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Multilayer piezo engine for nanomedicine research

Abstract

We received the structural circuit of the multilayer piezo engine for nanomedicine research. The characteristics of the multilayer piezo engine are obtained.

Keywords: multilayer piezo engine, structural circuit, transfer function, characteristic

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Introduction

The multilayer piezo engine with the piezoelectric effect is used for nanomedicine research in scanning microscopy, microdosing devices, nanomanipulates, nanopumps.[1–5] The structural circuit of the multilayer piezo engine is obtained in contrast to Cady's and Mason's equivalent circuits.[6–27]

Structural circuit

The structural circuit of the multilayer piezo engine is received from the equation of the electro elasticity and its matrix of the quadripole. The equation of the electro elasticity,[6,10,11] has the form

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

where S_i, v_{mi}, Ψ_m, s_{ij}^{Ψ}, T_j are the relative displacement, the coefficient of electro elasticity, the control parameter, the elastic compliance and the mechanical stress.

For the multilayer piezo engine the causes force is obtained in the form

$$F = v_{mi}S_0\Psi_m / s_{ij}^{\Psi}$$

where S_0 is the area of the multilayer piezo engine.

The matrix of the quadripole for the multilayer piezo engine,[6, 24–26] is received in the form

$$[M]^n = \begin{bmatrix} \mathrm{ch}(l\gamma) & Z_0\mathrm{sh}(l\gamma) \\ \dfrac{\mathrm{sh}(l\gamma)}{Z_0} & \mathrm{ch}(l\gamma) \end{bmatrix}$$

where l is the length of the multilayer piezo engine and γ is the coefficient propagation.

The structural circuit of the multilayer piezo engine for nanomedicine research on Figure 1 is obtained in the form

$$\Xi_1(p) = \left[1/\left(M_1p^2\right)\right] \times$$
$$\times\left\{-F_1(p) + \left(1/\chi_{ij}^{\Psi}\right)\left[v_{mi}\Psi_m(p) - \left[\gamma/\mathrm{sh}(l\gamma)\right]\left[\mathrm{ch}(l\gamma)\Xi_1(p) - \Xi_2(p)\right]\right]\right\}$$

$$\Xi_2(p) = \left[1/\left(M_2p^2\right)\right] \times$$
$$\times\left\{-F_2(p) + \left(1/\chi_{ij}^{\Psi}\right)\left[v_{mi}\Psi_m(p) - \left[\gamma/\mathrm{sh}(l\gamma)\right]\left[\mathrm{ch}(l\gamma)\Xi_2(p) - \Xi_1(p)\right]\right]\right\}$$

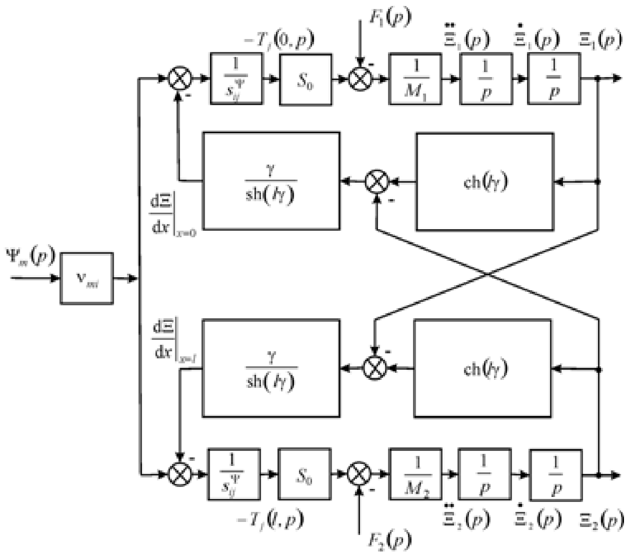

Figure 1 Structural circuit of multilayer piezo engine for nanomedicine research.

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

$c^{\Psi} = \begin{cases} c^E \\ c^D \end{cases}$, $\gamma = p/c^{\Psi} + \alpha$, $\chi_{ij}^{\Psi} = s_{ij}^{\Psi}/S_0$, $\Xi_1(p)$, $\Xi_2(p)$, $F_1(p)$, $F_2(p)$ are Laplace transforms of the displacements and the forces on the faces 1, 2 of the multilayer piezo engine; M_1, M_1 are the masses of the loads.

Accordingly, in the practical application of the multilayer piezo engine, we have its parameters: displacement 1 nm -10μm, fast response 1-10ms, force 100-1000 N.

For the system with the lumped parameters the transfer function of the multilayer engine with longitudinal piezoeffect and one fixed face is obtained in the form

$$W(p) = \frac{\Xi_2(p)}{U(p)} = \frac{d_{33}n}{\left(1 + C_e/C_{33}^E\right)\left(T_t^2p^2 + 2T_t\xi_t p + 1\right)}$$

$$T_t = \sqrt{M_2 / \left(C_e + C_{33}^E\right)}$$

$$\xi_t = \alpha \left(n\delta\right)^2 C_{33}^E \Big/ \left(3c^E \sqrt{M_2 \left(C_e + C_{33}^E\right)}\right)$$

where T_t, ξ_t are the time constant, the damping coefficient of the multilayer engine.

At d_{33} =4·10^{-10} m/V, n =16, U = 60 V, M_2 = 4 kg, C_{33}^E = 1.5·10^7 N/m, C_e = 0.3·10^7 N/m for the multilayer piezo engine from PZT are received the maximum static displacement of its second face ξ_2 =320 nm and the time constant T_t = 0.47·10^{-3} s. The discrepancy between the experimental data and the calculation results is 5%.

Conclusion

We received the structural circuit of the multilayer piezo engine for nanomedicine research with used the equation of the electro elasticity and the matrix of the quadripole. We obtained the static displacement and the time constant of the multilayer piezo engine for nanomedicine research. The static and dynamic characteristics of the multilayer piezo engine are used in the calculation of the mechatronic control system.

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Conflicts of interest

The authors declare there are no conflicts of interest.

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References

1. Schultz J, Ueda J, Asada H. Cellular Actuators. Oxford: Butterworth-Heinemann Publisher; 2017. p. 382.
2. Afonin SM. Piezo actuators for nanomedicine research. *MOJ Applied Bionics and Biomechanics*. 2019;3(2):56–57.
3. 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.
4. 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.
5. Uchino K. Piezoelectric actuator and ultrasonic motors. Boston, MA: Kluwer Academic Publisher; 1997. p. 347.
6. 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.
7. Afonin SM. Structural parametric model of a piezoelectric nanodisplacement transduser. *Doklady physics*. 2008;53(3):137–143.
8. Afonin SM. Solution of the wave equation for the control of an elecromagnetoelastic transduser. *Doklady mathematics*. 2006;73(2):307–313.
9. Cady WG. Piezoelectricity: An introduction to the theory and applications of electromechancial phenomena in crystals. McGraw-Hill Book Company, London: New York; 1946. p. 806.
10. Mason W. Physical Acoustics: Principles and Methods. Vol.1. Part A. Methods and Devices. New York: Academic Press; 1964. p. 515.
11. Afonin SM. Structural-parametric model and transfer functions of electroelastic actuator for nano- and microdisplacement. Chapter 9 in Piezoelectrics and Nanomaterials: Fundamentals, Developments and Applications. Parinov IA, editor. New York: Nova Science; 2015. p. 225–242.
12. Afonin SM. Stability of strain control systems of nano-and microdisplacement piezotransducers. *Mechanics of solids*. 2014;49(2):196–207.
13. Afonin SM. Structural-parametric model electromagnetoelastic actuator nanodisplacement for mechatronics. *International Journal of Physics*. 2017;5(1):9–15.
14. Afonin SM. Structural-parametric model multilayer electromagnetoelastic actuator for nanomechatronics. *International Journal of Physics*. 2019;7(2):50–57.
15. 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.
16. Afonin SM. Structural-parametric model of electromagnetoelastic actuator for nanomechanics. *Actuators*. 2018;7(1):1–9.
17. 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.
18. 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.
19. Afonin SM. Multilayer electromagnetoelastic actuator for robotics systems of nanotechnology, Proceedings of the 2018 IEEE Conference EIConRus. 2018. p. 1698–1701.
20. Afonin SM. Electromagnetoelastic nano- and microactuators for mechatronic systems. *Russian Engineering Research*. 2018;38(12):938–944.
21. Afonin SM. Structural-parametric model of electro elastic actuator for nanotechnology and biotechnology. *Journal of Pharmacy and Pharmaceutics*. 2018;5(1):8–12.
22. Afonin SM. Electromagnetoelastic actuator for nanomechanics. *Global Journal of Research in Engineering. A: Mechanical and Mechanics Engineering*. 2018;18(2):19–23.
23. 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.
24. 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.
25. Afonin SM. Static and dynamic characteristics of a multi-layer electroelastic solid. *Mechanics of Solids*. 2009;44(6):935–950.
26. Afonin SM. Structural-parametric model and diagram of a multilayer electromagnetoelastic actuator for nanomechanics. Actuators. 2019;8(3):1–14.
27. Springer Handbook of Nanotechnology. Bhushan B, editor. Berlin, New York: Springer; 2004. p. 1222.