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Short Communication

# Multilayer Engine for Microsurgery and Nano Biomedicine

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## Abstract

In this paper, the structural circuit of the multilayer engine for microsurgery and nano biomedicine is received. We obtained the characteristics of the multilayer engine.


**Keywords:** Multilayer engine; Structural circuit

## Introduction

The multilayer engine with the piezoelectric or electrostriction effects is used for microsurgery and nano biomedicine [1-9]. We received the structural circuit of the multilayer engine in contrast to Cady's and Mason's equivalent circuits [9-32]. We determined the mathematical model and the structural circuit of the multilayer engine with the equation of the electro elasticity and the matrix of the quadripole for the multilayer engine.

## Structural Circuit of the Multilayer Engine

We received the structural circuit of the multilayer engine for microsurgery and nano biomedicine in difference from Cady's and Mason's equivalent circuits [1–14]. We have the matrix equation electro elasticity [7,8,14] in the form

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

In this equation we write the relative displacement, the coefficient of electro elasticity, the control parameter, the elastic compliance, the mechanical stress in the forms $S_i, v_{mi}, \psi_m, s_{ij}^{\psi}, T_j$.

The causes force for the multilayer engine has the form

$$F = v_{mi} S_0 \Psi_m / s_{ij}^{\Psi}$$

where $S_0$ is the area of the multilayer engine

The matrix of the quadripole for the multilayer engine [7, 29, 31] has the form

$$[M]^n = \begin{bmatrix} \operatorname{ch}(l\gamma) & Z_0 \operatorname{sh}(l\gamma) \\ \dfrac{\operatorname{sh}(l\gamma)}{Z_0} & \operatorname{ch}(l\gamma) \end{bmatrix}$$

In this equation we write $l$ is the length of the multilayer engine and $\gamma$ is the coefficient propagation.

We have the structural circuit of the multilayer engine for microsurgsery and nano biomedicine on Figure 1 from its mathematical model in the form

$$\Xi_1(p) = \left[1/\left(M_1 p^2\right)\right]\left\{-F_1(p) + \left(1/\chi_{ij}^{\Psi}\right)\left[v_{mi}\Psi_m(p) - [\gamma/\operatorname{sh}(l\gamma)]\left[\operatorname{ch}(l\gamma)\Xi_1(p) - \Xi_2(p)\right]\right]\right\}$$

$$\Xi_2(p) = \left[1/\left(M_2 p^2\right)\right]\left\{-F_2(p) + \left(1/\chi_{ij}^{\Psi}\right)\left[v_{mi}\Psi_m(p) - [\gamma/\operatorname{sh}(l\gamma)]\left[\operatorname{ch}(l\gamma)\Xi_2(p) - \Xi_1(p)\right]\right]\right\}$$

where $v_{mi} = \begin{cases} d_{33}, d_{31}, d_{15} \\ g_{33}, g_{31}, g_{15} \\ d_{33}, d_{31}, d_{15} \end{cases}$, $\Psi_m = \begin{cases} E_3, E_1 \\ D_3, D_1 \\ H_3, H_1 \end{cases}$, $s_{ij}^{\Psi} = \begin{cases} S_{33}^E, S_{11}^E, S_{55}^E \\ S_{33}^D, S_{11}^D, S_{55}^D \\ S_{33}^H, S_{11}^H, S_{55}^H \end{cases}$

$$c^{\Psi} = \begin{cases} c^E \\ c^D \\ c^H \end{cases}, \quad \gamma = p/c^{\Psi} + \alpha, \quad \chi_{ij}^{\Psi} = s_{ij}^{\Psi}/S_0$$

We have the matrix equation of the multilayer engine for microsurgery and nano biomedicine in the form

$$[\Xi(p)] = [W(p)][P(p)]$$

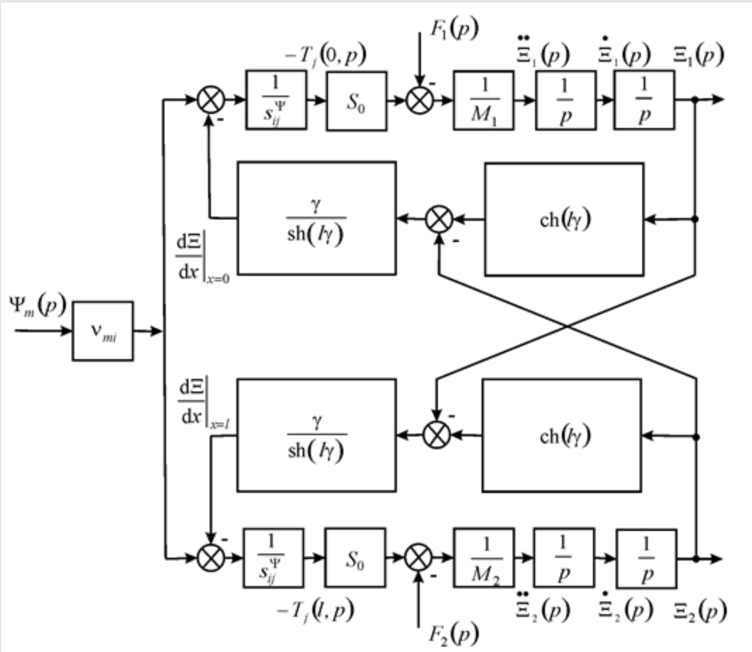


**Figure 1:** Structural circuit of the multilayer engine for microsurgery and nano biomedicine.

In this equation we write the matrixes $[\Xi(p)]$, $[W(p)]$, $[P(p)]$.

In static for the multilayer engine with longitudinal piezo effect and one fixed end we received displacement in the form

$$\xi_2 = \frac{d_{33} n U}{1 + C_e / C_{33}^E}$$

where $C_e$, $C_{33}^E$ are the rigidity of the load and the rigidity of the multilayer engine for $E = \text{const}$. We received for the multilayer engine at $d_{33} = 4 \cdot 10^{-10}$ m/V, n=12, U=200V, $C_{33}^E = 2 \cdot 10^7$ N/m, $C_e = 0.4 \cdot 10^7$ N/m the static displacement $\xi_2 = 800$ nm.

We obtained the transfer function with lumped parameters of the multilayer engine with longitudinal piezo effect and one fixed end in the form

$$W(p) = \frac{\Xi_2(p)}{U(p)} = \frac{d_{33} n}{\left(1 + C_e / C_{33}^E\right)\left(T_t^2 p^2 + 2 T_t \xi_t p + 1\right)}$$

$$T_t = \sqrt{M_2 / \left(C_e + C_{33}^E\right)}, \xi_t = \alpha (n\delta)^2 C_{33}^E / (3c^E \sqrt{(C_e + C_{33}^E)})$$

where $T_t$, $\xi_t$ are the time constant, the damping coefficient of the multilayer engine. Therefore, for the multilayer engine at $d_{33} = 4 \cdot 10^{-10}$ m/V, $n = 12$, $U = 200$ V, $M_2 = 4$ kg, $C_{33}^E = 2 \cdot 10^7$ N/m, $C_e = 0.4 \cdot 10^7$ N/m we have $\xi_2 = 800$ nm and $T_t = 0.4 \cdot 10^{-3}$ s.

## Conclusion

The structural circuit of the multilayer engine for microsurgery and nano biomedicine is obtained. The characteristics of the multilayer engine are received with using its structural circuit.

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