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Research Article

Calculation Deformation of an Engine for Nano Biomedical Research

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Abstract:

In the article the calculation of the deformation of an electromagnetoelastic engine for nano biomedical research is obtained. The structural schema of an electromagnetoelastic engine is found. In the visibility of energy conversion the structural schema of an electromagnetoelastic engine has a difference from Cady and Mason electrical equivalent circuits of a piezo vibrator. The matrix equation and the matrix transfer function of an electromagnetoelastic engine are received.

Keywords: electromagnetoelastic engine; piezo engine; nano biomedical research; deformation; structural schema; matrix equation; matrix transfer function

Introduction

In nano biomedical research an electromagnetoelastic engine in the form of piezo engine or magnetostriction actuator is used for laser system, nanopump, nanopositioner, nanomanipulator, scanning microscopy [1-6]. The piezo engine is applied for optical-mechanical device, adaptive optics system, fiber-optic system, microsurgery [5-14].

For an electromagneto elastic engine the electromagnetoelasticity equation and the ordinary differential equation of the second order are solved to obtain the structural schema of an engine. In the visibility of energy conversion the structural schema of an electromagnetoelastic engine has a difference from Cady and Mason electrical equivalent circuits of a piezo vibrator. By applying the methods of electromagnetoelasticity the structural schema of an electro magneto elastic engine for nano biomedical research is obtained [4-12].

Deformation of an engine

The equation electromagnetoelasticity of an electromagnetoelastic engine for nano biomedical research [1-30] has the form

$$S_i = d_{mi}\Psi_m + s_{ij}^{\Psi}T_j$$

where S_i, d_{mi}, Ψ_m, s_{ij}^{Ψ}, and T_j are the relative deformation, the module, the control parameter or the intensity of field, the elastic compliance, and the mechanical intensity.

In static the mechanical characteristic [4-42] of an electromagnetoelastic engine has the form

$$S_i\big|_{\Psi=\text{const}} = d_{mi}\Psi_m\big|_{\Psi=\text{const}} + s_{ij}^{\Psi}T_j$$

the regulation characteristic an engine has the form

$$S_i\big|_{T=\text{const}} = d_{mi}\Psi_m + s_{ij}^{\Psi}T_j\big|_{T=\text{const}}$$

The mechanical characteristic of an electromagnetoelastic engine has the form

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

$$\Delta l_{\max} = d_{mi}\Psi_m l,\ F_{\max} = d_{mi}\Psi_m S_0 / s_{ij}^{\Psi}$$

For the the transverse piezo engine after transforms the maximum values of deformation and force have the form

$$\Delta h_{\max} = d_{31}E_3 h,\ F_{\max} = d_{31}E_3 S_0 / s_{11}^{E}$$

At d_{31} = $2\cdot10^{-10}$ m/V, E_3 = $0.4\cdot10^{5}$ 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 the maximum values of deformation and force for the transverse piezo engine are found $\Delta h_{\max}$ = 200 nm and $F_{\max}$ = 8 N.

The regulation characteristic at elastic load of an electromagnetoelastic engine for nano biomedical research is obtained in the form

$$\frac{\Delta l}{l} = d_{mi}\Psi_m - \frac{s_{ij}^{\Psi} C_e}{S_0}\Delta l \ , \ F = C_e \Delta l$$

The equation of the deformation at elastic load of an electromagnetoelastic engine for nano biomedical research has the form

$$\Delta l = \frac{d_{mi} l \Psi_m}{1 + C_e / C_{ij}^{\Psi}}$$

After transforms the equation of the deformation at elastic load for the transverse piezo engine for nano biomedical research has the form

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

where k_{31}^{U} is the transfer coefficient.

At $d_{31} = 2 \cdot 10^{-10}$ m/V, $h/\delta = 16$, $C_{11}^{E} = 2.8 \cdot 10^{7}$ N/m, $C_e = 0.4 \cdot 10^{7}$ N/m, $U = 50$ V the transfer coefficient and the deformation of the transverse piezo engine are obtained $k_{31}^{U} = 2.8$ nm/V and $\Delta h = 140$ nm. Theoretical and practical parameters of the piezo actuator are coincidences with an error of 10%.

The ordinary differential equation of the second order for an electromagnetoelastic engine for nano biomedical research has the form [4-35, 42]

$$d^2\Xi(x,p)/dx^2 - \gamma^2 \Xi(x,p) = 0$$

$$\gamma = p/c^{\Psi} + \alpha$$

where $\Xi(x,p)$, p, γ, c^{Ψ}, and α are the transform of Laplace for displacement, the operator of transform, the coefficient of wave propagation, the speed of sound, and the coefficient of attenuation,

In dynamic the system of the equations for the transforms Laplace of forces on faces of an electromagnetoelastic actuator for nano biomedical research is received [10-42]

$$M_1 p^2 \Xi_1(p) + F_1(p) = S_0 T_j(0,p)$$

$$-M_2 p^2 \Xi_2(p) - F_2(p) = S_0 T_j(l,p)$$

where M_1, M_2, $\Xi_1(p)$, $\Xi_2(p)$, $F_1(p)$, $F_2(p)$, $T_j(0,p)$, $T_j(l,p)$, and S_0 are the masses of the loads, the transforms Laplace of displacements, forces and stress on faces 1 and 2 of an engine, and the area of an engine.

The system of the equations the transforms Laplace of stresses on faces of an engine has the form

$$T_j(0,p) = \frac{1}{s_{ij}^{\Psi}} \frac{d\Xi(0,p)}{dx} - \frac{d_{mi}}{s_{ij}^{\Psi}} \Psi_m(p)$$

$$T_j(l,p) = \frac{1}{s_{ij}^{\Psi}} \frac{d\Xi(l,p)}{dx} - \frac{d_{mi}}{s_{ij}^{\Psi}} \Psi_m(p)$$

After transforms the system of the equations for the structural schema on Figure 1 and model of an electromagnetoelastic engine for nano biomedical research has the form

$$\Xi_1(p) = \left(M_1 p^2\right)^{-1} \times \left\{ \begin{array}{l} -F_1(p) + \left(1/\chi_{ij}^{\Psi}\right) \\ \times \left[\begin{array}{l} d_{mi}\Psi_m(p) + [\gamma/\mathrm{sh}(l\gamma)] \\ \times [\Xi_2(p) - \mathrm{ch}(l\gamma)\Xi_1(p)] \end{array} \right] \end{array} \right\}$$

$$\Xi_2(p) = \left(M_2 p^2\right)^{-1} \times \left\{ \begin{array}{l} -F_2(p) + \left(1/\chi_{ij}^{\Psi}\right) \times \\ \times \left[\begin{array}{l} d_{mi}\Psi_m(p) + [\gamma/\mathrm{sh}(l\gamma)] \\ \times [\Xi_1(p) - \mathrm{ch}(l\gamma)\Xi_2(p)] \end{array} \right] \end{array} \right\}$$

where $\chi_{ij}^{\Psi} = s_{ij}^{\Psi}/S_0$, $d_{mi} = \begin{cases} d_{33}, d_{31}, d_{15} \\ d_{33}, d_{31}, d_{15} \end{cases}$, $\Psi_m = \begin{cases} E_3, E_1 \\ H_3, H_1 \end{cases}$,

$s_{ij}^{\Psi} = \begin{cases} s_{33}^{E}, s_{11}^{E}, s_{55}^{E} \\ s_{33}^{H}, s_{11}^{H}, s_{55}^{H} \end{cases}$, $\gamma = \begin{cases} \gamma^{E} \\ \gamma^{H} \end{cases}$, E and H are the intensity of electric field and the intensity of magnetic field in an engine.

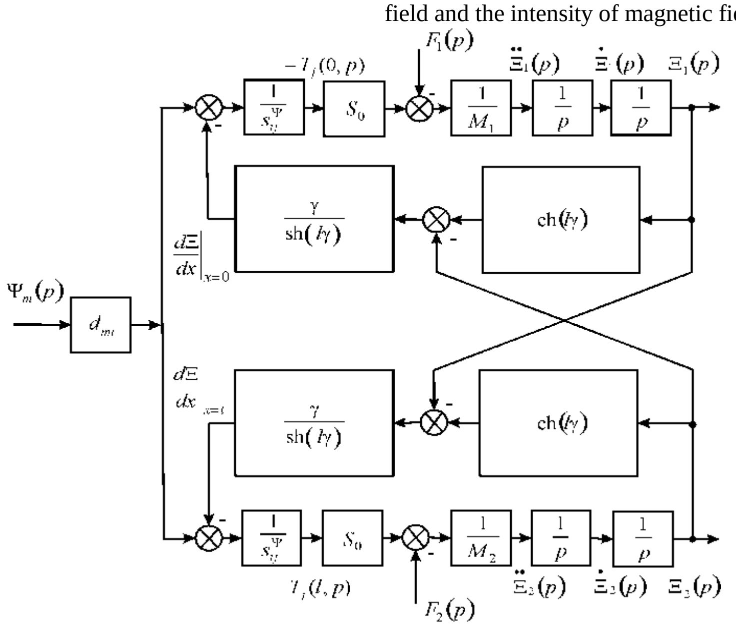

Figure 1: *Structural schema of an electromagnetoelastic engine for nano biomedical research.*

For nano biomedical science the structural research of an electromagnetoelastic engine replaces Cady and Mason electrical equivalent circuits [5-10].

The matrix equation of an electro magneto elastic actuator for nano biomedical research with matrix transfer function has the form

$$\begin{pmatrix} \Xi_1(p) \\ \Xi_2(p) \end{pmatrix} = \begin{pmatrix} W_{11}(p) & W_{12}(p) & W_{13}(p) \\ W_{21}(p) & W_{22}(p) & W_{23}(p) \end{pmatrix} \begin{pmatrix} \Psi_m(p) \\ F_1(p) \\ F_2(p) \end{pmatrix}$$

From the matrix equation of an electromagnetoelastic engine at the inertial load the steady-state deformations in the form $\xi_1(\infty)$, $\xi_2(\infty)$ of an actuator have the form

$$\xi_1(t)\big|_{t\to\infty} = \xi_1(\infty) = d_{mi}\Psi_m l\, M_2/(M_1+M_2)$$

$$\xi_2(t)\big|_{t\to\infty} = \xi_2(\infty) = d_{mi}\Psi_m l\, M_1/(M_1+M_2)$$

Therefore, after transforms the steady-state deformations of the transverse piezo engine at the inertial load have the form

$$\xi_1(\infty) = d_{31}(h/\delta)UM_2/(M_1+M_2)$$

$$\xi_2(\infty) = d_{31}(h/\delta)UM_1/(M_1+M_2)$$

At d_{31} = $2\cdot10^{-10}$ m/V, h/δ = 20, U = 60 V, M_1 = 2 kg and M_2 = 8 kg the deformations of the transverse piezo engine are received $\xi_1(\infty)$ = 192 nm, $\xi_2(\infty)$ = 48 nm, $\xi_1(\infty)+\xi_2(\infty)$ = 240 nm.

Conclusions

In the article the calculation of the deformation of an electromagnetoelastic engine for nano biomedical research is obtained. The structural schema of an electromagnetoelastic engine for nano biomedical research is shown. In the visibility of energy conversion the structural schema of an electromagnetoelastic engine has a difference from Cady and Mason electrical equivalent circuits of a piezo vibrator.

From the equation electromagnetoelasticity and the ordinary differential equation of the second order of an electro magneto elastic engine the structural schema of an engine is received. The matrix equation and the matrix transfer function of an electromagnetoelastic engine for nano biomedical research are found.

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