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INTERDISCIPLINARY APPROACH TO MODELING AND SYNTHESIS OF DIFFICULT TECHNICAL SYSTEMS

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Abstract
Problem of knowledge convergence in tasks of creating complex technical systems is analyzed. Developing technical systems facilities to the category of genetically organized hypothesis is proposed. General methodological approach to modeling and synthesis of complex technical objects based on the synthesis and identification of their genetic programs is propose. At example of electromagnetic and mechanical systems concept of genetic engineering is proved and this strategy expansion prospects to other technical disciplines with horizontal transfer of knowledge is proposed. The accuracy of proposed genetic models and methods of interdisciplinary synthesis confirmed by results of evolutionary experiments.

Keywords: complex technical system, convergence of discipline, genetically organized system, genetic program, genetic model, structural prediction, interdisciplinary synthesis, genetic design, evolutionary experiment.

INTRODUCTION

Increasing complexity of created systems is the topical tendency of technical development at present time. Systems, could be analyzed and synthesized by a multidisciplinary approach only, are under consideration at present work. Creating of such systems requires close cooperation of specialists in different areas of knowledge and necessity of new interdisciplinary scientific approaches development to their research and design.

Idea of interdisciplinary approach to knowledge of complex different physical nature systems is not new and is the basis of general systems theory, the task of which is to identify structural similarity laws or other forms of knowledge derived from different disciplines and establishment general laws of functioning of diverse systems on this basis. Knowledge about development of complex systems, accumulated to the present time, in most cases, have huge volumes of disjunct and limited directed information, which exceed organizational possibilities of individual user or researcher.

Trend of new scientific directions on the basis of biology, information technology and cognitive science, which acquire the status of "interdisciplinary" appearance is topical at present time [1].

Convergence of scientific disciplines and technologies is accompanied by the gradual elimination of the artificial boundaries between the various branches of science with appearance of integrated scientific fields, which contributes fundamentalization of disciplines and opens up the possibility of horizontal knowledge and research methodology exchange.

In recent years the role of above-branch level discipline takes genetics, because subjects of her study are interconnected processes of the past, present and future, taking place in developing systems of different physical nature. Live and anthropogenic system, independently of their complexity level, have two alternative properties: heredity and variability. Heredity is manifested in saving inherent genetic characteristics and properties in object, population or specie generations. Variability property determines variety of hereditary structures realization options and ways by adapting them to changing environmental conditions.

Genetic approach in modern science acquires a key role in the knowledge of fundamental structural organization principles and laws of complex systems development, which opens the possibility of implementing prediction scenarios and management heredity on the generalized language of genetic information, not only in biological systems, but also in the systems of human origin [2- 4].

In engineering sciences, highly directional passports separated specialties, there is an urgent need for a systematic compilation and ordering of accumulated knowledge, followed transition from the narrow-profile investigations and observed fragmented evolution to managed coevolution strategy.

Research development of this area opens up the possibility of formulating and solving new interdisciplinary fundamentally problems, including the problem of structural prediction and innovative synthesis of complex systems, combined with subsystems of different physical nature, for a given targeted function.

Genetically organized systems. Results of the structural-systematic and interdisciplinary research, recently obtained in the field of structural and genetic electromechanics, allowed to allocate a special class of genetically organized systems (GOS), which have not only biological, but also anthropogenic origin. Theoretical and experimental researches have established that structural organization and development of such systems are carried

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out in accordance with system heridity principles according to their genetic programs [5-7].

Theoretical basis of GOS are interconnected structural organization system principles and heredity information that determine diversity and development of different physical nature systems. Form of conservation principles and integral periodic law presentation in GOS are generative system – primary source genetic classification (GC) and their genetic codes. Therefore, discovery of such systems in a particular field of knowledge, opens the way for structural and systematic research and is a direct proof of supplies system to GOS category.

Invariant properties of electromagnetic field primary sources GC system analysis has revealed the principles of heredity in electromagnetic systems, and thus to establish a direct relationship elemental basis of GC and genetic information (genetic codes) with genetically valid and existing variety of electromechanical objects created in time of technological evolution [5]. Existence of such laws determined methodology of genetic predictions, theory of genetic synthesis and analysis of genetic programs and formed basis for development of theoretical foundations of electromechanical objects (EM- objects) genetic systematic.

System analysis of genetic organization principles in other disciplines results have confirmed their consistency and fundamentality, as well as to establish their belonging to GOS category (Fig. 1). At this time, the level of knowledge and use of system heredity laws and evolution in scientific research can be regarded as a maturity criterion of the relevant scientific knowledge branch, and its level of systematic and fundamentality.

Results of matrix interdisciplinary correspondences in GOS analysis (Fig. 1) show a high level of structural and systematic research in chemistry, biology and electromechanics. Genetic principles in a fragmented form are also used in linguistics. The lowest level of systematic research takes place in the technical disciplines, because of their disunity and narrow scientific specialization.

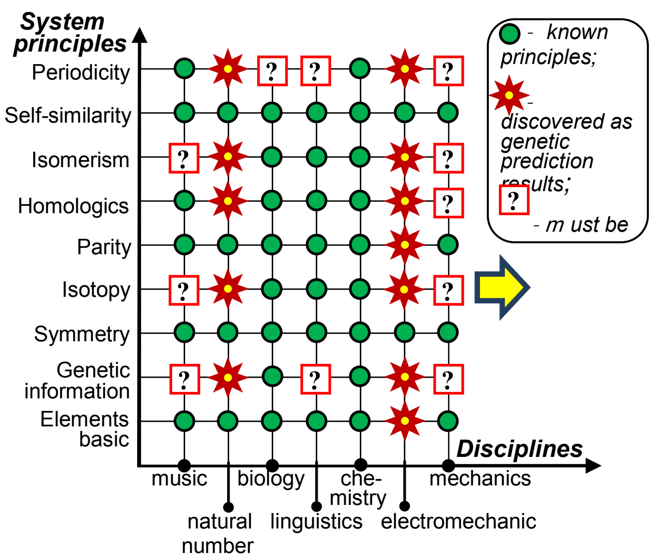

Fig. 1. Interdisciplinary analysis results of modern level system research in genetically organized systems

Results of structural-systematic research, obtained in recent years in the field of genetic and structural electromechanics, can significantly extend the boundaries of their applicability to other areas of knowledge. Using the technology of horizontal information transfer initiate such new scientifical areas of interdisciplinary research as a genetic theory of numbers [4], genetic history of technics [8]. Analysis of system correspondences matrix (Fig. 1) show existence of problem areas that violate the consistency of discipline, and thus determines the direction of basic research.

Task determination. Wide variety of structural and functional analogues in the mechanical and electromagnetic devices, indicate the common principles of their structure formation. In this paper, the authors determinate task as testing the genetic relationship hypothesis at the level of generating structures and genetic information of axisymmetrical type electromagnetic and mechanical structures. Confirmation of this hypothesis opens up possibility of horizontal information and knowledge exchange through the use of common models and methods of research. Validation of problems solution in this formulation will be the possibility of directed synthesis of mechanical devices genetic programs, as well as the formulation of evolutionary experiments. In genetic terms, the problem reduces to construction of generalized models of mechanical and electromagnetic devices-homologues using a common element and information basis – electromagnetic fields primary sources GC.

Genetic programs. Availability of genetic program is necessary condition for functioning and development of system with heredity. System tasks of genetic programs identifying and deciphering determination belongs to the category of interdisciplinary tasks and their decision will be possible only if existence of conceptual models of knowledge in the high-level synthesis, informational and methodological basis which are generating system. In this study the system carrier of genetic programs performs GC periodic structure. Periodic generating systems organize element and information systems-descendants basis and they are form of structural organization principles and laws of evolution of a particular GOS class.

Common element basis for complex systems, structurally combine electromagnetic and mechanical components modeling, using requires structural information of correspondences between compared electromagnetic and mechanical structures. Such compliance shall be established at the genetic (table 1), objective and system levels.

Table 1. Correspondence between genetic information components at the level of generating electromagnetic and mechanical structures

Genetic electromechanics	Genetic mechanics
Moving electric charge (Electromagnetic gene)	Material point (Mechanic gene)
Electromagnetic chromosome	Mechanic chromosome
Primary source of electromagnetic field (Primary chromosome)	Primary surface (Primary chromosome)
Secondary source of electromagnetic field (Secondary chromosome)	Secondary surface (Secondary chromosome)
Orientation (Electromagnetic)	Force application orientation (Mechanic)
Radial electromagnetic force	Radial mechanic force
Axial electromagnetic force	Axial mechanic force

As example in table 1 shows the system of correspondences between many-rotors electric machines and rolling bearings. Structural representatives of those classes have axial symmetry, identity of active parts spatial geometry and topology. If the genetic matches level is invariant to physical nature of the compared objects, object-level matching require refinement depending on the functional purpose of a mechanical system.

Presence of these matches mean that components of genetic information in the structure of universal genetic code will be invariant to functionality, level of difficulty and time evolution of the analyzed classes of technical objects. This reflects about commonality of elemental and information basis at the item level of GC subject area. In this case, the properties of objects belonging to different physical and functional classes will be characterized by a certain type of symmetry, common spatial geometry and topology of the primary and secondary parts, figures the concept of genetic information.

As an example, in Fig. 2 presents the structure of many-rotor conical motor and radial-thrust bearing with common genetic information at the chromosomal level. Taking into account the concordance (table 1), genetic information of generative parity chromosome can be represented by a common genetic code

$$2(KN\ 0.2y)_1 : n(KN\ 0.2y)_2 \qquad (1)$$

where: $2(KN\ 0.2y)_1$ – genetic code of primary (parental) chromosome; $n(KN\ 0.2y)_2$ – integral genetic information of secondary (moving) chromosome. Thus, genetic structure many-rotor motor and radial-thrust bearing are identical, as evidenced by the commonality of their genetic formula, even have differences in design, materials, and functions.

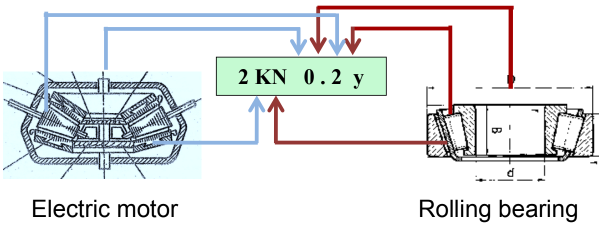

Fig. 2. Communion universal genetic code in axisymmetric electromechanical and mechanical objects

The commonality of structure and information basis opens the possibility of generalized genetic models of structure formation use in tasks of mechanical structures and EM-systems analysis and synthesis. Analyzed structures of many-rotor motor and bearing can be provide as generalized genetic model (Fig. 3).

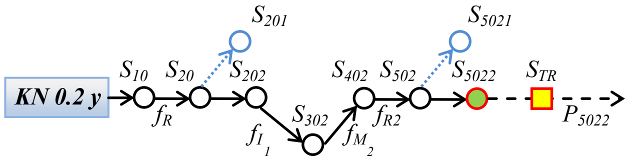

Fig. 3. Generalized genetic model of axially symmetric object: KN 0.2y – parental chromosome; S_{10}, S_{20}, …, S_{5021} – parity chromosomes; S_{201}, S_{5021} – isomers chromosome; S_{5022} – generative object chromosome; S_{TR} – real object; P_{5022} – object-heirs population

The results of models genetic analysis confirm the identity of genetic structure and information of compared objects (table 2).

Common element and information basis opens the possibility of transferring system principles (homology, isotopy, isomerism, parity, hybridization, etc.) with a genetic electromechanics to mechanics. For example, transfer the principle of homology to axisymmetric mechanical objects classes allows to define the structure of their homological series (Fig. 4) and synthesize the missing objects in the series. Determination of object to homological series through its genetic information with subsequent identification of the location of its parent chromosome in the subject area. Entire structure of perfect homologous series is determined by the known genetic information, at least one structural representative of series.

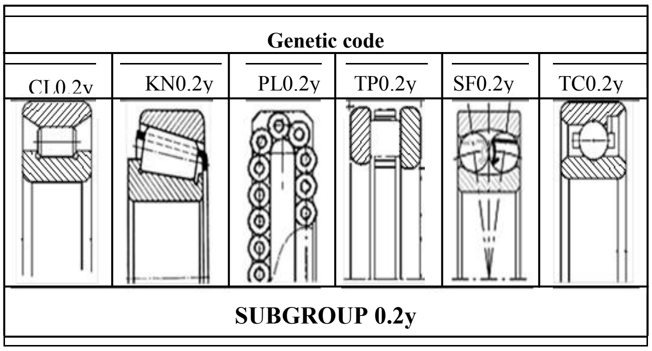

Fig. 4. Ideal homological series of rolling bearing structure (subgroup 0.2 of first great period of GC)

Table 2. Analysis of generalized genetic model results

Chromo-some	Structural formula	Structural equivalent	
		Electric motor	**Rolling bearing**
$KN\ 0.2y$	$KN\ 0.2y$	Parental chromosome	Parental chromosome
S_{10}	$(KN\ 0.2y)_1$: $(KN\ 0.2y)_2$	Electromechanic couple	Mechanic couple
S_{20}	$2(KN\ 0.2y)_1$: $(KN\ 0.2y)_2$	Double-stator performance	Bearing with two rings
S_{202}	$[2(KN\ 0.2y)$: $R_{OZ}]_1$: $(KN\ 0.2y)_2$	Radial composition	Radial composition (one-row)
S_{302}	$[2(KN\ 0.2y)$: R_{OZ} : $I]_1$: $(KN\ 0.2y)_2$	With two-side active surface	With external and internal rings
S_{402}	$[2(KN\ 0.2y)$: R_{OZ} : $I]_1$: $[N(KN\ 0.2y)$: $M]_2$	Elementary rotor performance ($R_2 << R_1$)	Elementary rolling body performance ($R_2 << R_1$)
S_{502}	$[2(KN\ 0.2y)$: R_{OZ} : I: $I_{ЭМ}]_1$: $[N(KN\ 0.2y)$: $M]_2$	N rotors performance ($R_2 << R_1$)	N rolling bodies performance ($R_2 << R_1$)
S_{5022}	$[2(KN\ 0.2y)$: R_{OZ} : I: $I_{EM}]_1$: $[N(KN\ 0.2y)$: M:$R_{OZ}]_2$	Radial structure with N rotors	Radial structure with N rolling bodies
S_{TP}	$[2(KN\ 0.2y)$: R_{OZ} : I: $I_{EM}]_1$: $[N(KN\ 0.2y)$: M:$R_{OZ}]_2$	Cone-type double-stator many-rotor motor	Cone-type radial-thrust rolling bearing

Practical use in mechanical structures found genetic principles such as hybridization, inversion, crossingover, replication (Fig. 5) and mutation [9].

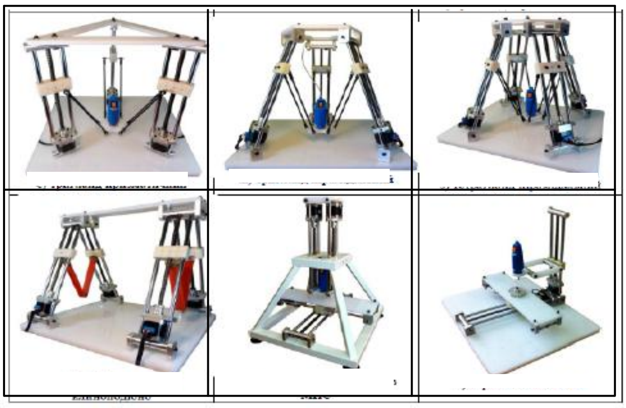

Fig. 5. Practical implementation of structural isomerism and replication principles at creation of modular design machines new generation example

Interdisciplinary synthesis. Commonality of genetic information electromechanical and mechanical structures presentation, opens the possibility of modeling and synthesis of complex systems that combine electromagnetic and mechanical components. As an example, consider the problem of motor-spindle (M-S) rotary motion synthesis. Target synthesis function F_ω is defined by the following combination of private claims:

- ensuring the spindle rotation function $(\pm \omega)$;
- ensuring alignment of the drive motor with spindle (S_{OX});
- ensuring the dynamic stiffness of the motor- spindle construction (C_D);
- combination of spindle with chuck (S_{ZP});
- implementation of the modular principle design (M).

In view of these requirements, an integrated search function in generating system R^n search space takes following form:

$$F_\omega = [\pm \omega; S_{OX}; C_D, S_{ZP}, M] \subset R^n \quad (2)$$

Specified target function F_ω is associated with genetic model of convergent type (Fig. 6).

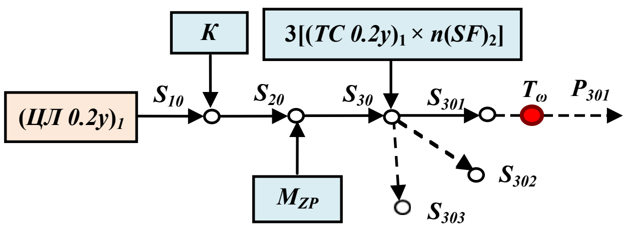

Fig. 6. Motor-spindle combined structure genetic model

Chromosome set of model S_{10}-S_{301} defines genetic complexity level and at the same time represents the genetic program of axisymmetric motor-spindle combined structure at object ($S_{301} \in T_\omega$) and population levels ($S_{301} \in P_{301}$). Combined third-generation chromosome S_{301} satisfies the given target function F_ω.

According to the analysis of genetic model is determined by the structural formula generates a combined third-generation chromosome S_{301}

$$S_{301} = \{[(CL\ 0.2y)_1: (CL\ 0.2y)_2] \times (K) \times (S_{ZP})_{OX} \times 3*[(TC0.2y)_1 \times n(SF)_2]:R_{OX} \subset F_\omega, \quad (3)$$

where: R_{OX} - replication operator at symmetry axe OX.

Synthesized version of M-S structure (Fig. 7), that corresponds to specified F_ω, contains the following set of basic units: spindle with clamping device(S_{ZP}); anchored in spindle chassis rotation motor stator$(CL\ 0.2y)_1$; combined with a spindle drive motor rotor $(CL\ 0.2y)_2$ and three ball bearing – $3*[(TC\ 0.2y)_1 \times n(SF)_2]$.

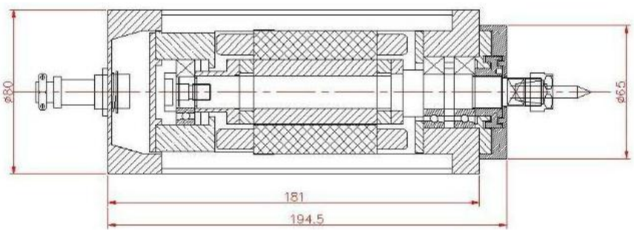

Fig. 7. Motor-spindle hybrid design construction, synthesized by structural formula combined isomeric chromosome S_{301}

Single structural representative genetic information availability opens the possibility of identifying genetic program of entire functional M-S class. Class program recognized through guaranteed consistent analysis of genetic susceptibility implementation of parental chromosomes to F_ω, within given search space R^n. Elemental basis of genetic program Q_F presents in the form of GC first big period homological series:

$$Q_F = (Q_{00}, Q_{02}, Q_{20}, Q_{22}), \quad (4)$$

where:

$$Q_{00} = (CL\ 0.0y;\ KN\ 0.0y;\ TP\ 0.0y;\ TC\ 0.0y); \quad (5)$$

$$Q_{02} = (CL\ 0.2y;\ KN\ 0.2y;\ TP\ 0.2y;\ TC\ 0.2y\ {}^3CL\ 0.2y;\ {}^3KN\ 0.2y;\ {}^3TP\ 0.2y;\ {}^3TC\ 0.2y); \quad (6)$$

$$Q_{20} = ({}^2CL\ 2.0x;\ {}^2KN\ 2.0x;\ {}^2TP\ 2.0x;\ {}^2TC\ 2.0x); \quad (7)$$

$$Q_{22} = (CL\ 2.2y;\ KN\ 2.2y;\ TP\ 2.2y;\ TC\ 2.2y;\ {}^2CL\ 2.2y;\ {}^2KN\ 2.2y;\ {}^2TP\ 2.2y;\ {}^2TC\ 2.2y). \quad (8)$$

Analysis of generating series (5-8) shows that structural diversity of the combined systems such as "motor- spindle" for a given F_ω, limited of 24 species, containing information of both the known and the genetically permissible species, still absent at present time of test class evolution.

Evolutionary experiments. Validation of synthesized genetic programs carried out by setting the evolutionary experiments. Staging of experiments carried out by the method of genome-historical analysis [10, 11], provides for certain structural-information correspondence between mechanical objects structures (bearings, planetary gear units, motor-spindles, etc.), created in the process of technological evolution, and the data corresponding to the genetic program.

Experimental results confirm the correctness and accuracy of genetic models and genetic programs. Results of patent-information searches also contain background information, necessary to identify the innovation potential of studied functional classes of axisymmetric type mechanical devices.

Genetic engineering concept. Developed methods of genetic programs recognition and decoding to technical objects, offer a fundamentally new approach to their design, which can be summarized by the concept of genetic engineering. Its theoretical basis is elemental and informational basis of genetic programs, methodology of genetic prediction and direct synthesis of technical objects (Fig. 8). Genetic programs act as systemic genetically valid diversity media about functional class particular structures. Distinctive property of this approach to design is guaranteed the completeness of information and its prediction feature that allows to manipulate information both towards the descendants objects already created in the process of technical evolution and in relation to genetically valid objects, but still missing at present evolution time [12].

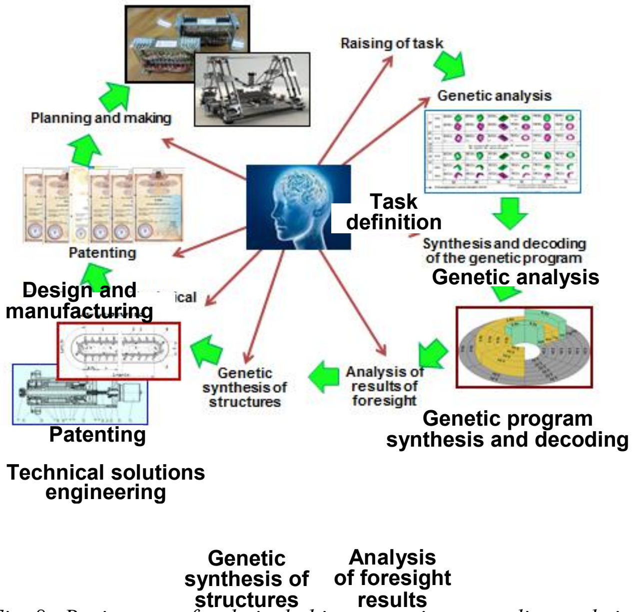

Fig. 8. Basic steps of technical objects creation according to their genetic programs

Practical testing of the genetic approach to challenges of new technnical objects design, based on analysis of their genetic programs, confirmed its high efficiency, especially in the early stages of search engine design. Using new technology, at this time created the world's first technical objects by their genetic codes.

CONCLUSION

For the first time nominated and confirmed scientific hypothesis about existence of a general structural-information basis in the structural diversity of electromagnetic and mechanical axisymmetric type systems. Proposed unified methodological approach to modeling of electromagnetic, mechanical and other axisymmetric systems, which creates real conditions for search automation design of complex technical systems, containing various genetic nature subsystems on given target function.

Results of evolutionary experiments confirm the veracity of working hypotheses and open up the possibility of horizontal transfer of knowledge between the technical disciplines. Any innovation, implemented within species S_E of some functional class F_E, is associated with homologue structure of some species S_M, belonging to the class of F_M. Challenge in this formulation contains a required element of genetic foresight and structural parallelism property in this case acquires the status of the united system homology.

Research results open up the possibility of interdisciplinary exchange of knowledge in the technical disciplines, enabling structural prediction and directed synthesis of complex technical objects on the basis of fundamental principles of information and structural inheritance, which has long used nature to create their own unique systems.

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