019) Decision matrix equation and block diagram of multilayer electromagnetoelastic actuator micro and nanodisplacement for communications systems, Transactions on Networks and Communications 7: 11-21.

32. Springer Handbook of Nanotechnology. Ed. by Bhushan B (2004) Springer 1222.