Stability Suspension And Dynamics of The Rotor With Superconducting Magnetic Bearing

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Abstract

We investigate the dynamics of electromechanical systems of magnetic levitation based on the effect of magnetic potential well. Rotor with contactless magnetic bearings has six degrees of freedom. We have worked out mathematical models, obtained regions of rotor equilibrium stability, investigated the dynamics, offered methods of improving suspension stiffness. New opportunities for the creation of magnetic bearings are revealed by the superconductive effect of the uncontrolled stable levitation called "magnetic potential well" (MPW) [1].

1 Magnetic Potential Well effect

Known ideas which are the basis of a contactless magnetic bearing for a free heavy rotor include auto-regulation and diamagnetic repulsion. New opportunities for the creation of magnetic bearings are revealed by the super-conductive effect of the uncontrolled stable levitation called "magnetic potential well" (MPW). Theoretical grounding and experimental corroboration of the effect of "magnetic potential well" (1975, V. Kozoriz, the Institute of Cybernetics of the Academy of Sciences of Ukraine) may be considered the next stage of the development of the idea of magnetic levitation stability of the free heavy body in magnetic field. This effect makes possible the realization of the contact free suspension of a superconducting circuit in the magnetic field of another superconductor. The effect of "magnetic potential well" takes place in the case of a "warm"- superconducting magnet pair. In 1988 a group of scientists from Arkansas University, Center of Space Research in Huntsville (Alabama), laboratory of rocket - space company «Lokhid» and other scientific centres repeated the MPW effect for high - temperature superconductors. Theoretical basis of the MPW effect, the results of the experiments checking it, some trends of practical application are set forth in works [1]. Hightened interest to the effect of magnetic levitation on the basis of superconductivity is caused by various possibilities of practical use: instrument making, vehicles, electromechanics, power, engineering industry, etc. Use of a suspended elastic element in measuring devices helps to increase accuracy in measurements of mechanic actions, seismic oscillations, gravitational field of the Earth etc. Creation of new transportation systems is another actively developing trend. In a German design "Transrapid" suspension of a carriage over a ferromagnetic viaduct is carried out with the help of automated control current in electromagnet windings. Japanese design "RTRI" is based on an electrodynamic principle of creation of magnetic support. Above mentioned designs have not only advantages over the existing vehicles but also some shortcomings. The development of Ukrainian scientists which uses the effect of MPW [2,3] is considered the third conception of creation of new magnetic levitation transport system. President of National Academy HSST of the USA Florian A. Vichalek in his review at the International Scientific Conference "Future Transport Technology" (August 5-8, 1991, Portland, Oregon, USA) and Douglas J. Malevsky and Drenk J. Baker "Airvision incorporation" admitted this development to be a new conception of levitation which has a number of essential advantages over the known development of German and Japanese scientists [4,5,6].

Another important application of MPW effect is creation of devices with a rapidly rotating heavy rotor suspended in the magnetic field of the stator. The advantages of such devices with contactfree magnetic bearings are obvious. No mechanical friction, no heat loss, no wear - this is not a complete list of the merits of MPW - bearings. The possibilities of application of the systems with magnetic bearings are determined by the necessity in different branches: improving accuracy of gyroscope systems; creation of cryogenic devices (pumps, pistons) insuring better reliability of liquid hydrogen pumping and the like; creation generator with superconducting rotor and so on.

In works [1,7-10] the possibility of creation of a steady magnetic suspension on the basis of MPW effect is grounded, its advantages and disadvantages are shown. Quite a number of problems appear during technical implementation of the above mentioned devices. Here are some of them: choice of the kind of the suspension depends on design requirements (rotor with a horizontal or vertical axis of rotation; selection of geometric and electrical parameters providing stability of a free rotor suspension; system parameters optimization according to maximal suspension rated load capacity and its stiffness; taking into account limitation on critical field level, when superconductivity fails; research of stress arising in magnetic bearings and the like.

MPW effect consists in the fact that the force of magnetic attraction of two magnetic elements (or super conductive circuits or a pair of magnet – superconductive circuit) does not increase when the elements are drawn towards each other, as it could be expected, but decreases, and beginning at a certain distance there appears magnetic repulsion. Minimal potential energy of magnetic interaction as a function of distance corresponds to the described behaviour of magnetic force. If one of the elements is considered immovable (stator) and the other having six degrees of freedom (rotor), when a number of conditions are met, MPW mechanism appears at every possible move of the free element from a certain position which is the position of stable equilibrium. In this case we can speak of minimal energy as function of six coordinates. A number of papers by author [10-13] are devoted to the conditions of existence of MPW effect, to its research and application.

Here is an obvious explanation of existence of magnetic potential well on the basis of the property of full magnetic flux stability, its graphic presentation as lines of force and Amper's law of currents magnetic interactivity. Let full magnetic fluxes of circular superconducting turns equal the number of lines of force piercing the plane of the turn (Fig.1). Thus, the smaller turn $\psi_2 = 5 = \text{const}$, and for the larger $\psi_1 = 13 = \text{const}$. In position 3 the turns like magnets face each other with the like poles, that means that they attract each other. If the smaller turn is approached to the immovable turn, the number of immovable coil lines of force piercing the plane of the smaller turn will increase. Then the number of the proper lines of force of the smaller turn must decrease by such a value that full magnetic flux $\psi_2 = 5 = \text{const}$ remains unchanged. It means that current in the moving turn must decrease. In a certain position 2 all the five lines will be created by the field of the larger turn, consequently, the current in the smaller turn will equal zero. Magnetic force will also equal zero. During further approach of the turns there will be induced such a current in the smaller coil that increasing the number of lines of forces to more than five (in position 1 $\psi_2 = 7 - 2 = 5$) will be made up.

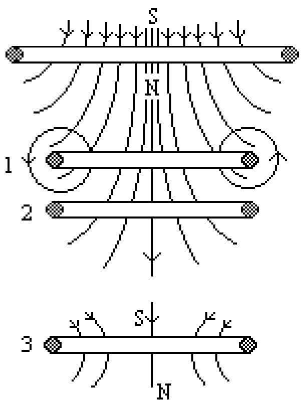

Fig.1

Evidently, the direction of current in position 1 will be opposite to the direction of current in position 3. The turns will repulse. Thus, a magnetic potential well has been obtained: when the turns are approaching magnetic attraction passing through zero changes to magnetic repulsion. In the described obvious explanation of MPW effect we did not take into account the fact that when the turns are approaching not only magnetic field of the larger turn affects the smaller turn but also the other way round. That is, in reality, to keep ψ_1 unchanged current changes in the larger turn also. So it can be concluded that an additional condition of occurrence of MPW effect is the requirement of noncoincidence of linked fluxes ψ_1 and ψ_2. Moreover, ψ_1 flux must sufficiently exceed flux ψ_2. The more the ratio of the fluxes, is the slower the current will decrease in the turn with the larger flux and the lesser its change will be by the moment of coming to zero in the turn with the smaller flux.

Realization of a superconducting suspension on the basis of MPW effect is possible in a wider field level range as compared to known ways of levitation. For example, a superconducting suspension based on Braunback's effect, preserves its ability to work in the fields of approximately 10^3E. MPW-support is possible in the fields with the level of 10^1-10^2E which considerably decreases electrodynamic friction in an elastic element, as dissipative phenomena in superconducting samples lessen with the decreasing of the field level. MPW - suspension can be realized in the field of 10^5E as well. Calculations show that pressure of 10^2 kg/cm^2 against a free elastic element can be reached in MPW - system (in Braunback's support - 50 g/cm^2, in hydrodynamic support - 12-15 kg/cm^2). Besides, MPW-effect has the opportunity of creating suspension version of various design. Current-carrying elements may have different geometric forms (ring, square, rectangle and others). Several free bodies can be suspended simultaneously. Another important peculiarity of MPW effect is the possibility of creation a steady suspension using a «warm»-«cold» magnet pair. Such an approach provided decreasing heat input into a cold area.

A number of works [1-15] are devoted to MPW effect existence conditions. Works [1,10] should be considered the most complete collection of results of the investigation of "magnetic potential well" appearance conditions.

2 Mathematical Model, Potential Energy of the System and Stability

Let us regard conservative electromechanical system with noncentral magnetic interaction of superconducting (SC) magnets in homogeneous gravitational field of Earth. The systems are considered electrically linear, without energy dissipation connected with reversal of magnetization, eddy currents, aerodynamic friction and other phenomena, appearing when a body moves in a magnetic field. MPW - systems are supposed to be situated in homogeneous environment (vacuum) with magnetic permeability equal to μ_0.

Major elements of electromechanical systems are superconducting current turns which can be modeled with a high level of accuracy by turns ideally conducting current. In a ring ideally conducting current the latter is spread uniformly across the section, while in a superconducting ring current is concentrated at a small depth of penetration λ (London depth of penetration has the order of $4 \div 6 \times 10^{-8}\,\mathrm{m}$). Difference between the system of ideal current loops and the system of superconducting current loops disappears when parameter $\tau = d/a$ tends to zero, which parameter is characteristic of the ratio of the section diameter d to the radius a of the circle loop, that is why the case with small τ (thin turns) is considered. Such an approach allows to use Neiman's formula for obtaining the mutual inductance of the system element. In superconducting magnets magnetic field takes effect on current conductors with the force which can cause deformation or sometimes damage of a superconductor or insulation often resulting in unpredictable deteriorating of magnet characteristic features (phenomenon of degradation). In designs of electromagnetic systems an opportunity of initiation of mechanic stress is stipulated, that is why special band devices are installed. In this connection it can be supposed that conductors under consideration are not liable to deformation.

Potential energy of the simplest system consisting of one pair of magnetically interacting superconducting circular turns is expressed by the following formula:

$$W = W_M + Gz\,,\; W_M = W^0 \left[1 + \frac{\left(L_{12} - L_{12}^0\right)^2}{L_{11}L_{22} - L_{12}^2} \right],\; G = mg\,, \tag{1}$$

where $L_{12} = L_{12}(q)$ is mutual inductance of the turns; L_{11}, L_{22} - are proper inductances of the turns; L_{12}^0 is mutual inductance calculated in the position of initial power supply; m is rotor mass; W^0 is initial energy in the position of initial power supply; q is the set of coordinates defining position and orientation of the rotor; z is a generalized coordinate characterizing the distance between the rotor and the stator along the vertical axis. The necessary conditions of rotor equilibrium are defined by the following system of equalities:

$$\frac{\partial W}{\partial q} = \frac{\partial W}{\partial L_{12}} \frac{\partial L_{12}}{\partial q} = 0\,. \tag{2}$$

Sufficient conditions of stability of equilibrium positions defined by the system of equations (2) are received due to the condition of positively defined quadratic form, into which potential energy (1) can be expanded according to generalized coordinates for their small increments. To obtain sufficient conditions of stability Sylvester criterion is used. As an example let us consider the stability area for a system consisting of two current circular loops. One SC-ring is rigidly fixed in a horizontal plane and the other has six degrees of freedom and levitates under the immovable one. The planes of the rings are parallel, and mass centers lie on the common vertical axis. The rings radii are supposed to be equal.

Stability area of such a system is shown in Fig.2. Value $\tilde{F} = a\,G/W^0$ is shown vertically on the plot, in which value a is a ring radius and z/a shown horizontally is a relative distance between ring centers along the vertical axis. The stability area is shaded. Curves 1-14 correspond to different variants of initial power supply. The point of intersection of the curve and the horizontal axis corresponds to relative distance of the initial power supply. Curves 1-14 are plotted according to (2) and define the character of force interaction when the rotor is removed from the stator along their common axis. Positive sections of the curves correspond to attraction and negative ones correspond to repulsion. Let us consider curve 3 as an example of force interaction of SC elements. If the rotor is approached to the stator from the position of initial power supply (the point of intersection of curve 3 with the axis) there appears a repulsive force. If the rotor is removed from the stator from the position of initial power supply (for example it sags under the action of gravity) there appears a force attracting the rotor to the stator. The attractive force increases till intersection with curve 16, then it decreases to zero. Stability according to all the generalized coordinates (one of the six coordinates is cyclic) is possible at the distances when curve 3 is enclosed between lines 15 and 16. Position of straight line 15 is defined by the value of pendulum motion (the distance between the center of the carrying ring of the rotor and mass center shifted along the axis of the rotor).

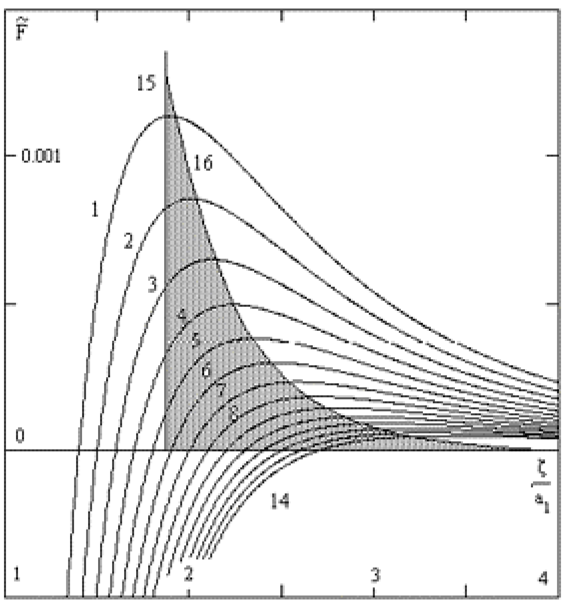

Fig.2 Stability area

3 Dynamics of Horizontal Rotor

The elements of the systems are SC-coils which are modeled by circular turns ideally conducting current. The system with a horizontal axis of rotation consists of a stator and a rotor (Fig.3).

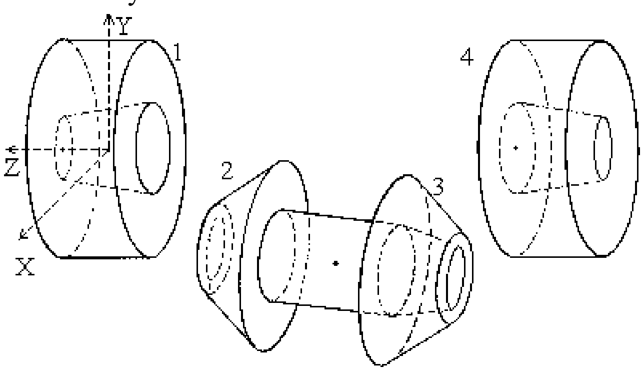

Fig.3 Horizontal rotor with magnetic bearings

Stator is a pair of immovable aligned super-conductive coils situated in such a way that their common axis is perpendicular to gravity direction. The main coordinate system is tied to one of the coils of the stator in such a way that axis Oz coincides with the axis of the stator, axis Oy is directed vertically upward and axis Ox is directed horizontally. Center O coincides with geometrical center of the stator coil. The other coil of the stator is situated in such a way that the coordinate along axis Oz of the center of the coil is negative. The rotor consists of three elements: two SC-coils connected with non-magnetic rod. The mass of the rotor is uniformly distributed, among the three elements. Center of mass of the rotor is situated in the center of the rod. Designs of the rotor and the stator are supposed to be unchanged.

The task consists in obtaining conditions of equilibrium stability of the rotor and investigating the dynamics of rotor oscillations near the position of equilibrium, and in obtaining the parameters ensuring the greatest lift and suspension stiffness.

Orientation of the rotor in relation to the stator is determined by Eulerian-Krylov angles, and position of the rotor mass centers is determined by Cartesian coordinates (Fig.3). Internal and mutual inductances of coils are calculated as the result of summing over all the turns of the coils according to the methods known in electrotechnics. Mutual inductance of a pair of thin circular turns is calculated by formula obtained from Neimann formula:

$$L_{ij} = \mu_0 \sqrt{a_i a_j} \cdot \tilde{L}_{ij}, \; \tilde{L}_{ij} = \frac{1}{2\pi} \int_a^b \frac{Mf}{A^{3/2}} d\lambda,$$

$$M = \left(\frac{2}{k} - k \right) K(k) - \frac{2}{k} E(k), \; a = a_i / a_j, \; k = 2\sqrt{(aA) \Big/ \left((a+A)^2 + H^2 \right)}$$

where $K(k), E(k)$ are complete elliptical integrals of modulus k; A, f, H are functions of the variables x, y, z (Cartesian coordinates of the mass center of a free body) and α, β, γ (are Eulerian- Krylov angles), a_i, a_j are circuits radii.

In a system with a horizontal axis of rotation two pairs of coils interact. Let us suppose that these pairs of coils have equal geometrical parameters. Expression for complete potential energy of the system is the following:

$$W = W_M - mgy, \qquad W_M^0 = \frac{1}{2}\left(L_{11} I_1^{02} + 2L_{12}^0 I_1^0 I_2^0 + L_{22} I_2^{02} \right)$$

$$W_M = W_M^0 \left[1 + \frac{\left(L_{12}^0 - L_{12} \right)^2}{L_{11}L_{22} - L_{12}^2} \right] + I_1^0 I_2^0 \frac{\left(L_{12}^0 - L_{12} \right) \cdot \left(L_{11}L_{22} - L_{12}^{02} \right)}{L_{11}L_{22} - L_{12}^2} +$$

$$+ W_M^0 \left[1 + \frac{\left(L_{12}^0 - L_{34} \right)^2}{L_{11}L_{22} - L_{34}^2} \right] + I_1^0 I_2^0 \frac{\left(L_{12}^0 - L_{34} \right) \cdot \left(L_{11}L_{22} - L_{12}^{02} \right)}{L_{11}L_{22} - L_{34}^2},$$

where I_1^0, I_2^0 are initial supply currents, W_M^0 is initial energy of the system, L_{12}^0,- mutual inductance calculated in the position of the initial supply of the system, L_{12}, L_{34} are mutual inductances of coils with correspondent numbers, $L_{11} = L_{44}, L_{22} = L_{33}$ are internal inductances of coils. In a system with a horizontal axis gravity acts in the direction perpendicular to the axis of the rotor, i.e. along axis Oy.

The position of the rotor is defined by five generalized and one ignorable coordinates. Free rotor is situated in the position of equilibrium if generalized forces on the coordinates in this position become zero. The position of equilibrium will be defined by the following set of coordinates:

$$q_r = \{ x_r, y_r, z_r, \alpha_r, \beta_r, \gamma_r \}.$$

The position of the initial supply will be defined by the following set:

$$q_0 = \{ x_0, y_0, z_0, \alpha_0, \beta_0, \gamma_0 \}.$$

Let us introduce the following designations:

$$b_q = \frac{\partial W_M^r}{\partial q}, C_{qp} = \frac{\partial^2 W_M^r}{\partial q \partial p}.$$

For the rotor with horizontal axis of rotation in the position of equilibrium with the following coordinates:

$$x = 0, y = y_r, z = z_r, \alpha = 0, \beta = 0$$

the following equalities: $b_x = b_z = b_\alpha = b_\beta = 0$, $b_y = mg$ are true. Near the position of equilibrium potential energy of magnetic interaction of the system can be expanded into a series in terms of coordinates:

$$W_M = W_M^r + b_y(y - y_r) + \frac{1}{2}C_{xx}x^2 +$$
$$+\frac{1}{2}C_{yy}(y - y_r)^2 + \frac{1}{2}C_{\alpha\alpha}\alpha^2 + \frac{1}{2}C_{\beta\beta}\beta^2 + +\frac{1}{2}C_{zz}(z - z_r)^2 + C_{z\alpha}(z - z_r)\alpha .$$

Sufficient conditions of stability can be obtained under the condition of positive definability of quadratic form of expansion of the potential energy into a series (Sylvester criterion). Force and moment system for the rotor with a horizontal axis of rotation, taking into account the necessary equilibrium conditions, will assume the following form:

$$F_x = -\left(C_{xx}x + C_{x\beta}\beta\right), F_y = -\left(C_{yy}y + C_{y\alpha}\alpha\right),$$
$$F_z = -C_{zz}(z - z_r), M_x = -\left(C_{y\alpha}y + C_{\alpha\alpha}\alpha\right)$$
$$M_y = -\left(C_{x\beta}x + C_{\beta\beta}\beta\right), M_z = 0 .$$

The equations of rotor motion are obtained on the basis of Lagrangian equation for a conservative system [1]:

$$\frac{d}{dt}\left(\frac{\partial L}{\partial \dot{q}_i}\right) = \frac{\partial L}{\partial q_i}, \; L = T - W, i = 1, \ldots 6,$$

where L is Lagrange function, T is system kinetic energy, W is potential energy, q_i are generalized coordinates, $\dot{q}_i$ - are generalized speeds.

$$m\ddot{x} = F_x, \; m\ddot{y} = F_y - mg, m\ddot{z} = F_z$$
$$A\dot{p} + (C - B)qr = M_x, B\dot{q} + (A - C)pr = M_y,$$
$$C\dot{r} + (B - A)pq = M_z, \; r = \dot{\alpha}\beta + \dot{\gamma},$$
$$p = \dot{\alpha}\cos\gamma + \dot{\beta}\sin\gamma, \; q = -\dot{\alpha}\sin\gamma + \dot{\beta}\cos\gamma,$$

where A, B, C are the main moments of inertia.

Conducting numerical experiments on modeling rotor dynamics in the magnetic field of the stator we solved the following problems:

- the impact of initial deviations from the position of stable equilibrium of mass center and deviations from the position of rotor and stator alignment upon the nature, amplitude, frequency of rotor oscillations;
- dependence of the nature of rotor oscillations on geometric parameters of the system and conditions of initial current supply;
- investigation of stiffness and stability of magnetic suspension of the rotor moments of forces speeds.

During modeling different numerical methods were used. For example, calculating mutual inductances we used Romberg method to evaluate certain integrals, we carried out numerical differentiation applying Ridder method, complete elliptic integrals were calculated by means of Landen decreasing transformation. We used Runge-Kutt method for numerical solution of sets of differential equations.

4 Results of Modeling Dynamics

Numerical modeling is fulfilled for a large number of systems of magnetic levitation with different geometric, electrical parameters and initial conditions. We show here one of the models. Coils with square section, equal for the stator and the rotor, are regarded. Average diameter of the coils is $0,12$ *m*, the width and the height of the coils section is $0,02$ *m*, the number of turns in the coils is 400. The initial current in the coils of the stator is 100 *A*. Half distance between the rotor coils centers is $0,15$ *m*, half distance between the stator coils centers is $0,18$ *m*. The initial current supply is carried out in the position of the rotor and stator alignment. In this case, when the rotor moves down by the action of gravity, magnetic force reaches the biggest values compared to other variants of initial supply. The position of initial supply of the rotor is defined by the following rotor coordinates

$$z_0 = -0,18\,m, x_0 = y_0 = \alpha_0 = \beta_0 = \gamma_0 = 0\,.$$

The position of equilibrium according to the necessary stability conditions is defined by the following equalities:

$$z_r = -0,18\,m, y_r = -0,01\,, x_r = \alpha_r = \beta_r = \gamma_r = 0\,.$$

In the position of equilibrium magnetic force directed upward and equal to the mass of the rotor *23,6771 N* acts on the rotor. In the position of initial supply initial mutual inductance of the pair of coils of the rotor and the stator is equal to $L_{12}^0 = 0,0108\,H$, initial energy of the system is $W_M^0 = 120,7523$ *J*. The rotor oscillates due to the initial deviations from the position of equilibrium. The initial position of the rotor is defined by the following coordinates of the rotor mass center $x = 0,01\,m, y = 0,0\,m$, $z = -0,185\,m$, and angular deviations of $\alpha = \beta = 0,017\,, \gamma = 0$ *(rad)*.

Numerical modeling shows that the system with the mentioned parameters and in the said positions of equilibrium is stable. Fig. 4-7 show the results of the rotor oscillations modeling subject to the restriction that the initial speeds equal zero. Horizontal axes of all the graphs show the time t in seconds, from the moment of beginning of the oscillations. In Fig.4 there are graphs of oscillations of the rotor mass center $x, y, z\,(\mathrm{m})$, in Fig.5 there are graphs of angular oscillations $Rx, Ry, Rz\,(\mathrm{rad})$ of the rotor about axes Ox, Oy, Oz, accordingly. In Fig.6 there are graphs of linear speeds of mass center movement $Vx, Vy, Vz\,(\mathrm{m/s})$ along the correspondent axes, in Fig.7 there are graphs of angular speeds of rotor rotation $Wx, Wy, Wz\,(\mathrm{rad/s})$ about the axes.

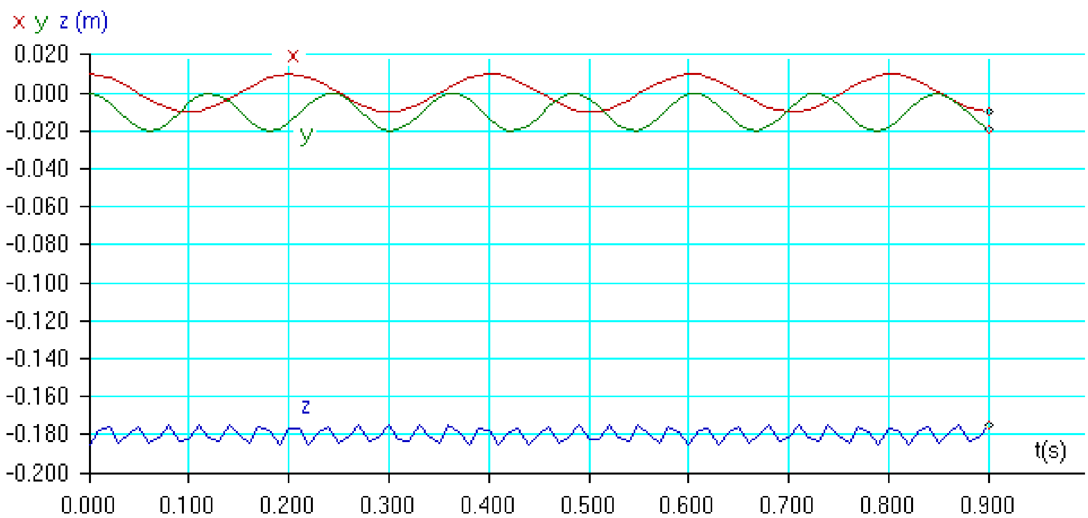

Fig. 4. Oscillations of rotor mass center.

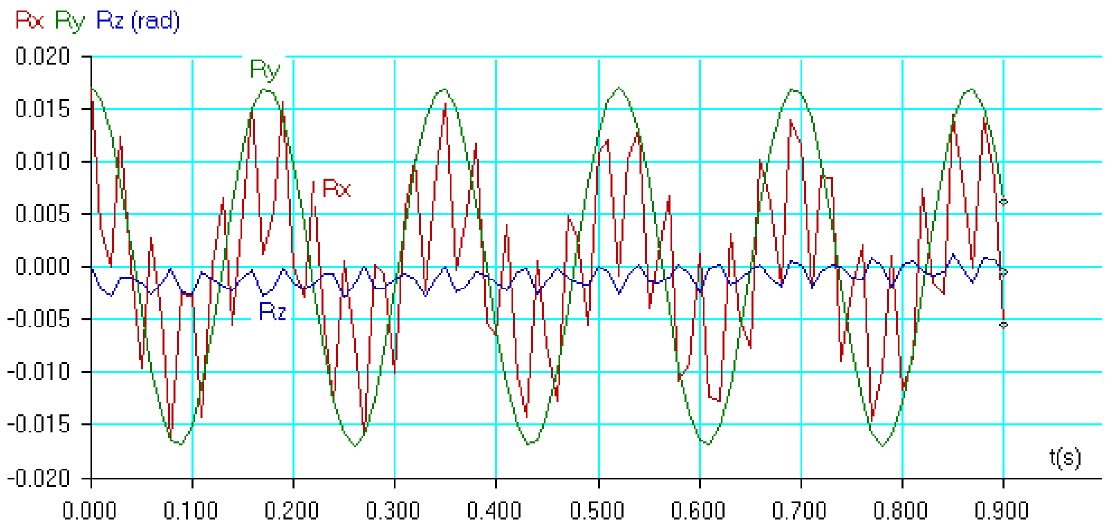

Fig. 5. Rotor angular oscillations.

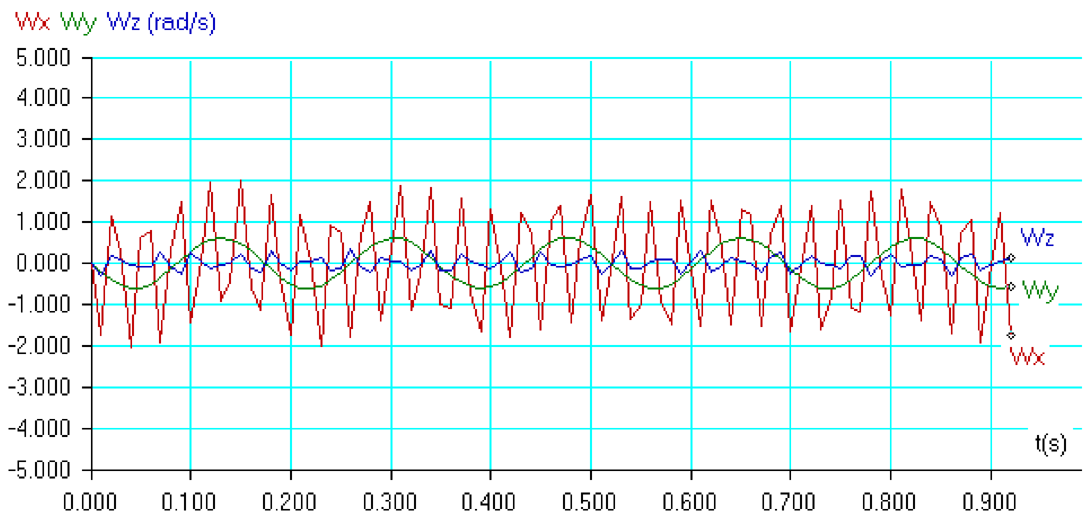

Fig. 6. Linear speeds of rotor mass center.

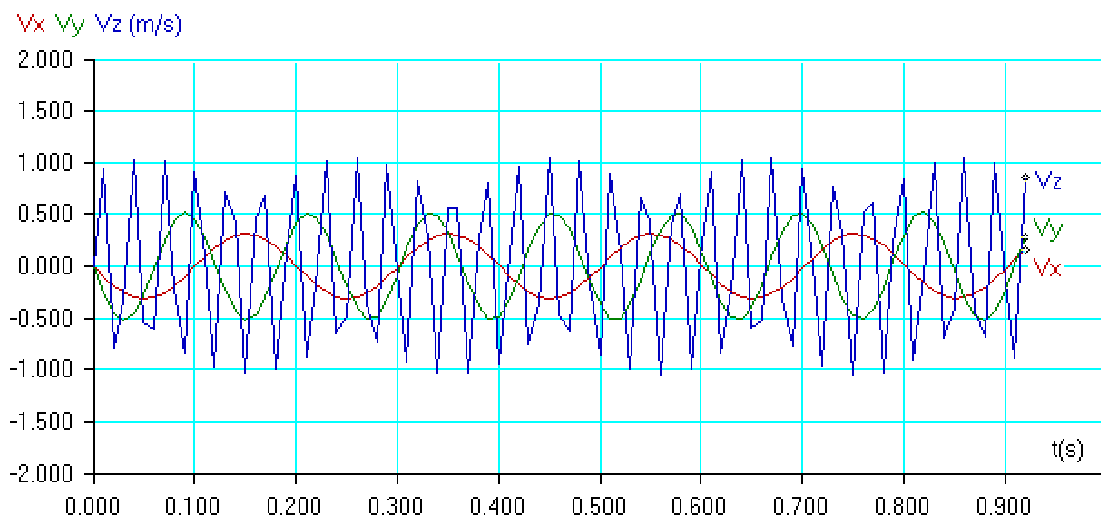

Fig. 7. Angular speeds of rotor rotation about axes.

Conducted investigation shows dependence of angular oscillations on initial shifts of the mass center. Maximal angular deviations from the horizontal axis do not exceed the value of initial deviations of the rotor. Rotor oscillations about axes Ox and Oy differ, as the system, position of equilibrium and force action are not symmetric about said axes. Oscillations about axis Oy (rotation in horizontal plane) are very uniform and even in comparison with oscillations about axis Ox (rotation in vertical plane). Let us also mention that twisting of the rotor itself is accompanied with additional periodical rotations.

As a result of fulfilled modeling of stability and oscillations dynamics and rotor rotation near the position of equilibrium we got exhaustive information about the attitude of the rotor to the stator (or immovable system of coordinates), which helped to create visual images of rotor dynamics. Modern computer graphics enabled observation of rotor oscillation and rotation from any view point. Such visualization significantly simplified the process of modeling and interpreting of the obtained results (fig.8).

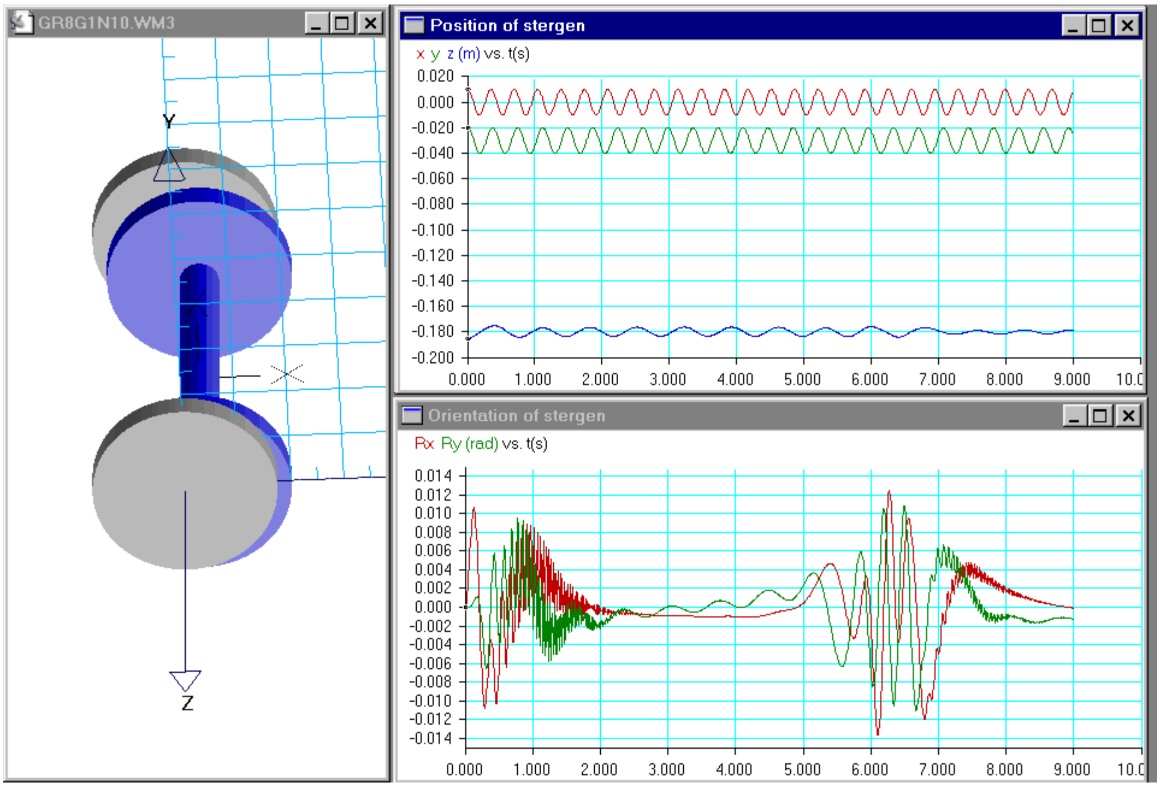

Fig. 8. Desktop of the numerical experiment with horizontal rotor.

All the experimental data were stored, and in the future rotor dynamics could be reproduced without repeated computations. More than that, video files in *.avi format were created on the basis of the obtained data and the results of modeling can be viewed now at any modern computer without additional installation of special software requiring significant computer resource and installation time. It is possible to investigate dynamics of various systems of magnetic levitation using the developed method of modeling.

The developed software enables us to solve a whole complex of dynamics problems. Let us enumerate some of them. Dependence of oscillations pattern on the initial deviations of the rotor from the position of equilibrium was investigated. Dependences of amplitude and frequency of oscillations on geometrical and electrical system parameters, initial deviations, pendulum motion were determined. Speeds and moments, forces characteristics were investigated.

Fig.9-12 show some other model types for which dynamics was studied.

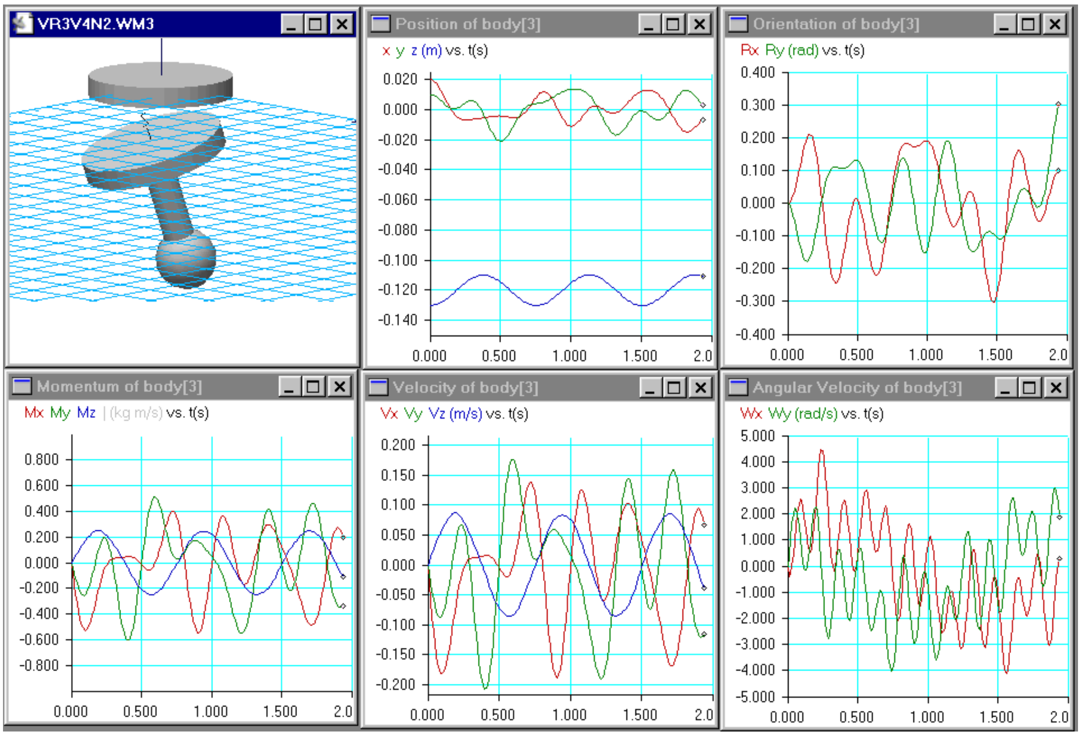

Fig.9 Desktop of the numerical experiment with vertical rotor.

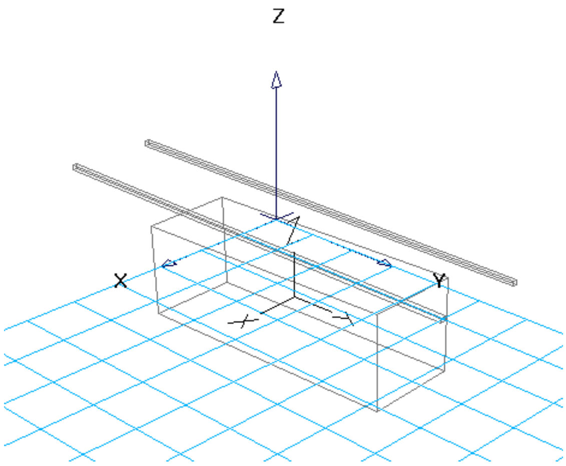

Fig.10 Model of MPW-vehicle.

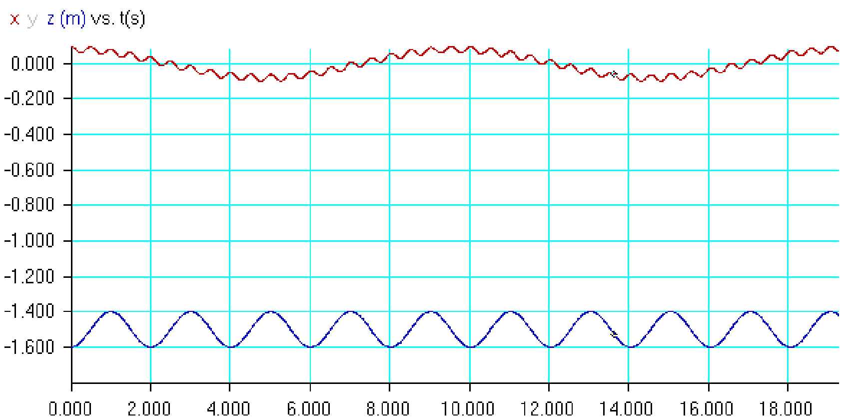

Fig.11 Oscillations of vehicle's mass center.

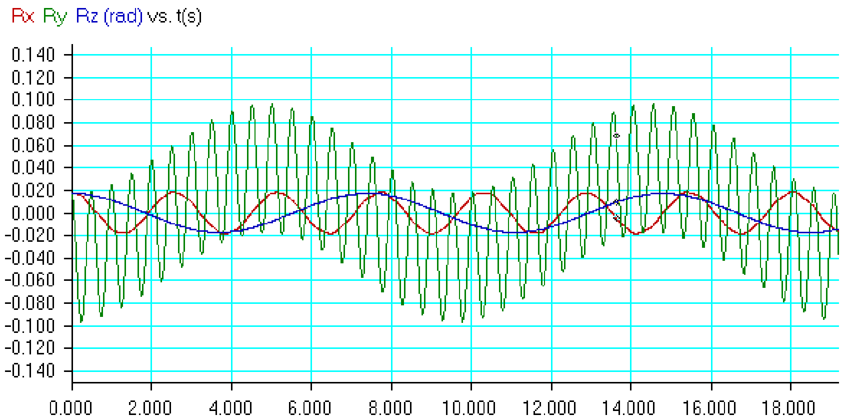

Fig.12 Vehicle angular oscillations.

5 Generalization and Other Results

The author has been working at creation of a rotor in superconducting magnetic bearings since 1985. We have developed models, have investigated stability and dynamics of the rotor with vertical and horizontal axes of rotation. We have considered different design variants using additional stabilizing and screening elements. We have obtained optimal parameters geometry of the stator and rotor [14,15], have found methods of creation of rigid suspension. We have investigated the dynamics of oscillations of revolving rotor. We have carried out about 300 numerical experiments on dynamics modeling.We have worked out the software for computer modeling the rotor dynamics. Developed models and software can be applied to modeling of dynamics of linear movement of a freely levitating body (maglev transport) and combined systems with linear movement and simultaneous rotation in different planes. Carried out experiments confirmed the results of modeling and realization possibility for rigid levitation of a free rotor having big mass.

6 ACKNOWLEDGMENT

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