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Information Technology of Process Modeling in the Multiparameter Systems

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***Abstract*— Information graphics technologies of designing models of the processes of multiparameter technical systems are argued and developed in order to increase the effectiveness of determining the influence of many operating parameters on their dynamics. The requirements for model designs are formulated on the basis of the formed numbers of different measurements of multidimensional spaces. Its implementation is proposed by a complex combination of the mathematical description of the parameters interconnection and the use of rational geometry. The features of the implementation of models are shown with the number of possible assumptions reduced.**

Keywords*— *information technology, modeling, multi-parameter system, processes, applied geometry

I. Introduction

Open systems that surround a person and part of which it is, are multiparameter. Their research, the discovery of useful features and the creation of more perfect directed intellectual activity of a scientist. The isolation of the characteristic features of the system leads to the identification of its significant parameters by accepting one or another number of assumptions. As the historical development of information technology neglected many factors of influence on the behavior of the system was reduced to the adoption of a minimum number of significant parameters that distinguish the studied system among others. In the process of creating and designing target models, it is important to take into consideration the ways in which the parameters of individual units of the studied systems are presented, for example, using clearly defined or fuzzy sets [1]. Construction of models of systems with the ability to study not only static but also dynamic characteristics requires the involvement of both classical and new methods [4].

This approach made it possible to create almost identical models for different physical entities and apply similar research methods to them, in particular, mechanical [12, 6] or mechatronic systems [11]. For example, the system of two differential equations of the first order with defining and constant parameters a, A, b, B, R, c, D is a basic mathematical model of many multi-parameter systems of diverse purposes, which, using a finite number of assumptions, are reduced to two-parameter systems. To them, as an example of IT technology in improving the quality of educational processes in the training of rescue workers [3], widely known biological systems, the operating elements of which are related to the model Lotka-Volterra, fire and technical systems, which, by a number of assumptions, are reduced to dual systems [4], direct or alternating current motors when powered from an electric network of infinite power [5] and others. Such models corresponded or sometimes correspond to the operational requirements within the limits of acceptable for engineering calculations of accuracy.

$$\frac{dy}{dt} = \frac{1}{a}(A - Ry - cx); \quad \frac{dx}{dt} = \frac{1}{b}(By - D) \tag{1}$$

The growth of requirements to systems, primarily to the technical, the maintenance of the technological requirements for the accuracy of the parameters prompts the development of modern methods and models, research, and therefore, on the contrary, reducing the number of assumptions, and as a consequence, requires the development and use of new information technology as an environment for the implementation of modern models, methods, algorithms for calculating the values of parameters of multiparameter objects, systems or processes. For example, research of the dynamics of a mechanism with a DC motor is possible based on a mathematical model using (1), which reproduces processes with sufficient accuracy. However, the higher harmonics of the power supply system of the thyristor converter significantly affect the quality of communication. Research of such influences requires the development and use of other specialized models.

In the scientific research [14], theoretically based propositions concerning the modeling and development of certain types of equipment with the use of artificial neural networks are proposed.

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The proposed approach to the scientific and practical process of model development is based on the fact that a wide class of systems reflects its behavior in universal models, which often differ in system variables and parameters [7].

The development of models in the classical version occurs sequentially from physical representations to the detection of the method of representing the interconnections of significant parameters with a rational number of assumptions. Due to the change of the philosophy of information technology, the transition to computerized means of scientific research, the development of the research process takes place due to the complexity of models taking into account sufficient for engineering calculations of the *number* of assumptions regulated by the capabilities of the computer, provided that all the relationships of parameters that are submitted mathematical or geometric means, equal regardless of their importance [14,15].

II. Scientific and Applied Principles of Constructing Models

The process of accumulation of human knowledge is continuous and inexhaustible. One of the means of cognition is simulation. The process of modeling in science is carried out for a thorough study of the properties of the object, the identification of the laws of the mutual influence of the connections of its parameters and the impact on them to optimize the functioning and establishment of useful properties.

In modeling, numerical values of parameters, are presented by graphic dependencies [16] which are used in the analysis of the system [17, 18].

The simulation process consists of two active elements, a simulation object and, in fact, its model, which in essence represents a dual system. Formation of an object model can be given, in particular, as follows (Fig. 1).

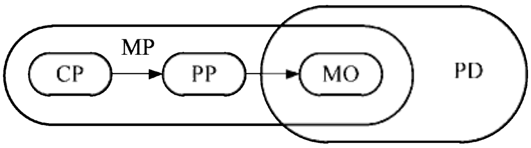


Fig. 1. The diagram of process for the development model of object MO

The process of constructing an object model begins because of the need to obtain additional knowledge about the object, based on the infinite fluidity of knowledge, which can be given by an infinite-dimensional linear vector space, mutually perpendicular orcs of which are the constituent parts of general knowledge. Such a space as the central in the process of modeling the CP space, interacting with the scope of the parameters of the object PP, forms a modeling space MP. Models of objects MO, configured to conduct research on the interconnection of their parameters, are represented by real numbers. Consequently, by immersing the modeling space MP in the field of real numbers PD, we obtain a model of the object of the study of MO as a common object of the modeling space MP and the field of real numbers PD. The model of the object of the MO is realized mainly in the multidimensional Euclidean space, the dimensionality of which as a derivative of the dimensionality of the central space CP is determined by the number of independent essential parameters of the investigated object.

In the presence of a positively directed axis, for the simulation of the flow of processes in time, space half-space is used as a space of multiparameter state with the parameters of the technical system (Fig. 2 a, c). Projection of the state space in a direction parallel to its axis, we obtain a phase space (Fig. 2 d) or a phase space with two and interconnected differential equations of essential parameters (Fig. 2 b).

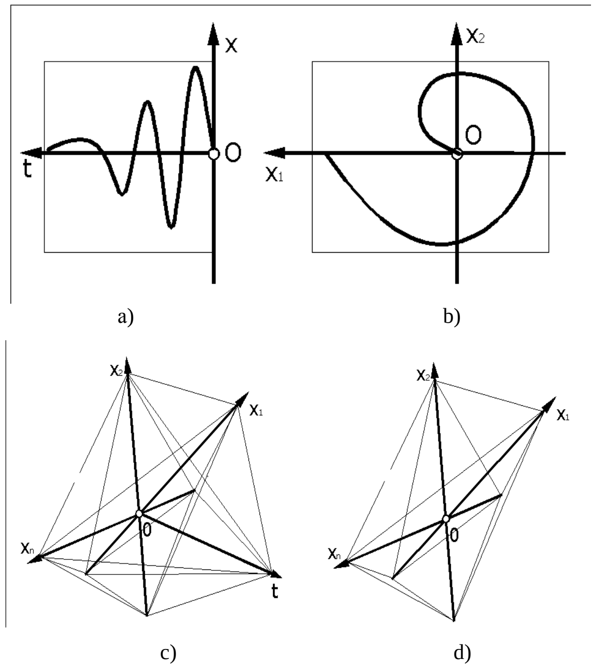


Fig. 2. Spaces of state and phase spaces of multiparameter technical systems

The integral curves (Fig. 2a) and the phase trajectories (Fig. 2b) are presented in the two-dimensional coordinate planes of the multidimensional space of the state of the technical system with measurements of the variables, for example, the time, current and frequency dependencies of the electric motor from time (Fig. 3) .

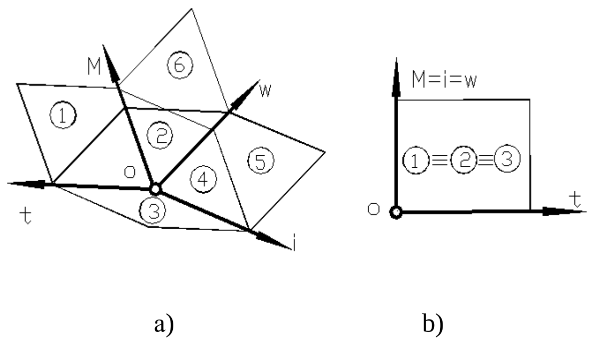


Fig. 3. Geometric model and complex drawing for dependencies of engine parameters

The rotation of the coordinate planes relative to the coordinate axes gives the Cartesian coordinate system (Fig. 3b) with the combined planes of projections as a complex drawing of the spatial geometric model of the dependencies of the engine parameters.

The overlap of geometric images in the combined planes of projections can be avoided using the proposed integrated drawings. For a four-dimensional Euclidean space, we map all the fields in two-dimensional coordinate planes (Fig. 4).

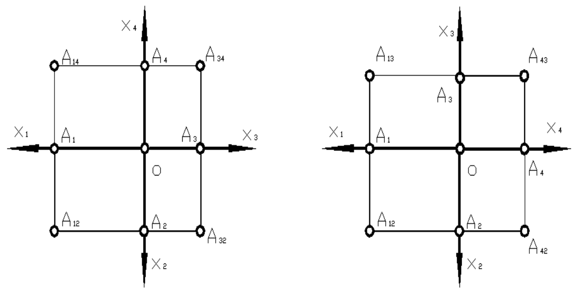


Fig. 4. Comprehensive drawing of a four-dimensional Euclidean space

This drawing, provided the smallest number of coordinate two-dimensional planes, has the form (Figs. 5a, b), with a generalization of it on three-dimensional coordinate planes (Fig. 5c, d).

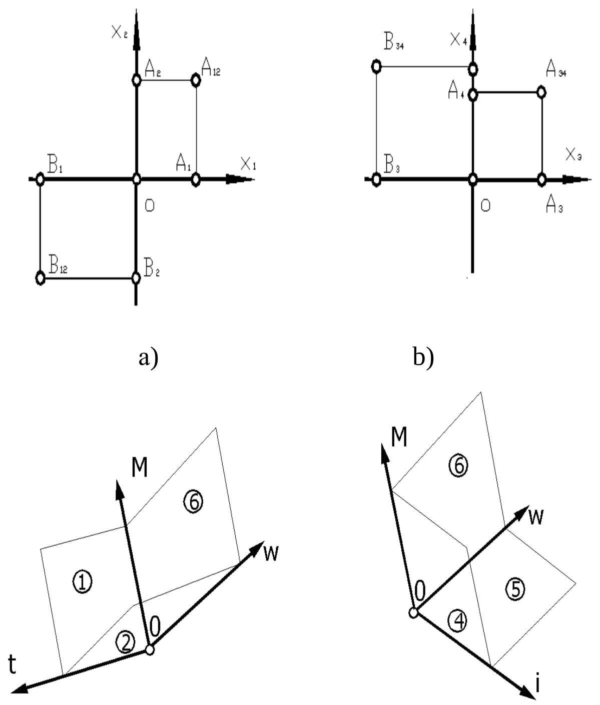


Fig. 5. Variants of complex drawings for computer visualization

The integral curves of the process of changing the time of two parameters are given by the three-space line of the Euclidean three-dimensional space [8,9]. To form a multi-spatial space line, it is quite sufficient that the change of each of the parameters reflected by the integral curve in the corresponding coordinate plane of the multidimensional state space. Each integral curve represents the direction of a multidimensional cylinder, the intersection of which forms the geometric multidimensional space. For its unambiguous definition it is necessary to have a minimal, but sufficient number of integral curves in coordinate planes, which determines the completeness of representation of the geometric image. Two integral curves in two coordinate planes of a three-dimensional space determine the position of a three-spatial integral curve: the curves form guides of two-dimensional cylinders, whose intersection is determined by a one-dimensional multidimensional, linear curve, three-dimensional space. Two of the six coordinate planes of the four-dimensional space pair the links of four parameters, for example, and and. Such connections in the form of plane curves determine the position of guides of three-dimensional cylinders whose intersections in the four-dimensional Euclidean space determine the position of the two-dimensional multidimensional. In addition, there is a change in time only for the parameter z. The minimum number of d multi-species, which determines the completeness of the mapping curves of the dimension of the transition multiparameter process, determine, drawing dependence [10]:

$$\eta = \sum_{i=1}^{d} m_i - n(d-1), \tag{2}$$

For the same measurements of multidimensional cylinders with guides with integral curves, their number is determined from (3):

$$d = \frac{n-1}{n-m} \tag{3}$$

In three-dimensional space the number of two-dimensional cylinders of measurements, is. For a four-dimensional space of state, when, we have.

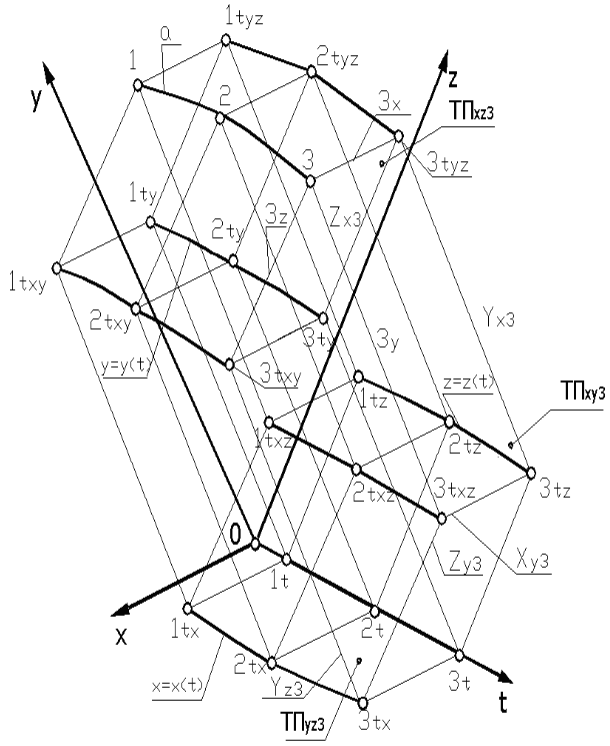


Fig. 6. Formation of the integral curve a in the space of the Oxyzt state

We set the completeness of the task of the integral curve of the four-dimensional space Oxyzt on the basis of (3). We will accept three integral curves as guides of three-dimensional cylinders with generating two-dimensional planes (Fig. 6). The interconnection of three-dimensional cylinders forms a curve as a one-dimensional four-spatial manifold of this space. Each point of the curve, for example, 3 is formed by the cross section of the corresponding geometric images.

3D dimensional plane $3_t 3_{tx} 3_{tz} 3_{ty}$ $m_{ГП}$ =3 with the foll 3_t on the axis $0t$ crosses each of three three-dimensional cylinders of dimensionality mc = 3 in a plane $T\prod_i$ dimensionality $r_n = m_c + m_{ГП} - n = 2$. The dimension of the geometric images r_t of the intersection of the hyperplane and each of the guides $x = x(t), y = y(t), z = z(t)$ $r_t = m_n + m_{ГП} - n = 0$

where $m_n = 1$ is the dimension of the guide of the three-dimensional cylinder. These geometric images are given points $3_{tx}, 3_{tz}, 3_{ty}$. The planes $ТП_{yz3}$ i $ТП_{xy3}$, $ТП_{xz3}$ i $ТП_{xy3}$, $ТП_{xz3}$ i $ТП_{xz3}$ intersect in points $3_{txz}, 3_{tyz}$, and 3_{txy} the set of which defines the position of the intersection of the two-dimensional and three-dimensional hyperplanes. The point 3_{txz} determines the position of the 3_y intersection of the two-dimensional plane $ТП_{yz3}$ and the three-dimensional plane $3_t 3_{tz} ТП_{xy3}$ The point 3_{txy} determines the position of the line 3_z of intersection of the two-dimensional plane $ТП_{yz3}$ and $3_t 3_{ty} ТП_{xz3}$ the point 3_{tyz} determines the position of the intersection 3_x of the two-dimensional plane $ТП_{xy3}$ and the three-dimensional hyperplane $3_t 3_{ty} ТП_{yz3}$. Direct $3_x, 3_y$ and 3_z intersect at point 3, the set of which forms the curve α of the four-dimensional space of the Oxyzt state of the technical system, and substantiates the assertion about the completeness of representation of the integral curves of multidimensional phase and space of the state of the technical systems. Trajectories of phase spaces are obtained by projection of integral curves of state space in the direction parallel to the axis *Ot* of this space, which describe the transition process in a multiparameter system by differential equations of the first order

$$\frac{dx_i}{dt} = f_i(x_1, x_2, ..., x_j, ..., x_{n,} t). \quad (4)$$

The integral curve, for example $x_1 = x_1(\mathrm{t})$, is a directing line of the cylinder with generator $n-1$ - dimensional subspaces, which are parallel to $n-1$ - dimensional coordinate subspace $Ox_2 x_3 ... x_i ... x_n$. The dimension of each cylinder is $k_i = 1 + (n-1) = n$.

Dimensionality of r_{k12} section of two arbitrary cylinders with dimension $k_1 = k_2 = n$ $n+1$ - dimensional state space $Ox_1 x_2 x_3 ... x_i ... x_n t$ is $r_{k12} = k_1 + k_2 - (n+1) = n + n - n - 1 = n - 1$, and its section using the third cylinder with dimensionality $k_3 = n$ forms multi-species with dimensionality $r_{k3} = r_{k12} + k_3 - (n+1) = n - 2$. The dimensionality of the cross-section $n-1$ - dimensional surface by the next multidimensional cylinder decreases by one.

III. IT-IMPLEMENTATION OF GEOMETRIC MODELING OF PROCESSES

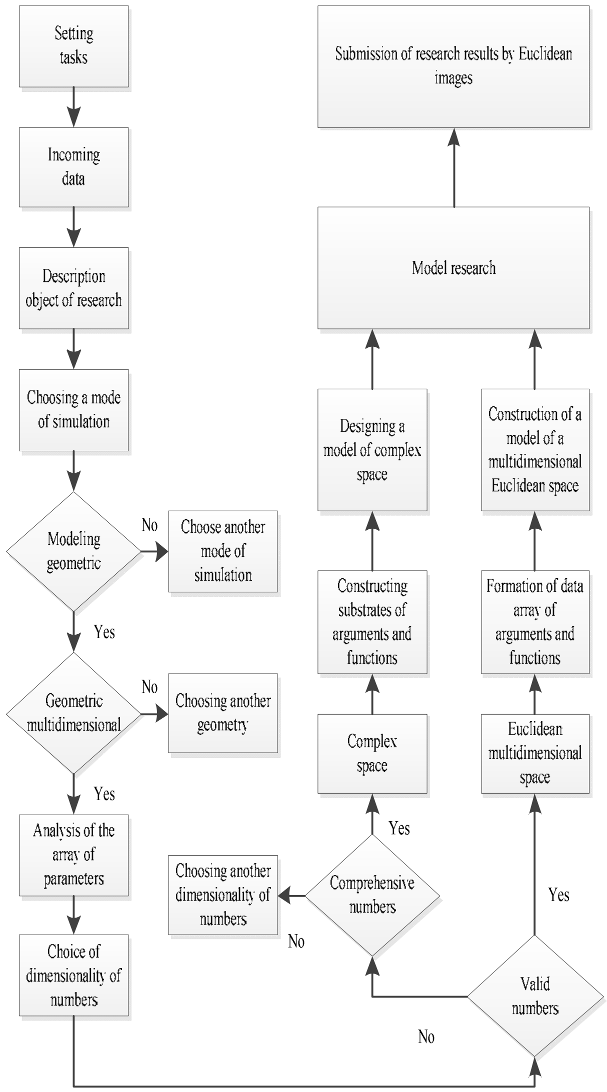


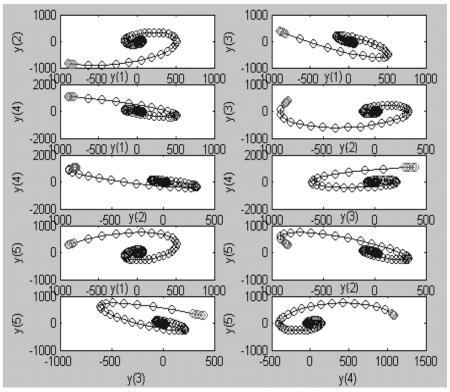
Fig. 7. Diagram of IT-modelling

Finally, dimensionality of r_{kn} multi-species as section $n-1$ - dimensional surface using n - dimensional cylinder is $r_{kn} = n - (n-1) = 1$, which is the dimensional n - spatial one-dimensional line $n+1$ - dimensional space of the system state. Projection of the curve as a guide of the projection cylinder of dimensionality $l = 2$ in the subspace of variables $Ox_1 x_2 ... x_i ... x_n$ as n - dimensional phase space we get a geometric image of dimensionality

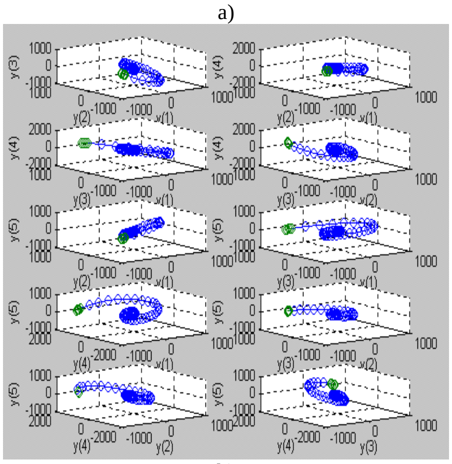
$$q = l + n - (\mathrm{n}+1) = 1,$$

which represents the dimensionality of the phase trajectory as a projection of the integral state space curve $Ox_1 x_2 ... x_i ... x_n t$ in the subspace of variables $Ox_1 x_2 ... x_i ... x_n$ as the phase space of the system.

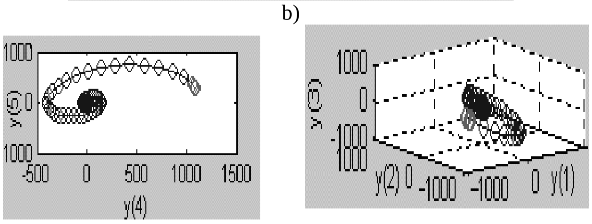
Geometric modeling of processes (Fig. 7) involves the selection of all stages of the basic stages, which include, in particular, the choice of input parameters and the use for simulation of the numbers of the corresponding measurements (real, complex, etc.), the method of geometric modeling, design and research of the model with presentation of research results in the Euclidean space.



a)



b)



c)

Fig. 8. Projections of the phase trajectory

The choice of the calculator determines to a greater extent the effectiveness of the research. Taking into account the possibility of projection of phase trajectories into two- and three-dimensional phase planes, it is effective to use the tools of computer mathematics Matlab.

An example of the realization of the projection of the phase trajectory of the solution of the differential equation, in particular, of the fifth order

$$\frac{d^5y}{dt^5}+\frac{d^4y}{dt^4}+\frac{d^3y}{dt^3}+\frac{d^2y}{dt^2}+\frac{dy}{dt}=0 \qquad (5)$$

indicates the need to reduce its order and to form a system of differential equations of the first order. For given values of the initial conditions y0 and the integration time *tspan* of the use of options *'odephas2'* and / or *'odephas3'* commands *options* , it is possible to obtain solutions as projections of the phase trajectory (5) in two-dimensional (Fig. 8a), three-dimensional (Fig. 8b) projection planes and their combination (Fig. 8c).

IV. Practical Implementation of Geometric Simulation of Process

A. Drive with asynchronous electric fire pump

The drive of low-power fire pumps is carried out using asynchronous short-circuited motors. The joint work is investigated by the analysis of so-called dynamic mechanical characteristics $M = M(\omega)$ in a two-dimensional space. Such curves represent one of the projections of an integral curve in a two-dimensional plane (Fig. 9) as one of the solutions of the system (6) of differential equations [3]

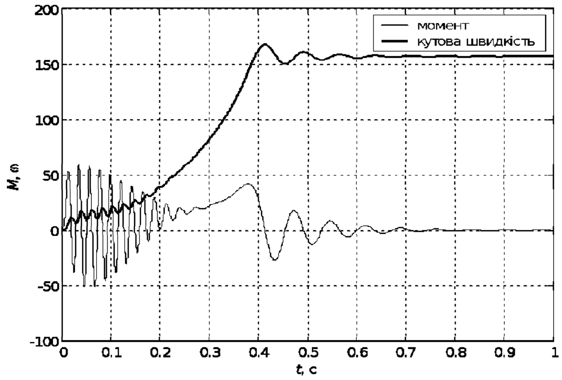


Fig. 9. Projection of the integral induction motor curve

$$\begin{aligned}
&\frac{d\psi_{x1}}{dt}=u_m\cos\gamma+\omega_0\psi_{y1}-\omega_0\alpha_s\psi_{x1}+\omega_0\alpha_s k_r\psi_{x2};\\
&\frac{d\psi_{y1}}{dt}=u_m\sin\gamma-\omega_0\psi_{x1}-\omega_0\alpha_s\psi_{y1}+\omega_0\alpha_s k_r\psi_{y2};\\
&\frac{d\psi_{x2}}{dt}=\psi_{y2}(\omega_0-\omega)-\omega_0\alpha_r\psi_{x2}+\omega_0\alpha_r k_s\psi_{x1};\\
&\frac{d\psi_{y2}}{dt}=-\psi_{x2}(\omega_u-\omega)-\omega_0\alpha_r\psi_{y2}+\omega_0\alpha_r k_s\psi_{y1};\\
&M=\frac{3}{2}\frac{p\omega_0 k_2}{x_s\sigma}(\psi_{x2}\psi_{y1}-\psi_{x1}\psi_{y2});\\
&\frac{d\omega}{dt}=\frac{p}{I}(M-M_c).
\end{aligned} \qquad (6)$$

where u_{u1}, u_{v1}, u_{u2}, u_{v2}, ψ_{u1}, ψ_{v1}, ψ_{u2}, ψ_{v2},

ω_0, ω, ω_k, $\alpha_s=\frac{r_1}{\sigma x_s}$; $\sigma_r=\frac{r_2}{\sigma x_r}$, $\sigma=1-\frac{x_0^2}{x_s x_r}=1-k_r k_s$,

r_1, r_2, x_0, x_s, x_r – asynchronous motor parameters.

M, MS - electromagnetic and moment of loading of asynchronous engine; p - number of pairs of poles of the asynchronous motor; And - moment of inertia of the system, brought to the shaft of the induction motor.

Projections of the phase trajectory of the transition process in the asynchronous motor (Fig.10) make it possible to conduct research of all its determining parameters.

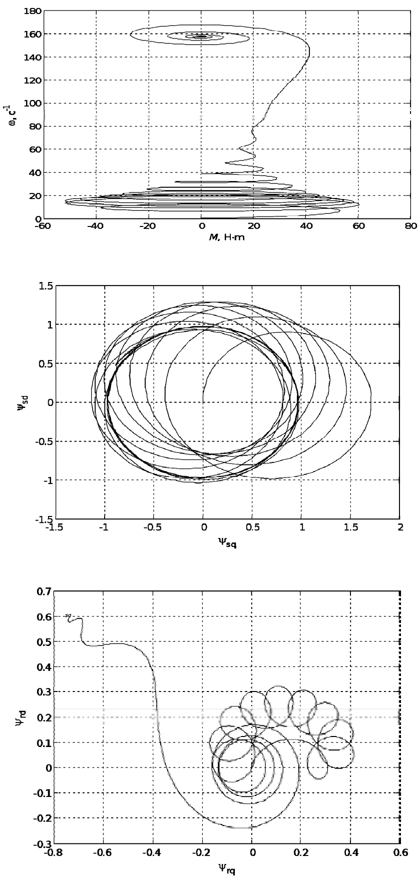


Fig. 10. Projection of the phase path of the start of the asynchronous motor

B. Drive with DC motor and periodic load torque

The co-use of two- and three-dimensional planes of phase planes illustrates the example of the implementation of the system of differential equations (7) of the DC motor and the periodic moment of the load on the shaft

$$u = L\frac{di}{dt} + i \times R + Ce\omega; \qquad I\frac{d\omega}{dt} = C_M i - M_c, \tag{7}$$

where L, R, c_e , $c_м$ - engine parameters u, i - voltage and current.

V. Conclusion

For the first time, the completeness of presentation of graphical information means of mapping of integral curves and phase trajectories of multidimensional phase spaces of the state of technical systems is substantiated. The development of graphical information technology tools expands the capabilities of model development and the study of the determinants of the parameters of processes of arbitrary material multiparameter systems, regardless of the physical content of the parameters, with the involvement of graphic capabilities of IT technologies. Further research relates to IT technologies for geometric modeling of processes by reducing the number of equations describing the state of a system with the use of numbers of higher measurements, in particular complex numbers.

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