Absolute Stability of Control System with Electro Magneto Elastic Actuator for Nano Science and Nano Biomedicine Research

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Abstract
The stationary set of the control system of the hysteresis deformation of the electro magneto elastic actuator is the segment of the straight line. The aim of this work is to determine the condition of the absolute stability on the derivative for control system of the deformation of the electro magneto elastic actuator in automatic nanomanipulators for nanoscience and nanobiomedicine research. The frequency methods for Lyapunov stable control system are used to calculate the condition the absolute stability of the control system with electro magneto elastic actuator. In result we obtained the condition of the absolute stability on the derivative for the control system with the electro magneto elastic actuator in automatic nanomanipulators for nanoscience and nanobiomedicine research.

Keywords: Absolute stability, Control system, Electro magneto elastic actuator, Piezoactuator, Hysteresis deformation, Stationary set, Transfer function.

Introduction
The control systems with electro magneto elastic actuator on piezoelectric, electrostrictive and magnetostrictive effects solves problems of the precise matching in the nanotechnology, the compensation of the temperature and gravitational deformations, the atmospheric turbulence by the wave front correction [1-15].

The piezoactuator for Nano science and Nano biomedicine research is used in the scanning tunneling microscope, the scanning force microscope, the atomic force microscope, in the gene manipulator [16-30].

The condition of the absolute stability on the derivative for control system of the deformation of the electro magneto elastic actuator is calculated. The problems of using criteria absolute stability of the control system with electro magneto elastic actuator for Nano science and Nano biomedicine research are discussed. The stationary set of the control system of the deformation of the electro magneto elastic actuator is determined.

Aim
The aim of this work is to calculate the condition of the absolute stability on the derivative for control system of the deformation of the electro magneto elastic actuator in automatic nanomanipulators for nanoscience and nanobiomedicine research.

Method
The frequency methods for Lyapunov stable control system are used to determine the condition of the absolute stability of control system with electro magneto elastic actuator in automatic nanomanipulators for nanoscience and nanobiomedicine research [2,3].

Results
We determined the expression for the sufficient absolute stability condition of the control system with the hysteresis nonlinearity of the electro magneto elastic actuator using the Yakubovich absolute stability criterion with the condition on the derivative, which is the development of the Popov absolute stability criterion [2,3].

For the Lyapunov stable control system and the Yakubovich absolute stability criterion for the systems with the single hysteresis nonlinearity provides the simplest and pictorial representation of results of the investigation of the stability of the strain control system with the electro magneto elastic actuator.

We use the transfer function of the linear part of the system \( W(p) \) and the hysteresis function of the relative deformation \( S(p) \) of the electro magneto elastic actuator for description of the system. We have the description of the hysteresis nonlinearity of the actuator in the form [17]

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\[ S_j = F \left[ \Psi_j(t), S_j(0), \text{sign} \Psi_j \right] \] (1)

Where \( S_j \) is the relative displacement of the cross section of the actuator along \( j \) axis. The hysteresis function \( S_j \) at each time \( t \) depends on the behavior of the function \( \Psi_j = E_j \) or \( \Psi_j = H_j \), where \( E_j \) and \( H_j \) are the electric field strength and the magnetic field strength on the interval \([0, t]\) the value of \( t \), the initial value \( S_j(0) \), and the sign of the rate of \( \Psi_j \), the field strength variation. We consider the alternating sign hysteresis characteristics deformation of the piezoactuator on Figure 1.

The set \( L \{ E_j(0) \} \) is the vertical segment \([S_j^0, -S_j^0]\) bounded by the points of intersection of the ordinate axis with the hysteresis loop at the maximum admissible field strength in the piezoactuator.

We receive the stationary set for the deformation of the piezoactuator on Figure 1 for the stable linear part of the control system. Therefore, we draw the straight line \( L \) with the equation

\[ E_i + W_i(0) S = 0 \] (2)

\[ E_{i0} + W_{ij}(0) S_{j0} = 0 \] (3)

The stationary set \( N \) of the system is the marked segment of straight line \( L \) in figure 1 with the set of pairs \( \{ E_{i0}, S_{j0} \} \). Each point of intersection of the hysteresis nonlinearity with the partial loops and the straight line \( L \) corresponds to one equilibrium position with the coordinates \( \{ E_{i0}, S_{j0} \} \).

Let us consider butterfly type characteristic of the deformation of the electro magneto elastic actuator for Nano science research. For the actuator with the electrostrictive effect the deformation characteristic on butterfly wings is observed for unipolar change of the electric field strength on Figure 2.

The particular cycle is the hysteresis loop. For butterfly type characteristic deformation of actuator in the control system the coordinate origin is moved to new zero with top dash on Figure 2. For the magnetostrictive actuator the deformation characteristic has the butterfly type.

The function \( S_j(E_j) \) of the hysteresis loop of the piezoactuator is continuous. Therefore, we have quantities

\[ V_{1j}, V_{2j} \in [0, V_{ij}], V_{ij} = \max \frac{dS_j}{dE_j} \] (4)

where the quantities \( V_{1j} \) and \( V_{2j} \) are calculated using the hysteresis characteristic on figure 1 for the maximum admissible electric field strength in the piezoactuator.

The quantities \( V_{1j} = 0 \) and \( V_{2j} = V_{ij} \) are the minimum and the maximum values of the tangent of the inclination angle of the tangent line to the hysteresis nonlinearity of the piezoactuator. Thus, we obtain

\[ V_{3j} : V_{31} : V_{15} = d_{3j} : d_{31} : d_{15} \] (5)

where the ratios of the tangents of the inclination angle of the tangent line to the hysteresis nonlinearity of the piezoactuator for longitudinal, transverse and shift piezoeffects are proportional to the ratios of the piezomodules. We have the expression for the sufficient absolute stability condition of the system with the hysteresis nonlinearity of the electro magneto elastic actuator using the Yakubovich absolute

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stability criterion with the condition on the derivative. The Yalabovich
criterion is the development of the Popov absolute stability criterion
[2].

For the Lyapunov stable control system the Yalabovich absolute
stability criterion for the system with the single hysteresis nonlinearity
provides the simplest and pictorial representation of results of the
investigation of the stability control system [2,3]. Therefore, the
sufficient absolute stability condition of the control system of the
def ormation of the electro magneto elastic actuator at \( \nu_{ij} = 0 \).

\[ V_{2g} = V_g \] has the form

\[ \Re \nu_{ij}W_{ij}(j\omega) \geq -1 \quad (6) \]

Where in brackets \( j \) is the imaginary unity and \( \omega \) is the frequency.
The amplitude-phase characteristic of the open-loop system
\( \nu_{ij}W_{ij}(j\omega) \) on Figure 3 should be situated to the right of the
straight line

\[ \Re \nu_{ij}W_{ij}(j\omega) = -1 \quad (7) \]

For all values of \( \omega \geq 0 \)

\[ \Im \nu_{ij}W_{ij}(j\omega) = 0 \]

For the absolute stability criterion for the system with electro magneto
elastic actuator on the plane of the logarithmic amplitude frequency
characteristic and the phase frequency characteristic we have

\[ L(\omega) = Q[\varphi(\omega)], L(\omega) = 20\log|\nu_{ij}W_{ij}(j\omega)| \quad (8) \]

The corrected logarithmic amplitude frequency characteristic is below the boundary curve in the form

\[ L(\omega) = 20\log[1/\cos\varphi] \quad (9) \]

For the piezoelement from PZT the value of the maximum tangent of the
inclination angle of the tangent line to hysteresis nonlinearity is
about 1 nm/V for longitudinal piezoeffect and about 0.6 nm/V for
transverse piezoeffect.

**Summary**

We used the frequency methods for Lyapunov stable control system to
calculate the condition the absolute stability of the control system with
electro magneto elastic actuator in automatic nanomanipulators.

**Conclusions**

We received the stationary set of the control system of the deformation
of the electro magneto elastic actuator. We determined condition of the
absolute stability on the derivative for the control system with the
electro magneto elastic actuator in automatic nanomanipulators for
nanoscience and nanobiomedicine research.

**References**

1. Schultz J, Ueda J and Asada H. Cellular actuators (2017)
   Butterworth-Heinemann, Oxford, USA pp: 382.
2. Yakubovich VA. Popov's method and its subsequent
development (2002) European J Control 8: 200-208.
   https://doi.org/10.1016/j.ejcon.2002.10.002
3. Afonin SM. Absolute stability conditions for a system
   controlling the deformation of an electromagnetoelastic
   transducer (2006) Doklady Mathematics 74: 943-948.
   https://doi.org/10.1134/S1064562406060391
4. Zhou S and Yao Z. Design and optimization of a modal-
independent linear ultrasonic motor (2014) IEEE Transaction
   on Ultrason, Ferroelectrics, and Frequency Control 61: 535-
   546. https://doi.org/10.1109/tufc.2014.2937
5. Przybylski J. Static and dynamic analysis of a flex tensional
   transducer with an axial piezoelectric actuation (2015)
   Engineering Structures 84: 140-151.
   https://doi.org/10.1016/j.engstruct.2014.11.025
6. Ueda J, Secord T and Asada HH. Large effective-strain
   piezoelectric actuators using nested cellular architecture with
   exponential strain amplification mechanisms (2010)
   IEEE/ASME Transactions on Mechatronics 15: 770-782.
   https://doi.org/10.1109/tmech.2009.2034973
7. Karpelson M, Wei G-Y and Wood RJ. Driving high voltage
   piezoelectric actuators in micro robotic applications (2012)
   Sensors and Actuators A: Physical 176: 78-89.
   https://doi.org/10.1016/j.sna.2011.11.035
8. Afonin SM. Solution of the wave equation for the control of an
   electromagnetoelastic transducer (2006) Doklady Mathematics
   73: 307-313. https://doi.org/10.1134/S1064562406020402
9. Afonin SM. Structural parametric model of a piezoelectric
   Nano displacement transducer (2008) Doklady Physics 53:
   137-143. https://doi.org/10.1134/S1028335808030065
10. Afonin SM. Block diagrams of a multilayer piezoelectric
    motor for Nano- and micro displacements based on the
    transverse piezoeffect (2015) J Comp Syst Sci Int 54:
    424-439. https://doi.org/10.1016/j.jcssi.2015.02.002
11. Afonin SM. Structural parametric model of a piezoelectric
    Nano displacement transducer (2008) Doklady Physics 53:
    137-143. https://doi.org/10.1134/S1028335808030065
12. Mason W. Physical acoustics: Principles and methods (1964)
    Academic Press, New York pp: 515.
13. Zwillinger D. Handbook of differential equations (1989)
    Academic Press, Boston, USA pp:673.
14. Afonin SM. In Piezoelectric and nanomaterials: Fundamentals,
developments and applications. Parinov IA (edr) Structural-parametric
    model and transfer functions of electro elastic actuator for Nano
    and micro displacement (2015) Nova Science, New York, USA pp:
    225-242.
15. Afonin SM. In Advances in nanotechnology. Bartul Z and
    Trenor J (edtrs). A structural-parametric model of electro
    elastic actuator for Nano- and micro displacement of

**Citation:** Afonin SM. Absolute stability of control system with electro magneto elastic actuator for Nano
science and Nano biomedicine research (2019) Nanomaterial Chem Technol 1: 19-22
16. Afonin SM. Nano and micro-scale piezometers (2012) Russian Engineering Research 32: 519-522. https://doi.org/10.3103/S1068798X12060022

17. Afonin SM. Elastic compliances and mechanical and adjusting characteristics of composite piezoelectric transducers (2007) Mechanics of Solids 42: 43-49. https://doi.org/10.3103/S0025654407010062

18. Afonin SM. Structural-parametric model electromagnet elastic actuator nano displacement for mechatronics (2017) Int J Phys 5: 9-15. http://doi:10.12691/jip-5-1-27

19. Afonin SM. Structural-parametric model of piezoelectric actuator Nano and micro displacement for Nano science (2017) AASCIT J Nano science 3: 12-18.

20. Afonin SM. Solution wave equation and parametric structural schematic diagrams of electromagnet elastic actuators Nano- and micro displacement (2016) Int J Math Analysis Appl 3: 31-38.

21. Afonin SM. Structural-parametric model of electromagnet elastic actuator for Nano mechanics (2018) Actuators 7: 1-9. https://doi.org/10.3390/act7010006

22. Afonin SM. Structural-parametric models and transfer functions of electromagnet elastic actuators Nano- and micro displacement for mechatronics systems (2016) Int J Theor Appl Math 2: 52-59. http://doi:10.11648/j.itam.20160202.15

23. Afonin SM. Parametric block diagrams of a multi-layer piezoelectric transducer of Nano and micro displacements under transverse piezoelectric effect (2017) Mechanics of Solids 52: 81-94. https://doi.org/10.3103/S0025654417010101

24. Afonin SM. Structural-parametric model of electro elastic actuator for nanotechnology and biotechnology (2018) J Pharm. Pharmaceutu 5: 8-12. https://doi.org/10.15436/2377-1313.18.1881

25. Afonin SM. In Advances in nanotechnology. Bartul Z and Tremor J (edtrs). A structural-parametric model of a multilayer electro elastic actuator for mechatronics and nanotechnology (2019) Nova Science, New York, USA 22: 169-186. https://doi.org/10.35841/nanotechnology.2.1.5-9

26. Afonin SM. Structural-parametric model and diagram of a multilayer electromagnet elastic actuator for Nano mechanics (2019) Actuators 8: 1-14. https://doi.org/10.3390/act8030052

27. Afonin SM. Electromagnet elastic actuator for Nano mechanics (2018) Global J Res Eng: A Mech Mechan eng 18: 19-23.

28. Afonin SM. Structural-parametric model multilayer electromagnet elastic actuator Nano displacement for Nano mechatronics (2019) Int J Phy 7: 50-57. https://doi.org/10.12691/ijp-7-2-3

29. Afonin SM. Actuator for Nano biomedical research (2019) Biomed J Sci Tech Res 19: 14300-14302. https://doi.org/10.26717/bjstr.2019.19.003295

30. Bhushan B. Springer Handbook of Nanotechnology (2004) Springer, New York, USA pp: 1222.