Crimson Publishers
Wings to the Research

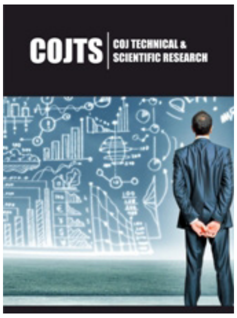
Review Article

Structural Scheme of Electro Magneto Elastic Actuator for Nanotechnology and Nanoscience

Afonin SM*

National Research University of Electronic Technology, MIET, Moscow, Russia

ISSN: 2643-7066



***Corresponding author:** Afonin SM, National Research University of Electronic Technology, MIET, Moscow, Russia

Submission: February 7, 2020
Published: February 24, 2020

Volume 2 - Issue 5

How to cite this article: Afonin SM. Structural Scheme of Electro Magneto Elastic Actuator for Nanotechnology and Nanoscience. COJ Technical & Scientific Research.2(5). COJTS.000546.2020.
DOI: 10.31031/COJTS.2020.02.000546

Abstract

The structural parametric model, the structural scheme, the matrix transfer function, the characteristics of the electro magneto elastic actuator for nanotechnology and nanoscience are obtained. We consider the method of mathematical physics for the solution of the wave equation of the electro magneto elastic actuator with using the Laplace transform. The transfer functions of the electro magneto elastic actuator are described the characteristics of the actuator regarding its physical parameters and external load.

Keywords: Electro magneto elastic actuator; Piezo actuator; Structural-parametric model; Structural scheme; Transfer function

Introduction

The electro magneto elastic actuator on the piezoelectric, electrostriction, magnetostriction effects is used in the mechatronics control systems for nanotechnology and nanoscience [1-6]. At work we consider the method of mathematical physics for the solution of the wave equation of the electro magneto elastic actuator with using the Laplace transform [7-14]. We have the structural-parametric model, the structural scheme and the matrix transfer function the electro magneto elastic actuator from equation of the magneto elastic elasticity and the decision of the wave equation [15-20]. The dynamic and static characteristics of the electro magneto elastic actuator are obtained for designing the mechatronics control systems of nanotechnology and nanoscience regarding its physical parameters and external load [21-30].

Structural scheme

The method of the mathematical physics with the Laplace transform is applied for the solution the wave equation. The structural scheme of the electro magneto elastic actuator for nanotechnology and nanoscience is changed from Cady and Mason electrical equivalent circuits [5-8]. The equation of the electro magneto elasticity [5,8,12] has the following form

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

where S_i is the relative displacement along axis *i* of the cross section of the piezo actuator, $\Psi_m = \{E_m, D_m, H_m\}$ is the control parameter, E_m is the electric field strength for the voltage control along axis *m*, D_m is the electric induction for the current control along axis *m*, H_m is the magnetic field strength for the magneto control along axis *m*, T_j is the mechanical stress along axis *j*, v_{mi} is the electro magneto elastic module, for example, the piezo module, s_{ij}^{Ψ} is the elastic compliance for the control parameter, $\Psi = \text{const}$ and the indexes *i*=1, 2, ... , 6; *j*=1, 2, ... , 6; *m*=1, 2, 3. The main size along axis *i* for the electro magneto elastic actuator is determined us the working length $l = \{\delta, h, b\}$ in form the thickness, the height or the width for the longitudinal, transverse or shift piezo effect.

For the construction the structural scheme of the electro magneto elastic actuator is used the wave equation [8,12,14] for the wave propagation in the long line with damping but without distortions. With using Laplace transform is obtained the linear ordinary second-order differential equation. The problem for the partial differential equation of hyperbolic type using the Laplace transform is reduced to the simpler problem [6,8,14] for the linear ordinary differential equation.

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

Where, $\Xi(x,p)$ is the Laplace transform of the displacement of the section of the electro magneto elastic actuator $\gamma = p/c^{\Psi}+\alpha$, is the propagation coefficient, c^{Ψ} is the sound speed for the control parameter, $\Psi = \text{const}$, α is the damping coefficient. Using method of the mathematical physics with the Laplace transform [6,12,23,26] for the solution of the wave equation, the equation of the electro magneto elasticity, the boundary conditions, we have the structural-parametric model and the structural scheme of actuator for nanotechnology and nanoscience on (Figure 1) in the following form

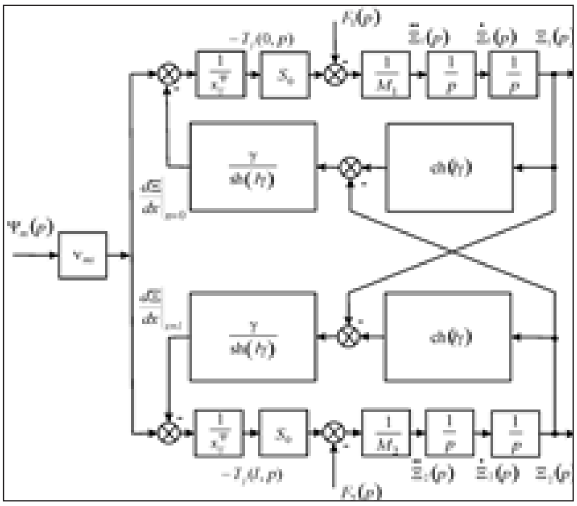


Figure 1: Structural scheme of electro magneto elastic actuator for nanotechnology and nanoscience.

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

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

where $\nu_{mi}=\begin{cases}d_{33},d_{31},d_{15}\\ g_{33},g_{31},g_{15}\\ d_{33},d_{31},d_{15}\end{cases}$, $\Psi_m=\begin{cases}E_3,E_1\\ D_3,D_1\\ H_3,H_1\end{cases}$, $s_{ij}^{\Psi}=\begin{cases}s_{33}^E,s_{11}^E,s_{55}^E\\ s_{33}^D,s_{11}^D,s_{55}^D\\ s_{33}^H,s_{11}^H,s_{55}^H\end{cases}$

$$c^{\Psi}=\begin{cases}c^E\\ c^D\\ c^H\end{cases},\quad \gamma=\begin{cases}\gamma^E\\ \gamma^D\\ \gamma^H\end{cases},\quad l=\begin{cases}\delta\\ h\\ b\end{cases},\quad \chi_{ij}^{\Psi}=s_{ij}^{\Psi}/S_0$$

ν_{mi} is the electro magneto elastic module: d_{mi} is the piezo module at the voltage-controlled piezo actuator or the magneto strictive coefficient for the magneto strictive actuator, g_{mi} is the piezo module at the current-controlled piezo actuator, S_0 is the cross section area, M_1, M_2 are the mass of the loads 1, 2, $\Xi_1(p)$, $\Xi_2(p)$ and $F_1(p)$, $F_2(p)$ are the Laplace transforms of the appropriate displacements and the forces on the faces 1, 2.

For nanotechnology and nanoscience, the structural scheme of the voltage controlled, or current controlled piezo actuator are obtained from its structural-parametric model. From the structural parametric model and the structural scheme of the electro magneto elastic actuator we have the transfer function, the static and dynamic characteristics of the actuator for nanotechnology and nanoscience.

Transfer function

The matrix transfer function [5,18,21,26] of the electro magneto elastic actuator for nanotechnology and nanoscience is received from its structural-parametric model in the form

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

where $\left(\Xi(p)\right)$ is the column-matrix of the Laplace transforms of the displacements for the faces 1,2 of the electro magneto elastic actuator, $\left(W(p)\right)$ is the matrix transfer function, $\left(P(p)\right)$ the column-matrix of the Laplace transforms of the control parameter and the forces. The transfer function of the voltage-controlled transverse piezo actuator is obtained for the elastic-inertial load at $M_1\to\infty$, $m<M_2$ and the approximation the hyperbolic cotangent by two terms of the power series in the form

$$W(p)=\Xi_2(p)/U(p)=k_t/\left(T_t^2p^2+2T_t\xi_tp+1\right)$$

$$k_t=\left(d_{31}h/\delta\right)/\left(1+C_e/C_{11}^E\right),\quad T_t=\sqrt{M_2/(C_e+C_{11}^E)}$$

$$\xi_t=\alpha h^2C_{11}^E/\left(3c^E\sqrt{M_2(C_e+C_{11}^E)}\right)$$

where $U(p)$ is the Laplace transform of the voltage on the plates of the piezo actuator, k_t is the transfer coefficient, T_t is the time constant. ξ_t is the damping coefficient of the piezo actuator. Therefore for the piezo actuator from PZT with the elastic-inertial load at d_{31} = 2.5·10^-10^ m/V, h/δ =20, M_2 = 4 kg, $C_{11}^E=2\cdot10^7$ N/m, C_e = 0.5·10^7^ N/m we obtain values the transfer coefficient k_t =4 nm/V and the time constant of the piezo actuator T_t = 0.4·10^-3^ s. For calculations the mechatronics control systems in nanotechnology and nanoscience with the electro magneto elastic actuator its transfer functions are obtained.

Conclusion

The method of mathematical physics for the solution of the wave equation of the actuator with Laplace transform is used for receiving the structural-parametric model and the structural scheme of the electro magneto elastic actuator for nanotechnology and nanoscience. The structural-parametric model, the structural scheme and the transfer functions of the electro magneto elastic actuator for nanotechnology and nanoscience are described the characteristics of the electro elastic actuator about its physical parameters, external load.

References

1. Schultz J, Ueda J, Asada H (2017) Cellular actuators. Butterworth Heinemann Publisher, Oxford, London, p. 382.
2. Afonin SM (2006) Absolute stability conditions for a system controlling the deformation of an elecromagnetoelastic transduser. Doklady Mathematics 74(3): 943-948.
3. Uchino K (1997) Structural-parametric model electromagnetoelastic actuator nanodisplacement for mechatronics. Piezoelectric actuator and ultrasonic motors, Kluwer Academic Publisher, Boston, Massachusetts, USA 5(1): 9-15.
4. Afonin SM (2015) Block diagrams of a multilayer piezoelectric motor for nano and microdisplacements based on the transverse piezoeffect. Journal of Computer and Systems Sciences International 54(3): 424-439.
5. Afonin SM (2008) Structural parametric model of a piezoelectric nano displacement transduser. Doklady Physics 53(3): 137-143.
6. Afonin SM (2006) Solution of the wave equation for the control of an elecromagnetoelastic transduser. Doklady Mathematics 73(2): 307-313.
7. Cady W (1946) Piezoelectricity: An introduction to the theory and applications of electromechancial phenomena in crystals. McGraw-Hill Book Company, New York, USA, p. 806.
8. Mason W (1964) Physical Acoustics: Principles and Methods. Academic Press, New York, USA, p. 515.
9. Zwillinger D (1989) Handbook of Differential Equations. Academic Press, Boston, USA, p. 673.
10. Afonin SM (2006) A generalized structural-parametric model of an elecromagnetoelastic converter for nano and micrometric movement control systems: III. Transformation parametric structural circuits of an elecromagnetoelastic converter for nano- and micrometric movement control systems, Journal of Computer and Systems Sciences International 45(2): 317-325.
11. Afonin SM (2016) Decision wave equation and block diagram of electromagnetoelastic actuator nano- and microdisplacement for communications systems. International Journal of Information and Communication Sciences 1(2): 22-29.
12. Afonin SM (2015) Structural-parametric model and transfer functions of electroelastic actuator for nano and microdisplacement. Chapter 9, Piezoelectrics and Nanomaterials: Fundamentals, Developments and Applications. Ed. Parinov IA Nova Science, New York, USA, pp. 225-242.
13. Afonin SM (2017) A structural-parametric model of electroelastic actuator for nano- and microdisplacement of mechatronic system. Chapter 8 in Advances in nanotechnology. Volume 19, Eds. Bartul Z, Trenor J, Nova Science, New York, USA, pp. 259-284.
14. Afonin SM (2018) Electromagnetoelastic nano and microactuators for mechatronic systems. Russian Engineering Research 38(12): 938-944.
15. Afonin SM (2012) Nano- and micro-scale piezomotors. Russian Engineering Research 32(7-8): 519-522.
16. Afonin SM (2007) Elastic compliances and mechanical and adjusting characteristics of composite piezoelectric transducers. Mechanics of Solids 42(1): 43-49.
17. Afonin SM (2014) Stability of strain control systems of nano-and microdisplacement piezotransducers. Mechanics of Solids 49(2): 196-207.
18. Afonin SM (2017) Structural-parametric model electromagnetoelastic actuator nanodisplacement for mechatronics. International Journal of Physics 5(1): 9-15.
19. Afonin SM (2017) Structural-parametric model of piezoactuator nano and microdisplacement for nanoscience. AASCIT Journal of Nanoscience 3(3): 12-18.
20. Afonin SM (2016) Solution wave equation and parametric structural schematic diagrams of electromagnetoelastic actuators nano and microdisplacement. International Journal of Mathematical Analysis and Applications 3(4): 31-38.
21. Afonin SM (2018) Structural-parametric model of electromagnetoelastic actuator for nanomechanics. Actuators 7(1): 1-9.
22. Afonin SM (2016) Structural-parametric models and transfer functions of electromagnetoelastic actuators nano- and microdisplacement for mechatronic systems. International Journal of Theoretical and Applied Mathematics 2(2): 52-59.
23. Afonin SM (2018) Structural-parametric model of electro elastic actuator for nanotechnology and biotechnology. Journal of Pharmacy and Pharmaceutics 5(1): 8-12.
24. Afonin SM (2015) Optimal control of a multilayer submicromanipulator with a longitudinal piezo effect. Russian Engineering Research 35(12): 907-910.
25. Afonin SM (2010) Design static and dynamic characteristics of a piezoelectric nanomicrotransducers. Mechanics of Solids 45(1): 123-132.
26. Afonin SM (2018) Electromagnetoelastic Actuator for Nanomechanics. Global Journal of Research in Engineering: A Mechanical and Mechanics Engineering 18(2): 19-23.
27. Afonin SM (2018) Multilayer electromagnetoelastic actuator for robotics systems of nanotechnology, Proceedings of the 2018 IEEE Conference EIConRus, Russia, pp. 1698-1701.
28. Afonin SM (2017) Structural-parametric model electromagnetoelastic actuator nanodisplacement for mechatronics. International Journal of Physics 5(1): 9-15.
29. Afonin SM (2019) Structural-parametric model and diagram of a multilayer electromagnetoelastic actuator for nanomechanics. Actuators 8(3): 1-15.
30. Nalwa HS (2004) Encyclopedia of nanoscience and nanotechnology. American Scientific Publishers, Los Angeles, USA, 10.