Short communication

Condition absolute stability of system with nano piezoactuator for astrophysics research

Abstract

For the nano piezoactuator with hysteresis in control system its set of equilibrium positions is the segment of line. By applying Yakubovich criterion for system with the nano piezoactuator the condition absolute stability of system is evaluated.

Keywords: condition absolute stability, control system, nano piezoactuator, hysteresis, set equilibrium positions

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Introduction

The nano piezoactuator is used in astrophysics, astronomy, nanotechnology, nanomechanics, adaptive optics for alignment, compensation deformation, image stabilization, autofocus.[1–15] The nano piezoactuator is the piezomechanical device that transforms electrical signals into mechanical nano movement and force and is applied to actuate mechanisms, systems, or management based on the piezoeffect. The nano piezoactuator works on the basis of the inverse piezoeffect due to its nano deformation at the electric field strength is applied.[16–34] On the characteristic of the nano piezoactuator deformation from the electric field strength, the initial curve is observed, on which the vertices of the main hysteresis loops lie. The main hysteresis loops have a symmetric change in the electric field strength relative to zero, and partial loops have an asymmetric change in the strength relative to zero.[2–4,35–59]

For calculation absolute stability of system with the nano piezoactuator is applied Yakubovich criterion.[3–35] Many equilibrium positions are found in system with nano piezoactuator for astrophysics.

Condition absolute stability of system

Yakubovich's criterion of absolute stability is development for Popov's criterion of absolute stability. Measurements of the deformations for the nano longitudinal piezoactuator were carried out by the electronic measuring system Model 214 of Calibre plant. The experimental static hysteresis characteristic of the deformation of the nano longitudinal piezoactuator made of ceramic PZT is shown on Figure 1 with the main hysteresis loop and with the partial hysteresis loop.

For written the hysteresis of the nano piezoactuator the Preisach model is used for its hysteresis deformation. The hysteresis function of the relative deformation the nano piezoactuator on Figure 1 is determined[3,35–52]

$$S_i = F\left[E_m\big|_0^t, t, S_i(0), \text{sign}\dot{E}_m\right]$$

here S_i - the hysteresis deformation, t - time, $S_i(0)$ - the initial condition, E_m - the strength of electric field and $\text{sign}\dot{E}_m$ - the sign for velocity of change strength.

In control system the set of equilibrium positions is the set of points M of intersection of the line L with the hysteresis characteristic on Figure 2 in the form of the selected line segment. The equation of the line L is evaluated

$$E_m + k\,S_i = 0$$

here k - the transfer coefficient for the linear part of system.

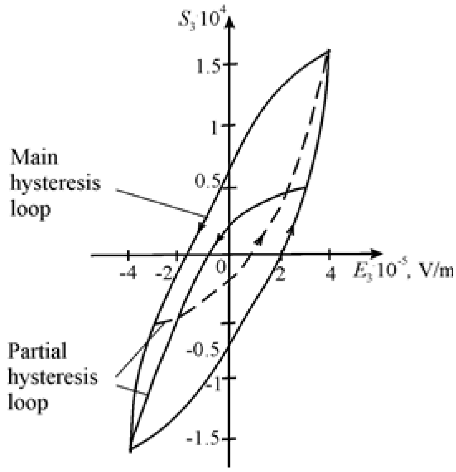

Figure 1 Hysteresis characteristic of nano longitudinal piezoactuator.

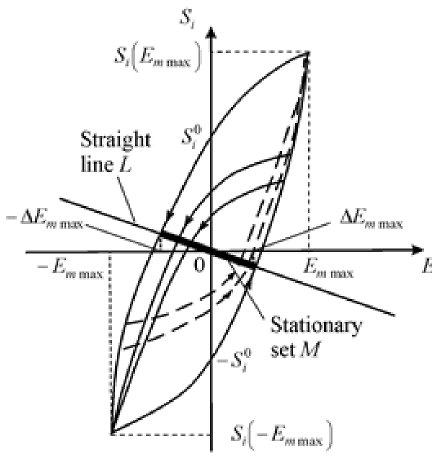

Figure 2 Hysteresis characteristic of nano piezoactuator.

The expression for the symmetric main hysteresis loop of the nano piezoactuator on Figure 2 is determined

$$S_i = d_{mi}E_m - \gamma_{mi}E_{m\max}\left(1-\frac{E_m^2}{E_{m\max}^2}\right)^{n_{mi}}\text{sign}\dot{E}_m$$

here d_{mi} - the piezomodule, $\gamma_{mi} = S_i^0 / E_{m\max}$ - the coefficient of hysteresis, S_i^0 - the relative deformation at $E_m = 0$, n_{mi} - the coefficient and for PZT $n_{mi} = 1$.

The width of the resting zone at $\Delta E_{m\max}$ is determined

$$\Delta E_{m\max} + k\, S_i^{+}\left(\Delta E_{m\max}\right) = 0$$

here Δ - the relative value of electric field strength; $S_i^{+}\left(\Delta E_{m\max}\right)$ - the value of the relative deformation on the ascending branch for $\dot{E}_m > 0$, $S_i^{-}\left(-\Delta E_{m\max}\right)$ - the value of the relative deformation on the descending branch for $\dot{E}_m < 0$ on Figure 2.

For the symmetric main hysteresis loop the equation is evaluated

$$S_i^{+}\left(\Delta E_{m\max}\right) = d_{mi}\,\Delta E_{m\max} - \gamma_{mi} E_{m\max}\left(1 - \frac{\left(\Delta E_{m\max}\right)^2}{E_{m\max}^2}\right)$$

After transformation the expression determined

$$S_i^{+}\left(\Delta E_{m\max}\right) = d_{mi}\,\Delta E_{m\max} - \gamma_{mi} E_{m\max}\left(1 - \Delta^2\right)$$

From the straight line equation the expression is calculated

$$\Delta E_{m\max} + k\,E_{m\max}\left[d_{mi}\Delta - \gamma_{mi}\left(1 - \Delta^2\right)\right] = 0$$

Therefore, the equation is determined

$$\Delta + k\left[d_{mi}\Delta - \gamma_{mi}\left(1 - \Delta^2\right)\right] = 0$$

The quadratic equation is calculated

$$\Delta^2 + \frac{\left(1 + k\,d_{mi}\right)}{k\,\gamma_{mi}}\Delta - 1 = 0$$

The relative width of the rest zone 2Δ of system with nano piezoactuator is obtained

$$2\Delta = -\frac{\left(1 + k\,d_{mi}\right)}{k\,\gamma_{mi}} + \sqrt{\frac{\left(1 + k\,d_{mi}\right)^2}{k^2\gamma_{mi}^2} + 4}$$

The minimum value ν_{1mi} and maximum value ν_{2mi} of the tangent the angle of inclination to the hysteresis of the nano piezoactuator are obtained in the form

$$\nu_{1mi}, \nu_{2mi} \in \left[0, \nu_{mi}\right]$$

$$\nu_{mi} = \max\left[d\,S_i / d\,E_m\right]$$

The values ν_{1mi} and ν_{2mi} are determined for the hysteresis characteristic at the maximum strength in the nano piezoactuator.

The ratio of the piezomodules of the nano piezoactuator with transverse, longitudinal, shear piezoelectric effects is proportional the ratio of its tangents of the angle of inclination to the hysteresis

$$d_{31} : d_{33} : d_{15} = \nu_{31} : \nu_{33} : \nu_{15}$$

From the Yakubovich criterion[35,52] the absolute stability of system with nano piezoactuator for astrophysics research is obtained. The condition absolute stability of system with nano piezoactuator on Figure 3 at $\nu_{1mi} = 0$ and $\nu_{2mi} = \nu_{mi}$ is evaluated

$$\mathrm{Re}\,\nu_{mi} W\left(j\omega\right) \geq -1$$

here ω - the frequency, *j* - the imaginary unit. On Figure 3 shows the amplitude-phase frequency characteristic for the frequency transfer function $W\left(j\omega\right)$ with boundary vertical line *B*, passing through -1 on the real axis.

For the nano transverse or longitudinal piezoactuator from PZT the experimental maximum tangent at transverse piezoeffect ν_{31} = 0.6 nm/V or at longitudinal piezoeffect ν_{33} = 1 nm/V are obtained.

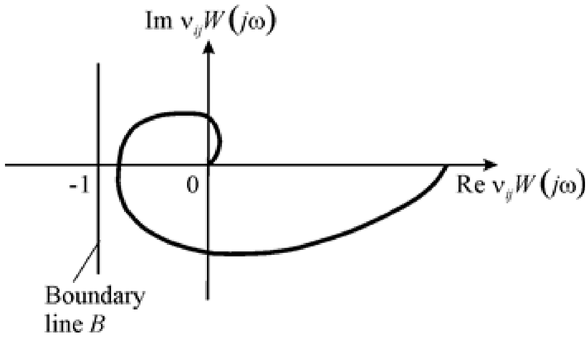

Figure 3 Condition absolute stability of system with nano piezoactuator.

For the condition absolute stable Lyapunov control system the Yakubovich absolute stability criterion have the visual and simple representation of the results for the system stability.

Conclusion

By using Yakubovich criterion for system with the nano piezoactuator the condition absolute stability of system is evaluated for astrophysics research. For the nano piezoactuator with hysteresis in control system for astrophysics research the set of equilibrium positions is the segment of line.

Acknowledgments

None.

Conflicts of interest

The author declares that there is no conflict of interest.

References

1. Uchino K. *Piezoelectric actuator and ultrasonic motors*. Boston, MA: Kluwer Academic Publisher; 1997. 350 p.
2. Andrievsky BR, Barabanov AE, Bondarko VA, et al. Nonlinear systems. Frequency and matrix inequalities. Eds. Gelig AKh, Leonov GA, Fradkov AL. Fizmatlit. Moscow; 2008. 608 p.
3. Afonin SM. Absolute stability conditions for a system controlling the deformation of an electromagnetoelastic transducer. *Dokl Math*. 2006;74:943–948.
4. Liu Y, Zeng A, Zhang S, et al. An experimental investigation on polarization process of a PZT-52 tube actuator with interdigitated electrodes. *Micromachines*. 2022;13(10):1760.
5. Shevtsov SN, Soloviev AN, Parinov IA, et al. Piezoelectric Actuators and Generators for Energy Harvesting. Research and Development. Springer; Switzerland; 2018. 182 p.
6. Afonin SM. Generalized parametric structural model of a compound elecromagnetoelastic transduser. *Dokl Phys*. 2005;50(2):77–82.
7. Afonin SM. Structural parametric model of a piezoelectric nanodisplacement transducer. *Dokl Phys*. 2008;53(3):137–143.
8. Afonin SM. Solution of the wave equation for the control of an elecromagnetoelastic transduser. *Dokl Math*. 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; New York, London; 1946. 806 p.
10. Mason W. *Physical Acoustics: Principles and Methods*. Vol.1. Part A. Methods and Devices. New York: Academic Press; 1964. 515 p.

11. Yang Y, Tang L. Equivalent Circuit Modeling of Piezoelectric Energy Harvesters. *J Int Mat Sys Str*. 2009;20(18):2223–2235.

12. Zwillinger D. *Handbook of Differential Equations*. Boston: Academic Press; 1989. 673 p.

13. Afonin SM. A generalized structural-parametric model of an electromagnetoelastic converter for nano- and micrometric movement control systems: III. Transformation parametric structural circuits of an electromagnetoelastic converter for nano- and micrometric movement control systems. *J Comput Syst Sci Int*. 2006;45(2):317–325.

14. Afonin SM. Generalized structural-parametric model of an electromagnetoelastic converter for control systems of nano- and micrometric movements: IV. Investigation and calculation of characteristics of step-piezodrive of nano-and micrometric movements. *J. Comput. Syst Sci Int.* 2006;45(6):1006–1013.

15. Afonin SM. Decision wave equation and block diagram of electromagnetoelastic actuator nano- and micro displacement for communications systems. *Int J Inf Com Sci*. 2016;1(2):22–29.

16. Afonin SM. *Structural-parametric model and transfer functions of electroelastic actuator for nano- and micro displacement.* Chapter 9 in Piezoelectric and Nanomaterials: Fundamentals, Developments and Applications. Parinov IA, editor. New York: Nova Science; 2015. p. 225–242.

17. Afonin SM. *A structural-parametric model of electroelastic actuator for nano- and micro displacement of mechatronic system.* Chapter 8 in Advances in Nanotechnology. Bartul Z, Trenor J, editors. New York: Nova Science; 2017. p. 259–284.

18. Afonin SM. Electromagnetoelastic nano- and microactuators for mechatronic systems. *Russ Engin Res*. 2018;38(12):938–944.

19. Afonin SM. Nano- and micro-scale piezomotors. *Russ Engin Res*. 2012;32(7-8):519–522.

20. Afonin SM. Elastic compliances and mechanical and adjusting characteristics of composite piezoelectric transducers. *Mech Solids*. 2007;42(1):43–49.

21. Afonin SM. Stability of strain control systems of nano-and micro displacement piezotransducers. *Mech Solids*. 2014;49(2):196–207.

22. Afonin SM. Structural-parametric model electromagnetoelastic actuator nanodisplacement for mechatronics. *Int J Physics*. 2017;5(1):9–15.

23. Afonin SM. Structural-parametric model multilayer electromagnetoelastic actuator for nanomechatronics. *Int J Physics*. 2019;7(2):50–57.

24. Afonin SM. Calculation deformation of an engine for nano biomedical research. *Int J Bio Res*. 2021;1(5):1–4.

25. Afonin SM. Precision engine for nanobiomedical research. *Bio Res Clinical Rev*. 2021;3(4):1–5.

26. Afonin SM. Solution wave equation and parametric structural schematic diagrams of electromagnetoelastic actuators nano- and micro displacement. *Int J Math Ana App*. 2016;3(4):31–38.

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

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

29. Afonin SM. Structural-parametric models and transfer functions of electromagnetoelastic actuators nano- and micro displacement for mechatronic systems. *Int J Theo App Math*. 2016;2(2):52–59.

30. Afonin SM. Design static and dynamic characteristics of piezoelectric nanomicro transducers. *Mech. Solids*. 45(1):123–132.

31. *Afonin SM. Electromagnetoelastic Actuator for Nanomechanics. Global Journal of Research in Engineering: A. Mechanical and Mechanics Engineering*. 2018;18(2):19–23.

32. Afonin SM. Multilayer electromagnetoelastic actuator for robotics systems of nanotechnology. 2018 IEEE Conference of Russian Young Researchers in Electrical and Electronic Engineering (EIConRus). 2018;1698–1701.

33. Afonin SM. A block diagram of electromagnetoelastic actuator nanodisplacement for communications systems. *Tran Net Com*. 2018;6(3):1–9.

34. Afonin SM. Decision matrix equation and block diagram of multilayer electromagnetoelastic actuator micro and nanodisplacement for communications systems. *Tran Net Com*. 2019;7(3):11–21.

35. Afonin SM. Condition absolute stability control system of electromagnetoelastic actuator for communication equipment. *Tran Net Com*. 2020;8(1):8–15.

36. Afonin SM. A Block diagram of electromagnetoelastic actuator for control systems in nanoscience and nanotechnology. *Tran Mach Learn Art Int*. 2020;8(4):23–33.

37. Afonin SM. Optimal control of a multilayer electroelastic engine with a longitudinal piezoeffect for nanomechatronics systems. *ASI*. 2020;3(4):1–7.

38. Afonin SM. Coded control of a sectional electroelastic engine for nanomechatronics systems. *ASI*. 2021;4(3):1–11.

39. Afonin SM. Structural scheme actuator for nano research. *COJ Rev Res*. 2020;2(5):1–3.

40. Afonin SM. Structural–parametric model electroelastic actuator nano and micro displacement of mechatronics systems for nanotechnology and ecology research. *MOJ Eco Environ Sci*. 2018;3(5):306–309.

41. Afonin SM. Electromagnetoelastic actuator for large telescopes. *Aeron Aero Open Access J*. 2018;2(5):270–272.

42. Afonin SM. Condition absolute stability of control system with electro elastic actuator for nano bioengineering and microsurgery. *Sur Case Studies Open Access J*. 2019;3(3):307–309.

43. Afonin SM. Piezoactuator of nanodisplacement for astrophysics. *Aeron Aero Open Acc J*. 6(4): 155–158.

44. Afonin SM. Piezo actuators for nanomedicine research. *MOJ App Bio Biomech*. 2019;3(2):56–57.

45. Afonin SM. Frequency criterion absolute stability of electromagnetoelastic system for nano and micro displacement in biomechanics. *MOJ App Bio Biomech*. 2019;3(6):137–140.

46. Afonin SM. Multilayer piezo engine for nanomedicine research. *MOJ App Bio Biomech*. 2020;4(2):30–31.

47. Afonin SM. Structural scheme of electromagnetoelastic actuator for nano biomechanics. *MOJ App Bio Biomech*. 2021;5(2):36–39.

48. Afonin SM. Multilayer engine for microsurgery and nano biomedicine. *Sur Case Studies Open Access J*. 2020;4(4): 423–425.

49. Afonin SM. *A structural-parametric model of a multilayer electroelastic actuator for mechatronics and nanotechnology*. Chapter 7 in Advances in Nanotechnology. Bartul Z, Trenor J, editors. New York: Nova Science; 2019. p. 169–186.

50. Afonin SM. *Electroelastic digital-to-analog converter actuator nano and micro displacement for nanotechnology*. Chapter 6 in Advances in Nanotechnology. Bartul Z, Trenor J, editors. New York: Nova Science; 2020. p. 205–218.

51. Afonin SM. Characteristics of an electroelastic actuator nano- and micro displacement for nanotechnology. Chapter 8 in Advances in Nanotechnology. Bartul Z, Trenor J, editors. New York: Nova Science; 2021. p. 251–266.

52. Afonin SM. An absolute stability of nanomechatronics system with electroelastic actuator. Chapter 9 in Advances in Nanotechnology. In: Bartul Z, Trenor J, editors. New York: Nova Science; 2022. p. 183–198.

53. Afonin SM. Rigidity of a multilayer piezoelectric actuator for the nano and micro range. *Rus Eng Res*. 2021;41(4):285–288.

54. Afonin SM. Piezo engine for nano biomedical science. *Open Access Journal of Biomedical Science*. 2022;4(5):2057–2059.

55. Afonin SM. An engine for nanochemistry. *Journal of Chemistry & its Applications*. 2022;1(1): 1–4.

56. Afonin SM. Electroelastic actuator of nanomechatronics systems for nanoscience. Chapter 2 in Recent Progress in Chemical Science Research. Editor, Min HS. B P International; India, UK; 2023. p. 15–27.

57. Afonin SM. Harmonious linearization of hysteresis characteristic of an electroelastic actuator for nanomechatronics systems. Chapter 34 in Physics and Mechanics of New Materials and Their Applications. Proceedings of the International Conference PHENMA 2021-2022, Springer Proceedings in Materials series. Eds, Parinov IA, Chang SH, Soloviev AN. Springer; 2023. p. 419–428.

58. Nalwa HS. Encyclopedia of Nanoscience and Nanotechnology. Los Angeles: American Scientific Publishers; 2004.

59. Bhushan B. Springer Handbook of Nanotechnology. New York: Springer; 2004. p. 1222.

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