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THE PRINCIPLE OF HYBRIDIZATION IN THE STRUCTURAL ORGANIZATION AND EVOLUTION OF ELECTROMECHANICS OBJECTS

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Abstract: The systemicity of hybridization phenomenon is analyzed. This study summarizes the mechanisms of manifestation and forms of submission of the hybridization law, which determines the principles and boundaries of structure formation, taxonomy, methodology of synthesis and analysis of hybrid electromechanical objects at the intraspecies and intergenic levels of their structural organization. The results of the study are important for the further development of the theory of genetic evolution of technical systems.

KEYWORDS: Hybrid electromechanical objects, the law of hybridization, electromagnetic chromosomes, genetic code, the principle of crossing, chromosomal theory of hybrid structure formation, genetic evolution of electromechanics.

1 Introduction

One of the dominant trends in the evolution of complex technical systems is directly related to the creation and widespread use of hybrid objects, aggregates and complexes. In modern society it is difficult to find a branch of knowledge where the concept of hybrids is not beeing in use: from hybrid atomic orbitals to hybrid galaxies, from hybrid organisms in biology to hybrid phrases in linguistics, from hybrid computing systems to hybrid cloud technologies, from hybrid art forms in modern culture to hybrid wars. A sensational publication in 2018 in the journal Nature shows that the facts of hybridization also took place in the genealogy of ancient people, the consequences of which are manifested in the genomes of many modern populations of the Homo genus [1]. The widespread distribution of hybrids is explained only by their unique properties, in particular, the ability to multilevel hybridization with components of different genetic nature and the possibility of obtaining a new emergent effect, the signs of which are absent in the primary parental forms. The rapid spread of hybrids in technics and technology is also facilitated by the trend of increasing complexity of systems. Apriori, it can be argued that an arbitrary complex technical system in its structure is hybrid.

The experience of the development of natural science shows that the theoretical maturity of a certain field of knowledge is associated with its ability to consider not only the existing variety of objects, but also the diversity permissible in view of the fundamental laws of this science [2]. It took almost 100 years for the efforts of scientists from different fields of knowledge to conclude that the principles of heredity and the laws of genetic evolution are not limited to biological systems, but are systemic in nature [3-12]. A significant role in the further study of

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the common principles of organization and functioning of biological and technical systems was performed by cybernetics, which considers the general principles of control and communication in living organisms and machines [13 - 19]. An important result of structural and systemic studies of the modern period was the discovery of the periodic structure of the genetic classification of primary sources of the electromagnetic field, which confirmed the hypothesis that all the incredible variety of complex electromagnetic systems is realized from a limited number of primary forms endowed with invariant (genetic) information inherited by generations of descendant structures [20]. These laws are true for both systems of natural and anthropogenic origin.

The fundamental difference between technical evolution and biological is the dominant role of man-creator, who, through his inherent cognitive instinct, carries out the discovery and cognition of the fundamental laws of nature and performs the function of a repeater of genetic information in a number of generations of created objects of technology. Systems of arbitrary physical nature, the functioning and structural evolution of which is carried out on the basis of the principles of heredity and genetic variability are generalized by the concept of genetically organized systems (GOS). Modern studies are limited of the analysis of only fragments of the systemic phenomenon – the creation of separate varieties of hybrid electric machines [21-22].

Therefore, the question of what are hybrid technical systems, what are their principles of structure formation, remain open and constitute the subject of scientific discussions [23, 24]. The process of increasing the variety of hybrid technical complexes that combine components of different physical nature (mechanical, electromechanical, hydraulic, electronic, informational, biological, ...), which actually occurs in the absence of a systematic theory of their structure formation and methodology of interdisciplinary synthesis, necessitates their structural and systemic research and theoretical generalizations.

This study sets the problem of generalizing the mechanisms of manifestation and forms of submission of the hybridization law, which determines the principles and boundaries of structure formation, taxonomy, methodology of synthesis and analysis of hybrid electromechanical objects at the intragenic and intergenenic levels of their structural organization. The meaning of specific terms generally accepted in gos theory is given in correspondence with their definitions in the explanatory dictionary [25].

2 Analysis of research level of the principles of structure formation of electromechanical objects

An arbitrary complex system in its organization should be endowed with the required level of complexity, which is determined by its invariant structural and information basis. According to Y.A. Urmantsev's theorems, the systemic nature of GOS objects requires that they implement the basic laws of consistency, namely: (1) the law of polysystemicity (belonging of each object to n systems); (2) the law of polymorphization (belonging of each object to n sets of polymorphic modifications; (3) the law of conformity or parallelism (there must be a certain equivalence between any two arbitrarily adopted systems S1 and S2); (4) the principle of preservation of symmetry (there must be common elements of symmetry between genetically related systems) [5].

The results of fundamental research performed at the Igor Sikorsky Kyiv Polytechnic Institute's Department of Electromechanics theoretically proved and experimentally confirmed that electromechanical converters of energy (EMCE) belong to the class of natural-anthropogenic origin GOS, the structural organization and development of which are determined by the systemic laws of genetic evolution.

According to the results of structural and systemic research, for the first time in the technical sciences, the basics of the theory and methodology of genetic synthesis of hybrid electromechanical structures (EM-structures) were developed, which became a logical component of the general theory of genetic evolution of electromechanical systems [20]. The development of the theory of hybrid EM-structures was preceded by the discovery of periodic genetic classification (GC) of primary sources of the electromagnetic field (electromagnetic chromosomes), the definition of the principle of coding of genetic information and the universal structure of genetic codes, development of chromosomal theory of synthesis and analysis, scientific substantiation of the genetic nature of genus and type of electromechanical objects (EM-objects), experimental confirmation of the systematic and reliability of genetic principles of structure formation in GOS of natural and anthropogenic origin. Today, the theory of hybrid EM-structures is at the stage of its formation. Its provisions form the basis of the technology of genetic prediction of hybrids and are used in educational technologies, in the methodology of interdisciplinary synthesis of hybrid technical complexes, in the problems of building genetic systematics, creating genetic banks of innovations and knowledge bases. The systemic nature of the principles of heredity is confirmed by the results of their interdisciplinary analysis (Table 1). The absence of individual components in the theoretical basis of individual disciplines should be considered as a temporary phenomenon, which is associated with the absence of a generative system of elements [26]. Existing inconsistencies disappear if the periodic system of primary elements, which performs the function of a system-creation basis and acts as a form of presentation of specific principles of preservation and integral periodic law, is discovered.

Table 1. Systemic isomorphisms in genetically organized systems of natural and anthropogenic origin (fragment)

System-creation principles of GOS	Electromec hanics	Natural numbers	Byology	Chem istry	Linguistics	Music
Existens of own elemental basis	⊛	+	+	+	+	+
The principle of symmetry saving	⊛	+	+	+	+	+
Genetic information	⊛	⊛	+	+	?	?
Universal genetic code	⊛	⊛	+	+	?	?
Homology	⊛	+	+	+	+	+
Hybrydization	⊛	?	+	+	+	+
Horizontal homological serieses	⊛	⊛	+	+	?	+
Mutation	⊛	?	+	+	+	+
Isotopy	⊛	⊛	+	+	+	⊛
Isomery	⊛	+	+	+	+	+
Principle of parity	⊛	+	+	+	+	+
Structural mutation	⊛	+	+	+	+	+
Taxonomic categories	⊛	+	+	+	+	+
Genetic memory	⊛	⊛	+	+	+	?
Integral peridicity of elemental basis	⊛	⊛	?	+	?	+
Initial periodical system of primary elements	⊛	+	?	+	?	+

+ discovered or under discovering; ⊛ - discovered for the first time according to the results of the analysis of the generating system of primary sources of the electromagnetic field; ? – not discovered at present time of GOS evolution

The fundamental difference between electromechanics, which has in its scientific arsenal a generating system of primary electromagnetic elements, is the possibility of analyzing the system-creation principles of GOS in their systemic relationship. The systematic nature of the invariant principles of genetic structure formation (Table 1) explains the nature of isomorphisms and the cause of structural parallelisms in the evolution of both natural and artificial origin GOS [27].

According to the results of the analysis of GC, systemic deterministic relationships between the phenomenon of chromosomal isotopia and twins electromechanical structures, the principle

of parity of electromagnetic chromosomes and doubles EM-objects, the principle of topological invariantness of the elemental basis of subgroups and horizontal homological series, the principle of electromagnetic disimmetry of Pier Curie and the structure of small periods, structural isomerism and the principle of modularity of EM-objects, evolutionary processes of structural parallelisms and genetic nature of categories of Species and Genus. It should be notice that the detection of such isomorphic interrelated categories as genetic information, universal genetic code, genetic information, isotopy, taxonomic categories of Species and Genus, the phenomenon of genetic memory, horizontal homological series, etc., is possible only if a generative periodic system of primary elements of the corresponding physical nature exists.

The results of interdisciplinary research are important for the horizontal exchange of information and knowledge in GOS of different physical nature. It gives us the possibility of predicting structures, phenomena and relationships that take place in both natural and technical systems that are currently at different levels of their development and cognition. This conclusion received its next confirmation based on the results of interdisciplinary analysis of the generating systems of primary sources of the electromagnetic field and the system of natural numbers, which confirmed the hypothesis of their belonging to GOS and allowed to establish common principles of coding of genetic information, the structural analogy of their genetic codes and open a new form of representation of the periodic system of natural numbers [28].

The main provisions of the chromosomal theory of evolution of electromechanics objects were first summarized in the monograph of 2002 [19]. Models and methods of chromosomal hybridization of EM-structures, further development in the works of students and followers [28-31]. Its main provisions can be summarized by the following conclusions:

- hybrid EM objects have a genetic nature, because the basis of their structure determines the system-wide principle of crossing the original (parental) electromagnetic chromosomes, the genetic codes of which differ in the components of genetic information;
- the function of the systemic carrier of universal genetic codes of electromagnetic chromosomes to be crossed performs the periodic structure of the GC of the primary sources of the electromagnetic field (electromagnetic chromosomes);
- the systemic basis of the structure formation of hybrid EM-structures fulfills the principle of crossing the components of genetic information, which is modeled by the corresponding interbreeding operator in genetic synthesis procedures;
- the processes of structural hybridization are modeled at the chromosomal level of the structural organization of EM-objects;
- in accordance with the principle of genetic information saving, synthesized hybrid electromagnetic chromosomes perform the function of generative in relation to the corresponding hybrid Species of EM-objects;
- system carriers of information are genetic programs endowed with a predictive function in relation to genetically permissible hybrid classes of EM-structures;
- arbitrary hybrid chromosome performs the function of generative in relation to the corresponding Specie of hybrid EM-objects;
- hybridization processes can occur at different levels of structural organization of EM systems: chromosomal, intraspecific, intragenic, intergeneric and intersystemic levels;
- hybrid descendant structures are endowed with emergent properties, they contain new features that are absent in the original structures;

- the theoretical basis for the analysis and synthesis of hybrid EM-structures are genetic models of convergent type crossings and methods of genetic combinatorics;
- the reliability of the theoretical provisions of genetic structure formation and the evolution of hybrid EM objects is checked by the evolutionary experiments.

3 The law of hybridization and forms of its presentation

The logical confirmation of the systematic principles of genetic structure formation was the discovery of the law of EM-structures hybridization [20, 28]. Under hybridization we will understand the processes of structure formation, which are carried out on the basis of the principle of crossing electromagnetic chromosomes, differing in the components of genetic information in the structure of their universal genetic codes. Hybrid is an object, obtained by the results of crossing genetically different forms. The principle of crossing is one of the genetic mechanisms of multilevel structure formation in GOS, which removes taxonomic and functional restrictions on the formation of complex intersystem complexes that can combine structural and information components of different genetic nature. If the principle of crossing has a systemic nature, then the law of hybridization reproduces its specific (expressed in quantitative form) statement, which is true only to the primary elements of a particular physical nature. This fundamental difference is confirmed by the analysis of ontology of the law of hybridization within the framework of the chromosomal theory of genetic evolution of EM-systems (Fig. 1).

The analysis of ontology (Fig. 1) confirm the existence of deterministic relationships of the law of hybridization with the structure of periods and groups of GC, the principles of primary electromagnetic structures and information saving, the principle of coding of genetic information, the structure of universal genetic codes, the mechanisms of genetic structure formation and the variety of hybrid EM-objects arising in the process of human-controlled evolution of objects of technology. It should be notice that the dominant processes of crossing hybrid EM structures are usually implemented with the direct participation of other operators of genetic synthesis: replication, inversion, crossingover and mutation.

The principle of crossing is determined by the structure of the genetic codes of electromagnetic chromosomes. The universal genetic code of an arbitrary chromosome contains a sequence of three components of genetic information that determine the generic geometry, electromagnetic symmetry and topological properties (connectivity and orientation) of an arbitrary primary source of the electromagnetic field. Generic geometry has the status of generalized in relation to local geometry of EM-objects Species, included in the structure of the Genus. The local geometry of the Species is determined by the signs of the corresponding topological space (the second component of the genetic code).

The components of genetic information uniquely determine the structure of the active zone of an arbitrary EM-object – its spatial geometry and the topology of the active surface, the electromagnetic symmetry of the poleotic system and the spatial structure of the magnetic field, the presence of longitudinal and transverse final electromagnetic effects, etc. (Fig. 2).

The enetic code is actually the quintessential periodic law and acts as a carrier of invariant genetic information of the primary source of the electromagnetic field, which remains unchanged in a number of generations-descendants.

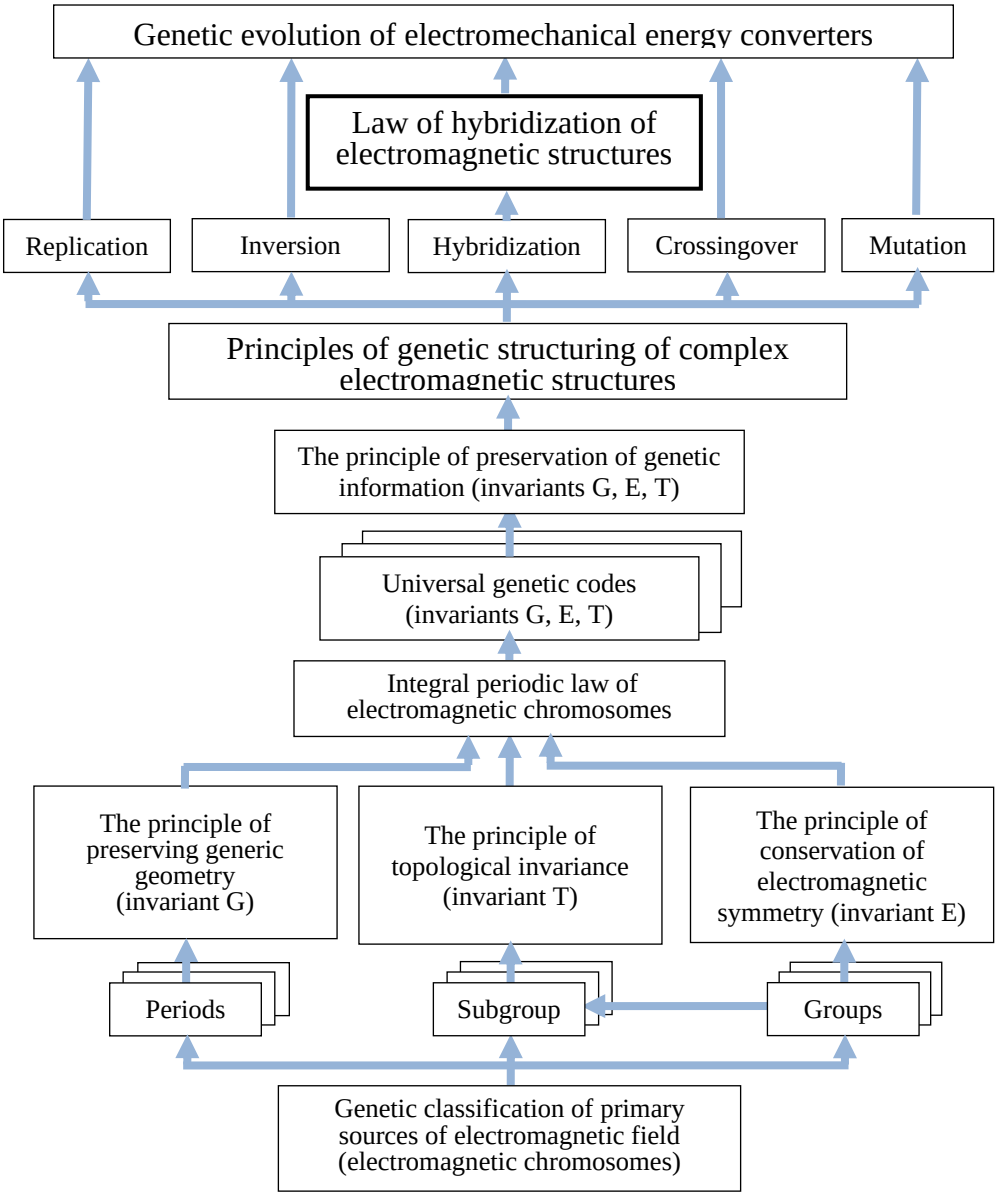


Fig. 1 Ontology of the law of hybridization in the theory of genetic evolution of electromechanical systems

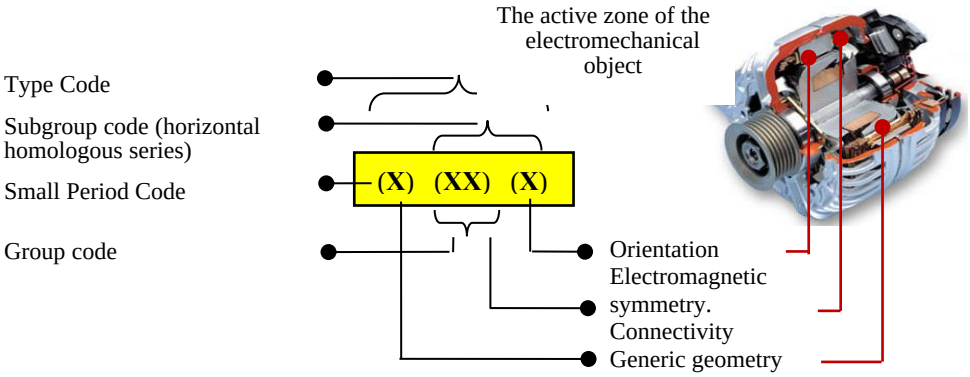


Fig. 2 The relationship of the components of the genetic information of the universal genetic code of the electromagnetic chromosome with the structure of taxones, groups, subgroups and periods of the GC and the structure of the active zone of the EM-object

At the intraspecific level, hybrid structure formation is modeled through the mechanisms of crossing primary and secondary electromagnetic chromosomes. Primary chromosomes are arranged by the periodic structure of the GC and have the status of parental chromosomes. In general case, the physical condition, genetic nature, structure and components of information of secondary chromosomes may have significant differences in comparison with primary chromosomes. In the vast majority of secondary chromosomes perform the function of moving, in relation to primary, for example:

$$(PL\ 2.2y)_1 \times [(CL\ 0.2y)_2 : M_R]_2, \quad (1)$$

where: $(PL\ 2.2y)_1$ and $(CL\ 0.2y)_2$ are genetic codes of primary and secondary moving electromagnetic chromosomes accordingly; M_R is operator of structural mutation of secondary chromosome.

The structure formula (1) corresponds to the design of the first hybrid electric motor particulary. The electromagnetic motor with an explicit flat inductor was created by Charles Whitston in years 1841-1845 [33]. The motor was used for electromagnetic transportation of cylindrical steel blanks. In the genetic evolution of electromechanics Whitston's unique motor serves as archetypes of the Genus of flat electric machines, a class of special motors with electromagnetic reduction, functional classes of electromechanical systems for the direct implementation of technological processes and is also the first representative of the class of intraspecific hybrid EM-structures-mutants.

Genetically permissible crossings at the intragenic and intergenic levels are determined by the law of hybridization, the mathematical basis of which is determined by the rules of combinatorics, taking into account the type and number of components of genetic information to be crossed. By the number of components of genetic information crossed, there are mono-, di- and polyhybrid crossing. As well known, this terminology of the mechanisms of crossing in biology was first introduced into scientific circulation by Gregor Mendel. But similar variants of crossings occur for arbitrary pairs of electromagnetic chromosomes. For their analysis, we will accept the following restrictions:

- crossing between two arbitrary primary chromosomes ($N_C = 2$) that have differences in the structure of genetic codes are analyzed;
- the space of crossings is limited to the elemental information basis of the first large period of the GC;
- does not take into account the space of crossings at the level of electromagnetic chromosomes-isotopes;
- intraspecific crossings that require independent systemic and genetic analysis are not considered.

The procedure of hybridization for an arbitrary pair of electromagnetic chromosomes can be represented by an expression

$$C_A \times C_B \subset H_{AB}, \quad (2)$$

where: C_A and C_B – parental electromagnetic chromosomes to be crossed ($C_A \neq C_B$); H_{AB} – hybrid chromosome.

Genetic information of C_A and C_B chromosomes can be represented by universal genetic codes:

$$C_A = (a_1, a_2, a_3);\ C_B = (b_1, b_2, b_3), \quad (3)$$

where: $a_1, a_2, a_3; b_1, b_2, b_3$ – components of genetic information in the structure of the universal genetic code, which may have partial or complete non-immolation.

The mechanisms of monohybrid crossing allow the synthesis of the following three classes of hybrid structures:

- geometric (spatial) monogibrides of the class *G*:

$$H_G = (a_1) \times (b_1) \subset \boldsymbol{G}, \quad (4)$$

The structures of geometric monogibrids can be formed only by the results of intergeneric crossing of homologous chromosomes, which have identical second and third components of genetic codes ($a_1 \neq b_1; a_2 = b_2; a_3 = b_3$).

- electromagnetic monogibrids of the class E:

$$H_E = (a_2) \times (b_2) \subset E, \quad (5)$$

Electromagnetic monohybrides can be synthesized only at the intragenic level by crossing chromosomes with identical generic geometry and orientation, but with a different group of electromagnetic symmetry ($a_2 \neq b_2; a_1 = b_1; a_3 = b_3$).

- topological monogibrids of the class T:

$$H_T = (a_3) \times (b_3) \subset T, \quad (6)$$

Topological monohybrid structures are formed by the results of intragenic crossing of electromagnetic chromosomes, which belong to the same group and differ only in topological sign of orientation ($a_3 \neq b_3; a_1 = b_1; a_2 = b_2$). Since the topological feature of orientation is directly related to the principle of parity of primary sources of the electromagnetic field at the chromosomal level and the structures of EM-objects-doubles at the object level, topological monogibrids are also called doubled.

Similarly, the results of digybrid crossing give rise to the following three classes of digybrid EM-structures:

- geometric-electromagnetic type digibrides ($a_1 \neq b_1; a_2 \neq b_2; a_3 = b_3$)

$$H_{GE} = [(a_1 \times b_1), (a_2 \times b_2)] \subset GE, \quad (7)$$

Dihybrid structures of geometric-electromagnetic type are the result of intergeneric crossing of two arbitrary chromosomes, which belong to different groups of symmetry, but have identical electromagnetic orientation.

- digibrides of geometric-electromagnetic type ($a_2 \neq b_2; a_3 \neq b_3; a_1 = b_1$):

$$H_{ET} = [(a_2 \times b_2), (a_3 \times b_3)] \subset ET, \quad (8)$$

Hybrid structures of class ET can be synthesized only by the results of intragenic interbreeding of two chromosomes with different type of orientation, which belong to different groups of electromagnetic symmetry.

- digibrids of geometrically-topological type ($a_1 \neq b_1; a_3 \neq b_3; a_2 = b_2$):

$$H_{GT} = [(a_1 \times b_1), (a_3 \times b_3)] \subset GT, \quad (9)$$

Geometric-topological EM-structures are the result of intergenerational crossing of electromagnetic symmetric chromosomes with different type of orientation. The *GT*-class hybrids area of existens is limited only of chromosomes belonging to two groups of electromagnetic symmetry of 0.0 and 2.2.

According to the results of crossing ($a_1 \neq b_1; a_2 \neq b_2; a_3 \neq b_3$), only one class of polyhybrid-type structures is formed, the parent chromosomes of which will have differences in all components of genetic information

$$H_{GTE} = [(a_1 \times b_1), (a_2 \times b_2), (a_3 \times b_3)] \subset GTE, \quad (10)$$

The crossing mechanism (10), which determines the structural potential of the *GTE* polygibride class belongs to the scenario of genetically distant crossing, which can be implemented provided that the crossed chromosomes *A* and *B* are non-homologous and have different generic affiliations and differ on the basis of electromagnetic orientation.

Formulas of structuring (4 - 10) exhaust the genetically permissible by law combinatorics of crossing the components of genetic information (for $N_C = 2$), determine the quantitative composition, establish the structure of relations between classes of mono-, di-, and polyhybrid EM-objects and form a symbolic form of submission of the law of hybridization of electromagnetic chromosomes.

Genetically permissible variants of combinatorial structure formation of hybrid classes of EM-structures (4 - 10) can be summarized by the following definition: "According to the results of crossing of two arbitrary electromagnetic chromosomes, the genetic codes of which differ in the components of genetic information, one of the seven permissible variants of hybrid chromosomes of the first generation with a genotype ratio of 3:3:1 is formed, which perform the function of generative for the corresponding 7 classes of hybrid EM objects-descendants: three classes of monogibrids (*G, T, E*), three classes of digibride objects (*GT, GE, ET*) and one class of polygibrids (*GET*)." This verbal form of submission of the law is invariant to the species and generic affiliation of the parent chromosomes, their genetic codes, the time of evolution, structural complexity and functional affiliation of objects-descendants that satisfies the status of the law. It is not difficult to notice the presence of systemic isomorphic parallels of this law in relation to the law of independent combination of signs of biological hybridization of Gregor Mendel, the law of multiple relations of John Dalton in the chemistry of compounds, the principles of chord synthesis in music theory and models of hybridization of electronic orbitals of Linus Pauling atoms.

The space of hybrid structure formation can also be represented by a symmetric matrix (Table 2), which determines the combinatorics and type of genetically permissible crossings by the number and type of components of genetic information.

The main diagonal of the matrix reproduces the genetically permissible classes of hybrid EM-structures. Each hybrid chromosome performs the function of generative in relation to the corresponding Specie of hybrid EM-objects, the diversity and power of which in structural evolution will be determined by the genetic predisposition of crossing chromosomes their ancestral affiliation and imposed restrictions.

Matrix way of presenting of the law (Table 2) reproduces the relationship between the ratio of mono-, di- and polyhybrid classes, the number and combinatorics of the crossed components of genetic information ($m = 1.2.3$), the level of complexity and generalized systemic properties (spatial geometry, electromagnetic symmetry and topology) of hybrid chromosomes that determine the quantitative composition and hereditary characteristics of hybrid structures-descendants.

The process of structuring hybrid classes of EM-structures can be represented graphically using a three-level genetic model of crossing (Fig. 3). The genetic model determines the hierarchy of levels of structural and information complexity of hybrids and visualizes the combinatorics of the mechanisms of mono- and polyhybrid crossings of the components of genetic information.

Table 2 Matrix of space of permissible crossings for two arbitrary electromagnetic chromosomes

Components of genetic information of chromosome B		Components of genetic information of chromosome A						
		$m = 1$			$m = 2$			$m = 3$
		a_1	a_2	a_3	a_1,a_2	a_2,a_3	a_1,a_3	a_1,a_2,a_3
$m = 1$	b_1	***G***	0	0	0	0	0	0
	b_2	0	***E***	0	0	0	0	0
	b_3	0	0	***T***	0	0	0	0
$m = 2$	b_1,b_2	0	0	0	***GE***	0	0	0
	b_2,b_3	0	0	0	0	***ET***	0	0
	b_1,b_3	0	0	0	0	0	***GT***	0
$m = 3$	b_1,b_2,b_3	0	0	0	0	0	0	***GET***

where: m – number of crossing components of genetic codes; 0 – components of genetic information of genetic codes that are not subject of crossing

The graphic form of submission of the law of hybridization of EM-structures can also be represented by a three-level Venn diagram (Fig. 4). The diagram visualizes the permissible zones of intersection of the three finite sets of crossed electromagnetic chromosomes. The combinatorial space of the structure formation of permissible classes of hybrid objects in the diagram is represented by three outer zones of monogibrids (*G, T, E*), three zones of double section, which simulate the corresponding classes of digibride-type structures (*GT, ET, GE*) and one triple-section zone that corresponds to a set of polygibrid class structures (*GET*).

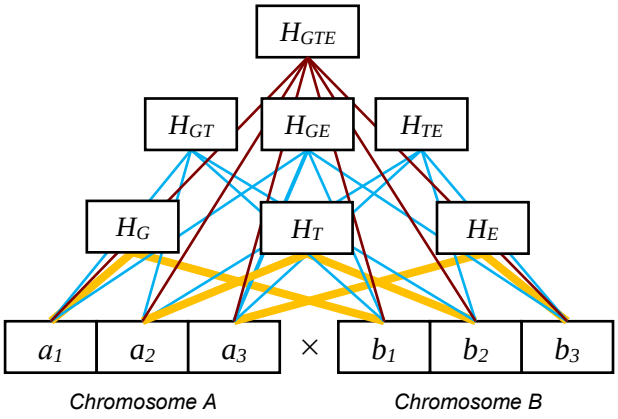


Fig. 3. Graphical interpretation of the space of admissible crosses for two arbitrary electromagnetic chromosomes

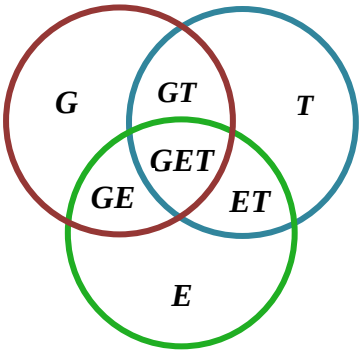


Fig. 4. Graphic representation of the law of hybridization of EM-structures by using the Venn diagram

The Venn diagram illustrates the structure of genotype relationships (3:3:1) between the legal classes of hybrid EMCE and also determines the level of complexity and systemic relationships between the finite sets of mono-, di- and polygibrids.

4 Hybridization within the arbitrary Genus of electromechanical structures

The law of hybridization of electromagnetic chromosomes provides a high level of predictability and orderliness in the mechanisms of structure formation of hybrid compositions, which opens up the possibility of transition from intuitive to formalized and predictable scenario of synthesis of hybrid EM-structures. According to the affiliation of the crossed electromagnetic chromosomes to the corresponding Generuses and Species in the structure of the GC the procedures for hybridization of structures are divided into intraspecific, intragenetic and intergenetic. The quantitative composition and genetic structure of hybrid Species within

the classes of hybrid objects determined by law will be determined by the location (coordinates) of the original chromosomes in the periodic structure of the GC.

Analysis of the genetic model of intragenic crossings (Fig. 5) shows that the permissible variety of hybrid chromosomes within the arbitrary Genus (geometric class of primary sources of the magnetic field) G_i is limited of 15 hybrid chromosomes.

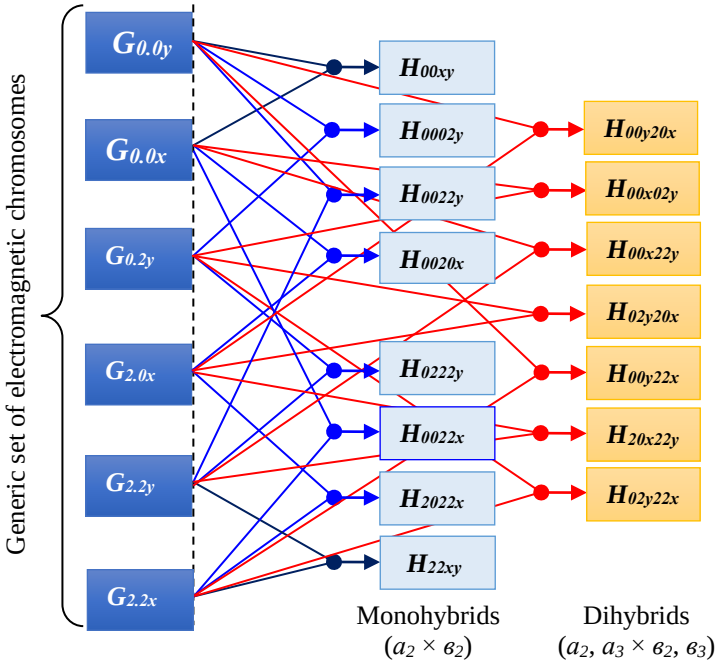


Fig. 5 Generalized genetic model of the space of permissible chromosomal crossings within the arbitrary Genus of electromechanical objects

According to the number of crossed components of genetic information the generic set of hybrid chromosomes C_G contains two subclasses:

$$C_G = (H_m + H_d) \subset G_i, \tag{11}$$

where: H_m, H_d – electromagnetic chromosomes of mono- and digibride type accordingly:

$$H_m = [0.0(x\times y);\ (0.2\times 0.0)y;\ (2.2\times 0.0)y;\ (2.0\times 0.0)x;\ (2.2\times 0.0)x;\ (2.2\times 0.2)y;\ (2.2\times 2.0)x;\ 2.2(x \times y)] \subset [E;\ T] \tag{12}$$

$$H_d = [(2.0x\times 0.0y);\ (2.2x\times 0.0y);\ (0.2y\times 0.0x);\ (2.2y\times 0.0x);\ (2.0x\times 0.2y);\ (2.2x\times 0.2y);\ (2.2y\times 2.0x)] \subset [ET] \tag{13}$$

It is quite logical that there are no structures in generic chromosomal sets (12, 13) with hybrid geometry of the active zone (representatives of the classes of monogibrids G, geometrically-topological and geometrically electromagnet types of digibrides GT and GE as well as GET polyhybrides) the principles of structure formation of which are determined by the mechanisms of intergeneric crossing only. Consequently within the arbitrary Genus G_i the formation of 8 monohybrid and 7 digybrid Species of EM-structures is allowed. Based on the principle of parity (the identity of the group of electromagnetic symmetry and spatial geometry in the structure of crossed features) hybrid chromosomes of the arbitrary Genus G_i contain 3 generating structures of the class of topological (double) H_{xy} hybrids represented by two subclasses of topological monogibrids T and one subclass of electromagnetic topological digibrides ET:

$$H_{xy} = [0.0(x\times y);\ (2.0x\times 0.2y);\ 2.2(x \times y)] \tag{14}$$

Generic sets of hybrid chromosomes represented by structural formulas (12) and (13) serve as a macrogenetic program of hybrid EM-objects of the intragenic level (classes *E*, *T* and *ET*), which is endowed with an explicit predictive function.

If the final set of intrageneric crossings is limited of 6 Generuses of the first large period of GC then the combinatorics of intergenerational crossing is determined by 15 intergeneric combinations. Intergeneric crossings determines the principles of structure formation and the Species composition of four hybrid classes of EM-structures: *G*, *GE*, *GT* and *GTE*. A common feature of these hybrids is the presence of dominant crossing on the basis of spatial geometry (the first component of genetic codes), which is allowed only by the mechanisms of intergeneric hybridization. At present a detailed genetic analysis of the mechanisms of crossing within all classes determined by law has been carried out. As an example at Fig. 6 a model of the space of intergeneric crossing, which determines the Species diversity of polygibrids of the *GTE* class, is shown. Polygibrids of this class are representatives of a genetically distant crossing scenario, which can be implemented only if chromosomes *A* and *B* are non-homologous, have different generic affiliations and differ in topological sign of electromagnetic orientation.

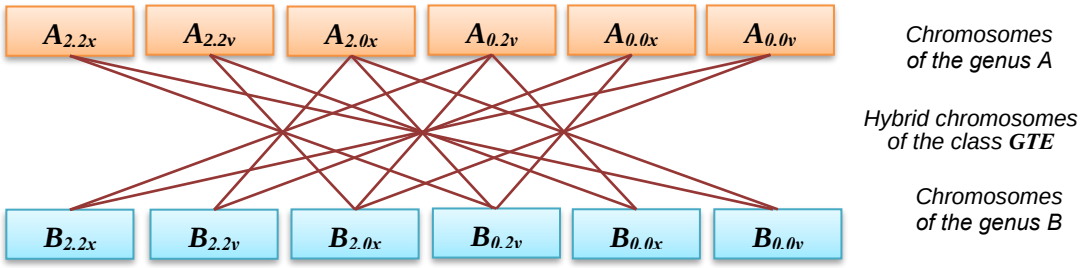


Fig. 6. Generalized genetic model of the space of intergeneric crossings (for arbitrary two Genus *A* and *B*) in the structure formation of *GTE* class of polygibrids

The results of the analysis of intrageneric and intergeneric crossings opened the possibility of obtaining complete information on the quantitative composition of genetically permissible hybrid Species of the basic level (N_H) within the framework of the hybrid classes of EMCE defined by law (Fig. 7).

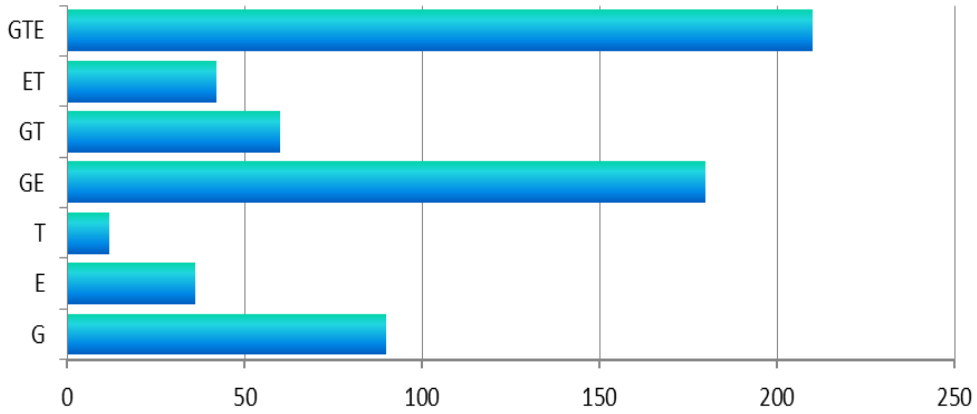


Fig. 7 Quantitative composition of genetically permissible Species within the genetically determined by law classes of hybrid electromechanical energy converters

5 Evolutionary experiments

The reliability of genetic principles and models of hybrid structure formation and their compliance with the real processes of technical evolution of electromechanics objects was tested based on the results of evolutionary experiments.

The implementation of experiments was carried out according to the programs of genomic-historical and evolution-predictive experiments [34]. The genomic-historical part of the experiments was determined on the basis of genetic analysis of data from patent information studies (according to the classical scenario of observed evolution T_E = 76 years, the number of evolutionary events N_E = 46) within the classes of hybrid EM-objects determined by law. The results of the experiments confirmed the presence in technical evolution of representatives of all seven classes of hybrid EM-objects defined by law and determine their Species composition (Fig. 8).

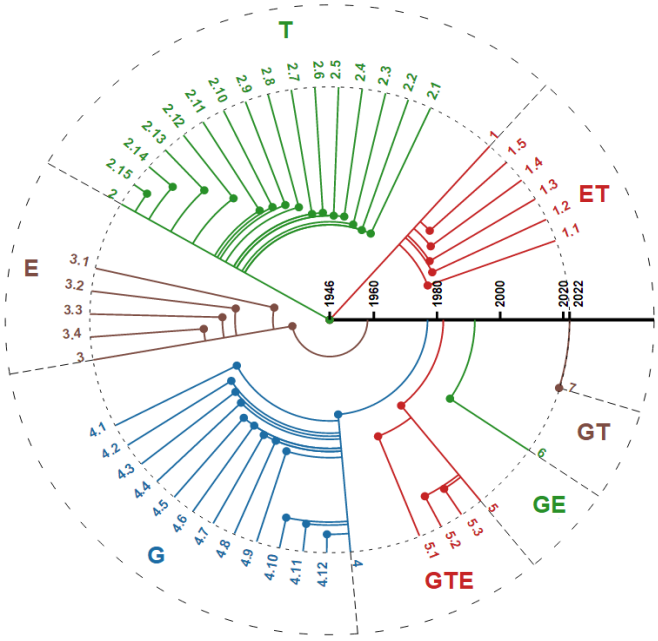


Fig. 8. Phylogenetic diagram of technical evolution of classes of hybrid EM-objects (T_E = 175 years; N_E = 46)

The implementation of the program of evolutionary-predictive experiments was carried out on the basis of technical solutions, the hybrid structures of which were first identified and synthesized based on the results of genetic prediction with their subsequent technical development and patenting, which is equivalent to their purposeful introduction into technical evolution (implementation of the scenario of controlled structural evolution over the period of years 2010 – 2020) [31, 35]. The results of evolutionary experiments confirm the reliability of the principles and models of chromosomal structure formation of hybrid EM-objects-descendants and the technology of genetic prediction of their new Species and classes.

According to the results of experiments it was established that at the current level of evolution of electromechanics objects are dominated by structural representatives of monohybrid (*G, T, E*) and digibride (*ET*) Species, the structures of which are characterized by simplicity of technical implementation and the presence of a stable emergent effect. Despite the significant spread of hybrid objects, the technical evolution of electromechanics objects involves no more than 5% of the species composition of the genetically permissible structural potential of hybrid Species.

CONCLUSION

The progressive variety of technical objects and systems of hybrid type is a natural direction of structure formation in the evolution of genetically organized systems of both natural and anthropogenic origin. The mechanism of hybridization is an integral part of the process of structuring in the evolution of EM-systems at all levels of their genetic complexity. For the first

time, the boundaries of the correct use and form of submission of the law of hybridization of electromagnetic structures have been established, which establishes a deterministic relationship between invariants of genetic information (genetic codes) of electromagnetic chromosomes to be crossed and the final set of hybrid classes of EM-objects. Genetically permissible classes of hybrid EM-structures are determined and systematized and for the first time the quantitative composition of Species and Generic affiliation of hybrid EM-objects are determined, which ensures their predictability and orientation of algorithms of genetic synthesis. The reliability of genetic models and scientific provisions of the chromosomal theory of hybridization is confirmed by the formulation of evolutionary experiments, the results of which identified structural representatives of hybrid classes determined by law. Structural evolution of electromechanics objects is carried out only within those classes that are genetically determined by the law of hybridization. The evolution of hybrid EM systems is determined by two factors: internal (genotypic), which establishes the boundaries, mechanisms and structure of genetically permissible crossings and external (phenotypic), which is determined by the technical and economic efficiency of their practical application. Currently, the technical evolution of electromechanics, the vast majority of hybrid types of EM-structures have the status of implicit, and their research and adaptive technical evolution are still waiting for their researchers. The results of the study are important for the further development of the theory of evolution of genetically organized systems, improvement of predictive technology, development of genetic systematics of hybrid electromechanical objects, creation of genetic banks of innovation and development of methodology of interdisciplinary synthesis of complex technical systems.

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