ISSN: 3066-8131
Research Article

Science Set Journal of Physics

Piezo Engine of Nano Displacement for Astronomical Techniques

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Submitted: 16 Oct 2022 **Accepted:** 24 Oct 2022 **Published:** 28 Oct 2022

https://doi.org/10.63620/MKSSJP.2022.1002

***Citation:** Afonin, S. M. (2022). Piezo Engine of Nano Displacement for Astronomical Techniques. Sci Set J of Physics 1(1), 01-04.*

Abstract
For astronomical techniques the parameters and the characteristics of the piezo engine are determined. The functions of the piezo engine are determined. The mechanical characteristic of the piezo engine is received.

Keywords: Piezo engine, Nano displacement, Characteristic, Astronomical techniques

Introduction

The piezo engine is widely used in astronomical techniques [1-9]. The piezo engine of nanodisplacement is applied for compound telescopes and interferometers [4-28].

Deformation

The equations of the piezo effects are determined [4-18].

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

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

where $(D) = (d)(T) + (\varepsilon^T)(E)$
are matrixes of electric induction, piezo module, dielectric constant, mechanical strength of field, electric strength of field, relative deformation, elastic compliance, transposed piezomodule. The differential equation [8-50] is obtained

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

where x, s, $\Xi(x,s)$, $\gamma = s/c^E + \alpha$, α, c^E
are the coordinate, the operator of Laplace transform, the transform of the deformation, the propagation and attenuation coefficients, the speed at $E = \text{const}$. Its decision has form

$$\Xi(x,s) = Ae^{-x\gamma} + Be^{x\gamma}$$

At fixed one face for the coordinate $x = 0$,
and this decision is written

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

At the elastic-inertial workload for $x = h$ the expression is obtained

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

Therefore, the expression is written

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

here d_{31} is the transverse piezo module.

Hence the expression by E is received

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

where $\Xi_2(s)$, $E_3(s)$, C_e, C_{11}^E are the transforms of the deformation and the electric strength of field, the stiffness of workload and engine.

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

The relative deformation has form [4-18]

$$S_i = d_{mi}E_m + s^E_{ij}T_j$$

The mechanical characteristic has form

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

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

$$F_{\max} = d_{mi} S_0 E_m / s^E_{ij}$$

where the maximums of the deformation Δl_{max} and force F_{max}.

The equation for the longitudinal piezo engine [4-18] has the form

$$S_3 = d_{33}E_3 + s^E_{33}T_3$$

For the longitudinal piezo engine its mechanical characteristic is obtained

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

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

$$F_{\max} = d_{33} S_0 E_3 / s^E_{33}$$

For $E_3 = 1.2\cdot10^5$ V/m, $S_0 = 1.5\cdot10^{-4}$ m², $\delta = 2.5\cdot10^{-3}$ m, $d_{33} = 4\cdot10^{-10}$ m/V, $s^E_{33} = 15\cdot10^{-12}$ m²/N the parameters on Figure 1 are received max $\Delta\delta_{max} = 120$ nm and $F_{max} = 480$ N for error 10%.

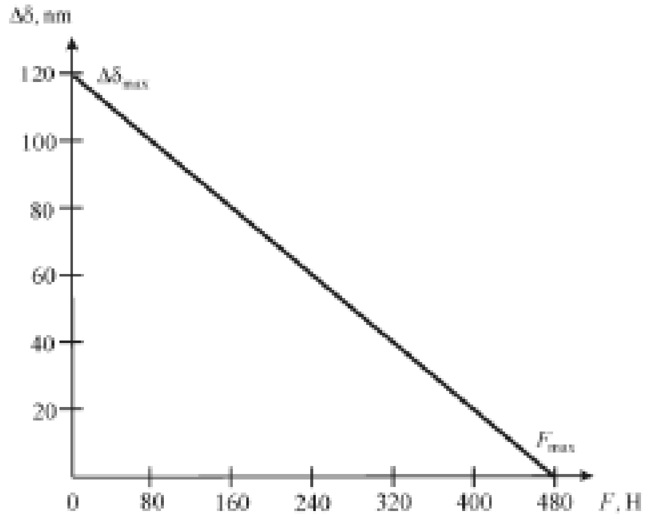

Figure 1: Mechanical characteristic.

The maximums of transverse deformation and force are determined

$$\Delta h_{\max} = d_{31}hE_3 = d_{31}\left(h/\delta\right)U$$

$$F_{\max} = d_{31}S_0E_3/s^E_{11}$$

The expression by U at $M >> m$ is written

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

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

$$\xi_t = \alpha h^2 C^E_{11}/\left(3l^2\sqrt{M\left(C_l + C^E_{11}\right)}\right), \quad \omega_t = 1/T_t$$

where M ,C_l , m, C^E_{11} are the masses and the stiffness of load and engine.

At $C_l = 0.1\ 10^7$ N/m, $C^E_{11} = 1\ 10^7$ N/m, $M = 2$ kg the time constant and the conjugate frequency are determined $T_t = 0.4\ 10^{-3}$ s, $\omega_t = 2.5\ 10^3$ s^{-1} for error 10%.

The settled displacement at elastic-inertial workload is determined

$$\Delta h = \frac{d_{31}\left(h/\delta\right)U}{1 + C_l/C^E_{11}} = k_{U31}U$$

At $d_{31} = 2.1\cdot10^{-10}$ m/V, $h/\delta = 20$, $C_l/C^E_{11} = 0.05$, $U = 100$ V the coefficient and the displacement are received $k_{U31} = 4$ nm/V and $\Delta h = 400$ nm for error 10%. This regulation characteristic of the piezo engine is obtained for astronomical techniques and adaptive optics.

Conclusions

The deformation of the piezo engine is obtained. The expressions engines are obtained for astronomical techniques. The characteristics for the piezo engine are received.

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