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doi:10.15199/48.2024.09.20

Macrogenetic program of distributed windings of electromechanical converters

Abstract. *The paper considers the definition of macrogenetic programs of distributed windings. It is shown that the windings perform the role of an energy and genetic core which determines the principles of genetic structure formation and evolution of an arbitrary complex electromechanic system. The systematic basis for the organization of further structural and systemic studies of structural and functional classes of windings (primarily, twin-type, hybrid and spatially adaptive) was determined.*

Streszczenie. *W artykule rozważono definicję programów makrogenetycznych uzwojeń rozproszonych. Pokazano, że uzwojenia pełnią rolę rdzenia energetycznego i genetycznego, który wyznacza zasady tworzenia struktury genetycznej i ewolucji dowolnego złożonego układu systemu elektromechanicznego. Określono systematyczne podstawy organizacji dalszych badań strukturalno-systemowych klasów strukturalnych i systemowych uzwojeń (przede wszystkim typu bliźniaczego, hybrydowego i adaptacyjnego przestrzennie). (**Program makrogenetyczny rozproszonych uzwojeń przekształtników elektromechanicznych**)*

Keywords: distributed winding, genetic code, macrogenetic program, systematics, prediction.
Słowa kluczowe: uzwojenie rozproszone, kod genetyczny, program makrogenetyczny, systematyka, przewidywanie.

Introduction

In the structural organization and evolution of genetically organized systems (GOS) of both natural and anthropogenic origin, the properties of integral structures that perform the generative function in relation to the existing and genetically permissible structural diversity of offspring systems of a higher level of complexity acquire fundamental importance. Setting and solving problems of this level in electromechanics became possible only after the discovery of the periodic structure of the genetic classification (GC) of the primary sources of the electromagnetic field and the development of the theory of genetic evolution of electromechanical systems based on it [1]. An important result of systematic and genetic research was the realization that such properties of GOS as: the presence of its own elemental and informational base, periodic reproductive system, genetic, information, universal genetic codes, genetic programs of structure formation, basic taxonomic categories of Genus and Species, principles of homology, isotopy and isomerism, are interconnected components that determine the integrity of the system organization and the structural and functional evolution of electromechanical systems (EM systems) [2]. The specified properties are determined by the presence of deterministic relationships between the elemental and informational basis of the generative periodic classification and the structural diversity of descendant objects that are created in the process of adaptive evolution. The physical carriers of components of genetic information (genetic codes) are windings of arbitrary electromechanical objects (EM objects), which allows their identification by methods of genetic analysis. The concept of genetic information integrates such fundamental properties as spatial geometry, topology, and electromagnetic symmetry of a pole-opening system (electromagnetic, magnetoelectric, or hybrid type) [3]. Therefore, the windings of EM objects play the role of an energy and genetic core, the information of which is invariant with respect to the time of evolution, complexity and scale, and its functional affiliation of an arbitrary EM system. Currently, huge volumes of information have been accumulated in the form of dissertations, monographs, handbooks, catalogs, scientific articles and patents, which describe specific parameters and properties of various types and schemes of windings of electric machines. Despite the large volume of research, attempts to systematize the variety of windings and determine the principles of their structure formation remain uncertain. This is confirmed by the absence of scientifically based classifications of both windings and electric machines themselves in modern textbooks and manuals on electromechanics [3-6].

The purpose of this study is to determine and analyze macrogenetic programs of distributed windings of electromechanical energy converters.

Archetypes and evolution of distributed windings

The evolution of electric machines is directly related to the evolution of their windings, the structure and properties of which are determined by the genetic information of the elemental basis of the GC. The history of the development and research of windings of electromechanical energy converters (EMEC) actually began after the experiments of Michael Faraday and his discovery of the law of electromagnetic induction. The first electric machines were clear-pole direct current machines with electromagnetic or magnetoelectric excitation, in which concentrated clear-pole windings of the solenoid type were used. A significant event that significantly influenced the further development of the science of windings was the discovery in 1860 by Antonio Pacinotti, professor of physics at the University of Pisa, of the ring winding of the armature of a direct current generator (Fig. 1, a) [7]. A distinctive feature of the Pachinoti electric motor was the replacement of the clearly poled armature with an implicitly poled one. After 10 years, an improved version of the generator with self-excitation and ring winding was created by the Belgian physicist-inventor Zenob Gramm (Fig. 1, b). Generators Pacinotti and Gram became the first representatives of electromechanical objects with distributed ring-type windings.

One of the most significant events of the next historical period was the appearance of the drum anchor, which was proposed in 1872 by the German electrical engineer Friedrich von Hefner-Altenek (Fig. 2) [8]. The Hefner-Altenek drum anchor was made in the form of a single-layer winding with involute connections in the frontal parts.

In 1883, the American electrochemical engineer, Edward Weston, patented the first two-layer drum winding - one of the types of surface-type windings that are widely used in modern electric machines. These types of windings, whose active sides of the sections form a corresponding active surface, were first summarized by Rudolf Richter by the term "surface" distributed windings.

a) b)

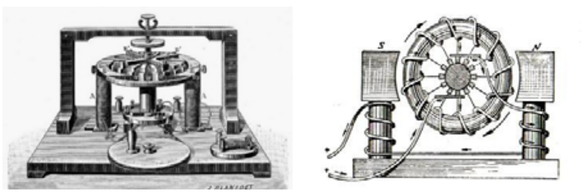

Fig.1. Archetypes of electric machines with circular windings: a) A. Pacinotti's generator (the archetype of the functional class of distributed circular-type windings); b) Z. Gramm's dynamo machine

The Hefner-Altenek dynamo machine, which in its modified form was known as the "Siemens dynamo", became the structural archetype of surface-type windings for subsequent generations of electric machines, both DC and AC machines.

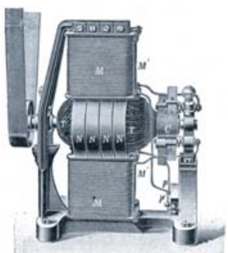

Fig.2. The drum-armature Hefner-Altenek DC machine (archetype of the functional class of electric machines with surface-type distributed windings)

In 1885 Galileo Ferraris (Italy) discovered a method of obtaining a rotating alternating electromagnetic field and built the first model of a two-phase asynchronous motor with a copper cylindrical rotor. In the same year, the first patent for a pattern-type winding was filed, and in 1877 a wave-type winding was proposed, which in 1891 was improved in the form of a multi-pass (with parallel branches) and manufactured by Arnold at the Erlikon plant [8]. In 1888 M. Dolivo-Dobrovolskyi patented and built the first three-phase asynchronous motors and the first three-phase transformers, the appearance of which began the era of three-phase current and the wide distribution of three-phase windings in serial electric machines. He also has priority in the development of the design of short-circuited rotor windings, which he patented in 1889-1893 with one-, two- and three-layer short-circued cage.

During the historical period of the technical evolution of electromechanics surface distributed windings of loop, concentric, wave, template, rod and short-circuited types, which turned out to be the most adapted to the genetic structure of electric machines of the CL 0.2y Specie [1], became the most widespread.

Macrogenetic programs of distributed windings

The existence of a development program is a fundamental property of the GOS of an arbitrary physical nature. Development programs have an informational nature, which is materialized in the structure of the corresponding genome. Mechanisms of copying, transmission, and protection of genetic programs are carried out using broad adaptive properties of genetic information, which refers to the most fundamental type of information. The most important thing is that the genetic program uses this information flawlessly, in an extremely planned and coordinated way, in the right places and never makes mistakes. The genetic classification of the primary sources of the electromagnetic field performs the function of a system model for determining the macrogenetic programs of arbitrary functional, structural and taxonomic classes of EM objects [1-3]. A highly ordered set of electro-magnetic chromosomes of the subject domain of GC performs the function of a global macrogenetic program of structure formation of arbitrary Species, Genera and functional classes of EM-objects of arbitrary complexity level.

The genetic nature of the windings of electric machines is due to the existence of a deterministic connection between the elemental information base of the GC and the EM objects-offspring, which are created in the process of their technical evolution. Genetically permissible classes and types of windings are recognized through the components of genetic information, which is represented by the structure of universal genetic codes. Due to the external simplicity of its structure, the code hides a multidimensional space of connections of information components of electromagnetic chromosomes in the periodic structure of the GC and related types of windings and structures of EM objects that are created in the process of technical evolution (Fig. 3).

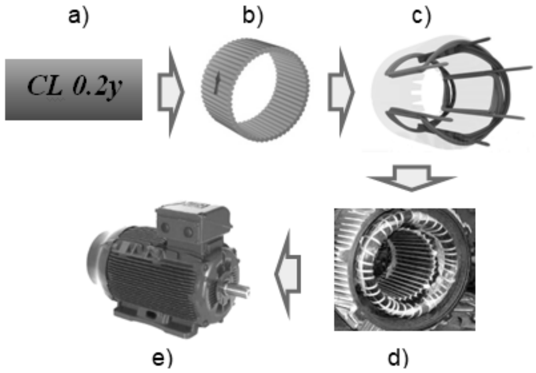

Fig.3. Levels of genetic structuring of electric machines: a) informational (genetic codes); b) chromosomal (electromagnetic chromosomes); c) structural-parametric (spatial schemes of windings); d) object (winding, active parts); e) system (electromechanical energy converters)

According to the research results, it was established that a genetically determined set of generative structures of the elemental base of the GC, as well as chromosomal sets of arbitrary functional classes of EM objects, perform the function of typical programs of structure formation in relation to the genetically permissible variety of structures descendants The genetic program is a highly intelligent information system that determines the finite set and genetic information of generative electromagnetic chromosomes and the quantitative composition of the genetically permissible diversity of their Species and Genera [2]. The presence of a macrogenetic program, subject to the conduct of patent information research, allows to identify the Species diversity that is already involved, as well as to determine the quantitative composition and genetic information of implicit Species of EM windings, the structural representatives of which are absent at this stage of their technical evolution.

Macrogenetic program of distributed annular type windings

The full set of primary field sources of the first major period of the GC, whose structural equivalents are ring distributed windings, is determined by the elemental basis of subgroups 0.0y, 0.0x and subgroup 2.0x:

(1) S_{00y} = *(CL 0.0y; KN 0.0y; PL 0.0y; TP 0.0y; SF 0.0y; TC 0.0y),*

(2) S_{00x} = *(CL 0.0x; KN 0.0x; PL 0.0x; TP 0.0x; SF 0.0x; TC 0.0x),*

(3) S_{20x} = *(CL 2.0x; KN 2.0x; PL 2.0x; TP 2.0x; SF 2.0x; TC 2.0x).*

The elemental information base (1–3), which is represented by 18 generative electromagnetic chromosomes corresponds to the status of the macrogenetic program, which determines the genetically permissible number of Species-descendants of ring windings, including:

- electromagnetically symmetrical (S_{00y}, S_{00x}) (Fig. 4);
- electromagnetically dissymmetric with x-dissymmetry (S_{20x}).

According to the type of spatial movement of the magnetic field wave, ring windings are represented by the following sets of chromosomes:

- with a rotating field:

(4) S_{ω} = *(CL 0.0y; KN 0.0y; TP 0.0y; SF 0.0y; TC 0.0y, TC 0.0x; TC 2.0x)*,

- with a progressive field:

(5) S_V = *(CL 0.0x; CL 2.0x; PL 0.0y; PL 2.0x;PL 0.0x)*,

- with a spatially-concentric wave field:

(6) S_{RC} = *(KN 0.0x; TP 0.0x; SF 0.0x; KN 2.0x; TP 2.0x; SF 2.0X).*

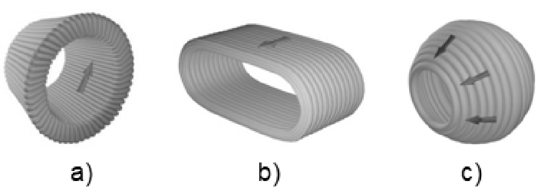

Fig.4. Models of electromagnetically symmetric chromosomes of group 0.0 (with ring windings without an edge): a) with a rotating field (KN 0.0u); b) with a progressive inverse magnetic field (PL 0.0x); c) with a spatially concentric inverse magnetic field (SF 0.0x)

By type of final electromagnetic effects (Table 1):

- without primary final effects (windings of subgroups S_{00y}, S_{00x});
- with longitudinal end effects (windings of subgroup S_{20x}).

Table 1. Spatial structure of the magnetic field of generating electromagnetic chromosomes of circular distributed windings

Subgroup code	Generic geometry of the active surface						Type of edge electromagnetic effects
	CL	KN	PL	TP	SF	TC	
0.0y	↻↻	↻↻	⇆	↻↻	↻↻	↻	None
0.0x	⇆	◎◎	⇆	◎◎	◎◎	↻	None
2.0x	→	◎	→	◎	◎	↻	Longitudinal

Where: ↻↻ rotating field on a two-sided surface; → progressive field; ⇆ progressive inverse field on a two-sided surface; ◎◎ spatially concentric field on a two-sided surface

The boundaries of the structure formation of electric machines with annular distributed windings, which function with solid moving parts, are limited by two homologous series 0.0y and 2.0x. The macrogenetic program of ring windings of group 0.0 of the first great period of the GC determines the quantitative composition and system-genetic properties of 12 Species that are endowed with the maximum group of electromagnetic symmetry. In electric machines that function with solid-state secondary parts, the use of ring windings of group 0.0 is limited to only 6 Species of subgroup 0.0y.

The specific group topology of "edgeless" active surfaces and their ideal electromagnetic symmetry ensures the genetic predisposition of chromosomes to the synthesis of EM objects with maximum use of the active volume [9-12]. Therefore, the use of such windings for single-rotor electric machines of the 0.2y group is impractical, and their comparison with surface windings is incorrect. Ring electromagnetically symmetric windings of subgroup 0.0x cannot function with solid-state moving parts, but they can be effectively used in electromechanical devices of technological purpose, the physical state of the secondary medium of which is represented by ionized gas, plasma, liquid conductive metals [13] or with discrete magnetic and electrically conductive particles (electromechanical disintegrators, magnetic and electrodynamic separators, etc. [5, 14, 15]).

A macrogenetic program of distributed surface type windings class

In the structure of the first great period of the GC the genetic program of distributed windings of the surface type is determined by the element basis of the subgroups 0.2y, 2.2y and 2.2x:

(7) S_{02y} = *(CL 0.2y; KN 0.2y; PL 0.2y; TP 0.2y; SF 0.2y TC 0.2y)*,

(8) S_{22y} = *(CL 2.2y; KN 2.2y; PL 2.2y; TP 2.2y; SF 2.2y; TC 2.2y)*,

(9) S_{22x} = *(CL 2.2x; KN 2.2x; PL 2.2x; TP 2.2x; SF 2.2x; TC 2.2x)*.

The macroprogram is represented by three homologous series that combine 18 Species of surface-type windings including:

- electromagnetically dissymmetric with y-dissymmetry (S_{02y});
- electromagnetically asymmetric with x-y-asymmetry (S_{00y}, S_{00x}) (Fig. 5).

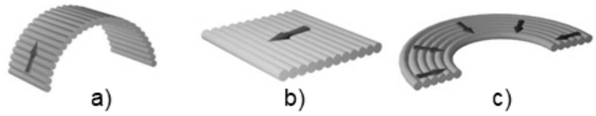

Fig.5. Examples of electromagnetically asymmetric chromosomes of group 2.2: a) with a rotating field (CL 2.2y); b) with a progressive magnetic field (PL 2.2x); c) with spatially concentric magnetic field (TP 2.2x)

According to the type of spatial movement of magnetic field waves, surface windings are represented by the following types:

- with a rotating field:

(10) S_{ω} = *(CL 0.2y; CL 2.2y*; *KN 0.2y; KN 2.2y; TP 2.2y; TP 0.2y; SF 0.2y; SF 2.2y; TC 0.2y; TC 2.2y)*,

- with a progressive field:

(11) S_V = *(CL 2.2x; PL 0.2y; PL 2.2y; PL 2.2x)*;

- with a spatially concentric field:

(12) S_{RC} = *(KN 2.2x; TP 2.2x; SF 2.2X)*.

By type of edge electromagnetic effects (EEE) (Table 2):
- with transverse edge effects (S_{02y});
- with longitudinal and transverse EE effects (S_{22y}, S_{22x}).

The species diversity and group properties of the generative class of surface-type distributed windings are determined by the elemental information base of three subgroups of GC: 0.2y, 2.2y and 2.2x, which are represented by the genetic information of electromagnetic chromosomes: with longitudinal dissymmetry of the magnetic field (subgroup 0.2y) and electromagnetically asymmetric chromosomes (subgroups 2.2y and 2.2x).

Table 2. The spatial structure of the magnetic field of generating electromagnetic chromosomes of distributed surface type windings

Subgroup code	Generic geometry of the active surface						Type of edge electromagnetic effects
	CL	KN	PL	TP	SF	TC	
0.2y	⟳	⟳	⇆	⟳	⟳	⟳	Transverse
2.2y	⟳	⟳	→	⟳	⟳	⟳	Longitudinal and transverse
2.2x	→	⊙	→	⊙	⟳	⊙	Longitudinal and transverse

Where: ⟳ rotating field; → progressive field; ⊙ spatially concentric field on a two-sided surface

The geometric, electromagnetic, and topological properties of the specified field sources are endowed with high adaptive properties, which is confirmed by the wide variety of their technical implementations in the evolution of electric machines and electromechanical devices [3, 16].

The boundaries of the structure formation of electric machines with solid moving parts (electric motors, generators) with surface distributed windings are limited by two homologous series of subgroups 0.2y, 2.2y and 2.2x.

Unlike ring-type windings, all three subgroups of surface windings are characterized by the presence of a certain type of electromagnetic dissymmetry and the presence of corresponding types of end electromagnetic effects: longitudinal (subgroup 0.2y) and longitudinal-transverse (subgroup 2.2y and subgroup 2.2x).

The specified types of final effects will also have a place in all types of electromechanical structures-descendants synthesized on the elemental basis of the specified subgroups. The results of the analysis of macrogenetic programs make it possible to determine the quantitative composition of the genetically permissible species diversity of the distributed windings of electric machines (Table 3).

Table 3. Species composition of structural and functional classes of distributed windings (1st great period of the GC)

Structural and functional classes of distributed windings	Number of Species (NS)
Circles	18
surface	18
With a rotating magnetic field	18
With a progressive magnetic field	9
With a spatially concentric field	9
Electromagnetically symmetrical	12
Electromagnetically dissymmetric with x-asymmetry	6
Electromagnetically dissymmetric with y-asymmetry	6
Electromagnetically asymmetric with x-y-asymmetry	12
Without edge electromagnetic effects	12
With longitudinal edge effects	6
With transverse edge effects	6
With longitudinal and transverse edge effects	12

A characteristic property of distributed windings of the surface type is the presence of the frontal parts of the windings, which do not participate in the creation of traction force (moment) and are a source of electrical power losses. Surface windings of the subgroup 0.2y have found the greatest practical use in the evolution of electric machines, which are characterized by the presence of longitudinal electromagnetic symmetry and the minimal influence of edge transverse electromagnetic effects, which must be taken into account when creating machines of maximum power.

Based on the results of the analysis of macrogenetic programs and genetic systematics, the genetic principles of the structure formation of new functional classes of windings were determined: twin and double-type windings, seven classes of hybrid-type distributed windings, spatially adaptive windings [2], as well as a large Species diversity of spiral and skrew windings of the II and III great periods of the GC, the analysis of which is still waiting for its researchers (Fig. 6).

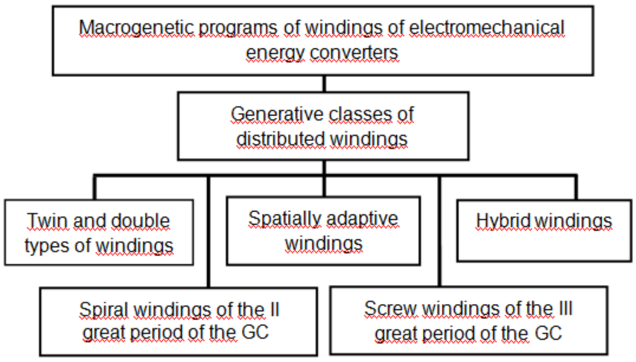

Fig.6. New functional classes of distributed windingss discovered by macrogenetic analysis

Conclusions

The main results of the macrogenetic analysis of distributed windings can be summarized by the following conclusions:

1. The progressive variety of types and schemes of distributed windings is the result of the genetic evolution of electromechanical energy converters, which is determined by the macrogenetic programs of two generative classes of windings (annular and surface).

2. The macrogenetic programs of structural formation of ring and surface distributed windings were determined for the first time. The presence of deterministic relationships of distributed windings with genetic information of electromagnetic chromosomes, the structure of subgroups and periods of genetic classification and structural evolution, which allows for identification and systematization according to their genetic codes, has been theoretically determined and experimentally confirmed.

3. It was established that the fundamental difference in the structures and properties of surface and annular windings is caused by their belonging to different groups of electromagnetic symmetry and topology.

4. It was shown that the structure of the genetic taxonomy of the functional class of distributed windings is consistent with the genetic taxonomy of electromechanical energy converters. The genetically permissible variety of windings is limited to 6 Genera and 36 Species with the ratio of the number of Species of annular and surface windings N_A/N_S=3:3 within an arbitrary Genus (small period), which are invariant to the time of evolution, complexity and functional affiliation of electromechanical energy converters.

5. The research results form a systematic basis for organizing knowledge, improving the methodology of systematic research and setting the problems of structural

prediction and innovative synthesis of new Species of distributed windings of electric machines and electromechanical devices.

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