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Engine for Nanotechnology and Nanoscience

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Abstract

For nanotechnology and nanoscience, the parameters and the characteristics of the electro elastic engine are obtained. The functions of the engine are determined. The mechanical characteristic of the engine is received.

Keywords: Electro Elastic Engine, Piezo Engine, Nano displacement, Deformation, Transfer Coefficient, Characteristic, Nanotechnology, Nanoscience

Introduction

The electro elastic engine with piezoelectric or electrostrictive effect is used in nanotechnology and nanoscience, tunel microscopy, microelectronics for matching in X-ray and photolithography [1-9]. The transformation of the electric to mechanical energy is clearly for engine [3-26]. The piezo engine is coming for nanotechnology, adaptive optics, nanobiomedicine and microsurgery for precise feeding of instruments [14-30].

Deformation

For electro elastic engine the equations [4-50] are received

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

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

here (*T*), (*E*), (*D*), (*S*), (*d*), (ε^T), (s^E), *t* are matrixes: mechanical field intensity, electric field strength, electric induction, relative deformation, electro elastic coefficient, dielectric constant, elastic compliance, and transposed index. For the engine from PZT the matrixes are received as

$$(d)=\begin{pmatrix} 0 & 0 & 0 & 0 & d_{15} & 0 \\ 0 & 0 & 0 & d_{15} & 0 & 0 \\ d_{31} & d_{31} & d_{33} & 0 & 0 & 0 \end{pmatrix}$$

$$(s^{E})=\begin{pmatrix} s_{11}^{E} & s_{12}^{E} & s_{13}^{E} & 0 & 0 & 0 \\ s_{12}^{E} & s_{11}^{E} & s_{13}^{E} & 0 & 0 & 0 \\ s_{13}^{E} & s_{13}^{E} & s_{33}^{E} & 0 & 0 & 0 \\ 0 & 0 & 0 & s_{55}^{E} & 0 & 0 \\ 0 & 0 & 0 & 0 & s_{55}^{E} & 0 \\ 0 & 0 & 0 & 0 & 0 & 2\left(s_{11}^{E}-s_{12}^{E}\right) \end{pmatrix}$$

Differential equation of engine [3-50] is received

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

$$\gamma=s/c^{E}+\alpha$$

where $\Xi(x,s)$, s, x, γ, α, c^E are the Laplace transform of the deformation, the operator, the coordinate, the coefficients of wave propagation and attenuation, the speed at $E=\text{const}$.

Decision differential equation of deformation has the form

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

Boundary conditions of deformation for the transverse piezo engine are obtained as

$$\Xi(0,s)=\Xi_{1}(s) \text{ at } x=0$$

$$\Xi(h,s)=\Xi_{2}(s) \text{ at } x=h$$

hence decision is received

$$\Xi(x,s)=\left(\Xi_{1}(s)\operatorname{sh}\left((h-x)\gamma\right)+\Xi_{2}(s)\operatorname{sh}(x\gamma)\right)/\operatorname{sh}(h\gamma)$$

For $x=0$ and $\Xi_1(s)=\Xi(0,s)=0$ decision is obtained

$$\Xi(x,s)=\Xi_{2}(s)\operatorname{sh}(x\gamma)/\operatorname{sh}(h\gamma)$$

For elastic-inertial load at $x=h$ the relative deformation is determined

$$\left.\frac{d\Xi(x,s)}{dx}\right|_{x=h}=d_{31}E_{3}(s)-\frac{s_{11}^{E}Ms^{2}\Xi_{2}(s)}{S_{0}}-\frac{s_{11}^{E}C_{e}\Xi_{2}(s)}{S_{0}}$$

hence equation has the form

$$\frac{\Xi_{2}(s)\gamma}{\operatorname{th}(h\gamma)}+\frac{\Xi_{2}(s)s_{11}^{E}Ms^{2}}{S_{0}}+\frac{\Xi_{2}(s)s_{11}^{E}C_{l}}{S_{0}}=d_{31}E_{3}(p)$$

The function of the engine by *E* is written in the form

$$W_{E}(s)=\frac{\Xi_{2}(s)}{E_{3}(s)}=\frac{d_{31}h}{Ms^{2}/C_{11}^{E}+h\gamma\operatorname{cth}(h\gamma)+C_{l}/C_{11}^{E}}$$

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

The function of the engine by *U* is received in the form

$$W_{U}(s)=\frac{\Xi_{2}(s)}{U(s)}=\frac{d_{31}h/\delta}{Mp^{2}/C_{11}^{E}+h\gamma\operatorname{cth}(h\gamma)+C_{l}/C_{11}^{E}}$$

Characteristics

Relative deformation S_i of the engine [1-20] has form

$$S_{i}=d_{mi}E_{m}+s_{ij}^{E}T_{j}$$

where d_{mi} is the piezo coefficient.

Mechanical characteristic of the engine is determined

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

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

$$F_{max} = d_{mi} S_0 E_m / s_{ij}^E$$

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

For the longitudinal piezo engine the equation [8-18] has form

$$S_3 = d_{33} E_3 + s_{33}^E T_3$$

where d_{33} is the longitudinal piezo coefficient.

The mechanical characteristic has the form

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

The maximums of deformation $\Delta\delta_{max}$ and force F_{max} are determined

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

$$F_{max} = d_{33} S_0 E_3 / s_{33}^E$$

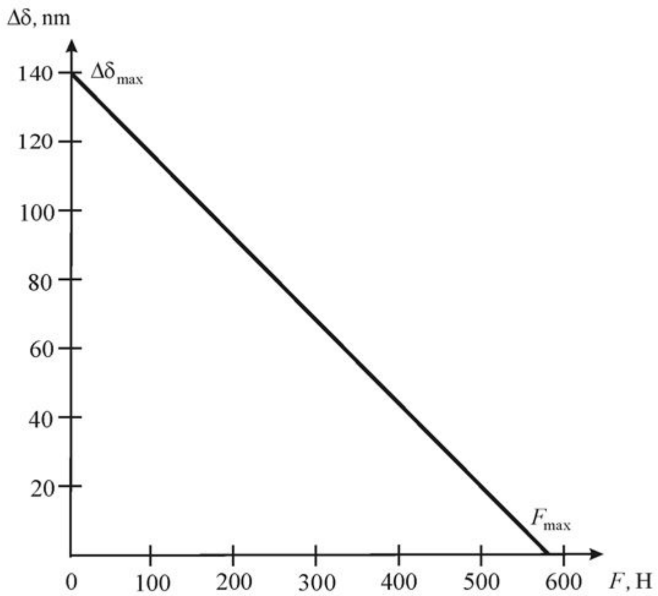

Figure 1: Mechanical characteristic of engine

For E_3 = 1.4·10^5 V/m, S_0 = 1.5·10^{-4} m^2, δ = 2.5·10^{-3} m, d_{33} = 4·10^{-10} m/V, s_{33}^E = 15·10^{-12} m^2/N for the engine from PZT its parameters received $\Delta\delta_{max}$ = 140 nm, F_{max} = 560 N on Figure 1 with error 10%.

The maximums of the deformation Δh_{max} and force F_{max} for the transverse piezo engine are received in the form

$$\Delta h_{max} = d_{31} h E_3 = d_{31}\left(h/\delta\right) U$$

$$F_{max} = d_{31} S_0 E_3 / s_{11}^E$$

where d_{31} is the transverse piezo coefficient.

The function of the transverse piezo engine by U at $M > m$ has the form

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

where M , m are the masses of load and engine, $k_{U31} = d_{31}\left(h/\delta\right)/\left(1 + C_l/C_{11}^E\right)$ is the transfer coefficient, $T_t = \sqrt{M/\left(C_l + C_{11}^E\right)}$ is the time constant, $\xi_t = \alpha l^2 C_{11}^E/\left(3c^E\sqrt{M\left(C_l + C_{11}^E\right)}\right)$ is the attenuation coefficient, $\omega_t = 1/T_t$ is the conjugate frequency.

At C_l = 0.1·10^7 N/m, C_{11}^E = 2·10^7 N/m, M = 2 kg the parameters are obtained T_t = 0.3·10^{-3} s and ω_t = 3.3·10^3 s^{-1} with error 10%.

Steady-state movement at elastic-inertial load is received

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

At d_{31} = 2.2·10^{-10} m/V, h/δ = 20, C_l/C_{11}^E = 0.05 the coefficient k_{U31} = 4.2 nm/V is determined with error 10%.

Conclusions

The deformation of the electro elastic engine is obtained for nanotechnology. The functions and the characteristics of the engine are determined for nanoscience. The characteristics for the piezo engine are received.

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