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 θ-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.


Keywords: chromosome set, generating structure, genetic model, structural genetic algorithm.

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 θ-oriented structures (genetic code – CL 0.2y) of the family of open working area magnetic separators. ThisSpecies 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); in the perpendicular direction (the second code figure). A CL 0.2y 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].

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 0.2y basic Species is shown in Fig.2. The following notations are used in Fig.2: S0 – the first generation chromosome set generative structure (electromagnetic chromosome) presenting the result of mating the primary solid-state structure S011 (magnetic field bipolar inductor) and a discrete secondary structure S02 (a set of ferromagnetic bodies); S11, S22 – the second generation chromosome set generative structures (electromagnetic chromosomes); S31, S32 – the third generation chromosome set structures (electromagnetic chromosomes); P11, P21, P22, P31, P32 – magnetic separators structural populations; fR, fE, fM – genetic operators of replication, electromagnetic inversion and mutation, correspondingly.

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

Fig.2. Graphical representation of CL 0.2y genetic code
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

\[
F_S = (p_{S1}, p_{S2}).
\]

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.

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

Electromechanical pair \( S_0 \) (Fig.3) is the first generation chromosome set genetic structure determining genetic properties of structural population \( P_{S1} \) and constitutes a subset (it is denoted by the symbol \( \subset \)) of structures set of the considered basic Species \( S_{CL,0.2y} \).

\[
\left\{(S_{0(1)}, S_{0(2)}), S_0 \rightarrow P_{S1}\right\} \subset S_{CL,0.2y}.
\]

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),

\[
f(S_0) \rightarrow (S_{X11}, S_{Y11}, S_{Z11}).
\]

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 « \( Y \) » 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 \( S_{Z12} \) and \( S_{Y22} \) determining structural features of populations \( P_{Z2} \) and \( P_{Y2} \) correspondingly (Fig. 2).

Generating structure \( S_{Y12} \) 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

\[
f_R(S_0) \rightarrow S_{Y12} \rightarrow P_{Z12} \subset S_{CL,0.2y}.
\]

Possible spatial compositions of replicated structures with poles polarity alteration along the inductor rotation axis can be obtained by transfer of structure \( S_{Y12} \), 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 \( S_{X12} \), 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 \( S_{Z12} \), includes the following structures: \( S_{X22}, S_{Y22} \) – spatial structures with direct
structures formed by bipolar \((k_R)\) to their magnetic force. Structural compositions of one-inductor four-pole \((k_R = 2)\) separators magnetic systems. In this case a four-pole structure \(S_{21}\) (Fig. 4, d) is equivalent to bipolar structure \(S_{XY21}\) (Fig. 3, b) as to their magnetic force. Structural compositions \(S_{21}, S_{XY21}\) (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

\[
\begin{align*}
S_{X11} \cup S_{Y11} &= S_{X1Y11} = S_{X2Y21}; \\
S_{X21} \cup S_{X11} &= \emptyset; \\
S_{X*21} \cup S_{X11} &= \emptyset; \\
S_{Y21} \cup S_{Y11} &= S_{X2Y11}; \\
S_{X*21} \cup S_{Y11} &= S_{X*21Y11}; \\
S_{X21} \cup S_{X*21} &= \emptyset; \\
S_{Y21} \cup S_{Y*21} &= \emptyset; \\
S_{X21} \cup S_{Y21} &= S_{XY21}; \\
S_{X21} \cup S_{Y*21} &= S_{X*Y21}; \\
S_{X*21} \cup S_{Y21} &= S_{X*Y21}; \\
S_{X*21} \cup S_{Y*21} &= S_{X*Y*21}
\end{align*}
\]

(5)

where the union of two sets is denoted by the symbol \(\cup\), the null set or empty set is denoted by the symbol \(\emptyset\).

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: \(S_{XY21}\) (Fig. 5, a); \(S_{X21}\) (Fig. 5, b); \(S_{XY21}\) (Fig. 5, c); \(S_{21}\) (Fig. 5, d); \(S_{XY21}\) (Fig. 5, e); \(S_{Y21}\) (Fig. 5, f); \(S_{Y*21}\) (Fig. 5, g). In this case spatial structures \(S_{21}\) (Fig. 5, b) and \(S_{XY21}\) (Fig. 5, e), as well as \(S_{XY21}\) (Fig. 5, c) and \(S_{Y*21}\) (Fig. 5, g) are equivalent as to their magnetic force.

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

\[
f(S_{21}) \rightarrow (S_{X21}, S_{X*21}, S_{X21Y21}, S_{Y21, S_{X21Y11}, S_{Y21Y11}})
\]

(6)

where \(S_{X21}, S_{XY21}, S_{X*21Y11}, S_{Y21Y11}\) – four-pole structures which can be both one- and two-inductor ones, \(S_{XY21}\) – one-inductor four-pole structures, \(S_{X*21Y11}, S_{Y21Y11}\) – two-inductor four-pole structures.

Generating structure \(S_{21}\) determines the structural filling of population \(P_{22}\) of replicated inverse structures

\[
(f_E(S_{21}) \rightarrow S_{22} \rightarrow P_{22}) \subset S_{CI2} 2_y.
\]

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 \(S_{21}\) can be presented in the form

\[
f(S_{22}) \rightarrow (S_{X22}, S_{X*22}, S_{X22Y22}, S_{X22Y11}, S_{X*22Y11})
\]

(7)

where \(S_{22},...S_{Y*22}\) 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 \(S_{21}\) 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 \(S_{21}, S_{31}\) (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,

\[
(f_M(S_{21}) \rightarrow S_{31} \rightarrow P_{31}) \subset S_{CL} 0.2_y.
\]

(9)

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

222
PRZEGLĄD ELEKTROTECHNICZNY (Electrical Review), ISSN 0033-2097, R. 87 NR 3/2011
on the basis of electromagnetic chromosome $S_{31}$ will make 12.

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

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

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 $CL0.2y$ 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 ($CL0.2y$) 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.

REFERENCES


Authors: prof. Mykhaylo V. Zagitnyak, Kremenchuk Mykhaylo Ostrogradsky National University, ul.Pershotravneva, 20, Kremenchuk, 39600, Ukraine, E-mail: mzagitn@kdu.edu.ua; as. prof. Irina A. Shvedchikova, East-Ukrainian Volodymyr Dal National University, kv. Molodezhniy, 20a, Lugansk, 91034, Ukraine, E-mail: snu2008@mail.ru; prof. Ph.D Damijan Miljavec, University of Ljubljana, Trzaska 25, 1000 Ljubljana, Slovenia, E-mail: miljavec@fe.uni-lj.si.