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Review Article

# Structural Scheme of Transverse Piezo Engine for Nano Medical and Clinical Research

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## Abstract

**Background/Aim:** With the availability of biosimilars, hospital formulary drug selection among biologics extends beyond clinical and safety considerations when comes to hospital resource management, to factors like human resource allocation and financial sustainability. However, research assessing the time and cost of labor, supplies, and waste disposal of biologics from the standpoint of hospitals remains limited. This study focuses on short-acting granulocyte-colony stimulating factor originators (Granocyte® and Neupogen®) and biosimilar (Nivestim®), comparing them based on mean total handling times per dose and total annual expenses.

**Materials and Methods**: Ten nurses from a Taiwanese cancer center were recruited; they each prepared three doses of each drug.

**Results:** Findings showed that the mean total handling times per dose of Granocyte® and Neupogen® were significantly higher than that of Nivestim®. Handling Nivestim® required the lowest total annual expense.

**Conclusion:** Nivestim® is an advantageous alternative to Granocyte® and Neupogen®, benefiting hospital resource management.

**Kew Words:** filgrastim; filgrastim biosimilar; granulocyte-colony stimulating factor; hospital resource management; lenograstim

## Introduction

For nano medical and clinical research, the transverse piezo engine is applied [1-15]. The transverse piezo engine is used in nano medical and clinical research, adaptive optics, scanning microscopy [4-29]. The structural scheme of the transverse piezo engine is obtained for nano medical and clinical research.

### Structural scheme

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

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

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

here $(D)$, $(d)$, $(T)$, $(\varepsilon^T)$, $(E)$, $(S)$, $(s^E)$, $(d)^t$ 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 $\Xi(x,s)$, $x$, $s$, $\gamma = s/c^E + \alpha$, $c^E$, $\alpha$ 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

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

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

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

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

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

here $M_1$, $M_2$ are the masses on its faces.

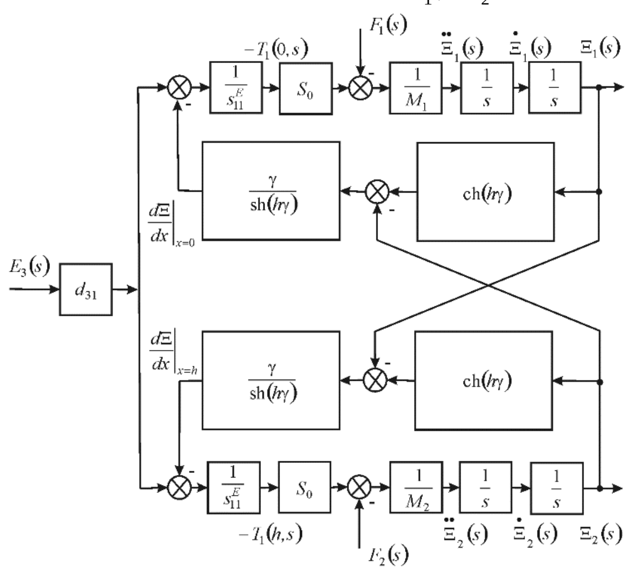


**Figure 1**. Structural scheme of transverse piezo engine for nano medical and clinical research.

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

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

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 $k_{U31} = d_{31}(h/\delta)/\left(1 + C_l/C_{11}^E\right)$, $T_t = \sqrt{M/\left(C_l + C_{11}^E\right)}$, $\omega_t = 1/T_t$, $\xi_t = \alpha l^2 C_{11}^E / \left(3c^E\sqrt{M\left(C_l + C_{11}^E\right)}\right)$ are the transverse transfer coefficient, the constant of time, the frequency of conjugate and the coefficient of attenuation.

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

The steady deformation of the transverse piezo 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, $h/\delta$ = 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 the transverse piezo engine are recorded

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

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

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

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

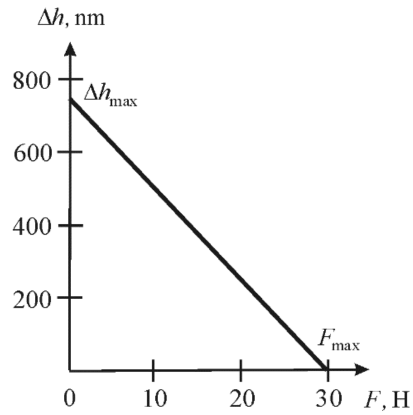


**Figure 2**. Mechanical characteristic of transverse piezo engine.

## Conclusions

The structural scheme of the transverse piezo engine is determined for nano medical and clinical research. The parameters of the transverse piezo engine are obtained. The transfer coefficient and function on the voltage are found. The mechanical characteristic of the transverse piezo engine is determined.

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