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CONSTRUCTIONAL DESIGN OF DC MACHINE AND ITS OPTIMIZATION BY THE METHODS OF ARTIFICIAL INTELLIGENCE

Summary: This paper is focused on the optimization of a DC machine constructional design using the optimized methods which are based on the artificial intelligence algorithms, mainly a genetic algorithm. The optimization should find a compromise between selected constructional parameters and the requirements for properties and operational functions of a machine to be designed.A machine design that was carried out by the "standard" method and a design of algorithm that performs the optimization using the genetic algorithm are described in the paper. In conclusion, the optimized calculation itself is performed and discussed. Results are presented and assessed, and the evaluation of a possible use of artificial intelligence algorithm for this specific optimizing task is carried out.

Key words: DC machine, constructional design, optimization, genetic algorithm, artificial intelligence

1. CONSTRUCTIONAL DESIGN OF DC MACHINE

1.1. General principles of constructional design

The constructional design of DC machine is usually based on demands of customers who specify concrete parameters which the designed machine should meet. Thus, various types may be obtained for the same output of a machine. The data necessary for the design is set forth in relevant standards, however, it can be also derived from tables and diagrams, by measurement in a manufacturer's testing office or even by designer's estimate based on his own experience. The design itself consists basically in finding a compromise between individual constructional parameters and contractor's demands.

1.2. Process of constructional design

The process of constructional design of DC machine can be divided into several basic parts.

- Determination of the principal armature sizes
- Armature winding and slot size
- Design of a magnetic circuit
- Design of a commutator and a collecting mechanism
- Design of a magnetic circuit
- Optimization of field winding
- Magnetic voltage of a rotor yoke
- Stator yoke, outside stator diameter
- Shunt-field winding
- Series field winding
- Losses, efficiency, and warming

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The description of the above parts of design would be too lengthy. Therefore, a list of some solution problems is further outlined only for two of the parts selected.
1) Determination of the principal armature sizes
- Ratio of internal power output per revolution
- Equivalent power output
- Internal power output
- Pole pitch
- Armature current frequency
- Armature current
- Ideal armature length

2) Losses, efficiency, and warming
- Magnetic flux
- Machine speed
- Motor input
- Total efficiency
- Moment
- Total losses of rotor iron
- Total machine efficiency
- Armature cooling surface
- Armature warming
- Commutator cooling surface
- Commutator warming
- Main pole warming

Thus, the calculation of DC machine parameters is not simple at all. There are already some computer programmes in practice that facilitate designer's work. In spite of all that, the constructional design of a machine is still very time consuming.

2. OPTIMIZATION OF THE CONSTRUCTIONAL DESIGN OF DC MACHINE

2.1. Principles of optimization

It is obvious from Section 1 that the constructional design of DC machine is affected by a great number of parameters. When selecting optimized parameters, the task was analyzed and those optimization parameters were chosen that have the greatest influence on the constructional characteristics of the motor being designed. These are basically those parameters that are chosen within the classic design by a designer, based on his own experience. However, these parameters can vary in a quite broad interval, and therefore the determination of their values is elaborate and lengthy.

These parameters are as follows:

Table 1

Identification	Interval	Name
Dk [m]	(0.06-0.085)	Commutator diameter (ČSN 350846)
c [mm]	(0.33 – 0.65)	Air gap under main pole
σ_h [-]	(0.05 – 0.1)	Main pole leakage coefficient
Δh_h [mm]	(3-10)	Pole height
B_{js} [T]	(1-1.5)	Stator yoke induction for steel
σ_{js} [-]	(0.1 –0.15)	Stator yoke leakage coefficient

2.2. Criterion function

In case the values that are going to be optimized have been selected, a criterion by which individual designs will be evaluated must also be chosen. This criterion is called a criterion function. A criterion function assigns a real number to the concrete designed motor which represents the "quality" of the design. Not only the form but also especially the selection of characteristics and parameters of this function are crucial for successful optimization. A criterion function is represented during optimization by the selected characteristics and constructional parameters of the described motor. These include:

- Total machine efficiency η[%]
- Momentary overload capacityM[N·m]
- Copper weightGai[kg]

$$\varepsilon = \mathrm{abs}(kG_{ai} * G_{ai}) + \mathrm{abs}(kM * M) + \mathrm{abs}(k\eta(1-\eta)) \text{ ,}$$

where $G_{ai} = G_a + G_{bs} + G_{bd}$

The effect of each parameter on the total error of optimization can be influenced by adjusting the value of relevant weight coefficient *k*. If there is demand for more pronounced optimization of one characteristic, the relevant weight coefficient increases, which happens at the expense of other parameters. The adjustment of these coefficients is another key problem of the entire optimization process.

2.3. Results of optimization

The "Nedys11" unit containing its own genetic algorithm was used to generate a relevant programme.

Programme "DCmotor" was generated for the constructional design of the optimized DC motor. This programme provides the design of a motor for randomly generated constructional parameters and entered input values, and at the same time evaluates the criterion function produced. This calculation is done for each genetic string representing a set of generated parameters. A number of these genetic strings in one programme cycle is entered directly into a source code. The decrease in the error of the best solution of the last population below the value of demanded error or the programme run through a demanded number of recurrences is a condition for the termination of a genetic algorithm.

The following parameters are adjusted for a genetic algorithm:

Number of estimations: 1
Population size : 160
Total accuracy demanded for the termination of a genetic algorithm: -0.001
Maximum number of cycle recurrences after which a genetic algorithm will be terminated: 15000
Number of genes: 3
Number of mutations: 140

The optimization of the motor design was performed with one optimized parameter, while the weight of other parameters was considered zero. The conclusions are summarized in the table below. For comparison, the results obtained by the classic design are also presented. When comparing the data obtained, it may be stated that relatively good compliance of Individual calculations was achieved.

Table 2

However, the calculation speeds up considerably by the application of genetic algorithms

Identification	1	2	3	4	Classic design
Dk [m]	0.06	0.06	0.06	0.07	0.071
c [mm]	0.48	0.42	0.33	0.45	0.40
σ_h [-]	0.05	0.012	0.012	0.012	0.05
Δh_h [mm]	3	7.8	7.9	3	3.5
B_{js} [T]	1	1	1	1.2	1.2
σ_{js} [-]	0.10	0.15	0.13	0.10	0.1
Ga[kg]	2.28	2.53	2.54	2.53	2.56

3. CONCLUSIONS

The present paper is an introduction to the problem of using genetic algorithms in the optimization of the constructional design of DC machine. This resulted in generating a programme which with the help of a genetic algorithm provides the constructional design of DC machine. Therefore, it may be stated that the use of artificial intelligence in the optimization of the constructional design of DC machines seems to be real and applicable in industrial practice.

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Wpłynęło do Redakcji dnia 20 lutego 2001 r.