Research Article

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Piezo Engine for Nano Biomedical Science

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ABSTRACT

For nano biomedical science the parameters and the characteristics of the piezo engine are obtained. The functions of the piezo engine are determined. The mechanical characteristic of the piezo engine is received.

KEYWORDS: Piezo engine; Deformation; Characteristic; Transfer coefficient; Nano biomedical

INTRODUCTION

Piezo engine is used in tunnel microscopy, X-ray and photolithography [1-9]. Piezo engine is applied for adaptive optics, nano biomedical science and microsurgery for moving of instruments [8-20].

Differential Equation

For the piezo engine the equations [4-30] are written

$$(D)=(d)(T)+(\varepsilon^T)(E)$$

$$(S)=(s^E)(T)+(d)^t(E)$$

where (T), (E), (D), (S), (d), (ε^T), (s^E), are matrixes of mechanical field intensity, strength of electric field, electric induction, relative deformation, piezo coefficient, dielectric constant, elastic compliance and t is transposed index. For PZT engine these matrixes are received

$$(d)=\begin{pmatrix} 0 & 0 & 0 & 0 & d_{15} & 0 \\ 0 & 0 & 0 & d_{15} & 0 & 0 \\ d_{31} & d_{31} & d_{33} & 0 & 0 & 0 \end{pmatrix}.$$

$$(\varepsilon^T)=\begin{pmatrix} \varepsilon_{11}^T & 0 & 0 \\ 0 & \varepsilon_{22}^T & 0 \\ 0 & 0 & \varepsilon_{33}^T \end{pmatrix}$$

$$(s^E)=\begin{pmatrix} s_{11}^E & s_{12}^E & s_{13}^E & 0 & 0 & 0 \\ s_{12}^E & s_{11}^E & s_{13}^E & 0 & 0 & 0 \\ s_{13}^E & s_{13}^E & s_{33}^E & 0 & 0 & 0 \\ 0 & 0 & 0 & s_{55}^E & 0 & 0 \\ 0 & 0 & 0 & 0 & s_{55}^E & 0 \\ 0 & 0 & 0 & 0 & 0 & 2(s_{11}^E - s_{12}^E) \end{pmatrix}$$

Differential equation of the piezo engine [10, 31-50] is written

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

where $\Xi(x,s), s, x, \gamma = s/c^E + \alpha, c^E, \alpha$ are the Laplace transform of the deformation, the operator, the coordinate, the coefficient wave propagation, the speed at, $E = \text{const}$ the coefficient attenuation,

At $x=0$, $\Xi_1(s)=\Xi(0,s)=0$ and $x=h$, $\Xi_2(s)=\Xi(h,s)$ decision of this differential equation is obtained

$$\Xi(x,s)=\Xi_2(s)\,\text{sh}(x\gamma)/\text{sh}(h\gamma)$$

At elastic-inertial load for $x=h$ the relative deformation is determined

$$\left.\frac{d\Xi(x,s)}{dx}\right|_{x=h} = d_{31}E_3(s) - \frac{s_{11}^E M s^2 \Xi_2(s)}{S_0} - \frac{s_{11}^E C_e \Xi_2(s)}{S_0}$$

the equation of the deformation is obtained

$$\frac{\Xi_2(s)\gamma}{\text{th}(h\gamma)} + \frac{\Xi_2(s) s_{11}^E M s^2}{S_0} + \frac{\Xi_2(s) s_{11}^E C_l}{S_0} = d_{31}E_3(s)$$

Functions

From this equation deformation the function of the piezo engine by E is determined in the form

$$W_E(s) = \frac{\Xi_2(s)}{E_3(s)} = \frac{d_{31}h}{Ms^2/C_{11}^E + h\gamma\,\text{cth}(h\gamma) + C_l/C_{11}^E}$$

where $\Xi_2(s)$, $E_3(s)$, C_l, C^E_{11} are the transforms of the deformation and the electric field intensity, the stiffness of the load and the piezo engine.

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For the transverse piezo engine the function by U is obtained in the form

$$W_U(s) = \frac{\Xi_2(s)}{U(s)} = \frac{d_{31}h/\delta}{Ms^2/C_{11}^E + h\gamma \operatorname{cth}(h\gamma) + C_l/C_{11}^E}$$

The relative deformation S_i of piezo engine [1-20] has form

$$S_i = d_{mi}E_m + s_{ij}^E T_j$$

here d_{mi} - the piezo coefficient.

Mechanical characteristic of piezo engine is determined

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

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

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

here the maximums $\Delta l_{\max}$ and $F_{\max}$ of the deformation and the force are received.

For the reverse longitudinal piezo effect the equation [8-18] has form

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

here d_{33} - the longitudinal piezo coefficient.

Mechanical characteristic is written

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

here maximums of deformation $\Delta\delta_{\max}$ and force $F_{\max}$ are written

$$\Delta\delta_{\max} = d_{33}\delta E_3 = d_{33}U$$

$$F_{\max} = d_{33} S_0 E_3 / s_{33}^E$$

For = $1.5\cdot10^5$ V/m, $S_0 = 1.5\cdot10^{-4}$ m^2, $\delta = 2.5\cdot10^{-3}$ m, $d_{33} = 4\cdot10^{-10}$ m/V, $s_{33}^E = 15\cdot10^{-12}$ m^2/N the parameters PZT engine are determined $\Delta\delta_{\max}$ = 150 nm, $F_{\max}$ = 600 N with error 10%.

The maximums of the deformation of the transverse piezo engine $\Delta h_{\max}$ and force $F_{\max}$ are obtained

$$\Delta h_{\max} = d_{31} h E_3 = d_{31}(h/\delta)U$$

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

here d_{31} - the transverse piezo coefficient.

The function of the transverse piezo engine by U at $M>>m$, M, m - the masses of load and piezo engine, has the form

$$W(s) = \frac{\Xi_2(s)}{U(s)} = \frac{k_{U31}}{T_t^2 s^2 + 2T_t\xi_t s + 1}$$

$$k_{U31} = d_{31}(h/\delta)\Big/\left(1 + C_l/C_{11}^E\right),\ T_t = \sqrt{M/\left(C_l + C_{11}^E\right)}$$

$$\xi_t = \alpha l^2 C_{11}^E \Big/ \left(3c^E\sqrt{M\left(C_l + C_{11}^E\right)}\right),\ \omega_t = 1/T_t$$

here k_{U31}, T_t, ξ_t, ω_t - its transfer coefficient, time constant, attenuation coefficient and conjugate frequency.

At $C_l = 0.2\cdot10^7$ N/m, $C_{11}^E = 2.3\cdot10^7$ N/m, M = 1 kg its parameters are obtained $T_t = 0.2\cdot10^{-3}$ s and $\omega_t = 5\cdot10^3$ s^{-1} with error 10%.

The steady-state deformation at elastic-inertial load has the form

$$\Delta h = k_{U31}U = \frac{d_{31}(h/\delta)U}{1 + C_l/C_{11}^E}$$

At $d_{31} = 2\cdot10^{-10}$ m/V, h/δ = 20, C_l/C_{11}^E = 0.1, U =50 V the parameters are received k_{U31} =3.6 nm/V and Δh = 180 nm with error 10%.

CONCLUSIONS

The deformation of the piezo engine is determined for nano biomedical science. Its functions are received. The characteristics of engine are obtained.

REFERENCES

1. Uchino K (1997) Piezoelectric actuator and ultrasonic motors. MA Kluwer Academic Publisher, USA.
2. Afonin SM (2006) Absolute stability conditions for a system controlling the deformation of an electro magnetoelastic transduser. Doklady Mathematics 74(3): 943-948.
3. Schultz J, Ueda J, Asada H (2017) Cellular Actuators. Butterworth Heinemann Publisher Oxford, UK, p382.
4. Afonin SM (2005) Generalized parametric structural model of a compound electro magnetoelastic transduser. Doklady Physics 50(2): 77-82.
5. Afonin SM (2008) Structural parametric model of a piezoelectric nano displacement transducer. Doklady Physics 53(3): 137-143.
6. Afonin SM (2006) Solution of the wave equation for the control of an electro magnetoelastic transduser. Doklady Mathematics 73(2): 307-313.
7. Cady WG (1946) Piezoelectricity: An introduction to the theory and applications of electro mechancial phenomena in crystals. McGraw Hill Book Company, USA, p806.
8. Mason W (1964) Physical acoustics: principles and methods. Vol.1. Part A. Methods and Devices. Academic Press, USA, p515.
9. Yang Y, Tang L (2009) Equivalent circuit modeling of piezoelectric energy harvesters. Journal of Intelligent Material Systems and Structures 20(18): 2223-2235.
10. Zwillinger D (1989) Handbook of differential equations. Academic Press, USA, p673.
11. Afonin SM (2006) Generalized structural parametric model of an electro magnetoelastic converter for nano- and micrometric movement control systems: III. Transformation parametric structural circuits of an electro magnetoelastic converter for nano and micrometric movement control systems. Journal of Computer and Systems Sciences International 45(2): 317-32.
12. Afonin SM (2006) Generalized structural-parametric model of an electro magnetoelastic converter for control systems of nano-and micrometric movements: IV. Investigation and calculation of characteristics of step-piezodrive of nano-and micrometric movements. Journal of Computer and Systems Sciences International 45(6): 1006-1013,
13. Afonin SM (2016) Decision wave equation and block diagram of electro magnetoelastic actuator nano- and micro displacement for communications systems. International Journal of Information and Communication Sciences 1(2): 22-29.
14. Afonin SM (2015) Structural parametric model and transfer functions of electro elastic actuator for nano- and micro displacement. In: Parinov IA (Eds.), Piezo electrics and Nanomaterials: Fundamentals, Developments and Applications. Nova Science, USA, pp225-242.
15. Afonin SM (2017) A structural parametric model of electro elastic actuator for nano- and microdisplacement of mechatronic system. In: Bartual Z, Treno J (Eds.), Advances in Nanotechnology. Nova Science, USA, pp259-284.
16. Afonin SM (2018) Electro magnetoelastic nano and microactuators for mechatronic systems. Russian Engineering Research 38(12): 938-944.
17. Afonin SM (2012) Nano and micro-scale piezomotors. Russian Engineering Research 32(7-8): 519-522.

18. Afonin SM (2007) Elastic compliances and mechanical and adjusting characteristics of composite piezoelectric transducers, Mechanics of Solids 42(1): 43-49.
19. Afonin SM (2014) Stability of strain control systems of nano-and micro displacement piezotransducers. Mechanics of Solids 49(2): 196-207.
20. Afonin SM (2017) Structural-parametric model electro magnetoelastic actuator nano displacement for mechatronics. International Journal of Physics 5(1): 9-15.
21. Afonin SM (2019) Structural parametric model multilayer electro magnetoelastic actuator for nanomechatronics. International Journal of Physics 7(2): 50-57.
22. Afonin SM (2021) Calculation deformation of an engine for nano biomedical research. International Journal of Biomed Research 1(5): 1-4.
23. Afonin SM (2021) Precision engine for nano biomedical research. Biomedical Research and Clinical Reviews. 3(4): 1-5.
24. Afonin SM (2016) Solution wave equation and parametric structural schematic diagrams of electro magnetoelastic actuators nano and micro displacement. International Journal of Mathematical Analysis and Applications 3(4): 31-38.
25. Afonin SM (2018) Structural parametric model of electro magnetoelastic actuator for nano mechanics. Actuators 7(1): 1-9.
26. Afonin SM (2019) Structural-parametric model and diagram of a multilayer electro magnetoelastic actuator for nano mechanics. Actuators 8(3): 1-14.
27. Afonin SM (2016) Structural-parametric models and transfer functions of electro magnetoelastic actuators nano- and micro displacement for mechatronic systems. International Journal of Theoretical and Applied Mathematics 2(2): 52-59,
28. Afonin SM (2010) Design static and dynamic characteristics of a piezoelectric nano micro transducers. Mechanics of Solids 45(1): 123-132.
29. Afonin SM (2018) Electro magnetoelastic Actuator for Nano mechanics. Global Journal of Research in Engineering: A Mechanical and Mechanics Engineering 18(2): 19-23.
30. Afonin SM (2018) Multilayer electro magnetoelastic actuator for robotics systems of nanotechnology, Proceedings of the 2018 IEEE Conference EIConRus, pp. 1698-1701.
31. Afonin SM (2018) A block diagram of electro magnetoelastic actuator nano displacement for communications systems. Transactions on Networks and Communications 6(3): 1-9.
32. Afonin SM (2019) Decision matrix equation and block diagram of multilayer electro magnetoelastic actuator micro and nano displacement for communications systems. Transactions on Networks and Communications 7(3): 11-21.
33. Afonin SM (2020) Condition absolute stability control system of electro magnetoelastic actuator for communication equipment. Transactions on Networks and Communications 8(1): 8-15.
34. Afonin SM (2020) A block diagram of electro magnetoelastic actuator for control systems in nanoscience and nanotechnology. Transactions on Machine Learning and Artificial Intelligence 8(4): 23-33.
35. Afonin SM (2020) Optimal control of a multilayer electro elastic engine with a longitudinal piezo effect for nanomechatronics systems. Applied System Innovation 3(4): 1-7.
36. Afonin SM (2021) Coded control of a sectional electro elastic engine for nanomechatronics systems. Applied System Innovation 4(3): 1-11.
37. Afonin SM (2020) Structural scheme actuator for nano research. COJ Reviews and Research 2(5): 1-3,
38. Afonin SM (2018) Structural–parametric model electro elastic actuator nano- and micro displacement of mechatronics systems for nanotechnology and ecology research. MOJ Ecology and Environmental Sciences 3(5): 306-309.
39. Afonin SM (2018) Electro magnetoelastic actuator for large telescopes. Aeronautics and Aerospace Open Access Journal 2(5): 270-272.
40. Afonin SM (2019) Condition absolute stability of control system with electro elastic actuator for nano bioengineering and microsurgery. Surgery and Case Studies Open Access Journal 3(3): 307-309.
41. Afonin SM (2019) Piezo actuators for nanomedicine research. MOJ Applied Bionics and Biomechanics 3(2): 56-57.
42. Afonin SM (2019) Frequency criterion absolute stability of electro magnetoelastic system for nano and micro displacement in biomechanics. MOJ Applied Bionics and Biomechanics 3(6): 137-140.
43. Afonin SM (2019) A structural-parametric model of a multilayer electroelastic actuator for mechatronics and nanotechnology. In: Bartul Z, Trenor J (Eds.), Advances in Nan technology Nova Science. USA, 22(7): 169-186.
44. Afonin SM (2020) Electroelastic digital-to-analog converter actuator nano and micro displacement for nanotechnology. In: Bartul Z, Trenor J (Eds.), Advances in Nanotechnology Nova Science. USA, 24(6); 205-218.
45. Afonin SM (2020) Structural scheme of electro elastic actuator for nanomechatronics, In: Parinov IA, Chang SH, Long BT(Eds.), Advanced Materials. Springer, Switzerland, pp487-502.
46. Afonin SM (2021) Absolute stability of control system for deformation of electro magnetoelastic actuator under random impacts in nanoresearch. In: Parinov IA, Chang SH, Kim YH (Eds.), Physics and Mechanics of New Materials and Their Applications. Springer, Noda, Switzerland, 10(43): 519-531.
47. Afonin SM (2021) Characteristics of an electro elastic actuator nano- and micro displacement for nanotechnology. In: Bartul Z, Trenor J (Eds.), Advances in Nanotechnology, Nova Science, USA, 25(8) 251-266.
48. Afonin SM (2021) Rigidity of a multilayer piezoelectric actuator for the nano and micro range. Russian Engineering Research 41(4): 285-288.
49. Bhushan B, editor (2004) Springer Handbook of Nanotechnology. USA, p1222.
50. Nalwa HS (2004) Encyclopedia of Nanoscience and Nanotechnology. 10th (vol.), American Scientific Publishers. USA.