Automatic generation of Active Magnetic Bearing geometry with COMSOL Multiphysics.

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Abstract: This paper presents a new approach in the AMB modeling and design methodology. The presented method and algorithm allows to generate the AMB components automatically. Number of poles and AMB dimensions can be set and modified in a programming way. The advantage of smooth stator corners is introduced and implemented in the realized algorithm. Solid modeling features are discussed while creating composite objects. Selected configurations are presented to show features of the realized method.

Keywords: rational curve, nonlinear shape, magnetic field, active magnetic bearing, quality.

1. Introduction

The interdyscyplinary analysis is required for such systems as magnetic suspensions and active magnetic bearings. Both of them can be designed in many ways but have common elements: electromagnet, control system with power actuators and target object of levitation. The cross-disciplinary analysis can be done with the COMSOL Multiphysics [5] software that allows connection with simulation environment dedicated to control. Before the complex system model will be modeled the most important design aspect ought to be considered – the effective execution unit. It means that the electromagnetic force generated by the electromagnet needs to satisfy static and dynamic properties in the controlled system. This force is generated by an electromagnet consisting of stator and coils. And thus the electromagnet construction, let’s say precisely: its shape that forms accurately the magnetic field flux is considered in the described research.

It is well known that the electromagnetic force [1, 2] acting on the ferromagnetic object depends on the flux and separating volume of media (Fig. 1). Many aspects during shape design could be taken into consideration to obtain an optimal form for the particular design.

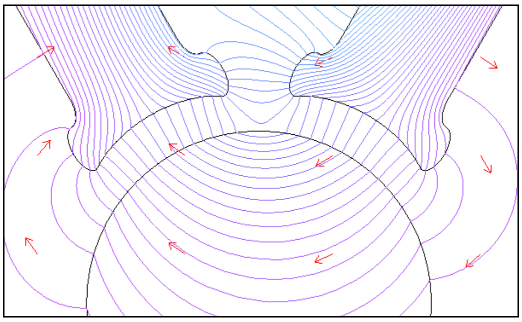

Figure 1. COMSOL - visualization of magnetic field flow while acting on the target object.

The area of magnetic field flow is characterized by length, width and smoothness. The electromagnetic force value depend on these parameters too. So to improve the quality and losses minimization the electromagnet stator geometry ought to be considered. As it was concluded in previous research [3] the magnetic field path ought to be as smooth as possible to eliminate flux concentration and losses.

2. Basis of stator shape

Typical construction of the AMB stator is created with a set of combined circles and lines defining magnetic flux path and poles for coil windings. Figure 2 presents a part of typical stator shape together with concentric rotor. The stator is characterized by: h, a, R_{be}, R_{bi}, R_b dimensions. and rotor by radius R_r

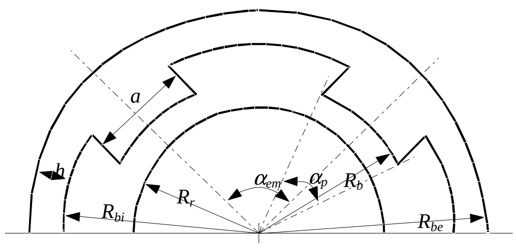

Figure 2. The caption should be centered underneath the figure and set in 9-point font.

The distance between pole and rotor is in the range of 100-400μm usually. For the research purposes it was required to specify a variable parameters for easy shape generation and modification by the method dedicated to automatic AMB design.

3. Algorithm

The algorithm (Fig. 3) is based on COMSOL *curve2* function [6] that allows to create 2D rational Bézier curve [4] object. This function accepts two vectors containing x and y coordinates of the selected points. When extra parameter w is used the points weight could be also specified.

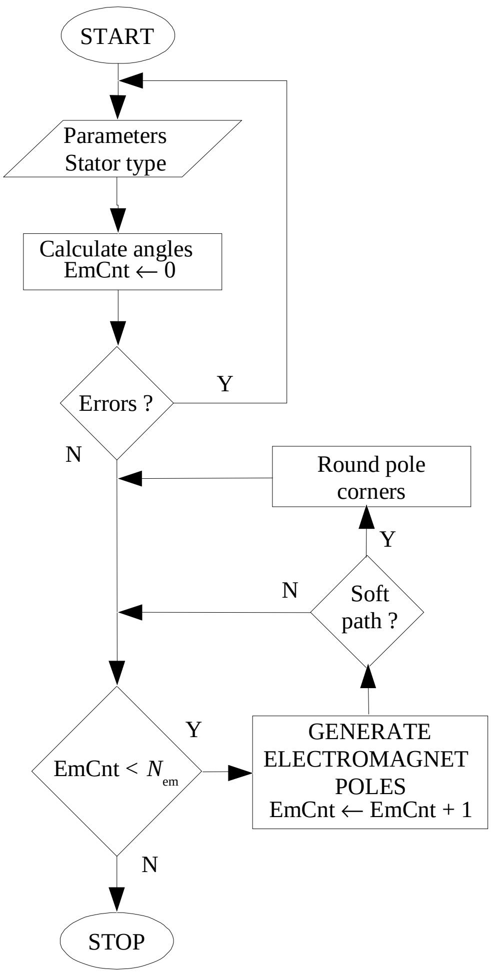

Figure 3. Algorithm of automatic AMB shape generation.

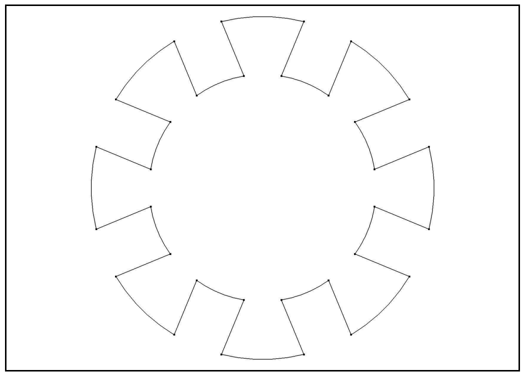

Figure 4. Generated stator shape –sharp corners.

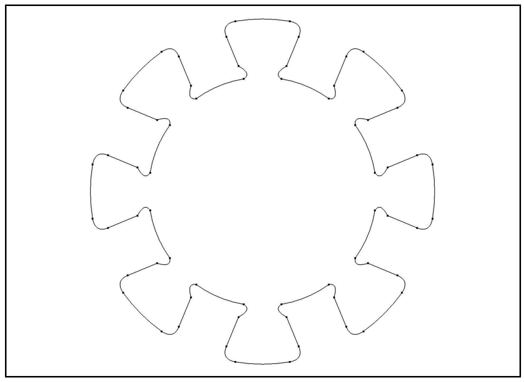

Figure 5. Generated stator shape – smooth corners.

To use this function the presented algorithm was equipped with additional user-defined function *bezcrv2abr* that generates knots and control points for the particular arc described by symmetry axis angle, arc angle and radius. This function allows to simplify calculations and gives the best fit of the created curve to the originally expected arc shape. The typical generated shape with marked knots is presented in Fig. 4. In the algorithm the procedure that makes smooth transition in pole corners (see Fig. 5) is also implemented. The user can specify a round-off radius. Such parameterization allows to perform a research of magnetic field path properties. The AMB front and back planes are parallel, thus the 3D form can be extruded from 2D shape. Figure 6 presents 3D view of AMB stator with a specified depth.

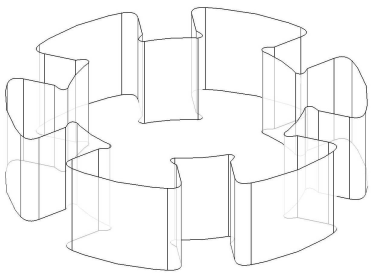

Figure 6. 3D surface of the AMB stator.

4. Creating AMB composite objects

To obtain a complex AMB model all components (stator, rotor, coils and the air gap) ought to be represented in a graphical form. With specified parameters the left-side and right-side coils are generated for all AMB poles. Their size is determined by fixed width and two radiuses constrained by R_{bi} and R_b values. The rotor is created as a circle type object or as a set of arc segments. When all shapes are defined the *geomcoerce* function is called to obtain solid rotor and coils objects. The stator and air gap are created automatically using COMSOL solid modeling features. Having the circle defined by radius R_e and using subtract operation on it and generated stator shape the stator object is composed (see Fig. 7). The air gap is a result of subtract operation on stator, coils and rotor objects (see Fig. 8) respectively. One of advantages of the presented method is, that all objects (see Fig,. 9) defining subdomains are fitted precisely to each other.

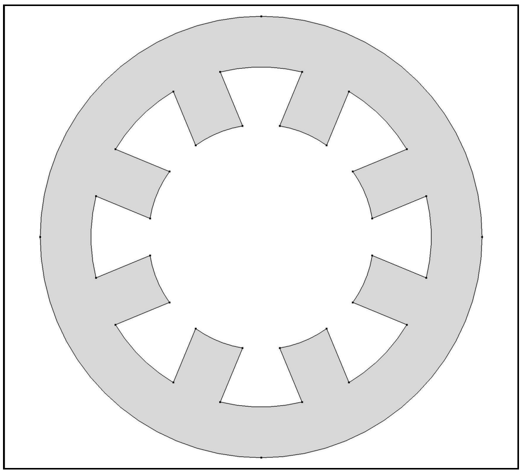

Figure 7. Composed stator.

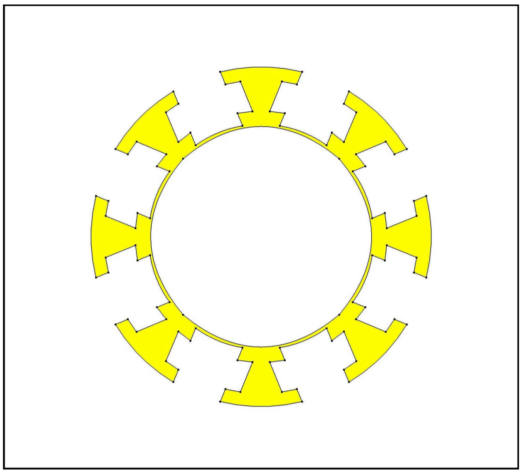

Figure 8. Air gap shape.

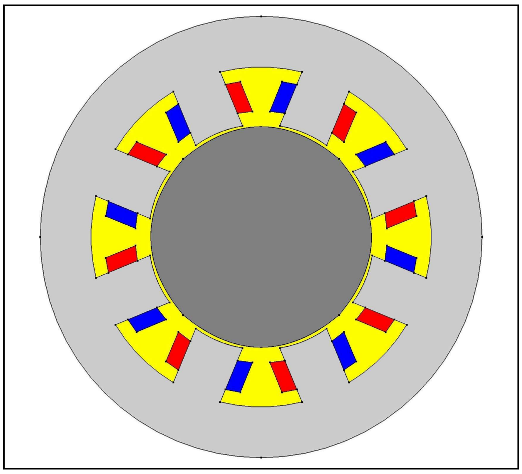

Figure 9. AMB elements (stator – light gray, rotor – dark gray, air gap – yellow, red and blue – coils) .

This feature avoids the problem that sometimes can occur while importing from CAD software and the manual user interaction is required.

5. View of selected AMB stator shapes

With the presented method a number of configurations can be obtained. All user-defined parameters a, R_{be}, R_{bi}, R_b, R_r, α_{rem} and α_p can be modified manually or automatically. With manual set-up the initial configuration can be created, while the automatic modification is required at the optimization stage.

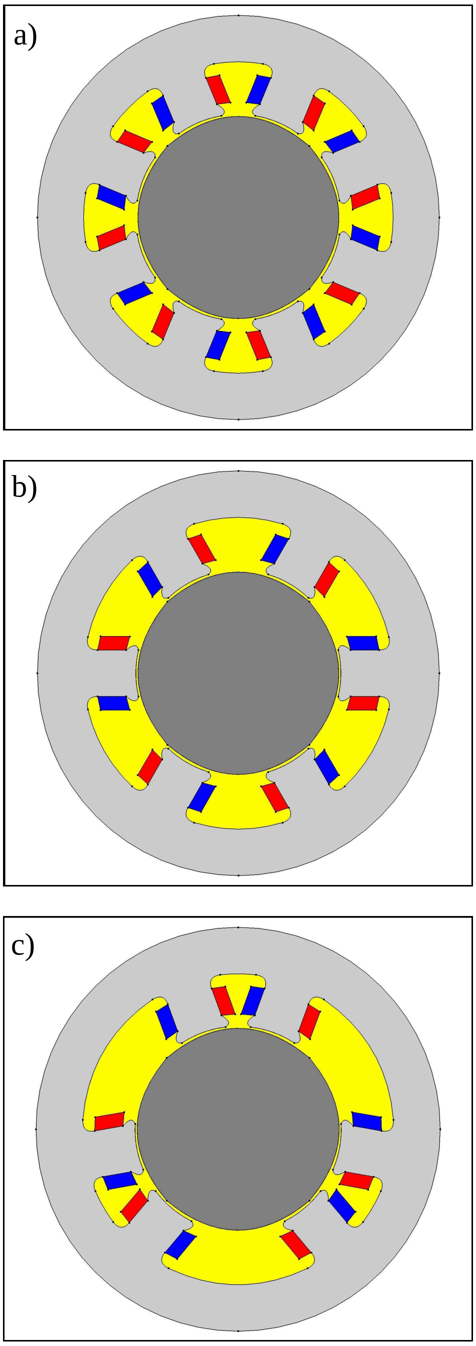

Figure 10. Possible AMB designs – selected examples: a) fully symmetrical 8 pole AMB, b) 6 pole AMB where $\alpha_{em} = \alpha_p$, c) 6 pole AMB where $\alpha_{em} > \alpha_p$,

The initial configuration can be done in an automatic way when the choice of AMB structure is a goal of best AMB type selection.

Figure 10 presents three different AMBs characterized by rounded corners, number of 8 or 6 poles and angles α_{em} *and* α_p. The results of the rounded corners extension implemented in the algorithm are visualized in presented AMB shapes. The generated shapes can be easily assigned to the *fem* structure of COMSOL package. Therefore automatically generated shapes and assignment of appropriate properties to the generated regions allows to solve the problem without any user interaction.

6. Conclusions

Using COMSOL Multiphysics software and COMSOL Script the AMB components were generated with the proposed method and described algorithm. The parametric approach allows to generate many different shapes characterized by number of poles, dimensions and corners smoothness. This automatic procedure is prepared for shape optimization and further research. Particular elements generated automatically compounds a stator frame, coils and rotor. The solid modeling techniques and Boolean features were used to easily obtain composite objects. The user-defined procedures and COMSOL Script advantages allowed to successfully realize a software that can generate a number of parameterized configurations in an automatic way. Due to front and back planes parallelism the 3D shape can extruded from the obtained 2D form.

7. References

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8. Acknowledgements

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