

Particle Swarm Design Optimisation of Single Phase Permanent Magnet Brushless DC Motor

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Abstract—In this paper a particle swarm based optimal design of single-phase permanent magnet brushless DC motor (SPBLDCM) is proposed. This approach employs a particle-swarm-optimisation (PSO) technique as a search tool for optimal design solution of a SPBLDCM based on the value of the objective function. The efficiency of the motor is selected as an objective function. Several optimisation solutions are analysed and a best solution is proposed based on the optimisation parameters, as well as other important motor parameters. An overall comparison of the best optimal solution and the prototype model of the motor is presented.

Keywords—design optimisation; particle swarm optimisation; single phase permanent magnet DC motor, energy efficiency.

I. INTRODUCTION

Efficiency improvement of electrical machines has become of wide interest to researchers and designers, due to the increase of electricity demand and price, as well as the stiff competition on the market. During the years different optimisation algorithms have been implemented in the design procedures for a variety of electrical machines. When optimising an electric motor, there are multiple choices of the objective function available. The objective function is the specific property of the machine to be optimised, for example efficiency, torque, volume or cost. The work in this paper will be focused on the optimisation of a motor design using efficiency as an objective function.

In general the optimal design of electrical machines is a constrained maximisation/minimisation problem with a large number of optimisation parameters and variety of constraints. This makes it a difficult problem to solve for the deterministic methods, but on the other hand quite an easy task for the stochastic methods, especially for Particle Swarm Optimisation (PSO) method. In this work an optimal design of a single-phase permanent magnet brushless DC motor using efficiency as objective function is performed. In the design procedure performed on the brushless PM motor, particle swarm optimisation, as an optimisation tool is used. Comparative analysis of the optimal motor solution based on the objective function value, as well as the values of other important parameters in relation to the initial model is presented.

II. DESCRIPTION OF PARTICLE SWARM OPTIMISATION

The initial PSO algorithm [1-3] was inspired by the social behaviour of biological organisms, and the ability of groups of some species of animals to work as a whole in locating desirable positions in a given area. Such behaviour

can be associated with the birds flocking to a food source. This behaviour is very much in relation to the optimisation search for a solution to a non-linear function in a real number search space.

In the PSO search the particles move through the search area using a combination of an attraction to their best solution they have independently found, as well as to the attraction to the best solution that any particle in the neighbourhood has found. The algorithm, which is based on a metaphor of social interaction, searches a space by adjusting the trajectories of moving points in a multi-dimensional space. The main advantages of PSO algorithm are summarised as simple concept, easy implementation, robustness to control parameters, and computational efficiency when compared with deterministic methods and other stochastic optimisation techniques. Unlike the other heuristic techniques, PSO has a flexible and well balanced mechanism to enhance and adapt both to the global and local exploration abilities. The PSO concept consists of, at each time step, changing the velocity each particle toward its personal best and global best locations. The acceleration is weighted by a random term, with separate random numbers being generated for acceleration toward personal best and global best.

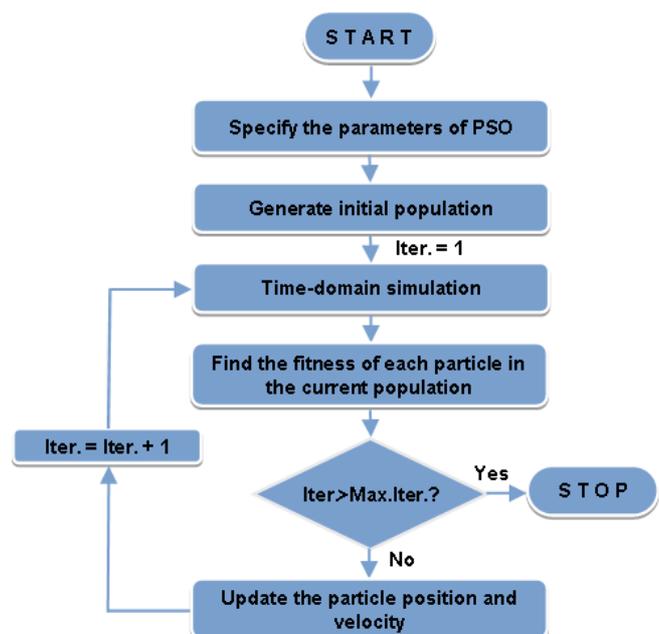


Figure 1. PSO main steps.

The following values of the PSO parameters have been considered: number of particles (variables) – 6, population size – 30 and number of iterations – 100. A block diagram of the PSO main steps is presented in Fig. 1.

III. IMPLEMENTATION OF PSO IN OPTIMAL DESIGN OF SPBLDCM

The efficiency of the motor is selected as an objective function of the optimisation, since the energy saving is especially important for the SPBLDCM. According to the design characteristics of the designed by hand prototype SPBLDCM, some of the parameters are chosen to be constant and some variable, such as: outside radius of the rotor core R_{ro} , permanent magnet radial thickness l_m , air-gap g , slot opening b_{so} , axial active length of the motor L , and single wire radius r_{cu} . Some of these parameters are presented in Figure 2. The objective function for the optimisation is presented by equation (1).

$$\text{efficiency} = \eta = \frac{T \cdot \omega_m}{T \cdot \omega_m + P_{Cu} + P_{Fe} + P_s} \quad (1)$$

where: T -rated torque, ω_m -rated speed, P_{Cu} -ohmic power loss, P_{Fe} -stator iron core power loss and P_s -other constant losses.

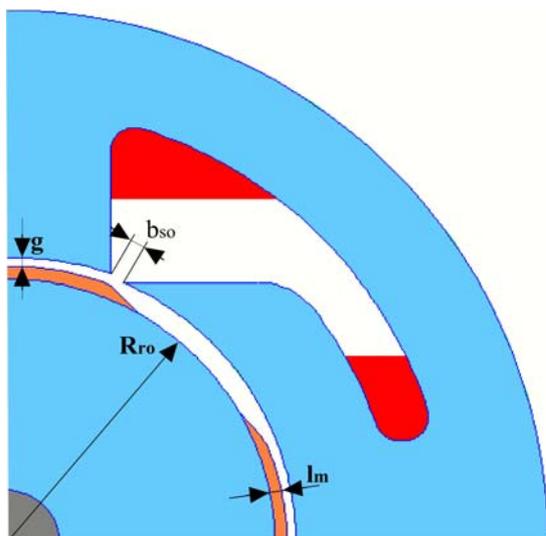


Figure 2. SPBLDCM optimisation parameter presentation.

TABLE I. PSO PARAMETER OPTIMISATION BOUNDS

Parameters	Lower bound	Upper bound	Basic model
R_{ro} (m)	0.0342	0.0418	0.0380
l_m (m)	0.0018	0.0022	0.0020
g (m)	0.0009	0.0011	0.0010
b_{so} (m)	0.0020	0.0030	0.0023
L (m)	0.0972	0.1188	0.1080
r_{cu} (m)	0.0003	0.0005	0.0004

The stopping rule of the programme PS-ODEM (Particle Swarm for Optimal Design of Electrical Machines) is selected to be the number of iterations. The lower and upper bound, and the optimisation parameters values of the prototype model, are presented in Table 1.

TABLE II. PARTICLE SWARM OPTIMISATION RESULTS

Variables	Units	Basic model	PSO Solution
R_{ro}	(m)	0.038	0.0418
l_m	(m)	0.002	0.00194
g	(m)	0.001	0.0009
b_{so}	(m)	0.0023	0.003
L	(m)	0.108	0.0972
r_{cu}	(m)	0.0004	0.0005
Efficiency	(/)	0.8823	0.9049

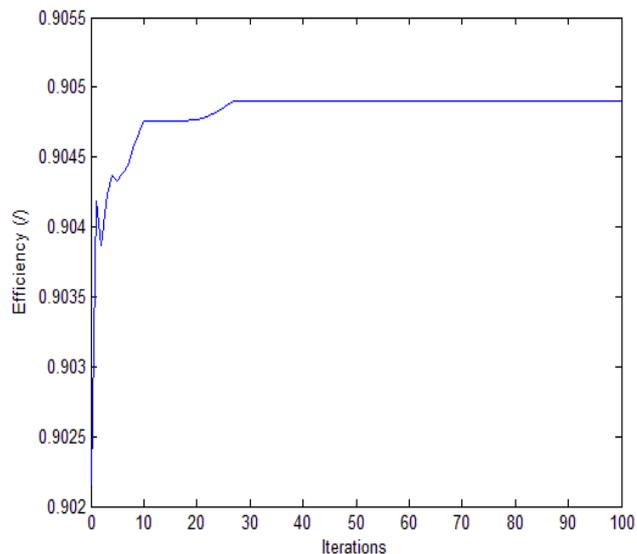


Figure 3. Efficiency change during PSO search.

The comparative optimisation parameters data of the basic and optimised model are presented in Table 2. The convergence of the efficiency of the motor as an objective function during the particle swarm optimisation search for 100 iterations is shown in Fig. 3.

In the full version of the paper a more detailed description of the PSO procedure will be presented. The comparison analysis of the optimised solution and the prototype is going to be based on the values of the optimised objective function, on the values of the optimisation parameters, and on a set of electric and magnetic parameters of the motor, as shown in Table 2. The change of the value of the objective function and the optimisation parameters through the optimisation procedure will be also presented. Finally the optimised model and the initial model, using the results of the 2D FEM magnetic field calculation, are going to be analysed and compared. Performance characteristics, as magnetic field and air gap flux density distribution will be presented and analysed for both models.

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