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Forming a genetic record of cylindrical magnetic separator structures

Abstract*. A possibility of realization of structural genetic algorithm (SGA) for synthesis of separators magnetic systems structural varieties is demonstrated taking basic Species of cylindrical longitudinally-symmetric y-oriented ones as an example. The veracity of synthesis results is proved by means of comparison of the synthesis results with the data of patent information research. A forecasted component of the synthesis results is determined.*

***Streszczenie.** W artykule przedstawiono możliwa realizację strukturalnego algorytmu genetycznego do syntezy magnetycznych separatorów. Jako przykładu takiej syntezy użyto separatora cylindrycznego z symetrią wzdłużną. Wiarygodność wyników syntezy wykazano przez porównanie wyników syntezy z danymi, pochodzącymi z informacji patentowej. Przewidywany składnik wyników syntezy został określony. (**Formowanie zapisu genetycznego struktur z cylindrycznymi separatorami magnetycznymi**).*

Keywords: chromosome set, generating structure, genetic model, structural genetic algorithm.
Słowa kluczowe: zespół chromosomów, struktura generacyjna, model genetyczny, strukturalny algorytm genetyczny

Introduction

Expansion of the sphere of magnetic separators application in modern conditions and increasing diversity of magnetic separation devices, connected with it, result in large percent of search design procedure in their designing [1]. In practice, search and synthesis of new structural variants are mainly of a heuristic character and based on the use of designer's intuition and personal experience. In such conditions research oriented to determination of the regularities of magnetic separators structure forming processes and development of methodological instruments providing realization of a directed search and synthesis of their new structural varieties is topical.

Research methodology substantiation

Determination of Species variety and development of genetic systematics of a class of open working area magnetic separators [2, 3] give the opportunity of systematic study and ordering of structure forming processes within separately taken basic magnetic separators Species.

Genetic models [2] reflecting the process of complication of the levels of an arbitrary Species structural organization in time are used for representation of the inner, genetically conditioned, structure. Statement and solution of the problems of directed search and generation of new structures, using genetic models, present the essence of genetic intraspecific synthesis of electromechanical systems. Methodology of such problems solution is based on the use of structural genetic algorithms (SGA). The results of the research of SGA application to the synthesis of magnetic separator new structures are discussed in this paper.

Problem statement

Statement and solution of the problem of intraspecific genetic synthesis will be made by the example of a basic Species of cylindrical longitudinally symmetrical y-oriented structures (genetic code – *CL* 0.2*y*) of the family of open working area magnetic separators. This Species has the status of the real informational and dominating one, which allows one to check the synthesis results reliability.

Genetic information of a basic Species presented by a universal primary field source (PFS) genetic code (Fig.1). A genetic code structure consists of two parts – alphabetic and numerical ones. An alphabetic part denotes a contracted name of the corresponding sculpted surface geometric class to which PFS belongs (*CL* – cylindrical). A genetic code numerical part represents topologic features and kind of PFS electromagnetic symmetry, i.e. points out presence or absence of PFS surface edges (dissymetrizing factors): in the direction of field wave propagation (the first code figure) and in the perpendicular direction (the second code figure). A *CL* 0.2*y* genetic code numerical part assumes the following numerical values: *0* – absolute electromagnetic symmetry (dissymetrizing factors or surface edges are absent on the way of electromagnetic wave propagation); *2* – electromagnetic asymmetry (absence of symmetry due to presence of two surface edges in the *x*-direction). Field source belongs to the class of transversal orientable surfaces (index *y*) [2].

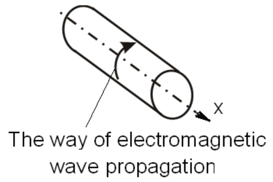

Fig.1. Geometric and topologic features of PFS with *CL* 0.2*y* genetic code

From the point of view of genetic concept, the structure formation process within the Species is carried out by the mechanisms of idealized spatial structures (chromosomes sets) generation at the level of the Species genome. According to the principle of the PFS genetic information preservation, features, peculiar to structures of the genetic level, remain in the following structure generations at a higher structural complexity level.

The species forming genetic model of a *CL* 0.2*y* basic Species is shown in Fig.2. The following notations are used in Fig.2: S_0 – the first generation chromosome set generative structure (electromagnetic chromosome) presenting the result of mating the primary solid-state structure $S_{0(1)}$ (magnetic field bipolar inductor) and a discrete secondary structure $S_{0(2)}$ (a set of ferromagnetic bodies); S_{21}, S_{22} – the second generation chromosome set generative structures (electromagnetic chromosomes); S_{31}, S_{32}– the third generation chromosome set structures (electromagnetic chromosomes); P_{11}, P_{21}, P_{22}, P_{31}, P_{32} – magnetic separators structural populations; f_R, f_E, f_M - genetic operators of replication, electromagnetic inversion and mutation, correspondingly.

To perform the procedure of magnetic separator structures directed synthesis using SGA it is necessary to determine synthesized structures essential features p_{s1}, p_{s2} meeting the synthesis objective function

$$F_S = (p_{S1}, p_{S2}) . \quad (1)$$

Synthesized structures essential features may include the following: p_{s1} – presence of one or two magnetic field cylindrical axisymmetric inductors; p_{s2} – axial sequence of cylindrical inductors spatial arrangement.

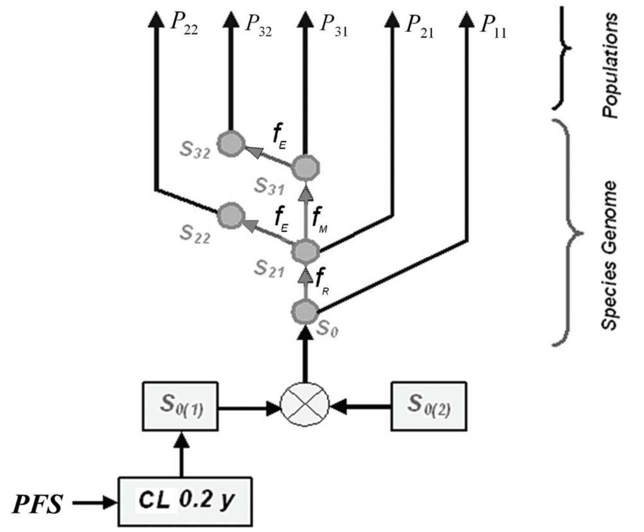

Fig.2. Genetic model of speciation of magnetic separators of the cylindrical longitudinally-symmetrical y-oriented (*CL* 0.2*y*) Species

To solve the synthesis problem correctly the following constraints $L=f(x)$ are imposed on domain Q_s of synthesis including a set of synthesized structures:

1. Replication genetic operator f_R is responsible for quantitative composition of spatial structures formed correspondingly from a number of separator multipolar inductor poles equal to k_R, where k_R is replication coefficient meeting the condition $k_R \leq 2$.
2. Electromagnetic inversion genetic operator f_E models processes in two-inductor structures whose specific feature consists in the opposite direction of rotation of one inductor magnetic field in relation to the direction of rotation of the magnetic field of the other one.
3. It is accepted that mutation genetic operator f_M models processes connected with the change of the poles width without the other geometric dimensions change of the structure elements and without the change of their form.

Taking the above stated into consideration, the problem of directed search and synthesis of structural varieties of magnetic separators of the basic Species *CL* 0.2*y* can be formulated in the following way: to synthesize a finite set of structures meeting function F_s and forming a gene pool of cylindrical magnetic systems of separators of the basic Species under consideration according to the synthesis known objective function $F_S=(p_{S1}, p_{S2})$ and given set $L=f(x_1, x_2, x_3)$ of restrictions using the speciation genetic model.

Chromosome sets generation

As it has already been stated, the process of structure creation within an arbitrary Species is carried out through the mechanisms of idealized spatial structures or chromosome sets generation. In this case the chromosome structures are determined by the principle of electromechanical structure integrity and combinatory variants of genetic information presentation.

Electromechanical pair S_0 (Fig.3) is the first generation chromosome set genetic structure determining genetic properties of structural population P_{11} and constitutes a subset (it is denoted by the symbol $\subset$) of structures set of the considered basic Species $S_{CL0.2y}$

$$\left(\left(S_{0(1)} \times S_{0(2)}\right) \to S_0 \to P_{11}\right) \subset S_{CL\ 0.2y} . \quad (2)$$

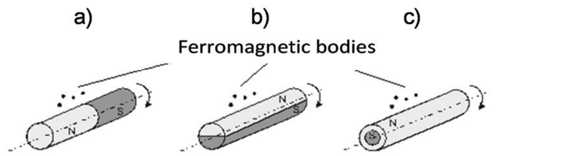

Fig.3. Spatial structures synthesized on the basis of electromagnetic chromosome S_0: a) structure S_{X11}; b) structure S_{Y11}; c) structure S_{Z11}

All the potentially possible variants of this chromosome set structures are three-dimensional space R^3 geometric objects. The synthesis of many possible spatial structures (or arrangements of magnetic field inductor poles) can be made using a geometric modeling device. Generation of possible spatial compositions is carried out by successive application of geometric transformations in relation to generating structure S_0 (Fig.3) in the form of alternate combinatory poles rearrangement along coordinate axes (structure S_{X11}, Fig. 3, a), in cylindrical inductor cross-section (structure S_{Y11}, Fig. 3, b), as well as in the direction orthogonal to inductor rotation axis (structure S_{Z11}, Fig. 3, c),

$$f(S_0) \to (S_{X11}, S_{Y11}, S_{Z11}) , \quad (3)$$

where f is a geometric transformation function.

In spatial structures S_{X11} (Fig. 3, a) and S_{Y11} (Fig. 3, b) the cylinder lateral surface is the attraction operation surface, which makes it possible to relate these structures to the basic Species *CL 0.2y* under consideration. Structure S_{Z11} (Fig. 3, c), where the attraction operation surface is situated in the end surface area, which is typical of representatives of the geometrical class of the “toroid flat”, should be excluded from the further consideration.

Let us assume in our further reasoning that index «X» in the synthesized structure reference designation refers to the alteration of inductor poles polarity along its rotation axis. Index «Y» shows alteration of the poles polarity in the inductor cross-section.

The second generation chromosome set is represented by generating structures S_{21} and S_{22} determining structural features of populations P_{21} and P_{22} correspondingly (Fig. 2). Generating structure S_{21} presents a result of electromagnetic chromosome S_0 replication at the replication coefficient k_R = 2 and is responsible for inherited characters of separators four-pole magnetic systems

$$\left(f_R\left(S_0\right) \to S_{21} \to P_{21}\right) \subset S_{CL\ 0.2y} . \quad (4)$$

Possible spatial compositions of replicated structures with poles polarity alteration along the inductor rotation axis can be obtained by transfer of structure S_{X11} poles (Fig. 3, a) along the symmetry (rotation) axis. In their turn, spatial structures with poles polarity alteration in the inductor cross-section can be obtained by scaling of structure S_{Y11} poles (Fig. 3, b) in 2-D plane-meridian space R^2 and their turn about the inductor axis of symmetry.

Then the finite set of spatial structures synthesized on the basis of electromagnetic chromosome S_{21}, includes the following structures: S_{X21}, S_{Y21} – spatial structures with direct poles alteration (Fig. 4, a, c); S_{X*21}, S_{Y*21} – spatial structures with inverse inductor poles alteration (Fig. 4, b, d).

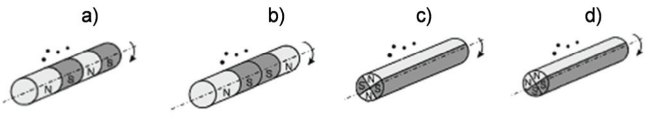

Fig.4. Spatial compositions of replicated structures at $k_R = 2$: a) structure S_{X21}; b) structure S_{X*21}; c) structure S_{Y21}; d) structure S_{Y*21}

The obtained structures (Fig. 4) represent spatial compositions of one-inductor four-pole (k_R = 2) separators magnetic systems. In this case a four-pole structure S_{Y*21} (Fig. 4, d) is equivalent to bipolar structure S_{Y11} (Fig. 3, b) as to their magnetic force. Structural compositions S_{X21}, S_{X*21} (Fig. 4, a, b) can also be regarded as two-inductor structures formed by bipolar (k_R = 1) inductors. Each of the structures shown in Fig.3 and Fig.4 forms a nonempty multitude of constituent elements (inductor poles). Successive combination of the said multitudes results in the following

$$
\begin{aligned}
&S_{X11} \cup S_{Y11} = S_{X11Y11} = S_{X21Y21};\\
&S_{X21} \cup S_{X11} = \varnothing;\\
&S_{X*21} \cup S_{X11} = \varnothing;\\
&S_{X21} \cup S_{Y11} = S_{X21Y11};\\
&S_{X*21} \cup S_{Y11} = S_{X*21Y11};\\
(5)\qquad &S_{X21} \cup S_{X*21} = \varnothing;\\
&S_{Y21} \cup S_{Y*21} = \varnothing;\\
&S_{X21} \cup S_{Y21} = S_{XY21};\\
&S_{X21} \cup S_{Y*21} = S_{XY*21};\\
&S_{X*21} \cup S_{Y21} = S_{X*Y21};\\
&S_{X*21} \cup S_{Y*21} = S_{X*Y*21}
\end{aligned}
$$

where the union of two sets is denoted by the symbol $\cup$, the null set or empty set is denoted by the symbol Ø.

It follows from expression (5) that new structures generation is only possible when initial structures with different directions of inductor poles alterations, i.e. with alteration of poles polarity along the rotation axis and in the inductor cross-section, correspondingly, are combined. Replicated structures spatial compositions obtained by means of sequential combination are shown in Fig. 5: S_{X21Y21} (Fig. 5, a); S_{X21Y11} (Fig. 5, b); $S_{X*21Y11}$ (Fig. 5, c); S_{XY21} (Fig. 5, d); S_{XY*21} (Fig. 5, e); S_{X*Y21} (Fig. 5, f); S_{X*Y*21} (Fig. 5, g). In this case spatial structures S_{X21Y21} (Fig. 5, b) and S_{XY*21} (Fig. 5, e), as well as $S_{X*21Y11}$ (Fig. 5, c) and S_{X*Y*21} (Fig. 5, g) are equivalent as to their magnetic force.

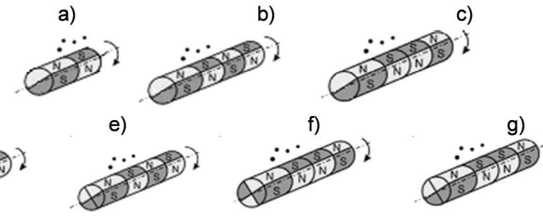

Fig. 5. Replicated structures spatial compositions obtained by means of successive combination: a) structure S_{X21Y21}; b) structure S_{X21Y11}; c) structure $S_{X*21Y11}$; d) structure S_{XY21}; e) structure S_{XY*21}; f) structure S_{X*Y21} ; g) structure S_{X*Y*21}

Out of the structures shown in Fig. 5 only one structure S_{X21Y21} (Fig. 5, a) meets the assigned replication coefficient k_R = 2. This structure can also be regarded as two-inductor one consisting of two bipolar (k_R = 1) inductors. Spatial structures S_{X21Y11} (Fig. 5, b) and $S_{X*21Y11}$ (Fig. 5, c) correspond to replication coefficient k_R = 4, and structures S_{XY21} (Fig. 5, d), S_{XY*21} (Fig. 5, e), S_{X*Y21} (Fig. 5, f) and S_{X*Y*21} (Fig. 5, g) – to replication coefficient k_R = 8, which exceeds its assigned threshold value ($k_R \leq 2$). Structural compositions S_{X21Y11} and $S_{X*21Y11}$ (Fig. 5, b, c) may also be considered as two-inductor systems formed by four-pole inductors with replication coefficient k_R = 2 each.

Thus, the total number of replicated structures synthesized on the basis of electromagnetic chromosome S_{21} and meeting the assigned synthesis objective function and the adopted restrictions system is equal to six

$$
(6)\qquad \begin{aligned} f(S_{21}) \rightarrow (&S_{X21}, S_{X*21}, S_{X21Y21}, S_{Y21},\\ &S_{X21Y11}, S_{X*21Y11}) \end{aligned}
$$

where S_{X21}, S_{X*21}, S_{X21Y21} – four-pole structures which can be both one- and two-inductor ones, S_{Y21} – one-inductor four-pole structures, S_{X21Y11}, $S_{X*21Y11}$ – two-inductor four-pole structures.

Generating structure S_{22} determines the structural filling of population P_{22} of replicated inverse structures

$$
(7)\qquad \left(f_E(S_{21}) \rightarrow S_{22} \rightarrow P_{22}\right) \subset S_{CL\hat{I}\,2y}\,.
$$

According to the adopted restrictions system, inverse structures can only be obtained for two-inductor structures in which the direction of one inductor magnetic field rotation is opposite to the direction of the other inductor magnetic field rotation. Taking this into account, the finite set of spatial structures synthesized on the basis of inverse electromagnetic chromosome-replicator S_{22} can be presented in the form

$$
(8)\qquad \begin{aligned} f(S_{22}) \rightarrow (&S_{X22}, S_{X*22}, S_{X22Y22},\\ &S_{X22Y11}, S_{X*22Y11}) \end{aligned}
$$

where $S_{X22}...S_{X*Y*22}$ are spatial two-inductor structures of an inverse type.

It follows from expression (8) that the total number of structures synthesized on the basis of inverse electromagnetic chromosome-replicator S_{22} is five. Thus, the second generation chromosome set, meeting the assigned synthesis objective function and accepted constraints, includes 11 (6+5) synthesized structures.

The third generation chromosome set is represented by generating structures S_{31} and S_{32} (Fig. 2). Structure S_{31} presents a result of action of mutation operator f_M in relation to structure S_{21}, which consists in the change of inductor poles geometric dimensions,

$$
(9)\qquad \left(f_M(S_{21}) \rightarrow S_{31} \rightarrow P_{31}\right) \subset S_{CL\ 0.2y}\,.
$$

In this case possible structures spatial compositions can be presented by variants of structures, in which the poles of the same or of different polarity of adjacent inductors differ in their geometric dimensions. It means that from each replicated structure of the second generation chromosome set (formula (6)) two new structures belonging to the third generation chromosome set and distinguished by geometric dimensions of poles of the same or different polarity can be obtained. Then the total number of structures synthesized on the basis of electromagnetic chromosome S_{31} will make 12.

Generating structure S_{32} determines structural filling of inverse structures population

$$(f_M(S_{31}) \rightarrow S_{32} \rightarrow P_{32}) \subset S_{CL\ 0.2y}\ . \qquad (10)$$

The total number of structures synthesized on the basis of electromagnetic chromosome S_{32} is 10. It means that from each structure presented in formula (8) two new ones, the inductor poles of the same or different polarity of which differ in their geometric dimensions, can be obtained. Thus, the third generation chromosome set meeting the given synthesis objective function and accepted restrictions includes 22 (12+10) synthesized structures.

Results validation

33 structures forming the gene pool of cylindrical magnetic systems of separators of the basic Species *CL*0.2*y* were received as a result of realization of a genetic algorithm. Veracity of genetic synthesis results was determined by way of comparison of the data of patent information retrieval and synthesis results.

Structural representatives of six synthesized structures belonging to the class of pulley magnetic separators [4] were found out, which proves the veracity of the adopted synthesis method. Structural potential of 27 structures which were not found during the retrieval can be regarded as a forecasted component of the synthesis results. The mentioned structures are potentially operable and can be the basis for solving problems of original engineering solutions directed synthesis.

Conclusions

33 structures belonging to one of the dominating basic Species of magnetic separators with open operating area (*CL* 0.2*y*) have been synthesized using a genetic algorithm.

The veracity of genetic synthesis results is proved by means of comparison of the synthesis results with the data of patent information research, in the course of which representatives of six synthesized structures were found out. A forecasted component of the synthesis results has been determined. It includes 27 potentially novel structures providing the basis for development of original technical solutions.

The research results can be used for subsequent synthesis of population structure of other implicit Species, as well as for creation of intelligence systems for the support of decision-making in improvement of the existent magnetic separators designs and development of new ones.

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