БЪЛГАРСКА АКАДЕМИЯ НА НАУКИТЕ • BULGARIAN ACADEMY OF SCIENCES

ПРОБЛЕМИ НА ТЕХНИЧЕСКАТА КИБЕРНЕТИКА И РОБОТИКАТА, **57**
PROBLEMS OF ENGINEERING CYBERNETICS AND ROBOTICS, **57**

София • 2006 • Sofia

Mechatronical Bioreactor Device with Two Parallel Axes of Rotation

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Introduction

The human body consist over 200 types of cells, which is build different type of organs like a skin, bones and muscles. More than organs are mix from different type of cells.

More over 70 years ago molecular biologist E. B. Wilson have writhed in his bock „The Cell in Development and Heredity" – "The key to the every biological problem in the end must be solved in the cell"

The cells are about 5 times less then smallest visible part and consists all types of molecules, which is needed one organism for his process of reproduction. This fact not allows the scientists to observe their structure, to uncover their molecular composition and to understand how function of their different type of components is. Methods "In Vivo" can't deliver the answers of these problems.

The cultivation of human cells out of the human body allowed the research of basic biological and physiological phenomena like of control of the normal live cycle and the most of his mechanisms.In the traditional research methods, the human cells are cultivated, with the help of containers, in which the cells are fixed in the bottom under gravitation force. The result is thin layer of cells, which was could "Monolayer" and this cells are not in condition to execute all functions of original organs. The cells aggregate in the human body are three-dimensional.

After repeatedly experiments were proved, that in conditions near of weightlessness in the Cosmos [1, 2, 3], the culture of cells grows up moor fast, the same time in 3D structures. The idea to simulate micro gravitation is very old and maybe was started from so could clinostats [4] – rotational containers. In the same principle are based and rotational bioreactors. [5, 6]. Micro gravitation is artificially, and effects at expense of balance of forces, which action is under the cells aggregates in the process of rotational transport.

In the same time is determine, that if the Resultant Force Vector is not equal of zero, but is realized periodically with fixed frequency variation of his directress, than the cells receiving this conditions like of micro gravitation. For example, stationers bioreactor devices is placed over the platform, which is making oscillating movements (Fig. 1), realized with the help of stoop mechanism. Under the experiments are bioreactors with two end three orthogonal axes of rotation [6] (Figs. 2 and 3).

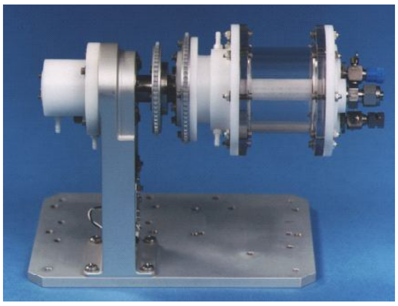

Fig. 1. Bioreactor device

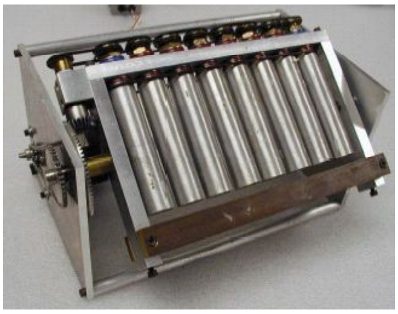

Fig. 2. Bioreactor two orthogonal axis of rotation

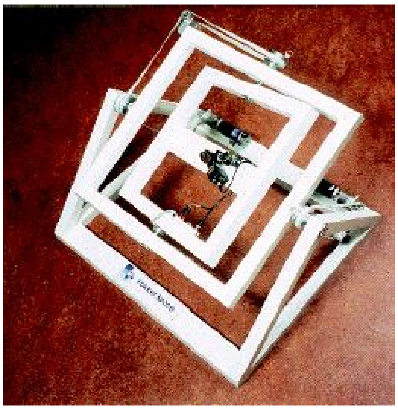

Fig. 3. Bioreactor three orthogonal axis of rotation

On Fig. 4 [3] is shown plan on mechatronical bioreactor device (MBD) with two parallel axes of rotation and image on bioreactor B type miniPERM. The one of axes coincide with the projection in point O_1, and the rotation in relation to O_2 is transmitting on the module of bioreactors.(BM) by means of the friction transmission between $2'$–2.The rotation axes 3 are free bearing and they to serve as two prop axes. The kinematics of the bioreactor device is researched from authors in the quotes literatures.

Fig. 4. Bioreactor type miniPerm

MBD with two parallel axes of rotation. (Fig. 5)

The kinematical parameters (functions of position, velocity and accelerations) were find [3] about a law of rotation of BM in combination with two laws of device B.

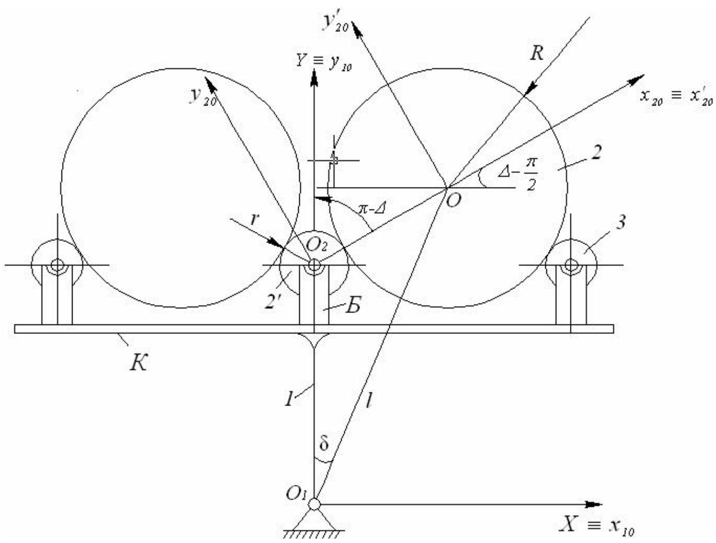

Fig. 5. Mechatronical bioreactor device with two parallel axes of rotation

Geometrical dependence

The equations for continuity transformations of the coordination systems are:

(1)
$$x_2 = x\cos\varphi_2 - y\sin\varphi_2,$$
$$y_2 = x\sin\varphi_2 + y\cos\varphi_2,$$

(2)
$$x_1 = x\cos\left(\Delta + \varphi_2 - \frac{\pi}{2}\right) - y\sin\left(\Delta + \varphi_2 - \frac{\pi}{2}\right),$$
$$y_1 = x\sin\left(\Delta + \varphi_2 - \frac{\pi}{2}\right) + y\cos\left(\Delta + \varphi_2 - \frac{\pi}{2}\right);$$

(3)
$$X' = x\cos\left(\Delta + \varphi_1 + \varphi_2 - \frac{\pi}{2}\right) - y\sin\left(\Delta + \varphi_1 + \varphi_2 - \frac{\pi}{2}\right),$$
$$Y' = x\sin\left(\Delta + \varphi_1 + \varphi_2 - \frac{\pi}{2}\right) + y\cos\left(\Delta + \varphi_1 + \varphi_2 - \frac{\pi}{2}\right);$$

(4)
$$X = l\cos\left(\frac{\pi}{2} - \delta + \varphi_1\right) + X',$$
$$Y = l\sin\left(\frac{\pi}{2} - \delta + \varphi_1\right) + Y'.$$

Kinematical dependence

The equations for velocity are

(5)
$$\dot{x}_2 = \dot{x}\cos\varphi_2 - x\dot{\varphi}_2\sin\varphi_2 - \dot{y}\sin\varphi_2 - y\dot{\varphi}_2\cos\varphi_2,$$
$$\dot{y}_2 = \dot{x}\sin\varphi_2 + x\dot{\varphi}_2\cos\varphi_2 + \dot{y}\cos\varphi_2 - y\dot{\varphi}_2\sin\varphi_2;$$

(6)
$$\dot{x}_1 = \dot{x}\cos\left(\Delta + \varphi_2 - \frac{\pi}{2}\right) - x\dot{\varphi}_2\sin\left(\Delta + \varphi_2 - \frac{\pi}{2}\right) -$$
$$- \dot{y}\sin\left(\Delta + \varphi_2 - \frac{\pi}{2}\right) - y\dot{\varphi}_2\cos\left(\Delta + \varphi_2 - \frac{\pi}{2}\right)$$

$$\dot{y}_1 = \dot{x}\sin\left(\Delta + \varphi_2 - \frac{\pi}{2}\right) + x\dot{\varphi}_2\cos\left(\Delta + \varphi_2 - \frac{\pi}{2}\right) +$$
$$+ \dot{y}\cos\left(\Delta + \varphi_2 - \frac{\pi}{2}\right) - y\dot{\varphi}_2\sin\left(\Delta + \varphi_2 - \frac{\pi}{2}\right);$$

$$\dot{X}' = \dot{x}\cos\left(\Delta + \varphi_1 + \varphi_2 - \frac{\pi}{2}\right) - x(\dot{\varphi}_1 + \dot{\varphi}_2)\sin\left(\Delta + \varphi_1 + \varphi_2 - \frac{\pi}{2}\right) -$$
$$- \dot{y}\sin\left(\Delta + \varphi_1 + \varphi_2 - \frac{\pi}{2}\right) - y(\dot{\varphi}_1 + \dot{\varphi}_2)\cos\left(\Delta + \varphi_1 + \varphi_2 - \frac{\pi}{2}\right),$$

(7)

$$\dot{Y}' = \dot{x}\sin\left(\Delta + \varphi_1 + \varphi_2 - \frac{\pi}{2}\right) + x(\dot{\varphi}_1 + \dot{\varphi}_2)\cos\left(\Delta + \varphi_1 + \varphi_2 - \frac{\pi}{2}\right) +$$
$$+ \dot{y}\cos\left(\Delta + \varphi_1 + \varphi_2 - \frac{\pi}{2}\right) - y(\dot{\varphi}_1 + \dot{\varphi}_2)\sin\left(\Delta + \varphi_1 + \varphi_2 - \frac{\pi}{2}\right);$$

(8)

$$\dot{X} = -l\dot{\varphi}_1 \sin\left(\frac{\pi}{2} - \delta + \varphi_1\right) + \dot{X}',$$
$$\dot{Y} = l\dot{\varphi}_1 \cos\left(\frac{\pi}{2} - \delta + \varphi_1\right) + \dot{Y}'.$$

Mechanism for (oscelirations) motions of the platform

We accept sliding block's mechanism for realization on osceliration motion of the platform (Fig. 6). The crank AB is driving from engine, which velocity can be constant, but it can be and manage with beforehand given law. Whit the sliding block O_1B is connection static with the platform P of the bioreactor.

The fluid and the cell's spheroids take part in two frame motions – the osciliration of the platform and rotation motion on BM.

Kinematical dependence for (oscelirations) motions

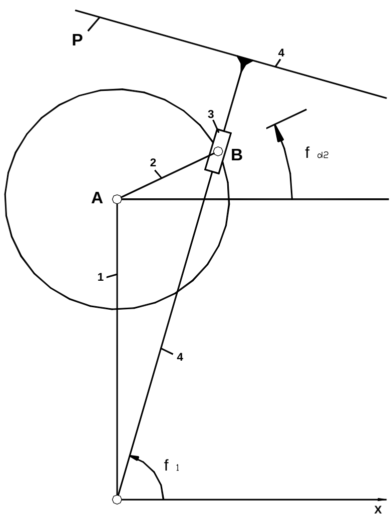

FIg. 6. Sliding block's mechanism

(9) $$\varphi_1 = \operatorname{arcctg}\left(\frac{l_2 \cos \varphi_{d2}}{l_1 + l_2 \sin \varphi_{d2}} \right),$$

(10) $$\dot{\varphi}_1 = l_2 \frac{l_2 + l_1 \sin \varphi_{d2}}{l_1^2 + 2 l_1 l_2 \sin \varphi_{d2} + l_2^2} \dot{\varphi}_{2d}^2,$$

(11) $$\ddot{\varphi}_1 = l_2 \frac{(l_1^2 - l_2^2) l_1 \cos \varphi_{d2}}{[l_1^2 + 2 l_1 l_2 \sin \varphi_{d2} + l_2^2]^2} \dot{\varphi}_{2d}^2.$$

With θ is denoted the angular of rotation of the crank AB. We will test the laws about the manage on velocity of BM.

(12) $$\dot{\varphi}_2 = A(1 + \sin \tilde{\varpi} t),$$

(13) $$\dot{\varphi} = -Ae^{-B \sin t} \sinh(\sin t + C) + D,$$

(14) $$\varpi = \pm A e^{-Bt^2} \sinh(C + t) + D,$$

(15) $$\dot{\varphi}_2 = iA \sin^2 \frac{\varpi t}{2},$$

(16) $$\varphi_2 = i \frac{A}{2} (\tilde{\varpi} t - \sin \tilde{\varpi} t),$$

(17) $$\ddot{\varphi}_2 = i \tilde{\varpi} \frac{A}{2} \sin \varpi t.$$

The functions (9), (10), (11) and (16), (17) are shown on Figs. 7 and 8.

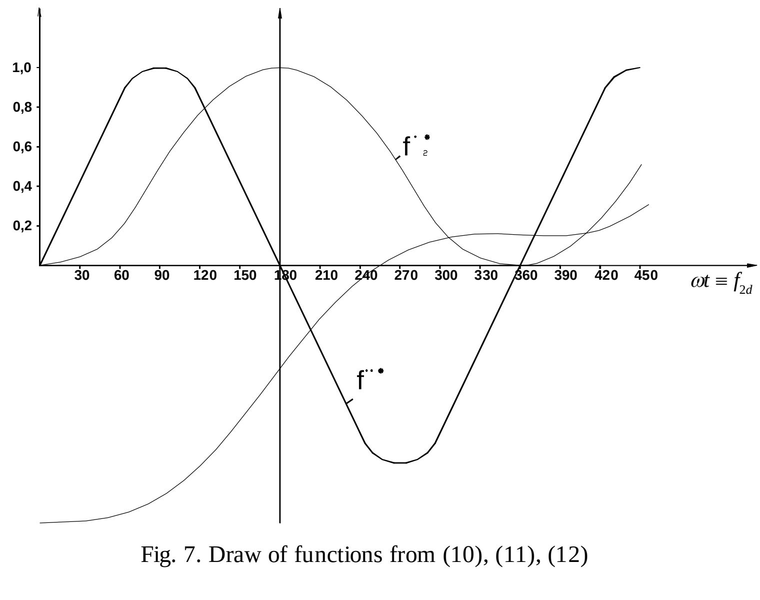

Fig. 7. Draw of functions from (10), (11), (12)

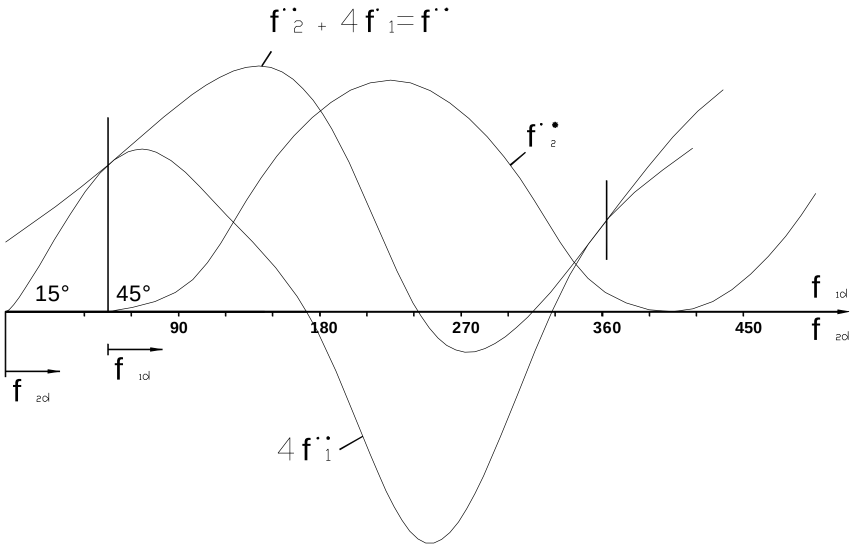

Fig. 8. Draw of functions from (16), (17), (18)

Analysis of the results and conclusions

The geometrical and static's analysis on the sliding block's mechanism show, that in third and fourth quadrant the gravity force is compensate partial from the centrifugal force. Thus the probability the cells to construct 3D structures grow up significantly, because the diminish on the gravitational field

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Мехатронный биореактор с двумя паралельными осями ротации

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(Р е з ю м е)

Представленны исследования автора относительно величины и ориентации результантных сил векторов в биореакторе класического типа с двумя паралельными осями ротации, без управления и с управлением скоростями ротации. Графичное изображение величины и ориентации силового вектора названо „полярная диаграмма”. Дальше автор будет публиковать свои исследования относительно биореакторах с двумя и тремя взаимно-перпендикулярными осями ротации.