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STRUCTURAL-AND-PARAMETRIC SYNTHESIS OF A REGULAR SYSTEM WITH USING A GENETIC ALGORITHM

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Abstract. Any system consists of interconnected elements. The elements parameters influence the operational mode and output system parameter. The complex system has control parts, several operational modes and output parameters. The regularity of any system means that rules of associating the elements in subsystems and rules of connecting the subsystems, i.e. creation of a system structure, are known. Usually a problem of synthesizing the structure is decided in the beginning. The suitable structure is selected. Then parameters of the system elements are found. In this paper we propose a general model of structural-and-parametric synthesis of the regular system with required output parameters. For the solution a genetic algorithm is used. The features of the regular systems with control parts are taken into account. Power transmission systems are considered as a characteristic practical object. The subsequent stage of lifetime synthesis is briefly discussed, when the system is virtually materialized, and some information on it can be used for optimizing the higher level system (machine or machines system).

Key Words. Regular system, Structure, Elements, Control parts, Parameters, Synthesis, Genetic algorithm, Power transmission system.

1 Introduction. The technical and other systems are regular. It means that rules of forming the systems are known. We suppose that if there is a universal analytical model, which allows calculating the output parameters of the system for any structure, control actions and values of internal parameters, the stages of structural and parametric synthesizing have to be aggregated. It is rationally that the structural-and-parametric synthesis is solved as a general problem with using of genetic algorithm (GA). Development of analytical models of

objects is not a problem for modern scientific and technical areas. A discrete representation of parameters is a feature of applying the GA. The discrete representation of system parameters in the practical selection is usually guessed. In a number of cases it is determined by an essence of parameters (they can be only discrete). In other cases the discrete regulated values of parameters will be used. Therefore it is rationally to find parameters values in discrete area at once.

The various models and algorithms are used for structural and parametric synthesizing different objects. As a particular manufacturing object we consider a power transmission. The algorithms of synthesizing some transmission structures types are known [1, 2]. The parametric synthesis of the tree type transmissions is developed in [3]. We propose the approach, which removes restrictions regarding the type and structure of transmissions. Its basis is the universal model for calculating parameters of any transmissions [4]. The features of object have resulted in features in realization of the GA.

The paper is organized as follows. Section 2 presents features of the considered regular system and used genetic algorithm; Section 3 deals with particular object (power transmission), and final remarks are given in Section 4.

2 Peculiarity of the system and algorithm used. It is supposed that the different variants of connections of elements in subsystems and variants of junction of subsystems are known. Each variant can be potentially used for synthesis of the system. The system has some control parts (CPs). Action of the CPs leads to modification of the system state. But not all combinations of the powered up CPs can be correct. The correct combination ensures the operation of the system. Values of the system output parameters depend as well on parameters of the elements. Instead of CPs combination we shall use variant of the CPs action. Determining the correct (suitable) variants is preliminary procedure with using the available analytical system model. It is carried out with the arbitrary accepted parameters of the elements.

In a considered task solved by means of the genetic algorithm, a chromosome will contain two sets of genes. One will contain parameters of the system elements. In second the powered up CPs will be encoded. The parameters of elements are described by independent integers. For encoding the powered up CPs would be possible to use numbers of CPs. But such way has essential disadvantages:

- Firstly, such combination of the powered up CPs can be obtained and the system is disabled. In some cases a number of disabled variants can exceed a number of efficient.
- Secondly, the chromosome should not contain the identical powered up CPs for different output parameters. Such situations result in the same output parameters of the system.

The mentioned difficulties are overcome by means of designed mode of using variants of CPs action (CPs variants) in the chromosome. Under its using there is no losing the chromosomes, in which the disabled variants can be encoded. Use of the only correct CPs variants accelerates convergence of a solution.

The gang of the unique CPs variants is formed by the same mode. For this purpose the variants are encoded through an intermediate array of accessible variants. Originally this array contains all accessible variants. Using any variants it is deleted from the intermediate array. Therefore it is impossible to use the same variant once more.

So it is possible to present a chromosome structure as follows:

$$[(Z_1,..,Z_{Nz})\ (V_1,..,V_{Nv})],$$

where Z_l is value of the element parameter (it can accept any value from an admissible set); Nz is number of the system elements; V_k is the position of the CPs variant in the intermediate array (it can possess the value from 0 up to Nv_0–k, where Nv_0 is number of the possible CPs variants, k is the position of the gene in the chromosome); Nv is number of the output system parameters (it can not exceed Nv_0).

For an estimation of chromosome fitness we use a value

$$\Delta=\sum(x_{0i}-x_i)^2,$$

where x_0 is the required value of the output system parameter; x_i is obtained value (i = 1, ... Nv). Indication of terminating a solution is the reaching the required accuracy Δ or realization of the given maximum number of iterations.

As the chromosome describes two such as parameters, at chromosome recombination the crossover of two gangs happens separately. The genes describing parameters of elements are recombined as integers.

3 Elementary example. The generalized structure of the elementary multiple-state mechanism is represented on Fig. 1

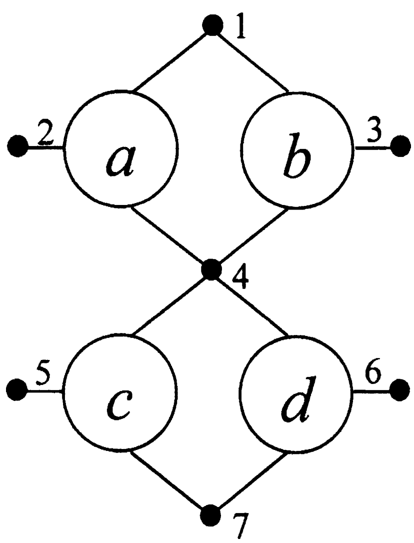

Fig. 1. The generalized structure of the elementary multiple-state mechanism

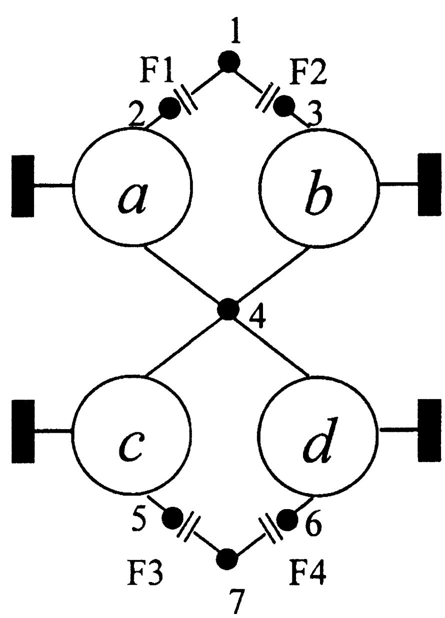

Fig. 2. Structure of not planetary transmission with simple gears

This structure is interpreted as structure of not planetary transmission with simple gears (see Fig. 2). On the basis of this structure one of possible schemes is generated. It is represented on Fig. 3.

In this scheme the input and output are selected (1 and 7 respectively). It is required to find the correct CPs combinations and the elements parameters (teeth numbers of gears), which ensure the given transmission ratios, for example: 1.21; 1.47; 2.81; 3.41. For three given transmission ratios the task is trivial, but for four ratios, as a rule, we have not the precise solution.

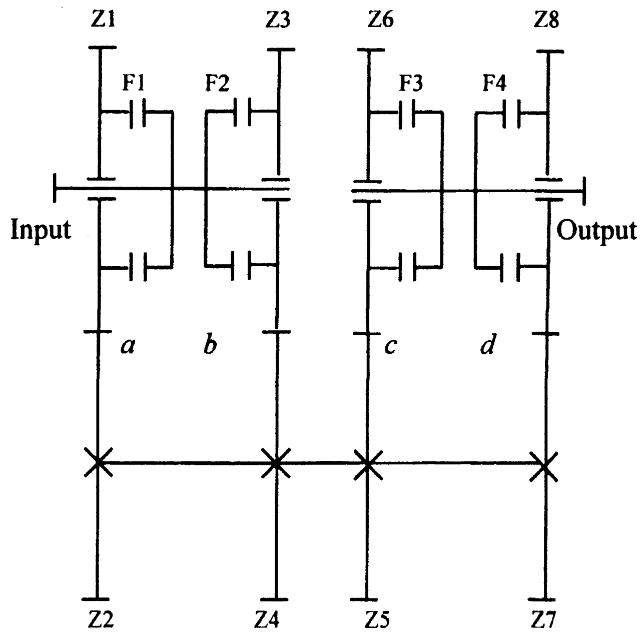

Fig. 3. One of possible transmission scheme with simple gears

We set the teeth numbers arbitrary ($z_i=10$) and determine suitable CPs variants. The following variants are possible:

Number of variant	I	II	III	IV
CPs combination	F1 F3	F1 F4	F2 F3	F2 F4

At first the intermediate array of CPs variants looks so:

Position	1	2	3	4
Number of variant	I	II	III	IV

The value from a column "Position" is located in a gene. Let's suspect that the variant located in a position 3 (variants III) is used. It is eliminated from the array. The intermediate array after that will look like this:

Position	1	2	3
Number of variant	I	II	IV

It has decreased. This way selection of the variants executes. Thus the genes can contain the same values, but the set of the unique variants will be formed after decoding. The process of decoding takes place similarly. The variant is selected from the intermediate array according to the position stored in the gene. After selection it leaves the intermediate array.

Such a way the allele of the gene decreases depending on its position (locus) in the chromosome. One more advantage of such approach is that it is possible to point the CPs variants, which we have to consider for finding a solution.

As a result the CPs combinations, ratios and teeth numbers of gears have been obtained:

Variant number	I	III	II	IV
CPs combination	F1 F3	F1 F4	F2 F3	F2 F4
Ratio	1.24	1.47	2.86	3.45
Version 1				
Gear	Z1	Z3	Z5	Z7
Teeth number	22	26	38	63
Gear	Z2	Z4	Z6	Z8
Teeth number	33	91	31	62
The sum of teeth numbers	55	117	69	125
Version 2				
Gear	Z1	Z3	Z5	Z7
Teeth number	47	26	61	59
Gear	Z2	Z4	Z6	Z8
Teeth number	70	91	53	58
The sums of teeth numbers is equal	117	117	117	117

4 Conclusion. The proposed method is effective for functional synthesis of the regular system. However a lifetime (reliability) problem also exists. Usually the lifetime problem is decided on the basis of the requirements to the sizes or weight of a system. Thus the material and technology of making the elements varies and according to this the cost of lifetime assurance changes. It is necessary to take into account that the lifetime is determined by conditions, in which the system operates, i.e. by system fulfilled jobs. For lifetime assurance we offer to use the universal analytical lifetime model and the genetic algorithm also. The kinds of materials and technologies for making elements will be the discrete varied parameters.

As a result of functional and lifetime synthesizing we shall have some necessary information about a materialized system. It can be used for the solution of a problem of designing a higher level system. This problem can be formulated as follows: DESIGNING A SYSTEM OF MACHINES AND UNITS FOR PERFORMING A GIVEN SET OF JOBS.

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