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An electromagnetoelastic engine for nano and micro bionics

Abstract

The structural model and scheme of an electromagnetoelastic engine are determined for nano and micro bionics. The structural scheme of an electromagnetoelastic engine is constructed. The matrix equation is obtained for an electromagnetoelastic engine.

Keywords: electromagnetoelastic engine, structural scheme, piezo engine, nano and micro bionics

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Introduction

An electromagnetoelastic engine is used for the nano alignment in adaptive optics, in tunnel microscopy and interferometers in nanomedicine and applied bionics, in the ring quantum generators, in the dampen mechanical vibrations, in the penetration in a cells and the genes.[1–15] For construction structural model of an electromagnetoelastic engine the methods mathematical physics are applied. In an electromagnetoelastic engines as active elements are used piezo or magnetostricton engenes. In difference from Cady and Mason equivalent electric schemes[8–10] for calculations the deformations an electromagnetoelastic engine its structural scheme and its transfer functions are applied.[14–23]

Structural model and scheme

Methods mathematical physics with decision the equation of the reverse electromagnetoelastic effect and the differential equation of an electromagnetoelastic engine at boundary conditions are used for calculation structural model of an engine and its structural scheme. An engine works on basis of the reverse electromagnetoelastic effect in the form[3–59]

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

where S_i, $\Psi_m = E_m, D_m, H_m$, T_j, s_{ij}^{Ψ}, $\nu_{mi} = d_{mi}, g_{mi}, d_{mi}$ are the relative deformation, control parameter in the form strength electric field, induction and strength magnetic field, strength mechanical field, elastic compliance at $\Psi = \text{const}$, the electromagnetoelastic module in the form piezo module, piezo const and magnitostriction const, *i*, *j*, *m* are indexes.

The differential equation[3–59] of an electromagnetoelastic engine has form

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

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

here $\Xi(x,s)$, *s*, x, γ, c^{Ψ}, α are the Laplace transform of the deformation, the parameter transform, the coordinate, the propagation factor, the speed of sound at $\Psi = \text{const}$, coefficient wave attenuation.

For an electromagnetoelastic engine we have its decision at $x = 0$ the trasform first deformation $\Xi(0,s) = \Xi_1(s)$ and at $x = l$ the trasform second deformation $\Xi(l,s) = \Xi_2(s)$.

The decision this differential equation has the form

$$\Xi(x,s) = \left\{ \Xi_1(s) \operatorname{sh}\left[(l-x)\gamma\right] + \Xi_2(s) \operatorname{sh}(x\gamma) \right\} / \operatorname{sh}(l\gamma)$$

where $\Xi_1(s)$, $\Xi_2(s)$ are the transforms of the deformations.

Then we have the system strength mechanical field for two faces an electromagnitoelastic engine in the form

$$T_j \;\; 0,s \;\; = \frac{1}{s_{ij}^{\Psi}} \frac{d\Xi \;\; x,s}{dx}\bigg|_{x=0} - \frac{\nu_{mi}}{s_{ij}^{\Psi}} \Psi_m \;\; s$$

$$T_j(l,s) = \frac{1}{s_{ij}^{\Psi}} \frac{d\Xi(x,s)}{dx}\bigg|_{x=l} - \frac{\nu_{mi}}{s_{ij}^{\Psi}} \Psi_m(s)$$

where l the length of an electromagnitoelastic engine.

The general structural model and structural scheme on Figure 1 of an electromagnitoelastic engine are determined

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

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

$$\chi_{ij}^{\Psi} = s_{ij}^{\Psi} / S_0$$

where

$$\Psi_m = \begin{cases} E_3, E_3, E_1 \\ D_3, D_3, D_1 \\ H_3, H_3, H_1 \end{cases}$$

$$\nu_{mi} = \begin{cases} d_{33}, d_{31}, d_{15} \\ g_{33}, g_{31}, g_{15} \\ d_{33}, d_{31}, d_{15} \end{cases}$$

$$s_{ij}^{\Psi} = \begin{cases} s_{33}^{E}, s_{11}^{E}, s_{55}^{E} \\ s_{33}^{D}, s_{11}^{D}, s_{55}^{D} \\ s_{33}^{H}, s_{11}^{H}, s_{55}^{H} \end{cases}$$

The structural model and the structural scheme of an electromagnetoelastic engine on Figure 1 are used for the design of a precise control system for nano and micro bionics.

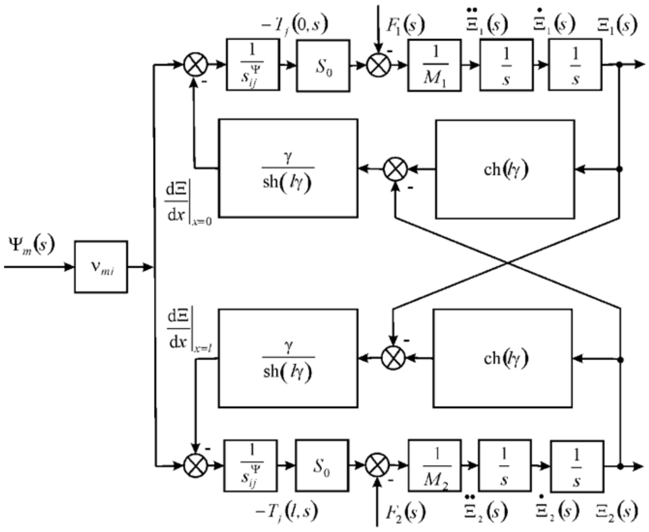

Figure 1 Structural scheme an electromagnetoelastic engine.

The matrix of the deformations is written

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

where

$$W_{11}(s)=\frac{\Xi_1(s)}{\Psi_m(s)}=-\frac{\nu_{mi}}{A_{ij}}\left[M_2\chi_{ij}^{\Psi}s^2+\gamma\,\mathrm{th}\left(\frac{l\gamma}{2}\right)\right]$$

$$W_{21}(s)=\frac{\Xi_2(s)}{\Psi_m(s)}=\frac{\nu_{mi}}{A_{ij}}\left[M_1\chi_{ij}^{\Psi}s^2+\gamma\,\mathrm{th}\left(\frac{l\gamma}{2}\right)\right]$$

$$W_{12}(s)=\frac{\Xi_1(s)}{F_1(s)}=-\frac{\chi_{ij}^{\Psi}}{A_{ij}}\left[M_2\chi_{ij}^{\Psi}s^2+\frac{\gamma}{\mathrm{th}(l\gamma)}\right]$$

$$W_{13}(s)=\frac{\Xi_1(s)}{F_2(s)}=W_{22}(s)=\frac{\xi_2(s)}{F_1(s)}=\frac{\chi_{ij}^{\Psi}\gamma}{A_{ij}\mathrm{sh}(l\gamma)}$$

$$W_{23}(s)=\frac{\Xi_2(s)}{F_2(s)}=-\frac{\chi_{ij}^{\Psi}}{A_{ij}}\left[M_1\chi_{ij}^{\Psi}s^2+\frac{\gamma}{\mathrm{th}(l\gamma)}\right]$$

$$A_{ij}=M_1M_2\left(\chi_{ij}^{\Psi}\right)^2s^4+\frac{(M_1+M_2)\chi_{ij}^{\Psi}}{c^{\Psi}\mathrm{th}(l\gamma)}s^3+\left[\frac{(M_1+M_2)\chi_{ij}^{\Psi}\alpha}{\mathrm{th}(l\gamma)}+\frac{1}{\left(c^{\Psi}\right)^2}\right]s^2+\frac{2\alpha}{c^{\Psi}}s+\alpha^2$$

The structural model and the structural scheme of an electromagnetoelastic engine are constructed at two mass load. In general the matrix of the deformations of an electromagnetoelastic engine are obtained for the constructions of the engine at two mass load in the step engine.

For $\Psi_m(t)=\Psi_{m0}\cdot 1(t)$, $F_1(t)=F_2(t)=0$ at inertial load the static displacement the faces of an electromagnetoelastic engine $\xi_1(\infty)$ and $\xi_2(\infty)$ we have the form

$$\xi_1(\infty)=\lim_{t\to\infty}\xi_1(t)=\frac{\nu_{mi}l\Psi_{m0}(M_2+m/2)}{M_1+M_2+m}$$

$$\xi_2(\infty)=\lim_{t\to\infty}\xi_2(t)=\frac{\nu_{mi}l\Psi_{m0}(M_1+m/2)}{M_1+M_2+m}$$

$$\xi_1(\infty)+\xi_2(\infty)=\lim_{t\to\infty}\left(\xi_1(t)+\xi_2(t)\right)=\nu_{mi}l\Psi_{m0}$$

where m is the mass of the electrmagnetoelastic engine, M_1, M_2 are the load masses.

For the static displacements of the longitudinal piezo engine for $m \ll M_1$ and $m \ll M_2$ we have equations in the form

$$\xi_1(\infty)=\frac{d_{33}U_0M_2}{M_1+M_2}$$

$$\hat{\imath}_2(\infty)=\frac{d_{33}U_0M_1}{M_1+M_2}$$

where δ is the thickness of the piezo engine. For the PZT longitudinal piezo engine d_{33} = 4·10⁻¹⁰ m/V, U = 100 V, M_1 = 1 kg, M_2 = 4 kg we have the module of displacements the faces ξ_1 = 32 nm, ξ_2 = 8 nm and summa module of displacements $\xi_1+\xi_2$ = 40 nm at error 10%.

For the static displacements of the transverse piezo engine for $m \ll M_1$ and $m \ll M_2$ we have equations in the form

$$\xi_1(\infty)=\frac{d_{31}(l/\delta)U_0M_2}{M_1+M_2}$$

$$\xi_2(\infty)=\frac{d_{31}(l/\delta)U_0M_1}{M_1+M_2}$$

For the PZT transverse piezo engine d_{31} = 2.5·10⁻¹⁰ m/V, l/δ = 20, U = 100 V, M_1 = 1 kg, M_2 = 4 kg we have the module of displacements the faces ξ_1 = 400 nm, ξ_2 = 100 nm and summa modules of displacements $\xi_1+\xi_2$ = 500 nm at error 10%.

For $M_1\to\infty$, $m \ll M_2$ and the control voltage for the resistance $R=0$ the transfer function on voltage for the transverse piezo engine is obtained in the form

$$W_U\ s\ =\frac{\Xi_2(s)}{U(s)}=\frac{d_{31}(l/\delta)}{\left(1+C_l/C_{11}^E\right)\left(T_t^2s^2+2T_t\xi_ts+1\right)}$$

$$T_t=\sqrt{M_2/\left(C_l+C_{11}^E\right)}$$

where $U(s)$ is the Laplace transform of the voltage, T_t is the timwhere $U(s)$ is the Laplace transform of the voltage, T_t is the time constant, ξ_t is the damping coefficient of the transverse piezo engine, C_l is the load rigidity, C_{11}^E is the transverse piezo engine rigidity at $E=\mathrm{const}$.

Then the transfer function on voltage for $M_1\to\infty$, $m \ll M_2$ for the transverse piezo engine at one the fixed face the transfer expression is obtained

$$W_U(s)=\frac{\Xi_2(s)}{U(s)}=\frac{k_{31}^U}{T_t^2s^2+2T_t\xi_ts+1}$$

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

$$T_t=\sqrt{M_2/\left(C_l+C_{11}^E\right)}$$

For $M_2=4$ kg, $C_l=0.2\cdot10^7$ N/m, C_{11}^E = 1.4·10⁷ N/m we have T_t = 0.5·10⁻³ s, $\omega_t=1/T_t$ = 2·10³ s⁻¹ at error 10%.

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The static transverse deformation has the form

$$\xi_2(\infty) = \frac{d_{31}(l/\delta)U}{1 + C_l/C_{11}^E} = k_{31}^U U$$

For $d_{31} = 2.5\cdot10^{-10}$ m/V, $l/\delta = 20$, $C_l/C_{11}^E = 0.14$ the coefficient is determined $k_{31}^U = 4.4$ nm/V at error 10%.

The parameters of the piezo engine with one the its fixed face are determined for nano and micro bionics. The parameters PZT transverse engine are found.

Conclusions

The general structural model and the structural scheme of an electromagnetoelastic engine are constructed at two mass load.

The matrix of the deformations of an electromagnetoelastic engine are obtained for the constructions of the engine at two mass load in the step engine.

The parameters of the piezo engine with one its fixed face are determined for nano and micro bionics.

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Conflicts of interest

The author declares that there is no conflict of interest.

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