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Research Article

Piezo Engine for Nano Medical Research

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Abstract

The characteristics of the piezo engine are obtained for nano medical research. The transfer coefficient and function on the voltage of the piezo engine are received. The mechanical characteristic of the piezo engine is determined.

Key words: piezo engine; deformation; differential equation; characteristic; nano medical research

Introduction

For nano medical research the piezo engine is applied [1-15]. The energy transformation is clearly for the piezo engine [4-29]. This engine is used in nano medical and pharmaceutics research, X-ray lithography, adaptive optics, nano medicine, scanning probe microscopy.

Deformation

The equations of the piezo effects [5-52] are written

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

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

here (D), (d), (T), (ε^T), (E), (S), (s^E), $(d)^t$ are matrixes for electric induction, piezo constant, strength mechanical field, dielectric constant, strength electric field, relative deformation, elastic compliance and transposed piezo constant. The matrixes for PZT are received

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

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

$$(\varepsilon^T)=\begin{pmatrix} \varepsilon_{11}^T & 0 & 0 \\ 0 & \varepsilon_{22}^T & 0 \\ 0 & 0 & \varepsilon_{33}^T \end{pmatrix}$$

For the transverse piezo engine its relative deformation [4-29] is obtained

$$S_1 = d_{31}E_3 + s_{11}^E T_1$$

here d_{31} is the transverse piezo constant.

The differential equation of deformation engine [8–50] is recorded

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

here $\Xi(x,s)$, x, s, $\gamma = s/c^E + \alpha$, c^E, α are the conversion of deformation, the position, the conversion operator, the coefficient of wave propagation, the sound speed, the coefficient of attenuation.

Edge conditions are written

$$\Xi(0,s) = \Xi_1(s) \text{ by } x = 0$$

$$\Xi(h,s) = \Xi_2(s) \text{ by } x = h$$

Decision of differential equation deformation at transverse piezo effect is recorded

$$\Xi(x,s) = \frac{\Xi_1(s)\mathrm{sh}((h-x)\gamma) + \Xi_2(s))\mathrm{sh}(x\gamma)}{\mathrm{sh}(h\gamma)}$$

here M_1, M_2 are the masses on its faces.

Structural model and scheme of transverse engine for nano medical research on Figure 1 are found

$$\Xi_1(s) = \left(M_1 s^2\right)^{-1}\left\{-F_1(s) + \left(\chi_{11}^E\right)^{-1}\begin{bmatrix} d_{31}E_3(s) - [\gamma/\mathrm{sh}(h\gamma)] \\ \times[\mathrm{ch}(h\gamma)\Xi_1(s) - \Xi_2(s)]\end{bmatrix}\right\}$$

$$\Xi_2(s) = \left(M_2 s^2\right)^{-1}\left\{-F_2(s) + \left(\chi_{11}^E\right)^{-1}\begin{bmatrix} d_{31}E_3(s) - [\gamma/\mathrm{sh}(h\gamma)] \\ \times[\mathrm{ch}(h\gamma)\Xi_2(s) - \Xi_1(s)]\end{bmatrix}\right\}$$

$$\chi_{11}^E = s_{11}^E / S_0$$

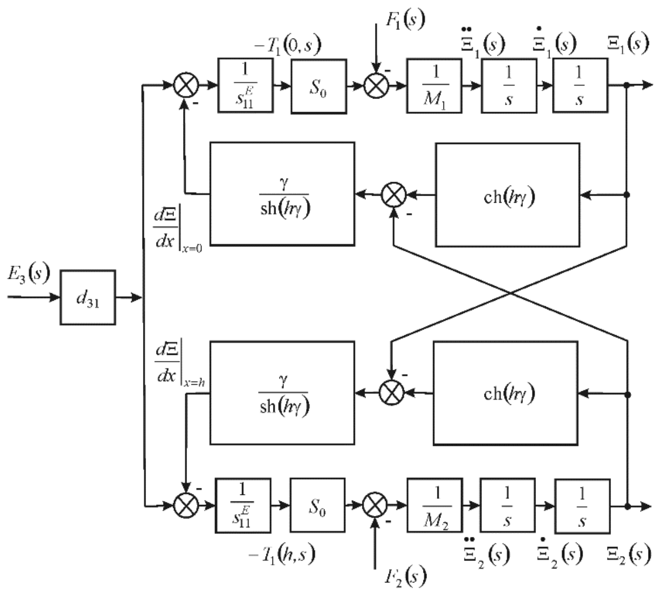

Figure 1. Scheme transverse piezo engine for nano medical research.

For fixed face of engine at $x = 0$, $\Xi_1(s) = \Xi(0,s) = 0$ the equation of deformation is written

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

For $x = h$ the equation is recorded

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

After conversions

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

For distributed parameters the function is determined in the form

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

here C_{11}^E, C_l are the stiffness of engine and load.

The function on voltage e is obtained

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

Characteristics

For the lumped parameters at elastic-inertial workload the function on voltage is received in the form

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

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

$\omega_t = 1/T_t$, $\xi_t = \alpha l^2 C_{11}^E \Big/ \left(3c^E\sqrt{M\left(C_l + C_{11}^E\right)}\right)$ are the transverse transfer coefficient, the constant of time, the frequency of conjugate and the coefficient of attenuation.

For M = 2 kg, C_l = $0.1\cdot10^7$ N/m, C_{11}^E = $0.5\cdot10^7$ N/m the parameters PZT engine are found T_t = $0.41\cdot10^{-3}$ s and ω_t = $2.4\cdot10^3$ s^{-1} with error 10%.

The steady deformation of the engine at elastic-inertial workload is found

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

At d_{31} = 2·10^-10^ m/V, h/δ = 20, C_l / C_{11}^E = 0.2 for PZT engine its transfer coefficient is received k_{U31} = 3.3 nm/V.

The characteristics of engine are recorded

$$\Delta h = \Delta h_{\max}(1 - F/F_{\max})$$

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

$$F_{\max} = d_{31}S_0E_3 / s_{11}^E.$$

For d_{31} = $2\cdot10^{-10}$ m/V, E_3 = $1.5\cdot10^{5}$ V/m, h = $2.5\cdot10^{-2}$ m, S_0 = $1.5\cdot10^{-5}$ m^2, s_{11}^E = $15\cdot10^{-12}$ m^2/N parameters PZT engine are determined $\Delta h_{\max}$ = 750 nm and $F_{\max}$ = 30 N.

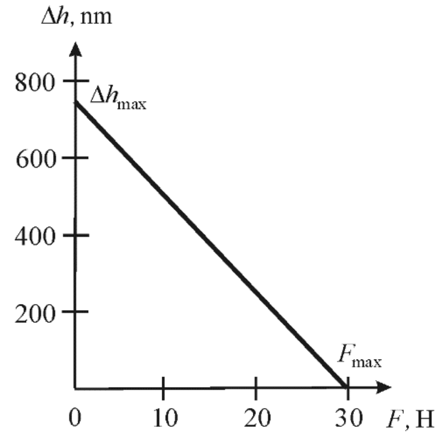

Figure 2. Mechanical characteristic of engine.

Conclusions

The parameters of the piezo engine are obtained. For nano medical research the transfer coefficient and function on the voltage are found. The mechanical characteristic of the piezo engine is determined.

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