Optimization of Electrostatic Micromotors using 3D Finite Elements

TB. Johansson, M. Van Dessel, K. Hameyer, R. Belmans
Dep. EE-Lab. EMA, K.U. Leuven, Kard Mercierlaan 94
B-3001 Heverlee- Leuven, Belgium

The paper will introducethe optimisation of an electrostatic micro motor with three dimensional finite element (FEM) model and numerical optimisation subject to global properties as average torque and torqueripple. It is an extension from [1] where an optimisation was performed in 2 dimensions. In this paper the modelling and analysis is combined with a new very powerful evolution strategy for optimisation [2].

The goal with the work presented here is to find tools to optimise a big range of different designs of electrostatic micromotors and actuators. One of the tools developed is a model builder for 3D meshes. All the model builder need to generate the 3D model is the outline of the motor crossection and the following parameters.

1. Number of stator poles (electrodes).
2. Width of stator-tooth (electrode).
3. Number of rotor poles (rotor-teeth).
4. Width of rotor-tooth.
5. Rotor position

These parameters can be chosen freely and, except for number of stator and rotor poles, the parameters are not restricted to integers. The technique used makes the model builder fast. Building the 3D mesh, typically 150000 tetrahedrons, takes only a few minutes. The model builder does futher-more ensure a high quality of 3D mesh.

The simulation is performed in four steps:

1. Generation of FEM models,
2. solving the equivalent circuit for each model,
3. evaluation of the average torque and torqueripple with excited equivalent circuit and
4. finally using the numerical optimisation algorithm to generate the parameters for the FEM model in the next step of iteration.

The optimisation aims to the maximisation of the average torque and simultaneously minimising the torque pulsations.

Also, as reported in [1] finding the stored energy for two different excitations is sufficient to find the equivalent circuit for each design. Thus the analyse-part finding the average torque is the same as the one used in [1]. In contrast to [1], where the optimisation in principle was based on inspecting the result from a large number of different designs, this optimisation is performed using a numerical optimisation method the so called evolution strategy. This technique earlier reported in [2]. For optimisation a combination of evolution strategy and simulated annealing is used. The application to a linear electrostatic problem is demonstrated by maximising the average torque by a given excitation voltage. Additional geometrical restrictions result from fabrication conditions. The basic concept of the evolution strategy is found in the substitution of DARWIN's notion of fitness to the quality of a technical problem. In the optimisation process the repetition of mutation and selection in successive steps leads from an initial to an improved solution. To get a global optimisation method the rules of simulated annealing are combined with the evolution strategy. The substitution of the term energy in the idea of simulated annealing for the quality of the system leads to a robust optimisation technique. The full paper will discuss in detail the methodology, characteristic features and behaviour of the methods used.

Figure 1 and 2 shows two geometries that have been investigated. Both these designs have a rotor diameter of 600 μm and a height of 100 μm. Due to reasons of fabrication the airgap was fixed to 10 μm

[1] T.B.Johansson, M.Van Dessel, R.Belmans, W.Geysen, R.Hanitsch: "An optimisation scheme of electrostatic micromotors based on an Equivalent Circuit - Finite Element approach." ICEM 1992, UMIST Manchester UK, September 15-17 1992 pp. 1157-1161.

[2] K. Hameyer and R. Hanitsch: "Numerical optimization of the electromagnetic field by stochastic search and MEC-model", COMPUMAG, November 1993, Miami, USA.

[3] MagNet Users Manual, Infolytica Corporation, Canada, 1991

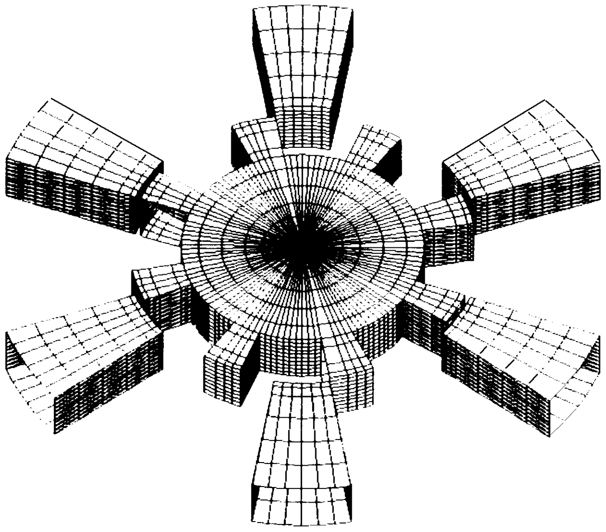

Fig. 1 Constraint surfaces of a 6/8 pole electrostatic "LIGA-type" micromotor

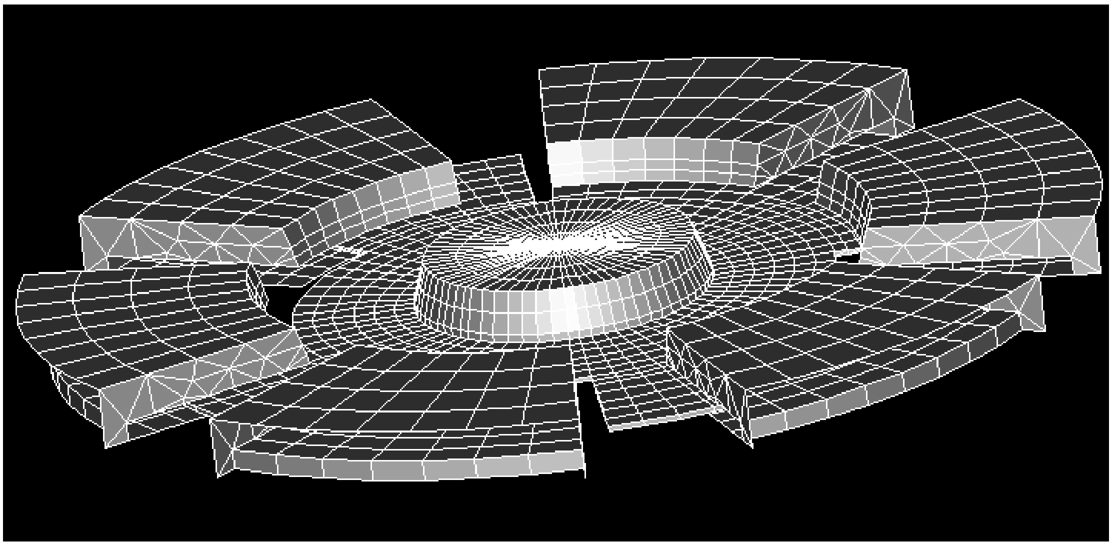

Fig. 2 Constraint surfaces of a 6/4 pole electrostatic "ESIEE-type" micromotor