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GENETICAL MODELING, AND EXPERIMENTAL ANALYSIS OF THE FUNCTIONAL EVOLUTION OF ELECTROMECHANICAL ENERGY CONVERTERS

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Abstract

Generating mechanisms and development laws of functional types of electromechanical energy converters are considered in the article. Authors offer the multilevel phylogenetic model for the analysis of functional evolution at the certain species level. The interrelation between the genetic program and functional evolution of electromechanical objects is shown by the example of the planar electromechanical energy converters. Comparison of the modeling results with evolutionary experiment is presented in the paper. Authors give the recommendations about the use of the research results in the tasks of creation of genetic data-banks of innovations, and in the tasks of genetic foresight of new types of energy converters.

Keywords: electromagnetic chromosome, electromechanical energy converters, evolution, evolutionary experiment, function, genetic code, genetic program, phylogenetic model, species, structure.

1. INTRODUCTION

Under conditions of progressive technical objects diversity, one of the key tasks of the science is to study the engineering development laws, i.e. to find, and describe specific characteristics of the technical systems changeover from the previous generations to new models, and generations. Today, there is no more doubt in the fact that technical systems, as well as the systems of natural origin, belong to the class of evolutionary systems. It becomes evident that ignoring of heredity principles and development processes in the projecting process of complex technical systems eventually results in creation of unsustainable or nonviable systems. Therefore, the tasks of learning, and experimental verification of genetic development laws of technical objects are one of the most actual scientific problems in technical sciences, which solving defines the strategy of the changeover from the observed evolution of the technical systems to the managed use of their innovation potential.

One of the main provisions of the genetic theory of complex systems development was realizing that a species was a fundamental category in evolution of both biological, and anthropogenic systems. The species problem is still one of the key, and the most complex problems not only in biology, but also in other scientific disciplines, which theoretical basis is represented with the fundamental provisions of genetic evolution theory [1].

Genetic nature of electromechanical systems (EM-systems), and their direct relation with elemental basis of the Generating periodic system of electromagnetic elements for the first time became scientifically proven only after discovering of the Genetic classification (GC) of the primary electromagnetic field sources, and development of theoretical basics of the genetic evolution theory of electromagnetic, and electromechanical energy converters (EMEC) [2]. The genetic evolution theory also presents theoretical, and experimental approval of existence of basic species, twin species, and sibling species in the EMEC technical evolution. The most important results of the recent evolutionary research represent the scientific ground of direct relation between the species diversity of human created electromechanical objects, and their genetic programs [3-6], the genetic programs, in their turn, are defined by elemental basis of Generating periodic systems. For the first time there were investigated, and experimentally proved the stable hereditary relations between generating electromagnetic structures (primary chromosomes), their genetic codes, species concept, and historically existing functional classes of EMEC.

Numerous evolutionary experiments, performed with objects of electromagnetic, and electromechanical origin (EM-objects, verified the genetic nature, and high structural order in the diversity of the created objects. The genetic nature of the EM-objects is identified by the elemental basis of Generating periodic system [7]. The next steps in the hereditary research were genetic programs interpretation, and development of genetic foresight methods of new species, and structural classes of EM-objects [8]. Practical approbation of the structural foresight technologies for different levels (object, species, and system levels) was successfully performed in the numerous innovation projects

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in Structural Electromechanics [9, 10], and in Mechanics [11]. The results of interdisciplinary analysis of the above mentioned laws allowed to ground the hypothesis that the structural evolution of anthropogenic systems is genetically universal, and predictable [12].

Technical system evolution has specific functional direction, which is defined by the need to solve daily problems of society, and is realized by human. Evolutionary processes occur simultaneously at all levels of the technical system structural organization – from object to system level. In genetically organized systems, the problem of interrelations between structure, and function has its specific character. The structural evolution is genetically predictable, because it is defined by the laws of electromechanical energy conversion, and their genetic programs. The functional evolution, in its turn, is undetermined, because it is defined by the time-dependent problems, and consequently to different set of specific requirements, and limitations, restricting its function. Therefore, the research of interrelations between the genetic structurization programs, and evolutionary functional species of EM-objects is a new, and actual scientific-and-practical task.

This article, for the first time, considers the phylogenetic approach to the modeling of evolutionary processes. This approach enables the simultaneous analysis of interrelation between the genetic programs (genetically acceptable structural potential) and expanding diversity of EMEC functional classes. Finding of the structural and functional correspondence is a key to solve the problems of the EM-objects structural foresight, and innovation projecting.

2. PHYLOGENETIC MODEL

The laws of evolutionary process are directly connected with the structural-and-functional interrelations of evolutionary system. Structural, and functional components of evolution of certain class of EMEC are interconnected. These two components represent two sides of the same evolutionary process. Such processes are investigated using phylogenetic models. E. Haeckel introduced the term “phylogenesis” in scientific use in 1886. As is known, it is translated from Greek as “genus”, “tribe”, and “origin”, which means historical development of both individual species, and systematic groups, and organic world in whole. The presence of systems concept in genetic organisation, and development of natural, and anthropogenic systems allows to spread the phylogenesis concept on evolutionary classes of EMEC also. Depending on the modeling purposes, phylogenetic models could be structural, functional or structural-and-functional.

In general, a sequence of levels of structural-and-functional organization of EMEC functional classes could be represented as follows: “Generating periodic system of electromagnetic elements (GC)” → “Parental chromosome” → “Species genetic program (genome)” → “Species generating object (archetype)” → “Population of object” → “Species” → “EMEC Genus”. Every level has its certain type of structural-and-functional correspondence (Table 1).

Hierarchical sequence of the levels is a representation of the general system inheritance principle in genetically organised systems. The hierarchical sequence of the levels also illustrates the relations between the GC elemental basis, the species formation concept, and expanding diversity of EMEC functional classes.

Table 1

Interrelation between the Genetic Structural Organisation Levels, and Functional Diversity of EMEC

Structural Organisation Level	**Type of Structural, and Functional Correspondence**
Parent chromosome	Genetic predisposition
Species genome (genetic program)	Genomic adaptation
Generating object	Structural adaptation
Object population	Diversity of functional alternatives
Species	Set of functional species
EMEC Genus	Set of functional types, compliant with the certain target function F_t

Above mentioned law was assumed as a basis of phylogenetic model for the species functional structure (Fig. 1). That has provided the universality, i.e., applicability to basic species, twin species, pair type species, and hybrid species of EMEC.

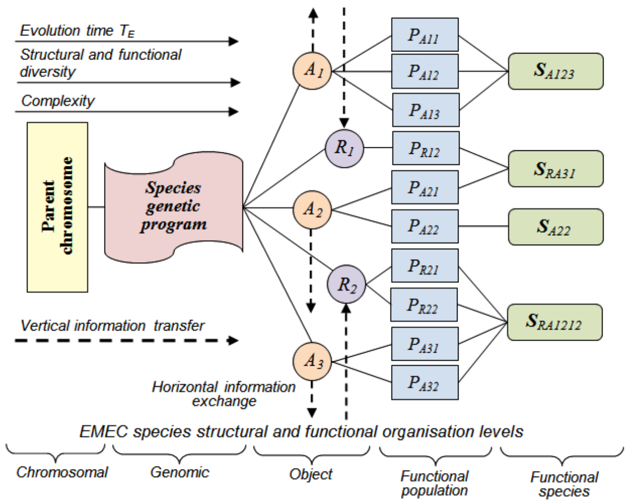

Fig. 1. *Generalized genetic model of EMEC functional evolution at the specific level: A_1, A_2, A_3 – Functional population archetypes; R_1, R_2 – Generating objects with imported information; P_{A11}, P_{A12}, ..., P_{R12}, P_{R21}, ... – Functional populations; S_{A123}, S_{RA31}, S_{A22}, S_{RA1212} – Functional species.*

The model (Fig. 1) represents succession between hierarchical levels, and satisfies with saving principle of generating electromagnetic structure (parental chromosome) genetic information.

Every structural representative of the certain functional level saves the genetic information of its parental chromosome. The objects of every superior level contain information of the previous one. The above mentioned law is informationally provided by vertical transfer of hereditary information. At the specific level it is generalized by the species form stability law. This law rules the species formation processes in genetically organized evolutionary systems of natural-and-anthropogenic origin. In Structural Electromechanics this law is represented by saving the genetically defined limits of morphogenesis, and structurization of certain species under conditions of progressive functional evolution of its structural representatives.

Presence of two genetic information transfer mechanisms in genetically organized evolutionary systems (vertical – hereditary, and horizontal – interspecific), gives three possible scenarios of generating objects formation, and the next functional evolution of the species populations:

- the structural adaptation using own archetypes (vertical information transfer);
- transfer of significant functional signs to correspondent genetically predisposed species structure with generation of translational type object (horizontal, interspecific, and intersystem mechanisms of information interchange);
- structural, and functional diversity, formed by the first scenario, eventually becomes a source of information for its subsequent transfer to other relative species.

It is possible to find only generating objects in the process of real technical evolution, and their subsequent improvements (equivalent to structural, and functional populations) may be selectively observed (within available information). Until recent time every other level stayed hidden, because of lack of EMEC genetic evolution theory.

The space-and-time structure of the certain species is represented with multilevel sequence, showing hierarchy of genetically stipulated organization levels of EM-objects functional diversity:

- Chromosomal level is represented with parental electromagnetic chromosome, which genetic information defines the existence limits of the considered species;
- Genomic level is represented with the finite set of paired electromagnetic chromosomes, containing the species genetic program;
- Object level (level of generating objects) is represented with own archetypes (A_1, A_2, …, A_n), evolutionary occurred within the studied species, or with generating objects (R_1, R_2, …, R_m), historically occurred as a result of horizontal information transfer from other related species with earlier functional evolution;
- Population level is represented with functional populations (P_1, P_2, … , P_K);
- Functional types level, combining functional populations into S_{Fi} functional types.

The set of functional species, compliant with generalized target function of the class, forms the concept of EMEC functional class:

$$\left(S_{F1}, S_{F2}, \ \ldots, S_{FN}\right) \subset K_F \qquad (1)$$

The category of functional classes in the hierarchical levels structure refers to the System (supraspecific) organization level of EMEC. For example, the class of traction motors represents a functional diversity of certain set of species at the basic taxonomic level: CL 0.2y; KN 0.2y; TP 0.2y; PL 2.0x; PL 2.2x, and others, compliant with the requirements of traction EMEC.

New species generation, and their subsequent development is accompanied with the processes of transfer, exchange, and transformation of both genetic and acquired (imported) information. Data flow analysis of phylogenetic model (Fig. 1) allows to identify three possible scenarios of the species functional evolution generation, and development:

- in the process of hereditary functional adaptation, and technical improvement of generic archetype (genetic information vertical transfer);
- due to horizontal information transfer from the objects (archetypes) of related species;
- as a result of structural foresight, based on genetic program identification, and interpretation with subsequent introduction into generating objects evolution by the defined target function.

Two former ways are traditional for real (observed) evolution of EMEC. At the level of functional populations, the first mechanism prevails. This mechanism is associated with intraspecific genetic modifications, and numerous technical improvements within the invariability of generating structure. Discovery of new species occurs in a latent form (as opposed to biology, the fact of the species discovery is not documentary recorded in invention practice) by the horizontal information transfer to a new space forms of the magnetic field sources. Such species are called latent. Realization of the third scenario became possible only using the structural foresight technologies (managed evolution) based on EMEC genetic programs identification, and interpretation [4, 12].

3. EXPERIMENTAL RESULTS. POLYFUNCTIONAL NATURE OF SPECIES

Validation of theoretical provisions on polyfunctional nature of taxonomic species was performed experimentally by the example of PL 2.2x basic species of planar EMEC. The experiment involved more than 2000 objects, representing full time interval of their functional evolution (Fig. 2).

The following assumptions were made in the experiment:

- selection, and classification of genetically identified species objects was performed by its main function;
- functional population was presented by its generating object;
- integration of populations into functional types was performed by criterion of functional similarity;
- the beginning of functional evolution was defined by the priority date of generating object.

Evolution time of electrical machines with running magnetic field wave is: T_E = 185 years, and it almost coincides with the evolution time of technical Electromechanics.

Practical realization of the experiment was based on the patent-information analysis, with subsequent identification of EM-objects genetic code, and their generic definition. The results of the patent-information source analysis represent that more than 60 micro-evolutionary events, described by functioning area commonness, presence of archetypes (generating objects), and evolution time (Fig. 2) were found. Species phylogenetic model represents real (documentary supported) microevolutionary processes of functional diversity expanding of the planar EMEC with running magnetic field, which occurred during 185 years of structural evolution.

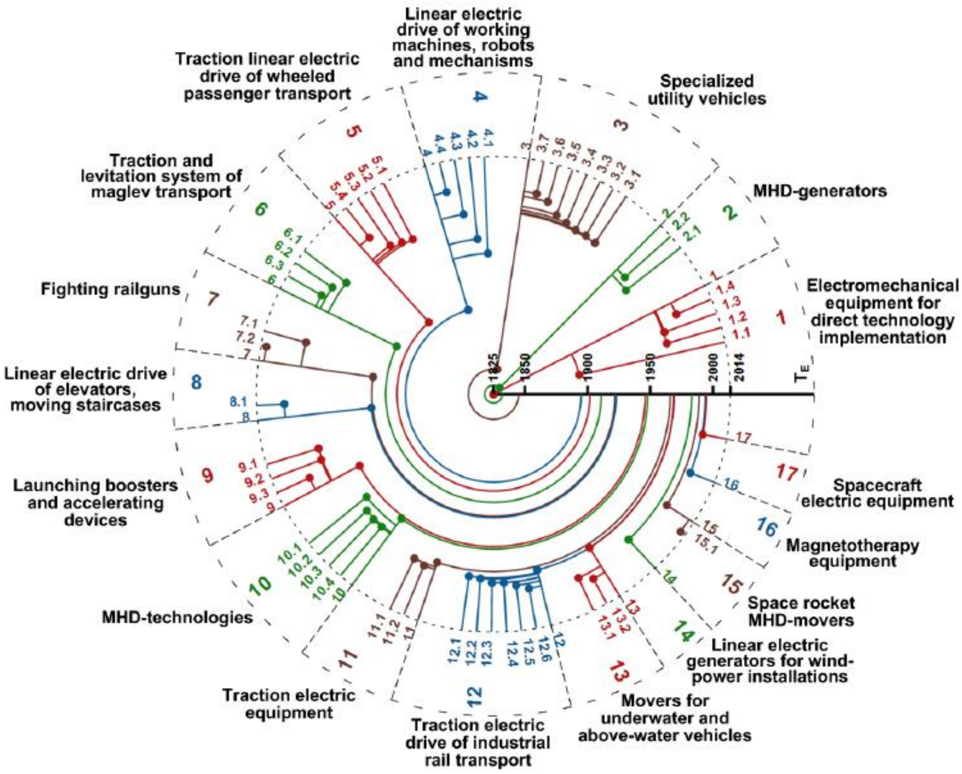

Fig. 2. *Representation of results of functional evolution of electromechanical energy converters with running electromagnetic field (PL 2.2x species, T_E = 185 years) by the phylogenetic diagram*

Species structure is represented with 63 functional populations in the order of their occurrence. In this evolution time, mentioned populations may be grouped into 17 functional types.

The process of EMEC functional diversity expanding is a logical consequence of the purposeful human activity. In general, quantitative composition of species S_{Fj} is to a great extent defined by degree of the genetic predisposition of functional species to a certain function performance, and by the evolution time T_E, during which their diversity will be expanded. Dynamics of the functional population expanding in time follows the exponential law (Fig. 3).

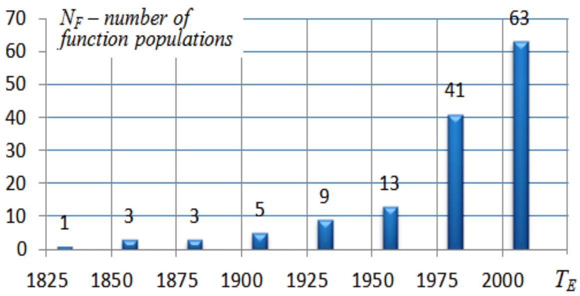

Fig. 3. *Dynamics of diversity change of EMEC functional populations with planar running magnetic field generating source in the technical evolution process of PL 2.2x species*

Hence, the certain structural EMEC species of real-informational type is not only space-and-time system, but functionally oriented evolutionary system of species. Depending on the evolution time, structural species may contain from several units to several tens species of functional type.

Evolutionary process of formation of several species of the functional type in the taxonomic species structure represents its polyfunctionality.

As is known, the functions variety with the invariance of genetic information of the generating parental chromosome displays the all-system law of the species form stability in structural-and-functional evolution of EMEC.

In general, stability of genetically organized system in its development process is defined by its ability to resist the destabilizing external influences. EM-system species formation is predestined by elemental basis (parental chromosomes) of the Generating periodic system of primary electromagnetic structures.

The analysis of phylogenetic modeling results (Fig. 2) allows to point out the main sources of structural-and-functional compliances:

- invariance of genetic information of generating structures (parent chromosomes) with respect to the time of evolution, complexity of descendant structures, and their functionality;
- presence, and universality of the species formation genetic programs;
- structural diversity of subspecies, and populations;
- polyfunctional properties of the generating chromosomes;
- existence of interrelation between genetic predisposition of the generating chromosomes and functioning space of EM-objects.

4. STRUCTURAL, AND FUNCTIONAL CORRESPONDENCE ANALYSIS

The investigation was performed by comparison of decoding results of planar species (PL 2.2x) genome with the results of evolutionary experiments. Comparison of the species genome structure with the results of the structural evolution (Fig. 4) demonstrate the correspondence between the structural, and functional components of the species formation evolutionary process.

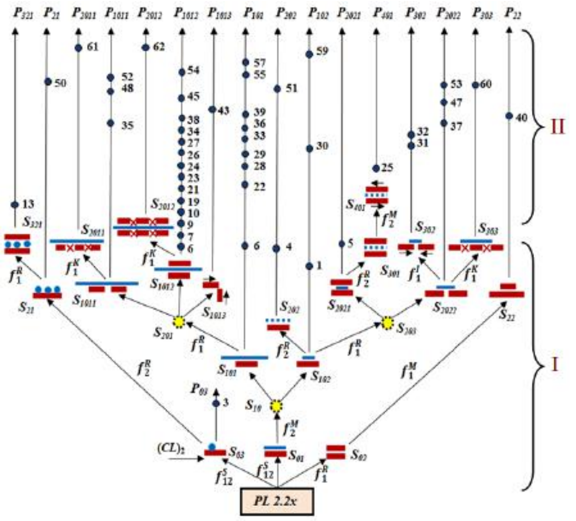

Fig. 4. *Phylogenetic model of functional evolution of planar EMEC (PL 2.2x species) with solid (continuous, and discrete) secondary element (T_E = 165 years): PL 2.2x – parental electromagnetic chromosome; I – genetic program; II – real evolution; $f_1^R, f_1^M, f_1^I, f_1^K, f_{12}^S, f_2^R, f_2^M$ – genetic synthesis operators; S_{01}, S_{02}, S_{21}, S_{101}, …, S_{2022} – paired generating chromosomes; S_{10}, S_{201}, S_{203} – information chromosomes; P_{21}, P_{22}, …, P_{2022} – structural populations; 1, 3, 4, …, 62 – evolutionary events (generating objects of functional populations).*

Every generating chromosome in the genetic program of the considered species has its corresponding certain functional population of EM-objects. Thus, the structure of certain real-informational species S_0 may be represented as the set of functional populations P_i, and corresponding functional types S_{Fj}:

$$\left(P_{f1}, P_{f2}, \ldots, P_{fi}\right) \subset \left(\underline{S_{F1}, S_{F2}}, \underline{\ldots, S_{Fj}}\right) \subset S_0, \quad i = \overline{1, N_f};\ j = \overline{1, K_f}, \qquad (2)$$

where N_f – number of P_{fi} populations; K_F – number of S_{Fj} functional types for current evolution time of structural species S_0.

Using the results of genetic program decoding (Table 2) there were defined the generating chromosomes of real-informational populations. It gives reliable information on interrelation between the structures of generating chromosomes, descendant objects, and their functional identification.

Quantitative distribution of generating objects in the species populations is irregular. Every electromagnetic chromosome of genetic program is potentially the source for the functional population series formation (from several units to several tens).

Table 2

The Results of Genetic Program Interpretation of Planar Species of EMEC with Solid Continuous Secondary Part (Fragment)

Electromagnetic Chromosome	**Paired Chromosome Structural Formula**	**Chromosome Status**	**Functional Population (№)**
PL2.2x	*PL 2.2x*	Parental	–
S_{01}	$(PL\ 2.2x)_1 \times (PL\gamma_\mu)_2$	Informational	–
S_{02}	$(PL\ 2.2x)_1 \times [(PL\ 2.2x){:}I]_2$	Informational	–
S_{03}	$(PL\ 2.2x)_1 \times [(CL_\mu){:}M]_2$	Generating	3
S_{10}	$(PL\ 2.2x)_1 \times [(PL\gamma_\mu){:}M]_2$	Informational	–
S_{21}	$(PL\ 2.2x)_1 \times [(PL\gamma_\mu){:}M{:}R]_2$	Generating	50
S_{22}	$(PL\ 2.2x)_1 \times [(PL\ 2.2x){:}I{:}M]_2$	Generating	40
S_{101}	$(PL2.2x)_1 \times [(PL\gamma_\mu){:}M(L_2>L_1)]_2$	Generating (isomer)	6; 22; 28; 29; 33; 36; 39;55; 57
S_{102}	$(PL2.2x)_1 \times [(PL\gamma_\mu){:}M(L_2<L_1)]_2$	Generating (isomer)	1; 30; 59
S_{201}	$[(PL\ 2.2x){:}R]_1 \times [(PL\gamma_\mu){:}M_{L2>L1}]_2$	Informational	–
S_{202}	$(PL\ 2.2x)_1 \times [(PL\gamma_\mu){:}M(L_2 \approx \tau_1){:}R]_2$	Generating	4; 52
S_{203}	$[(PL2.2x){:}R]_1 \times [(PL\gamma_\mu){:}M(L_2<L_1)]_2$	Informational	–
S_{321}	$[(PL\ 2.2x){:}R{:}I]_1 \times [(PL\gamma_\mu){:}M{:}R]_2$	Generating	13
S_{1011}	$[(PL2.2x){:}R_{OX}]_1 \times [(PL\gamma_\mu){:}M_{L2>L1}]_2$	Generating(isomer)	35; 48; 52
S_{1012}	$[(PL2.2x){:}R_{OZ}{:}I]_1 \times [(PL\gamma_\mu){:}M_{L2>L1}]_2$	Generating (isomer)	6; 7: 9; 10; 19; 21; 23; 24; 26; 27; 34; 38; 45; 54
S_{1013}	$[(PL\ 2.2x){:}R_{OX\times OZ}]_1 \times [(PL\gamma_\mu){:}M_{L2>L1}]_2$	Generating (isomer)	43
S_{2011}	$[(PL\ 2.2x){:}R_{OX}{:}K_m]_1 \times [(PL\gamma_\mu){:}M_{L2>L1}]_2$	Generating	61
S_{2012}	$[(PL\ 2.2x){:}R_{OZ}{:}I{:}K_m]_1 \times [(PL\gamma_\mu){:}M_{L2>L1}]_2$	Generating (isomer)	62
S_{2021}	$[(PL2.2x){:}R_{OZ}{:}I]_1 \times [(PL\gamma_\mu){:}M(L_2<L_1)]_2$	Generating (isomer)	5
S_{2022}	$[(PL2.2x){:}R_{OX}]_1 \times [(PL\gamma_\mu){:}M(L_2<L_1)]_2$	Generating (isomer)	37; 47; 53
S_{302}	$[(PL\ 2.2x){:}R_{OZ}{:}I]_1 \times [(PL\gamma_\mu){:}M(L_2 \approx \tau_1)]_2$	Generating	31; 32
S_{22}	$[(PL\ 2.2x){:}R_{OX}{:}I]_1 \times [(PL\gamma_\mu){:}M(L_2<L_1)]_2$	Generating	40
S_{303}	$[(PL\ 2.2x){:}R_{OX}{:}K_m]_1 \times [(PL\gamma_\mu){:}M(L_2<L_1)]_2$	Generating	60
S_{401}	$[(PL\ 2.2x){:}R_{OZ}{:}I]_1 \times [(PL\gamma_\mu){:}M(L_2 << \tau_1)]_2$	Generating	25

In the current evolution time the genetic program of the considered species is represented with 17 structural populations with corresponding 63 functional populations. Currently, there were identified two dominant structural populations (P_{101}, and P_{1012}), containing 39.7% of functional types. They are presented by the most widespread populations of electrical machines of forward motion with one-, and two-side arrangement of inductors. These populations are the descendants of genetically predisposed chromosomes of mentioned types. The next group of five structural populations (P_{1011}, P_{102}, P_{2022}, P_{202}, and P_{302}) is associated with 20.6% functional populations. Other 39.7% of functional populations are the descendants of the rest 10 structural populations. Structural-and-functional compliance of the specified populations is predetermined by the variants of their combinatory genomic variability.

Sets of the evolutionary events relating to a certain functional population are the result of the technical adaptation, carried out by the human. Analysis of the species phylogenetic model suggests another one important conclusion. While the species genetic program stays unchanged (its decoding is performed only once), the quantitative composition, and capacity of the functional populations during its evolution will be certainly expanded in accordance with this program.

As it is evident from the joint analysis of phylogenetic models, and genetic program, the functional populations diversity of planar EMEC is defined, to a great extent, by physical condition, and structure of the secondary part of energy converter. The secondary part may be performed by technological medium itself, as well as individual minor details of machined, and mechanisms.

Due to the physical condition, and its structure, the secondary part (technological medium) of EMEC could be: solid (continuous or discrete); fluid; ionized gas or plasma; biological object or medium.

5. CONCLUSIONS

The analysis of results of genome-and-historical experiments allows to make the following conclusions:

1. The multifunctional structure of a taxonomical species which is a data carrier of a variety and quantitative structure of functional populations and species is experimentally confirmed.
2. Structural-and-functional evolution of any species of EMEC is predetermined by two genetically organized processes: a structural variety is developing according to the genetic program of a species, and their functional purpose is defined and operated by human.
3. It is established that in the process of evolution, with the invariable genetic program of the species, the dynamics of quantity increase of functional species follows the exponential law.
4. Time process of functional evolution of the EMCE species represents the sequence of adaptation stages of its genetically defined structures.
5. There are proved and experimentally confirmed the basic principles of genomic-and-functional compliances which are defined by the following:

- genetic predisposition of the generating electromagnetic chromosomes (spatial geometry and topology of active surfaces, variants of isomeric composition, group of electromagnetic symmetry);
- physical state and structure of a secondary chromosome;
- the combinatory mechanisms of genotypic variability, realized by means of genetic synthesis operators;
- opportunities of technical realization for the demanded function realization.

6. There are for the first time scientifically grounded and experimentally confirmed the three possible scenarios of formation and development of functional species, to each outcome is assigned a hereditary (vertical), an acquired (horizontal) or genetically predictable way of transfer of genetic information.

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