Research Article

Open Access
CrossMark

Deformation of electromagnetoelastic actuator for nano robotics system

Abstract

The regulation characteristic and the transfer function of the electromagnetoelastic actuator are investigated for nano robotics system. The electromagnetoelastic actuator is used in nanotechnology, scanning microscopy, adaptive optics, laser systems, focusing and image stabilization systems, vibration damping, nano and micro manipulator to penetrate the cell and to work with the genes. The mechanical and control characteristics of the electromagnetoelastic actuator are obtained to calculate the nano mechatronics robotics system. The piezo actuator is used in nano and micro dosing devices, nano manipulators in nano and micro surgery.

Keywords: electromagnetoelastic actuator, piezo actuator, deformation, regulation characteristic, transfer function, mechanical and control characteristics, nano robotics system, nanotechnology

Volume 6 Issue 2 - 2020

Afonin SM

National Research University of Electronic Technology, MIET, Russia

Correspondence: Afonin SM, National Research University of Electronic Technology, MIET, Moscow, Russia, Email learner01@mail.ru

Received: May 11, 2020 | **Published:** June 25, 2020

Introduction

The electromagnetoelastic actuator with the piezoelectric or electrostriction effect for nano robotics system is used in nanotechnology, nano manipulator, nano pump, scanning microscopy, adaptive optics. The use of the electromagnetoelastic actuator is promising in nano robotics system[1–6] and nano manipulator[7–24] for nanotechnology. The electromagnetoelastic actuator is the electromechanical device for actuating and controlling mechanisms, systems with the conversion of electrical signals into mechanical displacements and forces.[16–34]

The piezo actuator is used for nano scale motion in adaptive optics, laser systems, focusing and image stabilization systems, nano and micro surgery, vibration damping, nano and micro manipulation to penetrate the cell and to work with the genes. The electromagnetoelastic actuator is provided range of movement from nanometers to ten microns; force 1000 N, response 1-10 ms.[6–34]

Deformation of actuator

Let us consider the characteristics of the electromagnetoelastic actuator with fixe one face. From the equation of the electromagnetoelasticity[7,10–32] the regulation characteristic of the actuator is received with elastic force in the form

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

$$F = C_e \Delta l \ ,$$

where l, Δl, d_{mi}, Ψ_m, s_{ij}^{Ψ}, C_e, S_0 are the length, the deformation or displacement of the electromagnetoelastic actuator, the electromagnetoelastic module or the piezo module, the electric or magnetic field strength, the elastic compliance at $\Psi = \text{const}$, stiffness of the load, the area of the actuator. This length of the actuator is equal to the thickness, the height or the width, respectively, at the longitudinal, transverse or shear piezo effect, i, j, m are the indexes.

The displacement of the electromagnetoelastic actuator with fixe one face for elastic load is obtain in the form the regulation characteristic

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

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

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

The regulation characteristic for the transverse piezo actuator is received for fixe one face and the elastic load in the following form

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

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

where k_{31}^{U} is the transfer coefficient for voltage. For the piezo actuator from ceramic PZT at d_{31} = $2\cdot10^{-10}$ m/V, l/δ = 20, C_{11}^{E} = $2\cdot10^{7}$ N/m, C_e = $0.5\cdot10^{7}$ N/m, U = 100 V we obtain values the transfer coefficient for voltage k_{31}^{U} = 3.2 nm/V and the displacement Δl = 320 nm. Therefore, we have the transfer function for voltage with lumped parameter of the transverse piezo actuator[7,11,12,16–19,27,31] with fixe one face for the elastic-inertial load in the form

$$W(p) = \Xi(p)/U(p) = k_{31}^{U} / \left(T_t^2 p^2 + 2T_t \xi_t p + 1\right)$$

$$T_t = \sqrt{M / \left(C_e + C_{11}^{E}\right)} \ ,$$

where $\Xi(p)$, $U(p)$ are the Laplace transforms of the displacement and the voltage, T_t, ξ_t are the time constant and the damping coefficient of the piezo actuator, M is the load mass. At d_{31} = $2\cdot10^{-10}$ m/V, l/δ = 20, M =4 kg, C_{11}^{E} = $2\cdot10^{7}$ N/m, C_e = $0.5\cdot10^{7}$ N/m values the transfer coefficient for voltage k_{31}^{U} = 3.2 nm/V and the time constant of the piezo actuator T_t = $0.4\cdot10^{-3}$ s are obtained for the transverse piezo actuator with the elastic-inertial load.

The mechanical characteristic of the electromagnetoelastic actuator for nano robotics system is received from the equation of the electromagnetoelasticity[7,10–33] in form the characteristic $S_i(T_j)$ or $\Delta l(F)$ at $\Psi = \text{const}$

$$S_i\big|_{\Psi=\text{const}} = d_{mi}\Psi_m\big|_{\Psi=\text{const}} + s_{ij}^{\Psi} T_j ,$$

where S_i, d_{mi}, Ψ_m, s_{ij}^{Ψ}, T_j are the relative deformation, the electromagnetoelastic module, the electric or magnetic field strength, the elastic compliance, the mechanical stress.

The control characteristic of the electromagnetoelastic actuator for nano robotics system is obtained in the form $S_i(E_m)$ or $\Delta l(U)$ at $T = \text{const}$. The control characteristic has 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 electromagnetoelastic actuator is received in the form

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

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 electromagnetoelastic actuator has the form

$$\Delta l_{\max} = d_{mi}\Psi_m l .$$

The maximum mechanical stress of the electromagnetoelastic actuator has the form

$$T_{j\max} = d_{mi}\Psi_m / s_{ij}^{\Psi} .$$

The maximum force of the electromagnetoelastic actuator is written as the expression

$$F_{\max} = T_{j\max}S_0 = d_{mi}\Psi_m S_0 / s_{ij}^{\Psi} ,$$

where S_0 is the area of the actuator.

The maximum displacement and the maximum force for the piezo actuator with the transverse piezo effect are obtained in the form

$$\Delta l_{\max} = d_{31}E_3 l ,$$

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

At $d_{31} = 2\cdot10^{-10}$ m/V, $E_3 = U/\delta = 3\cdot10^5$ V/m, $l = 2\cdot10^{-2}$ m, $S_0 = 1\cdot10^{-5}$ m^2, $s_{11}^{E} = 15\cdot10^{-12}$ m^2/N for the mechanical characteristic of the transverse piezo actuator from ceramic PZT the maximum displacement $\Delta l_{\max}$ = 1200 nm and the maximum force $F_{\max}$ = 40 N are received on Figure 1.

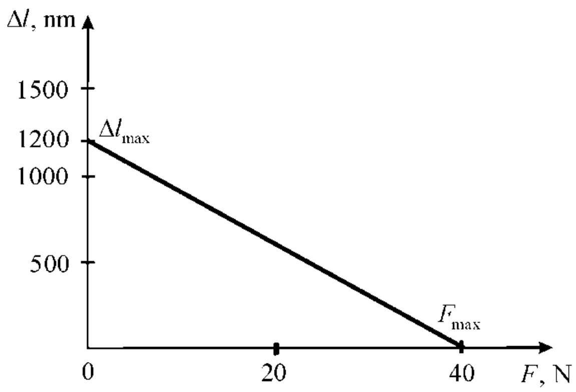

Figure 1 Mechanical characteristic of transverse piezo actuator for nano robotics system.

The discrepancy between the experimental and calculation data for the piezo actuator is 10%.

Discussion

The transfer function and the characteristics of the electromagnetoelastic actuator are calculated for nano robotics system of the deformation the actuator in nano manipulator for nanotechnology. The mechanical and control characteristics of the electromagnetoelastic actuator are received to calculate the nano mechatronics robotics system.

The piezo actuator is used in the nano manipulator for scanning microscopy. The nano manipulator with the piezo actuator is key component in the nano mechatronics system for nanotechnology.

Conclusions

The regulation characteristic and the transfer function of the electromagnetoelastic actuator are received for the nano robotics system. The maximum displacement and the maximum force are obtained for the mechanical characteristic of the electromagnetoelastic actuator.

The mechanical and controm characteristics of the electromagnetoelastic actuator are received for nano robotics system. The characteristics of the electromagnetoelastic actuator are used for the calculation the nano mechatronics robotics system and the control system with nano manipulator for nanotechnology.

Funding

None.

Acknowledgments

None.

Conflicts of interest

The author declares that there was no conflict of interest.

References

1. Schultz J, Ueda J, Asada H. Cellular Actuators: Modularity and Variability in Muscle-inspired Actuation. United Kingdom: Butterworth-Heinemann Publisher; 2017. p. 382.
2. Mehta M, Subramani K. Nanodiagnostics in microbiology and dentistry. Emerging Nanotechnologies in Dentistry: Chapter 21. 2012:365-390.
3. Li J, Esteban-Fernández AB, Gao W, et al. Micro/nanorobots for biomedicine: Delivery, surgery, sensing, and detoxification. *Science Robotics*. 2017;2(4).
4. Ma W, Zhan Y, Zhang Y, et al. An intelligent DNA nanorobot with in vitro enhanced protein lysosomal degradation of HER2. *Nano Letters*. 2019;19(7):4505–4517.
5. Nadikattu RR. The emerging role of nanoinformatics in America. *SSRN*. 2020.
6. Hu C, Pane S, Nelson BJ. Soft micro- and nanorobotics. *Annual Review of Control, Robotics, and Autonomous Systems*. 2018;1:53–75.
7. Afonin SM. Piezo actuators for nanomedicine research. *MOJ Applied Bionics and Biomechanics*. 2019;3(2):56–57.
8. Afonin SM. Condition absolute stability of control system with electro elastic actuator for nano bioengineering and microsurgery. *Surgery and Case Studies Open Access Journal*. 2019;3(3):307–309.

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

10. Uchino K. Piezoelectric actuator and ultrasonic motors. USA: Kluwer Academic Publisher; 1997. p. 347.

11. Afonin SM. Block diagrams of a multilayer piezoelectric motor for nano- and microdisplacements based on the transverse piezoeffect. *Journal of Computer and Systems Sciences International*. 2015;54(3):424–439.

12. Afonin SM. Structural parametric model of a piezoelectric nanodisplacement transduser. *Doklady Physics*. 2008;53(3):137–143.

13. Afonin SM. Solution of the wave equation for the control of an elecromagnetoelastic transduser. *Doklady Mathematics*. 2006;73(2):307–313.

14. Cady WG. Piezoelectricity: An introduction to the theory and applications of electromechancial phenomena in crystals. USA: McGraw-Hill Book Company; 1946. p. 806.

15. Mason WP. Physical Acoustics: Principles and Methods: Vol.1, Part A. USA: Academic Press; 1964. p. 515.

16. Afonin SM. Chapter 9: Structural-parametric model and transfer functions of electroelastic actuator for nano- and microdisplacement. Piezoelectrics and Nanomaterials: Fundamentals, Developments and Applications. 2015:225–242.

17. Afonin SM. Chapter 8: A structural-parametric model of electroelastic actuator for nano- and microdisplacement of mechatronic system. Advances in Nanotechnology. 2017;(19):259–284.

18. Afonin SM. Structural-parametric model electromagnetoelastic actuator nanodisplacement for mechatronics. *International Journal of Physics*. 2017;5(1):9–15.

19. Afonin SM. Structural-parametric model multilayer electromagnetoelastic actuator for nanomechatronics. *International Journal of Physics*. 2019;7(2):50–57.

20. Afonin SM. Solution wave equation and parametric structural schematic diagrams of electromagnetoelastic actuators nano- and microdisplacement. *International Journal of Mathematical Analysis and Applications*. 2016;3(4):31–38.

21. Afonin SM. Structural-parametric model of electromagnetoelastic actuator for nanomechanics. *Actuators*. 2018;7(1):1–9.

22. Afonin SM. Structural-parametric models and transfer functions of electromagnetoelastic actuators nano- and microdisplacement for mechatronic systems. *International Journal of Theoretical and Applied Mathematics*. 2016;2(2):52–59.

23. Afonin SM. Parametric block diagrams of a multi-layer piezoelectric transducer of nano- and microdisplacements under transverse piezoelectric effect. *Mechanics of Solids*. 2017;52(1):81–94.

24. Afonin SM. Multilayer electromagnetoelastic actuator for robotics systems of nanotechnology. Proceedings of the 2018 IEEE Conference EIConRus. 2018:1698–1701.

25. Afonin SM. Electromagnetoelastic nano- and microactuators for mechatronic systems. *Russian Engineering Research*. 2018;38(12):938–944.

26. Afonin SM. Structural-parametric model of electro elastic actuator for nanotechnology and biotechnology. Journal of Pharmacy and Pharmaceutics. 2018;5(1):8–12.

27. Afonin SM. Electromagnetoelastic actuator for nanomechanics. Global Journal of Research in Engineering. A: Mechanical and Mechanics Engineering. 2018;18(2):19–23.

28. Afonin SM. Structural–parametric model electroelastic actuator nano– and microdisplacement of mechatronics systems for nanotechnology and ecology research. *MOJ Ecology and Environmental Sciences.* 2018;3(5):306–309.

29. Afonin SM. Static and dynamic characteristics of multilayered electromagnetoelastic transducer of nano- and micrometric movements. *Journal of Computer and Systems Sciences International*. 2010;49(1):73–85.

30. Afonin SM. Static and dynamic characteristics of a multi-layer electroelastic solid. *Mechanics of Solids*. 2009;44(6):935–950.

31. Afonin SM. Structural-parametric model and diagram of a multilayer electromagnetoelastic actuator for nanomechanics. *Actuators*. 2019;8(3):1–14.

32. Afonin SM. A block diagram of electromagnetoelastic actuator nanodisplacement for communications systems. *Transactions on Networks and Communications*. 2018;6(3):1–9.

33. Afonin SM. Decision matrix equation and block diagram of multilayer electromagnetoelastic actuator micro and nanodisplacement for communications systems. *Transactions on Networks and Communications*. 2019;7(3):11–21.

34. Bhushan B. Springer Handbook of Nanotechnology. USA: Springer; 2004. p. 1222.

Citation: Afonin SM. Deformation of electromagnetoelastic actuator for nano robotics system. *Int Rob Auto J.* 2020;6(2):84–86.
DOI: 10.15406/iratj.2020.06.00205