Strojnícky časopis – *Journal of* MECHANICAL ENGINEERING,
VOL 74 (2024), NO 1, 45 - 56

INNOVATIONS IN TECHNICAL SYSTEMS

KUZNIETSOV Yurii[1*], SHEVCHENKO Oleksandr[2], YURCHYSHYN Oksana[3]

[1] *Institute of Mechanical Engineering, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Department of Machine Design, Beresteysky Ave. 37, 03056 Kyiv, Ukraine, e-mail: info@zmok.kiev.ua*
[2] *Institute of Mechanical Engineering, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Department of Machine Design, Beresteysky Ave. 37, 03056 Kyiv, Ukraine, e-mail: alex0507305251@gmail.com*
[3] *Institute of Mechanical Engineering, National Technical University of Ukraine "Igor Sikorsky Kyiv Polytechnic Institute", Department of Machine Design, Beresteysky Ave. 37, 03056 Kyiv, Ukraine, e-mail: urchyshynoks@ukr.net*

Abstract: In accordance with modern world trends in the field of higher education, technical creativity and a creative approach are gaining more and more importance as a system-forming factor of an effective educational process. Ensuring the proper level of study of modern methods of finding new technical solutions for the creation of new objects of technology in some places requires making fundamental changes in the educational process of domestic institutions of higher technical education. At the same time, such approaches are useful both for achieving the practical orientation of engineering education and for providing optimal conditions for the research activities of students of various levels.

KEYWORDS: technical creativity, technical system, learning, heuristics, creatology.

1 Introduction

The application of a creative system in the training of engineers requires a revision of curricula and programs, the introduction of new disciplines related to the mastery of progressive methods of searching and creating new technical systems (TS), as well as decision-making methods, in particular, in conditions of incomplete input information with the provision of maximum level of automation of this process. Despite the variety of objects and methods of educational disciplines of the technical direction, there is an interdisciplinary character in the formulation of their tasks, the application of methods and principles of analysis and synthesis. This led to the need to generalize such knowledge in the form of the science of TS theory, which largely determines the methodology of building engineering sciences and serves as a basis for solving many practical problems. This methodology, in contrast to the reproductive system, is oriented towards a creative system of knowledge transfer and accumulation [20]. Thus, the subject "Theory of technical systems" plays a special role in the organization of higher technical education because it provides the function of a logical and systematic connection between its main disciplines.

2 Literature review

An extended study of aspects of this discipline related to research and the application of creative (non-formalized) approaches to the creation of TS provides an opportunity to increase the level of systematicity and sequence of connections not only between educational components of theoretical and practical directions, but also educational levels. In particular, it

DOI: 10.2478/scjme-2024-0005, Print ISSN 0039-2472, On-line ISSN 2450-5471

is important to ensure continuity between educational and professional (bachelor, master) and educational-scientific (Ph.D.) programs, which contributes to the improvement of the quality of training of applicants. A separate evidence of the demand for educational materials in this discipline can be considered the significant spread on the Internet of unsystematically presented excerpts, including from ten-year-old editions [13] of textbooks authored by professors Yurii Kuznetsov, Yurii Novosyolov and Igor Lutsiv. This also indicates the expediency of publishing a textbook with updated scientific and technical information, which is presented in accordance with the principles of didactics. Materials from the seminal works of Polovynkin A.I.were used in part and in a concentrated form to highlight traditional ideas about the main aspects of the TS theory "Fundamentals of engineering creativity" (1988), Hubky V. "Theory of technical systems" (1987, translated from German), Chernova L.B. "Fundamentals of Machine Design Methodology" (1978). The works [2,3,5,6,17,18,26,31,32] of contemporary scholars deserve special attention and others.

3 Methods

The authors published the textbook [30], which is aimed at creating a tool for the successful formation of key competencies of students of higher education in accordance with modern requirements in the field of mechanical engineering. The proposed material contains a systematic exposition of the main concepts and provisions of the theory of technical systems. It reveals the essence of the system approach, gives the classification of TS, outlines the basic principles of analysis, synthesis, mathematical modeling and management of TS. Special attention is paid to the issues of creating new, more advanced TS, forecasting their development and genetic prediction. Materials related to the genetic approach in the creation and prediction of TS characteristics are presented in the material for the first time as an author's development that has undergone a number of tests in scientific events and publications. The main object considered in the materials are TS and their elements. The subject of study is a set of contradictions that are inherent in various structures of the TS and create a problematic situation, the solution of which is possible through the synthesis of a new system. The purpose of studying the materials is to master the methodology of system analysis, synthesis, management and design of TS.

4 Results and discussion

The creation of new technical means, along with the increase in requirements for them, on the one hand, and new methods of solving problems (for example, by means of computer technology) on the other hand, calls for the development of the methodological science "Technical Systems Theory". Since then, the theory of TS has found recognition as a basis and source of information for several related fields of knowledge. So, for example, the theory of construction is partly based on the theory of TS. From the point of view of modern ideas, systematicity has always been one of the methods of science - every scientist in the past unconsciously operated with systems and models.

The general theory of systems was formulated as an independent science in the second half of the 20th century, the founder of which is considered to be the Austrian physiologist Ludwig von Bertalanffy, who in the 1920s and 1930s dealt with the issues of a systems approach to the study of living organisms, developing a point of view on the need for a holistic approach in biology and physiology. In 1962-1968 L. von Bertalanffy includes many sciences in the general theory of systems: cybernetics, information theory, decision theory, topology, factor analysis, set theory, network theory, automata theory, mass service theory, graph theory. Today, a system is understood as a set of elements that are in relations and connections with each other. Such a concept covers many spheres of human life: creation of the world, science, religion, and others. From this population, TS are distinguished. Systems are characterized by a number of features. One of the first variants of such signs was formulated by Robert McColl. For TS, the main features are: 1. Origin of the system. The system is created by a person from various types of equipment and raw materials. 2. Hierarchy of the structure. Each of the systems can be divided into separate subsystems, which in turn can be considered as a set of separate subsystems and elements. A system can be a subsystem of a larger system. For example, a machine tool consists of individual units and nodes (subsystems) and at the same time can be considered as a subsystem of a machine-building enterprise. 3. The system has integrity. All its parts serve to achieve a single goal, namely the production of certain products with the help of optimized outputs with given input influences [4]. What is this goal, how do we determine the optimality of the system and what is the nature of the input influences, all this often turns out to be unknown until the moment when construction (design) begins. Elucidation of such questions is one of the important parts of the problem. 4. Connections between elements. The presence of connections between elements that prevail in terms of the strength of the connection between these elements and elements that are not part of the system. 5. Availability of integrated qualities. The system has integrated qualities, for example, a simple collection of machine parts that are not properly combined does not have the properties of a machine. 6. The system is semi-automatic. This means that part of the system's functions are always performed by automata (computer, automaton), and part of the system's functions is performed by a person. Thus, completely non-automated systems are excluded from consideration because they are not very efficient. At the current stage of the development of science and technology, the system can be fully automatic, the role of a person is reduced to preparing tasks for the operation of the system.

Based on the concept of system, systems can be divided into classes according to the principle of origin (Fig. 1). At the same time, individual elements of this structure are determined on the basis of the generally accepted classification of fields of knowledge. TS classes correspond to well-known branches of technology-mechanical engineering, electrical engineering, construction, etc.

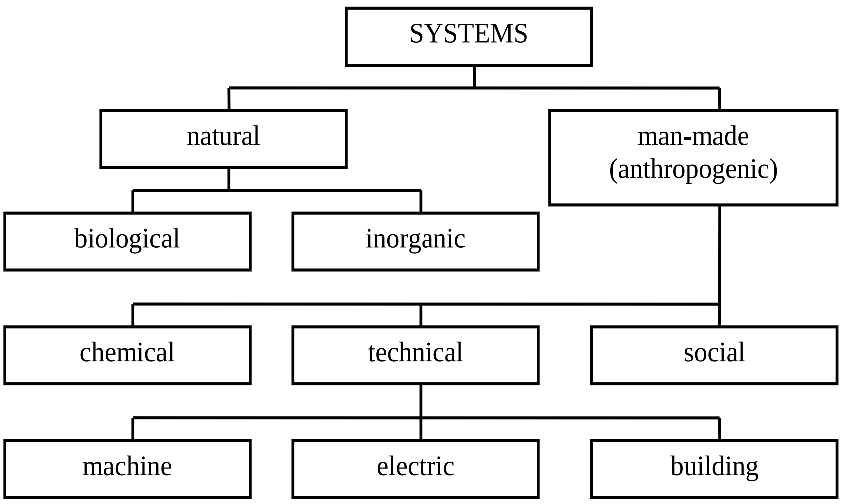


Fig. 1 Classification of systems according to their origin

In the future, we will schematically depict the system in the form of a quadrilateral, a circle, or their combination (Fig. 2). It is customary to divide all connections of the system with the environment into input variables X, controlling influences U(t), disturbing influences Ω(t) and output variables Y(t). In addition, the system itself is characterized by a set of state parameters Z(t).

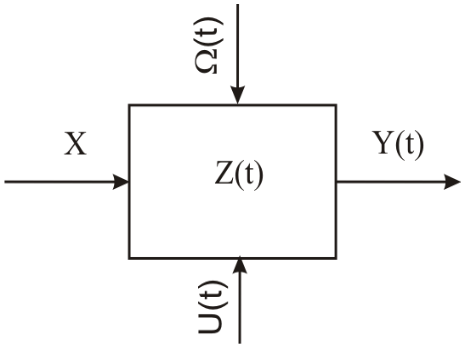


Fig. 2 Graphic image of the TS

Input variables include variables that enter the system from the environment and whose values do not change during a certain period of observation. In the space of variables, they form a vector $X=(x_1, x_2, \ldots x_n)$. For a car, such input variables are the mass of the cargo being transported, the composition of gasoline, tuning parameters, etc. For a technological operation – elements of the cutting mode that do not change during processing, parameters of the workpiece, input parameters of the cutting tool. For example, when turning the outer surface on a universal machine, the speed of rotation of the machine spindle, longitudinal feed, movement of the machine caliper, cutting depth are selected and set with mechanical switches.

In the process of surface treatment, none of the listed parameters changes. Controlling influences are such input variables, the values of which can change during the operation of the system according to the given algorithm, they form the vector $U(t)=(u_1(t),u_2(t),\ldots,u_k(t))$ at the moment of time t. The presence of a controlling influence significantly expands the functional properties of the TS. In mechanical processing, these are mode elements that change during the processing of the workpiece. The disturbance vector characterizes the influence on the system of random factors, $\Omega(t)=(w_1(t),w_2(t),\ldots w_i(t))$ as well as random deviations of input variables, control influences and state parameters. In the presence of disturbances, even with constant input variables and control, the output variables change, they are random. For example, when a car is moving, random road irregularities, wind speed fluctuations, transmission defects from the engine to the wheels, and others are considered disturbing influences. During mechanical processing, disturbing influences can include: fluctuations in the size and hardness of the workpieces within the batch, voltage fluctuations in the electrical network, and others. Due to the influence of these factors, it is impossible to obtain the same dimensions in all parts of the batch being processed.

A greater share of TS are stochastic to one degree or another, that is, they have a vector of disturbing influences. In practice, they strive to reduce the influence of random factors on the operation of the TS. The theory of automatic control envisages a method of control based on the disturbance effect, when the control of the disturbance factor is introduced and on the basis of this, the control influence is changed. For example, during mechanical processing, you can control the size of each workpiece and introduce a correction in the position of the cutting tool relative to the processing surface.

When the system is affected by variable, controlling and disturbing influences, as well as due to the processes occurring in the system itself, its state parameters change, which are determined by the vectors $Z(t)=(z_1(t),z_2(t),\ldots z_m(t))$. With regard to systems, three characteristic problems are considered: analysis, optimal control (management) and synthesis. The task of the analysis includes: studying the laws of system functioning; development of its mathematical model, which allows predicting the behavior of the system; description of the system structure; study of physical, chemical, functional properties of the subsystem and interaction of the subsystem and elements.

The task of optimal control of system operation is one of the main tasks of system operation. When solving it, optimal connections of the system with the environment and connections of subsystems among themselves are established, as well as optimal laws of system management are determined.

The task of synthesizing rational TS is solved at the stage of its creation. We will consider the understanding of these problems on a simple example of the main motion drive of a lathe, which includes: engine 1, gearbox 2 with their control system 3, spindle assembly 4 with a workpiece 6 of the flange type clamped in a chuck 5 (Fig. 3).

1. The task of analysis. Known: the structure of the system, variants of the input variables *X* (engine speed $n_Д$), the state of the object *Z* (the transmission ratio U_K of the speed box, which is set by the control system U). Find the frequency of rotation of the shafts of the gearbox n_K, the spindle $n_Ш$ (output *Y*) according to the balance equation of the kinematic chain of the main motion drive:

$$n_K(Z) = n_Д(X) \cdot U; \qquad n_Ш(Y) = n_Д(X) \cdot U_K.$$

2. The problem of optimal control. Known: the structure of the system, options for changing the input variables X and control influences *U*. It is necessary to ensure automatic adjustment of the main motion drive (*U*) during cutting (end processing) of the flange with maximum performance, provided that the cutting speed v remains constant when the processing diameter *d(t)*, i.e. $v = \pi d n_Ш = const$ at any time interval. At the beginning of trimming $d = d_{max}$ frequency $n_Ш = n_{Ш\,min}$, and at the end of trimming $d = d_{min}$, rotation frequency $n_Ш = n_{Ш\,max}$ from the condition $d_{max} \cdot n_{Ш\,min} = d_{min} \cdot n_{Ш\,max} = dn_Ш = const$.

This can be achieved in different ways, for example, when using an engine with adjustable rotation frequency or a variator for continuously changing the gear ratio.

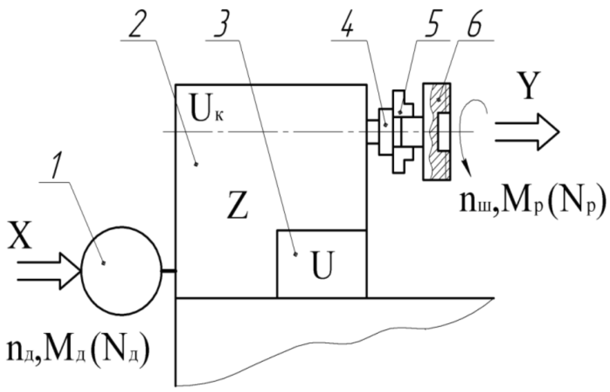


Fig. 3 The drive of the main movement of the lathe with different control systems

3. The task of synthesis. Known: variants of input variables *X* (for example, the nomenclature of produced electric motors with rotation frequency $n_Д$), possible control variants and output Y (spindle rotation frequency $n_Ш$). Design the gearbox (state Z) with the selected control system. Kinematic synthesis is performed, which provides the necessary transmission ratio

$$U_K = \frac{n_Ш(Y)}{n_Д(X)}$$

The same problems are solved when it comes to power ($M_Д, M_P$), energy ($N_Д, N_P$), dynamic and other characteristics of TSs at the stage of their design, modernization and operation.

5 A new look at the material point

Philosophers, among whom the term “monado” [3,22], borrowed from the Greek philosophy of Giordano Bruno, Leibniz (his philosophy is called “monadology”), were engaged in attempts to restore order in the vast diversity and multidimensionality of the world. According to Leibniz, the foundations of existing phenomena or phenomena are simple substances or monads (from the Greek monados - unit). The idea that there are no absolutely similar monads or two completely identical things in the world, Leibniz formed as the principle of "universal difference" and at the same time, as the identity of "indistinguishable", putting forward a deeply dialectical idea - monads, self-expanding all their contents due to self-consciousness . They are independent and self-active forces that bring all material things into a state of motion, form an intelligible world, from which the phenomenal world arises. For the process of evolution from disorder to order (the entropy in the system must decrease), the concepts of self-organization and interdisciplinary science of synergetics have arisen in open systems [7,8,21].

Synergetics (eng. Synergetics, Greek syn - "general" and ergos - "action") as an interdisciplinary science [8], which studies the processes of self-organization and the emergence, maintenance of stability and decay of structures (systems) of various nature based on the methods of mathematical physics (“formal technologies”). According to the author of the theory of synergetics Herman Haken [21]: “The main distinguishing feature of complex systems is their truly inexhaustible diversity, which cannot be sorted out, despite numerous attempts to fully understand the nature of complex systems ... . We are faced with the acute problem of finding unified principles that would allow us to properly approach the study of such systems ... "

In the expanding variety of objects and systems created by Nature and Man, general principles of their structural organization are observed, which manifest themselves in the form of intersystem analogies or hidden intrasystem homologies. Such properties take place both in natural (biological, chemical, electromagnetic, etc.) systems, and in systems of natural-anthropogenic origin (numerical, linguistic, technical, etc.) [25]. Thanks to the principles of self-organization and the genetic principle “from simple to complex”, a new view of the material point is proposed as a carrier of genetic information when creating a TS of the “object” and “process” types [11,12,14,16,22]. For the first time, the material point in the force flows of clamping mechanisms was announced by the author in the report [9] with their alphanumeric coding. This material point at the genetic level is conditionally called a mechanical gene and carries information about translational and rotational movements, loads and their directions (Fig. 4). A material point can be immobile, like information about static AGS (structures, supporting systems of technological equipment).

A set of material points form a material body, the state of equilibrium or movement of which depends on the nature of interaction with other bodies, i.e. from those pressures, attractions or repulsions that the material body experiences as a result of these interactions. With the help of a gene, hereditary information is transmitted in a number of generations (the laws of mechanics, theoretical mechanics, the theory of machines and mechanisms, strength of materials, machine parts, etc.) [1,11,19,22]. By analogy with the electromagnetic field [23], in mechanics we can talk about a force field, which can serve as an initial structure containing an ordered set of mechanical genes with a given spatial sequence of their placement (distribution) within the boundaries of a geometrized topological space (surface). The value, which is a quantitative measure of solid-state mechanical systems at the genetic level in the form of a material point O (Fig. 5) in Euclidean space, is the force F.

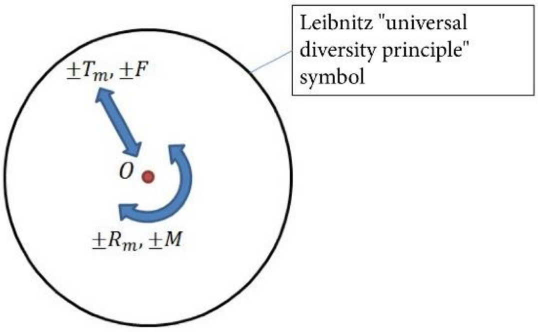


Fig. 4 Material point (O) - a mechanical gene that carries information about displacements and loads of translational ($\pm T_m$;$\pm F$) and rotational ($\pm R_m$;$\pm M$) indicating the direction

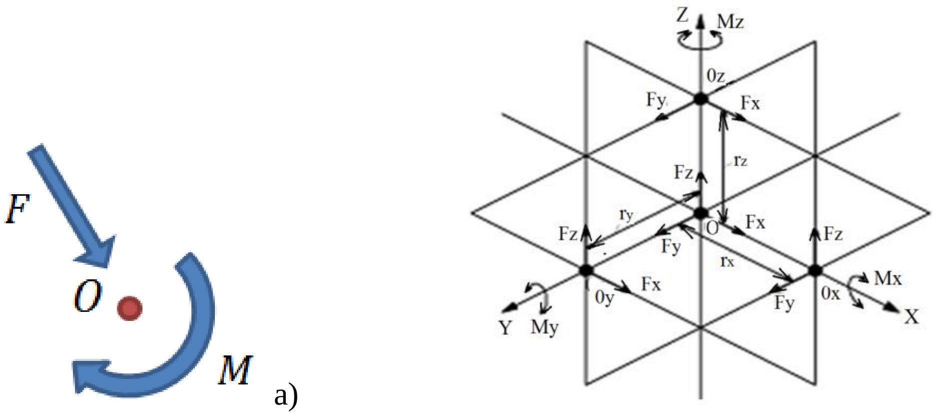


Fig. 5 Mechanical gene - a moving material point (a) in the XYZ Cartesian coordinate system (b)

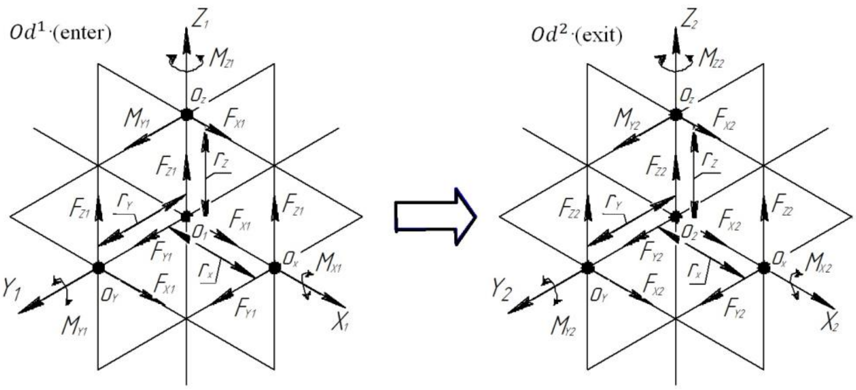
This force F can be mentally applied directly to a material point, which causes its translational movement in space along the coordinates X, Y, Z (F_x, F_y, F_z), or at a certain distance-radius (r_x, r_y, r_z), which indicates about the rotation of a material point around the coordinate axes X, Y, Z under the action of moments M:

$$M_x = F_y \cdot r_z = F_z \cdot r_y$$
$$M_y = F_x \cdot r_z = F_z \cdot r_x$$
$$M_z = F_x \cdot r_y = F_y \cdot r_x.$$

Using the genetic-morphological approach [10-12,16], the transfer of displacement, force and energy in space can be represented as a force (energy) flow from one material point O_1 at the input in the coordinate system X_1 Y_1 Z_1 to another material point O_2 in the system coordinates X_2 Y_2 Z_2 (Fig. 6), giving 144 variants of streams (parental chromosomes).

The vector of force F or moment M can have a directly opposite direction, which we will consider positive in the direction of the coordinate during translational movement and clockwise during rotational movement (the rule of the right hand is that if the thumb is directed along and towards the positive coordinate, then the bent fingers will show the direction rotation). The negative direction of force F or moment M will be denoted by underlining from below, i.e. $\underline{F_x}, \underline{F_y}, \underline{F_z}, \underline{M_x}, \underline{M_y}, \underline{M_z}$.

The systematic genetic and morphological approach makes it possible to successfully combine structural studies in various fields of science and technology due to its interdisciplinary nature using the relevant philosophical categories, provisions of the general systems theory. According to the degree of functional and structural organization, ACS are static (building structures, supporting systems of technological equipment, etc.) and dynamic (machine tools, machines, their mechanisms and drives), which are characterized by continuous and discrete processes of transformation and metabolism (matter), energy and information [2,13]. Recently, there has been a penetration of evolutionary genetic ideas into technical and humanitarian disciplines (genetic electromechanics, hereditary mechanics, technological heredity, genetic psychology, genetic linguistics, genetic history, evolutionary cybernetics, genetic standardization, etc.) [23-25,27].



a)

$$M_{EN}=\begin{vmatrix}\pm F_{X1}\\ \pm F_{Y1}\\ \pm F_{Z1}\\ \pm M_{X1}\\ \pm M_{Y1}\\ \pm M_{Z1}\end{vmatrix}\rightarrow M_{EX}=\begin{vmatrix}\pm F_{X2}\\ \pm F_{Y2}\\ \pm F_{Z2}\\ \pm M_{X2}\\ \pm M_{Y2}\\ \pm M_{Z2}\end{vmatrix}$$

b)

Fig. 6 Generalized model of power (energy) flows in a mechanical system (a) and the corresponding morphological model-matrix (b)

6 Examples of applying a new look at a material point

Evolutionary and genetic synthesis of chucks

In accordance with the generalized model (Fig. 6), all power (energy) flows in clamping chucks are described below by the morphological matrix with one input and output, giving 48 parental chromosomes [12]. The matrix is presented in a cylindrical coordinate system, where the following designations are introduced:

$$F_{x1}=F_{a1};\ F_{y1}=F_{r1};\ F_{z1}=F_{t1};\ M_{x1}=M_{a1};\ M_{y1}=M_{r1};\ M_{z1}=M_{t1};\ F_{x2}=F_{a2};\ F_{y2}=F_{z2}=F_{r2}.$$

$$M'_{EN}=\begin{vmatrix}\pm F_{a1}\\ \pm F_{r1}\\ \pm F_{t1}\\ \pm M_{a1}\\ \pm M_{r1}\\ \pm M_{t1}\end{vmatrix}\rightarrow M'_{EX}=\begin{vmatrix}\pm F_{a2}\\ \pm F_{r2}\end{vmatrix}$$

The most commonly used parental chromosome F_{a1}-F_{r2}, and for 2/3 of the parental chromosomes, their use is not yet known. At the object level of genetic information for clamping chucks, there can be different closures of power flows in the form of elementary power circuits at the output [9,10,12]. As the structure becomes more complex by introducing various transducers, populations of clamping chucks appear, and among the known simple mechanical transducers, seven are used [22]: lever, wedge, spiral, plunger, screw, gear, spring (Fig. 7).

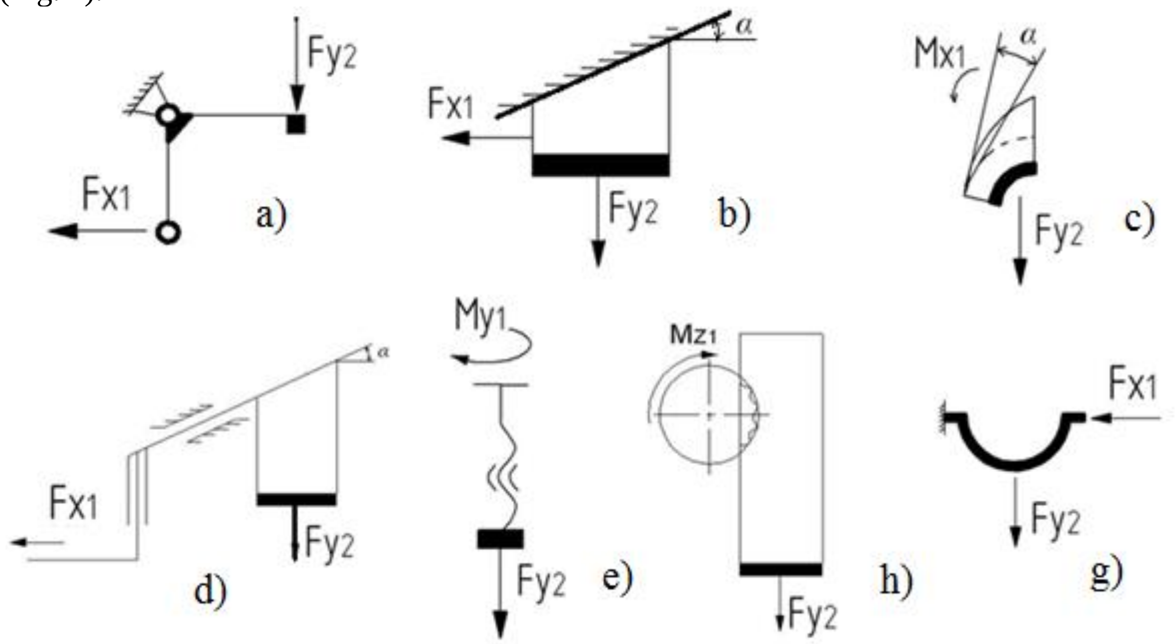


Fig. 7 Solid-state simplest mechanical transducers of displacement and forces:
a - lever (LV); b - wadge (WD); c - spiral (SP); d - plunger (PL); e - screw (SC); h - gear (GR); g - spring (SR)

Arbitrary power flow structures (parental chromosomes), which play the role of generative elements, become more complex in the process of genetic development, forming combinatorial groups of n-th generation descendant chromosomes using five universal synthesis operators: replication, crossing, inversion, crossing over, and mutation [10,15,22]. Below is a description of the clamping mechanism at various levels of structural organization (parental chromosome F_{a1} - F_{r2} or F_{x1}-F_{y2}): genetic, F_{x1}; chromosomal, F_{x1}-F_{y2}; object, F_{x1}-F_{y2} ($1 \cdot K_R$); population, F_{x1}-LV-F_{y2} ($1 \cdot K_R$); specific, F_{x1}-LV-F_{y2} ($1 \cdot K_R$)-CL; system, E-EM-F_{x0}-(WD-LV)-F_{x1}-LV-F_{y2} ($1 \cdot K_R$).

Here E is an electrical energy source; EM – electromechanical transducer (primary), which creates axial force F_{x0}. at the input of the clamping drive (PrZ); (WD-LV) - hybrid wedge-lever transmission and amplifying mechanism in the clamp drive with output force F_{x1} , which is the input to the clamping chuck, LV - lever converter in the clamping chuck; F_{y2} ($1 \cdot K_R$) is the output radial clamping force F_2 with a closed power circuit (number 1, and if the circuit is open - number 0) and the number of clamping elements n, determined by the replication multiplier K_R (for a three-jaw clamping chuck K_R=3).

7 Implementation of the concept of creating new generation machines

The presented concept includes [15,28,29]: -genetic-morphological multilevel approach to the classification, description, evolution, prediction and synthesis of complex TS; -application of frame and shell structures of load-bearing systems; - aggregate-modular layout principle; -use of advanced information technologies and intelligent computer systems. The proposed concept has been successfully implemented in the creation of small-sized machine tools with computer control of various layouts, including those with parallel structure mechanisms (MPS), using a limited number of modules (linear movements with the additional function of a frame rib, a motor-spindle, rods of constant length, swivel joints, bases and traverses).

8 Synthesis of technological principles-objects of the "process" type

Any technological principle can be represented as two material points that have come into contact and interact with each other - the processed object O_1 (part) and the processing object O_2 (tool) (Fig. 8), each of which performs translational and rotational movements in space in system of their coordinates X_1 Y_1 Z_1 and X_2 Y_2 Z_2 [10, 22]. According to fig. 8 with the main rotational motion ω (x_1, y_1, z_1), the material point O_1 can be described taking into account the translational movement of the feed S (x_1, y_1, z_1) and the radius of the coordinate R (x_1, y_1, z_1) and similarly the material point O_2 sets

$$O_1 \begin{Bmatrix} \omega_{x_1}, S_{x_1}, R_{x_1} \\ \omega_{y_1}, S_{y_1}, R_{y_1} \\ \omega_{z_1}, S_{z_1}, R_{z_1} \end{Bmatrix};$$

$$O_2 \begin{Bmatrix} \omega_{x_2}, S_{x_2}, R_{x_2} \\ \omega_{y_2}, S_{y_2}, R_{y_2} \\ \omega_{z_2}, S_{z_2}, R_{z_2} \end{Bmatrix};$$

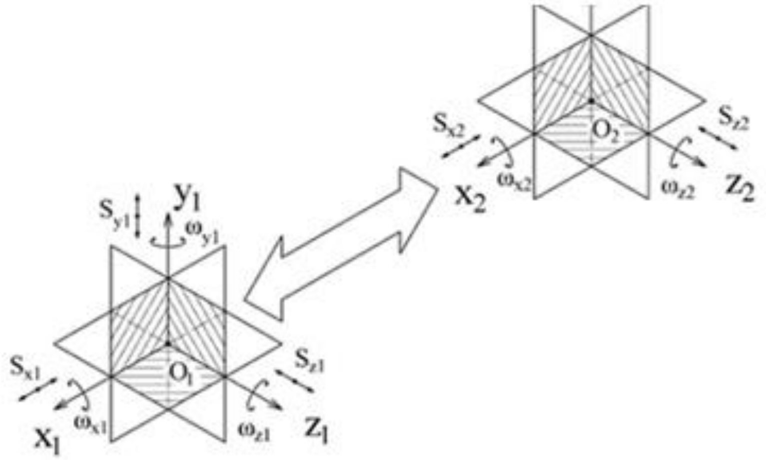


Fig. 8 The proposed spatial kinematic cutting scheme in the form of the interaction of two material points O_1 and O_2 in Cartesian coordinate systems

The interaction of these points O_1 and O_2 (Fig. 8) can be represented as a collapsed morphological model at the chromosomal level [22]:

$$M_{KC} = \left| \begin{Bmatrix} \omega_{x_1}, S_{x_1}, R_{x_1} \\ \omega_{y_1}, S_{y_1}, R_{y_1} \\ \omega_{z_1}, S_{z_1}, R_{z_1} \end{Bmatrix} \right| \wedge \left| \begin{Bmatrix} \omega_{x_2}, S_{x_2}, R_{x_2} \\ \omega_{y_2}, S_{y_2}, R_{y_2} \\ \omega_{z_2}, S_{z_2}, R_{z_2} \end{Bmatrix} \right|$$

If there is no rotational or translational movement and the placement of points on the geometric axis of the machine, the value 0 (zero) is used as an alternative to the implementation of the feature in the morphological model. Using the genetic-morphological approach [10, 15, 22], from the morphological model, Fig. 9 shows the kinematic cutting scheme with the digital code 401 [4], which for specific processing schemes is written as variants of the genetic code at the chromosomal level:

(ω_{x1}, 0, 0) – (0, S_{x2}, 0) - axial drilling of a rotating part (point O_1) by a non-rotating translationally moving drill tool (point O_2);
(0, 0, 0) - (ω_{x2}, S_{x2}, 0) - axial drilling of a non-rotating part (point O_1) by a rotating and translationally moving coaxial tool (point O_2);
(0, S_{x1}, 0) – (ω_{x2}, 0, 0) – axial drilling of a translationally moving part (point O_1) with a rotating coaxial tool (point O_2);
(ω_{x1}, S_{x1}, 0) - (0, 0, 0) - axial drilling of a rotating and translationally moving part (point O_1) with a stationary tool (point O_2).

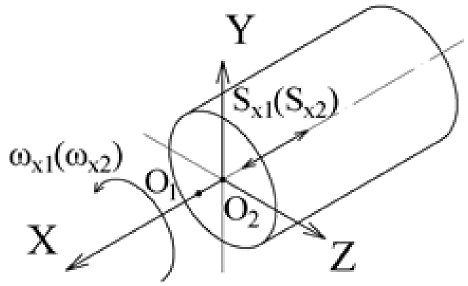


Fig. 9. Kinematic scheme of cutting, described by different variants of the genetic code at the chromosomal level

CONCLUSION

The proposed material contains a systematic exposition of the main concepts and provisions of the theory of technical systems. It reveals the essence of the system approach, gives the classification of TS, outlines the basic principles of analysis, synthesis, mathematical modeling and management of TS. A new look at a material point as a carrier of genetic information allows one to effectively synthesize and anticipate the emergence of new TS of the “object” and “process” types. The systematic genetic and morphological approach makes it possible to successfully combine structural studies in various fields of science and technology due to its interdisciplinary nature using the relevant philosophical categories, provisions of the general systems theory.

REFERENCES

[1] Artobolevsky I.I. “Theory of mechanisms and machines”, / I.I. Artobolevsky, - M: Nauka, **1988**. - 638 p.

[2] Balashov E.A. “Evolutionary synthesis of systems”, / E.P. Balashov. - M .: Radio and communication, **1985**. - 328 p.

[3] Hegel F.G.W. “Science of Logic” - St. Petersburg, **1997**. - 191 p.

[4] Granovsky G.I. “Kinematics of cutting” /G.I. Granovsky. – M.: Mashgiz, **1948**. – 200 p.

[5] Zablonsky K.I. “Theory of mechanisms and machines: Textbook” / K.I. Zablonsky, I.M. Belokonev, B.M. Shchekin. - K .: Vishcha school. Head publishing house, **1989**. - 376 p.

[6] Ishlinsky A.Yu. “Mechanics: ideas, tasks, applications” / A.Yu. Ishlinsky. – M.: Nauka, **1985**. – 624 p.

[7] Korotkova G.P. “Principles of integrity (on the question of the ratio of living and non-living systems)” / G.P. Korotkova - L .: ed. Leningrad. Univ., **1968**. – 160 p.

[8] Knyazeva E.N. Synergetics. “Nonlinearity of time and landscapes of coevolution” / E.N. Knyazeva, S.P. Kurdyumov. M.: Komkniga publishing house, **2014**. - 272 p.

[9] Kuznetsov Yu.N. “Theoretical foundations of optimal design of clamping mechanisms”, - Sat. report Anniversary scientific. conf. with international participation, dedicated to the 1300th anniversary of Bulgaria and the 90th anniversary of the BKP, Gabrovo (NRB), pp. 37 – 58, **1982**.

[10] Kuznetsov Yu.N. “Morphological synthesis of machine tools and their mechanisms” / Yu.N. Kuznetsov, Joaquim A. G. Hamuyela, T.O. Hamuyela, ed. Yu.N. Kuznetsova. - K .: Gnosis LLC, **2013**. 401 p.

[11] Kuznetsov Yu.N. “Evolutionary and genetic synthesis of technological equipment of a new generation”, Cutting and tools in technological systems: Intern. scientific - tech. Sat. - Kharkov: NTU "KhPI", Issue 85, pp. 149 – 162, **2008**.

[12] Kuznetsov Yu.M., Khamuyela Zh.A. Guerra, Poparov A. “Genetics - a morphological approach to the creation and forecasting of the development of clamping mechanisms for rotating parts”, Journal of the Technical University - Sofia. - Plovdiv branch, Bulgaria “Fundamental Sciences and Applications. – Bulgaria, vol. 19, Book 2, p.p. II 7 - II 13, **2013**.

[13] Kuznetsov Yu.N. “Theory of technical systems: Textbook”, Yu.N. Kuznetsov, Yu.K. Novoselov, I.V. Lutsiv. - Sevastopol: publishing house of SevNTU, 256 p., **2012**.

[14] Kuznetsov Yu.N. “Creation of machine tools of a new generation using the genetic and morphological approach”, Collection of reports int. scientific conf. UNITECH-10, v.2, November 19-20, pp. 79 – 91, **2010**.

[15] Kuznetsov Yu.N. “Layouts of machine tools with parallel structure mechanisms”, Yu.N. Kuznetsov, D.A. Dmitriev, G.E. Dinevich. - Kherson: PP Vishemirsky V.S., 471 p, **2010**.

[16] Kuznetsov Yu.N., Shinkarenko V.F. Genetic approach is the key to innovative synthesis of complex technical systems // Journal of the Technical University Sofia, branch Plovdiv, Bulgaria “Fundamental sciences and applications, Vol. 16, Book 2, pp. 15 – 34, **2011**.

[17] Smirnov V.A. “Genetic method for constructing a scientific theory” / V.A. Smirnov // Philosophical questions of modern formal logic. - M: **1962**. - 283 p.

[18] Stepin V.S. “Theoretical knowledgeL / V.S. Stepin. – M.: **1999**. – 390 p.

[19] Targ S.M. “A short course in theoretical mechanics” / S.M. Targ. - M.: The main edition of the physical and mathematical literature of the publishing house "Nauka", **1970** - 478 p.

[20] Urmantsev Yu.A. “Evolutionism, or the general theory of the development of systems of the nature of society and thinking”, - M .: Book house "LIBROKOM", 240 p., **2009**.

[21] Haken G. “Information and self-organization. Macroscopic approach to complex systems”, -M.: Mir, **1991**. – 240 p.

[22] Hamuyela J.A. Guerra, Kuznetsov Yu.N., Hamuyela T.O. “Genetic and morphological synthesis of clamping cartridges”, Lutsk: Vezha-Druk, **2017**. - 328 p.

[23] Shinkarenko V.F. “Fundamentals of the theory of evolution of electromechanical systems”, V.F. Shinkarenko. - K .: Naukova Dumka, **1989**. - 288 p.

[24] Shinkarenko V.F., Lysak V.V. “Genetic programs for the structural evolution of functional classes of electromechanical systems”, №2., pp. 56 – 62, **2012**.

[25] Shinkarenko V.F. “Genetic programs for the structural evolution of anthropogenic systems. (Interdisciplinary aspect)”, Practice of the Taurian State Agrotechnological University. Vip.13, volume 4. Melitopol, pp. 11 – 20, **2013**.

[26] Trader G.Yu. “Evolution of basic physical ideas”, - K .: Naukova Dumka, **1989**. - 368 p.

[27] Mason O.T. “The Origins of inventions: A study of Industry Among Primitive Peoples”, Cambridge, Massachusetts, The M.I.T. Press, **1966**.

[28] Shinkarenko V., Kuznietsov Y. “Genetic Programs of Complex Evolutionary Systems”, 11th Anniversary International scientific Conference “Unitech’11”, 18-19 November Gabrovo. Bulgaria. Vol. 1, pp 33 – 43, **2011**.

[29] Kuznetsov Y., Gaidaienko Iu. “Genetic modeling and structural synthesis of CNC multi-spindle automatic machines of new generation”, International scientific journal “Industry 4.0” 3, pp. 115 – 119, **2018**.

[30] Kuznetsov Y., Prydalny B. “Theory of technical systems in the aspects of research and technical creativity” - Lutsk: Vezha-Druk, 284 p., **2023**.

[31] Protsenko V., Nastasenko V., Babiy M., Protasov R. “Marine Ram-type Steering gear mainability increasing“ Strojnícky časopis – Journal of Mechanical Engineering 72 (2), pp. 149 – 160, **2022**. DOI: 10.2478/scjme-2022-0025

[32] Ziaran, S., Chlebo, O., Soos L. “Determination of bearing quality using frequency vibration analysis”, Strojnícky časopis – Journal of Mechanical Engineering 71 (2), pp. 343 – 350, **2021**. DOI: 10.2478/scjme-2021-0040