OPTIMAL DESIGN OF A SINGLE-PHASE CONDENSER ASYNCHRONOUS MOTOR USING A MODIFIED LAGRANGE MULTIPLIERS METHOD

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Abstract. In this paper a method is proposed and a software product is developed for optimal design of electric machines of low power, in particular single-phase asynchronous condenser motor. The result of application of the developed software is to reduce the mass of active materials engineered in comparison with the base 15% while maintaining the basic parameters of the base engine.

Introduction. The electrical machine as the object of operation must have high energy performance, efficiency and $\cos\varphi$ at a minimal cost, which reduces the contribution of materials to the energy complex. This guarantees a reduction in the current costs of machine operation and capital investments of the consumer. However the current stage of the economic complex of Ukraine is characterized by a significant temporary reduction of production capacity, technological base and the scientific-technical potential in the given area. The number of profile electromechanical productions decreases, the level of needs of many types of electric machines of low capacity is reduced in connection with the increase of import substitution. The constant rise in energy prices requires improvements in the energy performance of electric machines, increased reliability and longer service life.

Today consumer dictates its conditions, so the choice of target function for optimal design is determined by the technical task that the user gives. The choice of methods should permit the rapid adaptation of the goal function to the task. The most important requirement for production is the minimum material capacity of electric machines and, accordingly, the saving of expensive copper, electrotechnical steel, aluminum, insulators and other structural materials.

Wide automation of design works in the near future will make significant changes in the process of building electrical machines. It will also change the direction of the learning design. In order to prevent unnecessary time losses, automated CAD systems should be created.

New conditions require from engineers-electromechanics new approaches to the design and organization of the production of electric machines, the design and preparation of production of small but various modifications, series of electric machines, in particular asynchronous single-phase low-power engines, is considerably shortened. The variety of types and modifications of electric machines significantly reduces the possibilities of automation of production and puts the technological opportunities for the rapid transition to the production of small series of electric machines. In this paper, an optimal design approach has been implemented to minimize the use of active materials, namely the reduction of the mass of electrical steel.

Main part. From the point of view of formalization, the optimal design of electric engines is a partial case of multi-parameter optimal design. The object of optimization - an electric machine - can be considered as a system of functions from variables input parameters X_1, X_2, ..., X_n and the output value F. In the general case, such a system has n variable parameters, which are called independent variables. The input of the system is an n-dimensional vector $\bar{X} = (X_1, X_2, \dots, X_n)^T$, and the output of the system is a functionally dependent scalar value independent of the state of independent variables $F(\bar{X})$. Value $F(\bar{X})$, characterizing the quality of the machine being designed, has been called the criterion of optimality or quality function.

Both the input parameters and the characteristics of an object of optimization may be subject to restrictions that are conditioned by the requirements of standards, specifications and other regulatory documents. These are vector-dependent restrictions $\bar{X}$ it is possible to bring to mind $G_j(\bar{X}) \geq 0$, where j = 1, 2, ..., m.

When designing a single-phase induction motor, it is expedient to limit seven independent variables: the diameter of the stator's stroke, the length of the stator package, the stator's width, the width of the rotor, the height of the stator wall, the height of the rotor wall and the outside diameter of the stator sheet.

Controlled characteristics of single-phase asynchronous motor - are regulated by standards or technical conditions the value of the multiplicity of the starting torque, the multiplicity of the starting current, the multiplicity of the maximum torque, the excess of the stator winding temperature, the coefficient of filling of the groove, the efficiency factor and the power factor.

The criterion of optimality of the engine was taken a mass of electrical steel (F). It is the sum of the steel masses of the back and teeth of the stator and the rotor:

$$F = GAS + GAR + GZS + GZR,$$

where GAS is the weight of the stator backrest, kg;
GAR is the weight of steel rotor back, kg;
GZS is the mass of steel of stator teeth, kg;
GZR is the mass of steel of teeth of a rotor, kg.

Thus, the following problem of conditional nonlinear optimization was obtained:

$$\begin{cases} F(\bar{X}) \to min \\ \tilde{G}_j(\bar{X}) \geq 0, j = 1, \dots, m \\ X_i \geq 0, i = 1, \dots, n \end{cases}$$

where m = n = 7;
$\tilde{G}_j(\bar{X})$ – modified restrictions function: $\tilde{G}_j(\bar{X}) = G_j(\bar{X}) - b_j$ or $\tilde{G}_j(\bar{X}) == b_j - G_j(\bar{X})$;
$b_j -$ limitations on engine specifications.

Using built-in algorithms in space R^n a finite sequence of points is constructed, which starts from a certain starting point and ends with a point that gives the best approximation to the solution of the problem among all points of the constructed sequence. The calculation of the function-constraints and the optimality criterion is performed by multiple calculation, which is described in detail in the work [2].

The solution of this problem was carried out by four methods:

1) by the method of penalty functions;
2) by the modified Lagrange multipliers method;
3) by the method of acceptable directions;
4) by the method of complexes.

A modified method of Lagrange multipliers was chosen, since it was the most stable, in comparison with the method of complexes, and did not accumulate arithmetic errors, in comparison with methods of penalty functions and acceptable directions.

For optimal design of a single-phase asynchronous motor, an application was written in a C# programming language with a user-friendly interface written using the Windows Presentation client application builder Foundation (WPF).

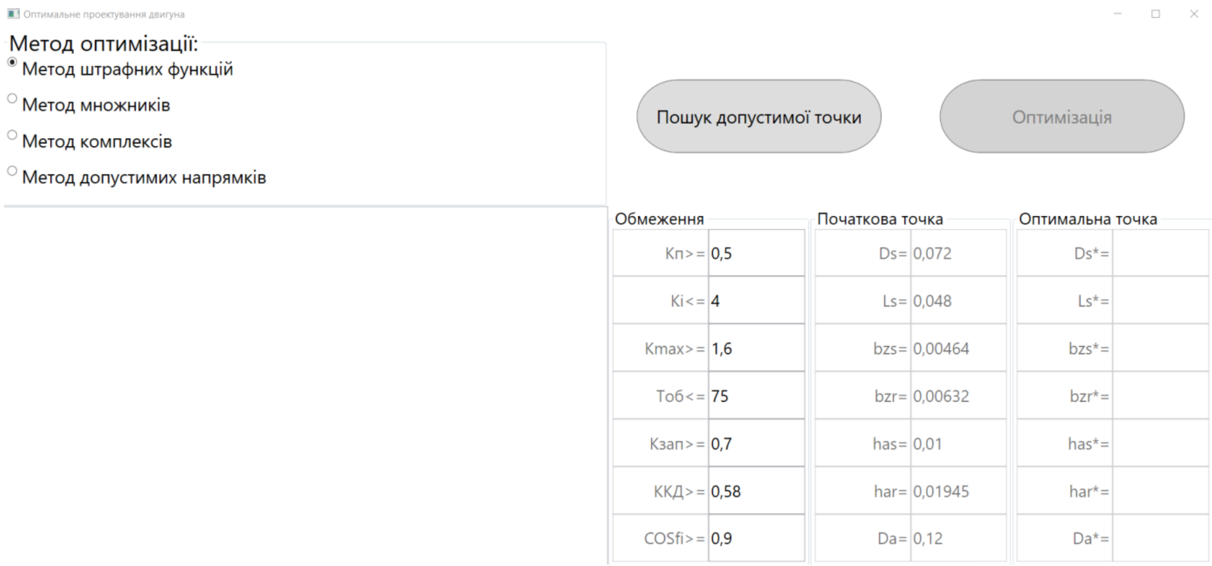

Figure 1 – Main menu of the program

Input data for calculating the condenser engine:

1) the diameter of the stator's blade $(D_s) = 0{,}072$ m;
2) the length of the stator bag $(L_s) = 0{,}048$ m;
3) the width of the stator's tower $(b_{zs}) = 0{,}00464$ m;
4) the width of the rotor's tooth $(b_{zr}) = 0{,}00632$ m;
5) the height of the stator's back $(h_{as}) = 0{,}01$ m;
6) the height of the back of the rotor $(h_{ar}) = 0{,}01945$ m;
7) external diameter of the stator sheet $(D_a) = 0{,}12$ m.

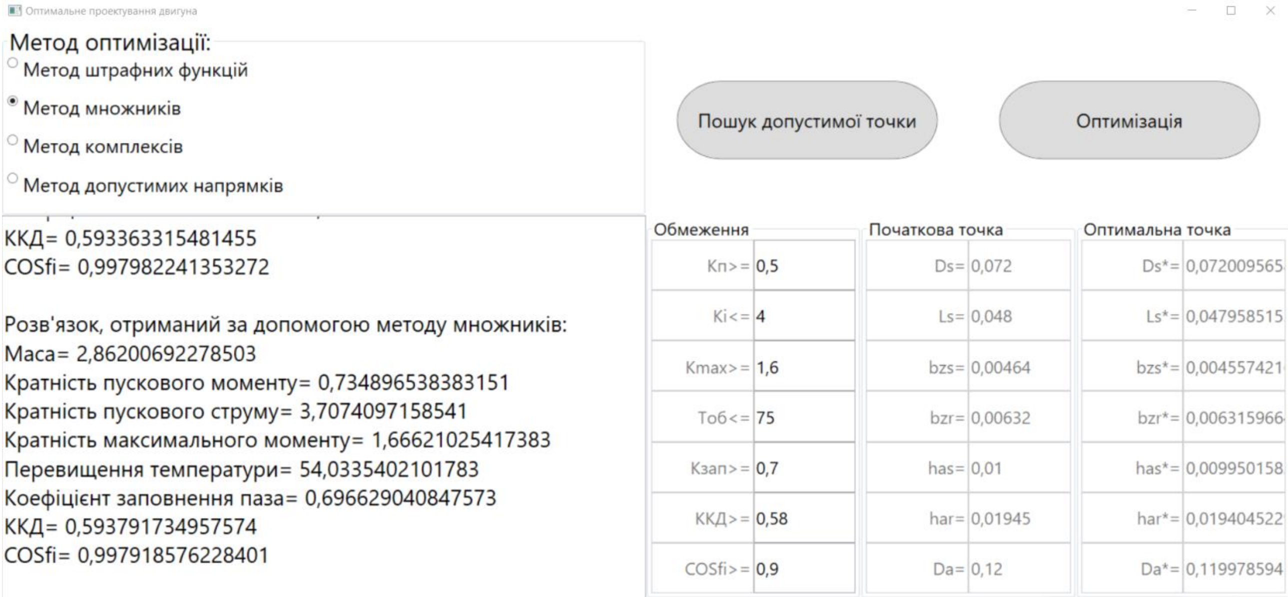

Figure 2 – Calculation results

Results. Optimal result of the calculation:

1) the diameter of the stator's blade $(D_s) = 0{,}072$ m;
2) the length of the stator bag $(L_s) = 0{,}04796$ m;
3) the width of the stator's tower $(b_{zs}) = 0{,}00456$ m;
4) the width of the rotor's tooth $(b_{zr}) = 0{,}00632$ m;
5) the height of the stator's back $(h_{as}) = 0{,}01$ m;
6) the height of the back of the rotor $(h_{ar}) = 0{,}0194$ m;
7) external diameter of the stator sheet $(D_a) = 0{,}12$ m.

When comparing the parameters of the base engine with the received, the mass of active materials was reduced by 15%.

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