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Absolute Stability of System with Nanopiezoactuator for Nanomedicine Sciences

Mini Review

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Abstract

For the nanopiezoactuator with hysteresis in control system its set of equilibrium positions is the segment of line. By applying Yakubovich criterion for system with the nanopiezoactuator the absolute stability of system is calculated for nanomedicine sciences.

Keywords: Absolute Stability system, Nanopiezoactuator, Hysteresis, Set equilibrium positions, Nanomedicine sciences

Introduction

The nanopiezoactuator is used for nanomedicine sciences in scanning microscopy, microdosing devices, nanomanipulates, nanopumps [1-60]. For calculation absolute stability of system with the nanopiezoactuator is using Yakubovich criterion, which is the development of the Lyapunov and Popov criterions [3-35]. Many equilibrium positions are found in system with nanopiezoactuator for nanomedicine sciences.

Absolute Stability of System

For written the hysteresis of the nanopiezoactuator for nanomedicine sciences the Preisach model is used for its hysteresis deformation [3-21].

The hysteresis function of the relative deformation the nanopiezoactuator on (Figure1) is determined [35-58]

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

here S_i- the hysteresis deformation, t - time, $S_i(0)$-the initial condition, E_m - the strength of electric field, $sign\dot{E}_m$ - 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 (Figure1) in the form of the selected line segment.

The equation of the line L is evaluated

$$E_m + kS_i = 0$$

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

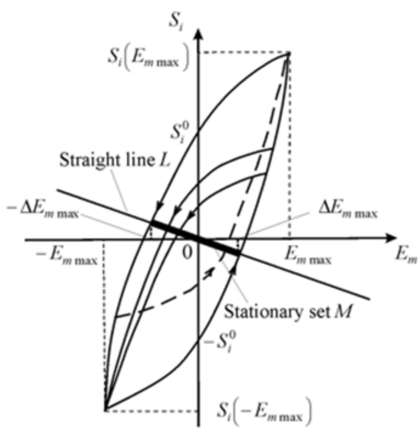

Figure 1: Hysteresis characteristic of nanopiezoactuator.

The expression for the symmetric main hysteresis loop of the nanopiezoactuator on (Figure1) is determined

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

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

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

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 (Figure1).

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

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

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

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

The relative width of the rest zone 2Δ of system with nanopiezoactuator for astrophysics is obtained

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

For the asymmetric loop characteristic its relative width of the rest zone $\Delta^+ + \Delta^-$ of system is evaluated

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

The minimum ν_{1mi} and maximum ν_{2mi} of the tangent the angle of inclination to the hysteresis loop of the nanopiezoactuator for nanomedicine sciences are obtained [9 -10] in the form

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

$$\nu_{mi} = \max\left[dS_i / dE_m\right]$$

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

The ratio of the piezomodules of the nanopiezoactuator 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 [3 - 52], which is the development of the Lyapunov and Popov criterions, the absolute stability of system with nanopiezoactuator for astrophysics is obtained. The condition for the absolute stability of system with nanopiezoactuator for nanomedicine sciences on (Figure2) at ν_{1mi} = 0 and $\nu_{2mi} = \nu_{mi}$ is evaluated

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

here ω - the frequency, j - the imaginary unit. On (Figure 2) shows the amplitude-phase frequency characteristic for the frequency transfer function $W\left(j\omega\right)$ with boundary vertical line B, passing through point -1 on the real axis.

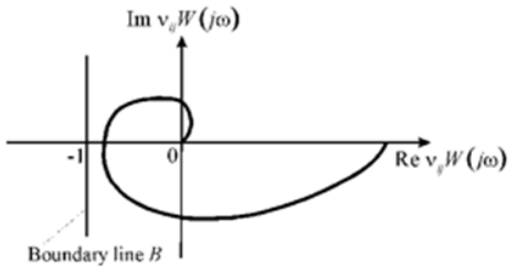

Figure 2: Absolute stability of system with nanopiezoactuator.

For the nanopiezoactuator from PZT for nanomedicine sciences its maximum tangents ν_{31} = 0.6 nm/V at transverse piezoeffect and ν_{33}= 1 nm/V at longitudinal piezoeffect.

Conclusion

By using Yakubovich criterion for system with the nanopiezoactuator the absolute stability of system is calculated for nanomedicine sciences. For the nanopiezoactuator with hysteresis in control system for nanomedicine sciences its set of equilibrium positions is the segment of line.

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