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DAC electro elastic engine for nanomedicine

Abstract

The DAC electro elastic engine is used for nanomedicine and nanotechnology. The mechanical and regulation characteristics of the DAC electro elastic engine are found. In work we are consider the characteristics of the DAC transverse, longitudinal and shift piezo engines. The characteristics of the DAC electro elastic engine are determined by using method of mathematical physics.

Keywords: DAC electro elastic engine, DAC piezo engine, characteristics, nanomedicine

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Introduction

The digital-to-analog converter (DAC) electro elastic engine on piezoelectric or electrostriction effect is used for nanomedicine and nanotechnology,[1–10] adaptive optics, interferometers, nanomanipulators, nanopumps, microsurgery, scanning microscopy and nanophysics.[8–29]

The problem of use the coded control and the DAC electro elastic engine is promising for nanomedicine. The DAC electro elastic engine can be applied to increase the range of displacement from nano- to microdisplacement in control systems.[1–10]

The DAC electro elastic engine consists of N sections with n electro elastic layers. The electro elastic layers in the DAC electro elastic engine are connected electrically in parallel and mechanically in series for the section. In this work, the mechanical and regulation characteristics of the DAC electro elastic engine are determined by using method of mathematical physics.

DAC electro elastic engine

The number of the layers in the section of the DAC electro elastic engine is equal to the degree of 2. For the DAC transverse piezo engine for nanomedicine on Figure 1 its equation of the reverse piezo effect[1–12] has the form

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

here S_1, E_3, T_1, d_{31}, s_{11}^E – the relative deformation on axis 1, the electric field stress on axis 3, the mechanical stress on axis 1, the transverse piezo module and the elastic compliance at $E = \text{const}$.

We have the displacement Δl_k of the section k with the length l_k of the DAC transverse piezo engine at $F = 0$ in the form

$$\Delta l_k = 2^{k-1} \frac{d_{31} l_1 U}{\delta} = 2^{k-1} \Delta l_1 = \frac{d_{31} l_k U}{\delta}$$

here $1 \le k \le N$, δ – is the thickness of the DAC electro elastic engine.

Therefore, the displacement of the DAC transverse piezo engine on Figure 1 at $F = 0$ is found in the form

$$\Delta l = \frac{d_{31} l_1 U}{\delta} \left(\sum_{k=1}^{N} a_k 2^{k-1} \right) = \Delta l_1 \left(\sum_{k=1}^{N} a_k 2^{k-1} \right)$$

here l, a_k – the length of the DAC transverse piezo engine and the binary code of the section.

The displacement of the DAC transverse piezo engine has the form

$$\Delta l = \frac{d_{31} l_1 U}{\delta} \left(\sum_{k=1}^{N} a_k 2^{k-1} \right) - \frac{s_{11}^E l F}{S_0}$$

Therefore, the displacement is written in the form

$$\Delta l = \frac{d_{31} l_1 U}{\delta} \left(\sum_{k=1}^{N} a_k 2^{k-1} \right) - \frac{F}{C_{11}^E}$$

here $C_{11}^E = S_0 / \left(s_{11}^E l \right)$ – the rigidity of the DAC transverse piezo engine. In this equation we have the maximum displacement and maximum force of the DAC transverse piezo engine in the form

$$\Delta l_{\max} = \frac{d_{31i} l_1 U}{\delta} \left(\sum_{k=1}^{N} a_k 2^{k-1} \right) = \Delta l_1 \left(\sum_{k=1}^{N} a_k 2^{k-1} \right) \text{ at } F = 0$$

$$F_{\max} = \frac{d_{31} l_1 U}{\delta} \left(\sum_{k=1}^{N} a_k 2^{k-1} \right) C_{11}^E \text{ at } \Delta l = 0$$

In general for the digital-to-analog converter (DAC) electro elastic engine its equation of the reverse piezo effect[1–19] has the form:

$$S_i = d_{mi} E_m + s_{ij}^E T_j$$

here S_i, E_m, T_j, d_{mi} and s_{ij}^E – the relative deformation on axis i, the electric field stress on axis m, the mechanical stress on axis j, the piezo module and the elastic compliance at $E = \text{const}$.

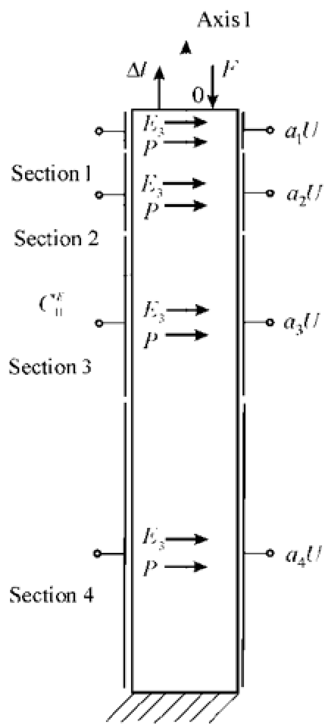

Figure 1 DAC transverse piezo engine.

Characteristics DAC electro elastic engine

In general the mechanical characteristic of the DAC electro elastic engine is written in the form

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

here $\Delta l_{\max}$ and $F_{\max}$ are written in the form

$$\Delta l_{\max} = \frac{d_{mi} l_1 U}{\delta}\left(\sum_{k=1}^{N} a_k 2^{k-1}\right) = \Delta l_1\left(\sum_{k=1}^{N} a_k 2^{k-1}\right) \text{ at } F = 0$$

$$F_{\max} = \frac{d_{mi} l_1 U}{\delta}\left(\sum_{k=1}^{N} a_k 2^{k-1}\right) C_{ij}^{E} \text{ at } \Delta l = 0$$

$$C_{ij}^{E} = S_0 \Big/ \left(s_{ij}^{E} l\right),\ \Delta l_1 = d_{mi} l_1 U/\delta,\ l = \sum_{k=1}^{N} l_k = \left(2^N - 1\right) l_1$$

here C_{ij}^{E}, Δl_1, l − the rigidity of the DAC electro elastic engine, the displacement of first section, the length of the DAC electro elastic engine.

The static characteristics of the DAC electro elastic engine at elastic load has the form

$$\Delta l = \frac{d_{mi} l_1 U}{\delta}\left(\sum_{k=1}^{N} a_k 2^{k-1}\right) - \frac{C_e \Delta l}{C_{ij}^{E}}$$

In general the adjustment characteristic of the DAC electro elastic engine on Figure 2 is found in the form

$$\Delta \tilde{n} = k_a U = \frac{\left(d_{mi} l_1/\delta\right) U}{\left(1 + C_e/C_{ij}^{E}\right)}\left(\sum_{k=1}^{N} a_k 2^{k-1}\right) = \Delta l_1 \quad ,$$

$$k_a = \frac{\left(d_{mi} l_1/\delta\right)}{\left(1 + C_e/C_{ij}^{E}\right)}\left(\sum_{k=1}^{N} a_k 2^{k-1}\right),\ \Delta l_1 = \frac{\left(d_{mi} l_1/\delta\right) U}{1 + C_e/C_{ij}^{E}}$$

here $\tilde{n} = \sum_{k=1}^{N} a_k 2^{k-1}$ − the decimal code.

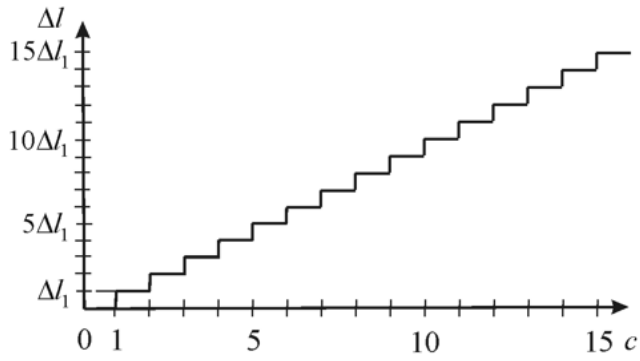

Figure 2 Adjustment characteristic of DAC electro elastic engine.

Therefore, for the DAC piezo engine from PZT ceramic at d_{31} = 0.2 nm/V, d_{33} = 0.4 nm/V and d_{15} = 0.5 nm/V, $l_1/\delta = 1$, $C_e = 0$, and U =20 V we have on Figure 2, therefore, the parameters for the DAC transverse, longitudinal and shift piezo engines Δl_1 = 4 nm, Δl_1 = 8 nm and Δl_1 = 10 nm with error 10%.

Let us consider the mechanical characteristic of the DAC longitudinal piezo engine.

Its maximum parameters of the mechanical characteristic of the DAC longitudinal piezo engine on Figure 3 are determined in the form

$$\Delta l_{\max} = d_{33} U\left(\sum_{k=1}^{N} a_k 2^{k-1}\right) = \Delta l_1\left(\sum_{k=1}^{N} a_k 2^{k-1}\right)$$

$$F_{\max} = d_{33} U\left(\sum_{k=1}^{N} a_k 2^{k-1}\right) C_{33}^{E}$$

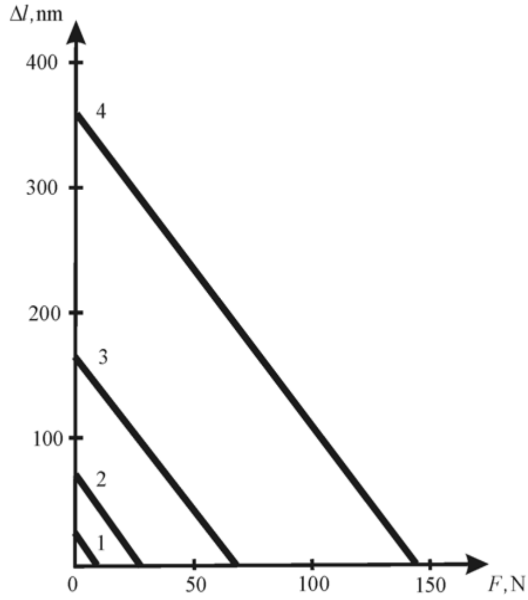

Figure 3 Mechanical characteristic of DAC longitudinal piezo engine.

here $C_{33}^{E} = S_0 \Big/ \left(s_{33}^{E} l\right)$ is the rigidity of the rigidity of the DAC longitudinal piezo engine.

For the DAC longitudinal piezo engine from PZT ceramic at d_{33} = 0.4 nm/V, $l_1/\delta = 1$, $C_{33}^{E} = 4\cdot 10^8$ N/m, and U = 60 V for 1) $a_1 = 1$, $a_2 = 0$, $a_3 = 0$, $a_4 = 0$; 2) $a_1 = 1$, $a_2 = 1$, $a_3 = 0$, $a_4 = 0$; 3) $a_1 = 1$, $a_2 = 1$, $a_3 = 1$, $a_4 = 0$; 4) $a_1 = 1$, $a_2 = 1$, $a_3 = 1$, $a_4 = 1$ the parameters of the DAC longitudinal piezo engine on Figure 3 are determined in the form 1) $\Delta l_{\max}$ = 24 nm, $F_{\max}$ = 9.6 N; 2) $\Delta l_{\max}$ = 72 nm, $F_{\max}$ = 28.8 N; 3) $\Delta l_{\max}$ = 168 nm, $F_{\max}$ = 67.2 N; 4) $\Delta l_{\max}$ = 360 nm, $F_{\max}$ = 144 N with error 10%.

Thus, the mechanical and regulation characteristics of the DAC electro elastic engine are found.

Discussion

Through the use of mathematical physics we have obtained the mechanical and regulation characteristics of the DAC electro elastic engine for nanomedicine. The problem of use the coded control and the DAC electro elastic engine are promising for nanomedicine and nanotechnology. The generalized mechanical and adjustment characteristics of DAC electro elastic engine are determined using the equations of the reverse piezo effect and the mechanical load. Additionally, we have obtained the mechanical and adjustment characteristics of the DAC transverse, longitudinal and shift piezo engines.

Conclusion

The DAC electro elastic engine is used for nanomedicine in Nano pumps, Nano manipulators, scanning microscopy, and adaptive optics. The characteristics of the DAC electro elastic engine are obtained by using method of mathematical physics. The parameters and the characteristics of the DAC transverse, longitudinal and shift piezo engines are determined.

In general the mechanical and regulation characteristics of the DAC electro elastic engine are found for nanomedicine and nanotechnology.

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Conflicts of interest

The author declares that there is no conflict of interest.

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