Script Controlled Modeling of Low Noise Permanent Magnet Synchronous Machines \by using JMAG Designer

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Abstract – ***This paper deals with the parameterized modeling of permanent magnet synchronous machines (PMSM) by means of JMAG Designer, an advanced simulation software for electromechanical design. This method enables the designer to simulate diverse topologies of the machines by only changing some basic parameters of the script controlling the preprocessing phase of the simulations. For this purpose a graphical user interface for modeling the machine was built up in Visual Basic. Thru it the users can enter the main design parameters of the studied machine. The motor model is developed in JMAG-Designer by using the parameters. For each machine topology taken into study finite elements analysis (FEA) can be employed, as magnetostatic analysis or time-stepping study via coupling the machine model to electrical circuits. The parameterized modeling and script writing are both detailed in the paper. The developed simulation tool was tested for a particular surface magnet PMSM, having 4 poles and 24 stator slots.***

Keywords: permanent magnet synchronous machine, JMAG Designer, parameterized modeling scripts, design parameters.

I. INTRODUCTION

Nowadays permanent magnet synchronous motor (PMSM) drives are gradually replacing induction motors drives in many advanced applications. This is becoming a trend due to some key features of PM motors, including compactness, efficiency, robustness, reliability and shape adaptation to the working environment. Generally, they exhibit low noise compared to their counterparts intended for similar applications [1], [2].

An important electrical engineering challenge is to design optimal electrical machines tailored for specific applications. This research implies a very time consuming simulation of numerous topologies. The development time can be radically reduced as the simulation process is simplified by applying an automated, script based problem formulation.

For the finite elements analysis (FEA) of the PMSMs under study the JMAG software produced by the JSOL Corp. (Japan) was used [3]. It is an advanced simulation tool specially developed for the FEA of electromechanical devices. JMAG was originally released in 1983 as a tool to support design for electrical motors, actuators, circuit components and antennas. It incorporates simulation technology to accurately analyze a wide range of physical phenomenon that includes complicated geometry, various material properties, and the heat and structure at the center of electromagnetic fields.

The general flow of a FEA is described below. When performing a magnetic field analysis the ability to create the geometry, to set materials, to specify conditions, and generate mesh is vital [4]. JMAG provides various functions to accomplish all these goals.

When a model is created, several steps need to be completed:

- to create a geometry
- to set the materials and sources
- to set the boundary conditions
- to generate the mesh.

Because creating a model of an electrical machine is a difficult task and takes a lot of time, a first objective was to implement a PMSM model for which the main geometrical parameters can be easily changed from a graphical user interface (GUI). The second goal was to automatically link it with other software packages such as MATLAB-Simulink, Mathcad, or others. A block schematic of the links between different software is given in Figure 1.

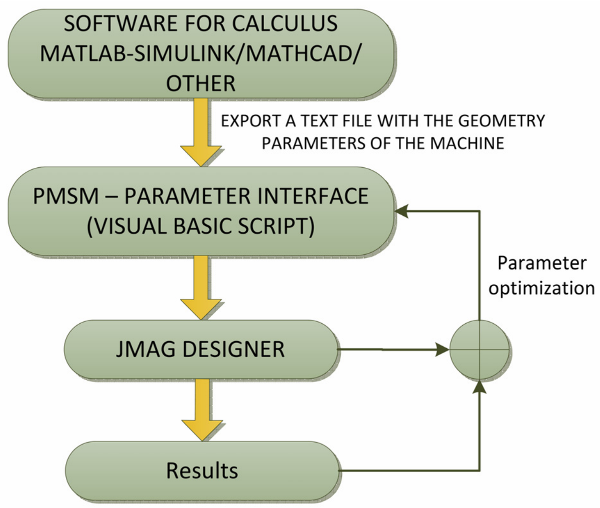

Figure 1. Software chain of the parameterized model

An interface for specifying geometric design parameters has been created by combining JMAG-Designer with a user interface that is based on familiar scripting languages Visual Basic. The interface will be presented in more detail in the next section

Innovative is the fact that the new motor design can be configured in less time, the specifications can be modified easily and the results of the electromagnetic analysis can be optimized with minimum effort.

II. CREATING THE SCRIPT IN VISUAL STUDIO

The JMAG Designer preprocessor, postprocessor and the solver can be controlled using scripts. This allows all procedures from creating a model to displaying the results to be run automatically. This advanced simulation technique can be used to either automate commonly performed operations, or to link JMAG to other software, such as optimizers, which need to control JMAG programmatically. In this case scripts were written in Visual Basic, a programming language within the Visual Studio Software Package, due to the interface advantages.

A flowchart of the developed script is shown in Figure 2

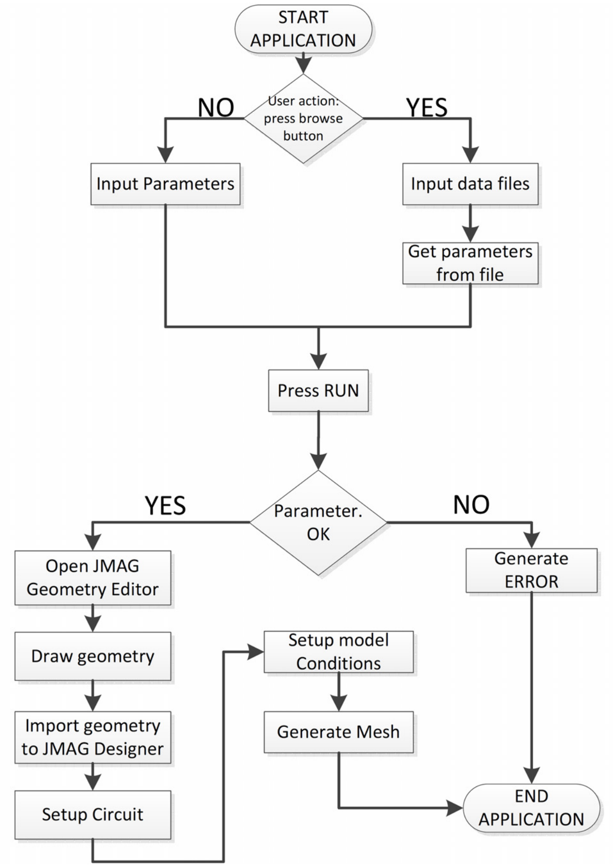

Figure 2. Logic block scheme of the script for parameterized PMSM FEA

The application was developed in VB.NET 2012 because it was simple to link with JMAG Designer.

As shown in the flowchart, the "START Application" command will call the execution of the script.

The GUI allows the user to set geometry parameters of the motor either from keyboard in fields of parameters or by uploading a data file. This data file must be a text file, and each distinct line must contain a value for each parameter in respective order. The imported file can be resulted from an analytical calculation in Mathcad, MATLAB, or other software.

The following parameters can be configured:

- number of stator slots
- outside diameter and inside diameter of the stator
- the number of rotor poles
- distance between magnets
- shaft diameter
- air-gap length.

All dimensions have to be given in the GUI in millimeters.

Figure 3 shows the GUI developed for the PMSM parameterization.

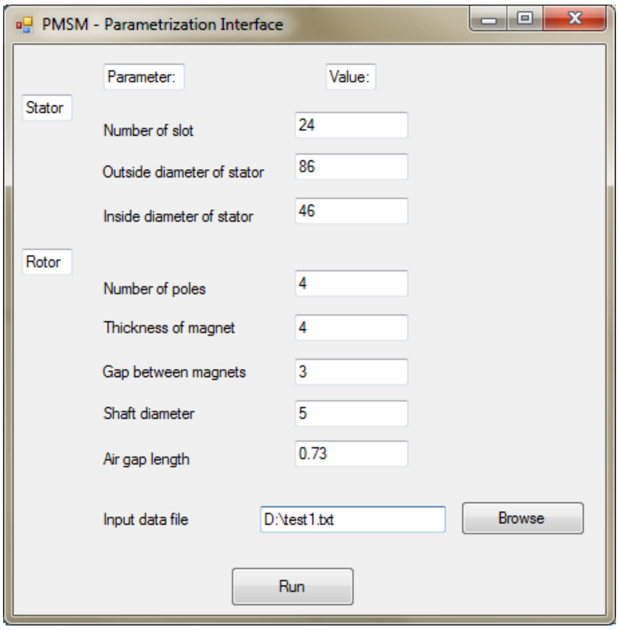

Figure 3. The GUI for the PMSM geometry parameterization

Upon pressing the "Run" button, the input parameters are being checked for syntax and logical errors. If the check is not successful, an error screen is generated and the application stops. When no error occurs, JMAG: Geometry Editor is called and using the ActiveX framework with different methods, the model's geometry characterized by the previously entered parameters will be drawn. When the geometry is completely drawn it is automatically saved and exported to the JMAG Designer.

JMAG Designer application uses its built-in settings for creating the corresponding circuit. Also default materials, windings, conditions and mesh are being used, but these can be easily changed if the user requires.

III. RESULTS FOR A PARTICULAR CASE. A 24 SLOT AND 4 POLE PMSM

After running the parameterization interface, JMAG Designer Geometry Editor generates the geometry for the new model, and then this model is imported to JMAG Designer, where materials, conditions, winding, circuit and others settings can be changed from the ones implemented in the script.

The generated geometry model for a 24 slot and 4 poles PMSM is given in Figure 4.

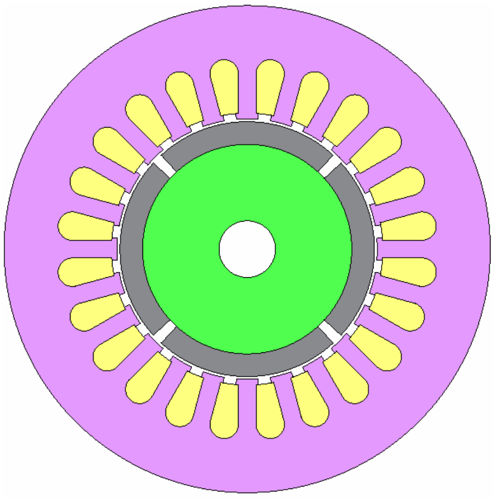

Figure 4. PMSM model generated in JMAG Designer

Next the main steps of the pre-processing stage of the FEA to be performed are detailed.

A. Selecting the Materials

In this step the materials used for construction of each part of the PMSM have to be selected
The performed selections are given Table I.

Table I. Materials used for the motor

Part	Material data
Rotor core	JFE Steel: 50JN1300, lamination factor 98%
Stator core	JFE Steel: 50JN1300, lamination factor 98%
Permanent magnet	Hitachi Metals (SSMC): NEOMAX-42(reversible) Parallel Pattern (Circular Direction)
Coils	Copper

The iron cores are built up from non-linear magnetic materials facing magnetic saturation. Such a nonlinear material was set for the magnetizing property of both the rotor core and the stator core. The magnetization direction of the PM can be set easily by selecting a magnetization pattern when the magnet is magnetized uniformly. The parallel pattern (circular direction) was selected for this analysis.

B. Creating the Circuit

A circuit model of a three-phase star connection was created.

C. Setting the Simulation Conditions

The rotation motion condition specifies the motion of the motor. In an actual motor, the rotor turns by excitation. In JMAG, the rotor does not rotate by excitation without setting the rotation motion condition.
Nodal Force condition was set to obtain the torque for a specified part. The value of the torque is positive if the rotor spins in the counterclockwise direction.

D. Generating the Mesh

In order to make the numerical analysis for a model, a mesh had to be created. Figure 5 depicts the automatically generated mesh.

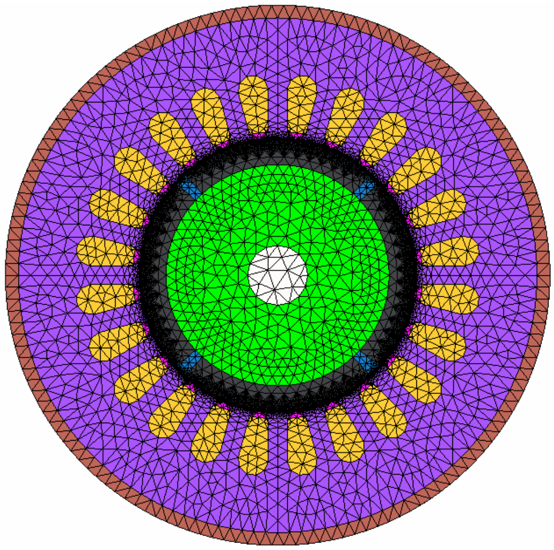

Figure 5 Generated mesh for the PMSM

A zoomed area of the mesh is shown in Figure 6 in order to observe also the very small finite elements generated in the air-gap and its surroundings.

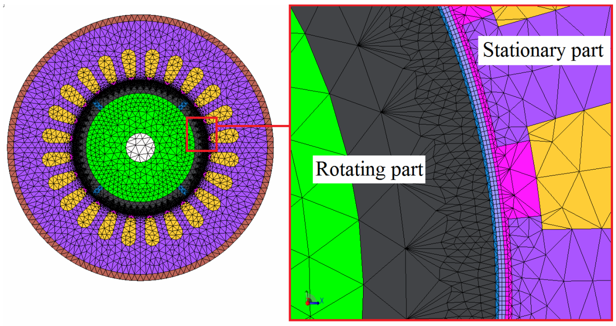

Figure 6. Zoomed view of the mesh

The slide mesh option is used to generate mesh that accounts for the rotation motion in the air region which includes the air-gap, as well as to automatically set the slide plane between the rotor and stator.
The torque can be calculated more accurately by increasing the number of divisions in the circumferential direction. However, if the number of divisions is too large, the number of elements increases and the amount of time to run the analysis increases. Therefore, the appropriate number of divisions needs to be specified. The number of divisions also needs to be set to account for the time interval to prevent distortion of the mesh in the gap.
Next some of the most significant results of the simulations are given. In all the cases the PMSM is not supplied in order to see the distribution of the magnetic flux generated by the PMs.
In Figure 7 flux lines are plotted for two distinct positions of the rotor.

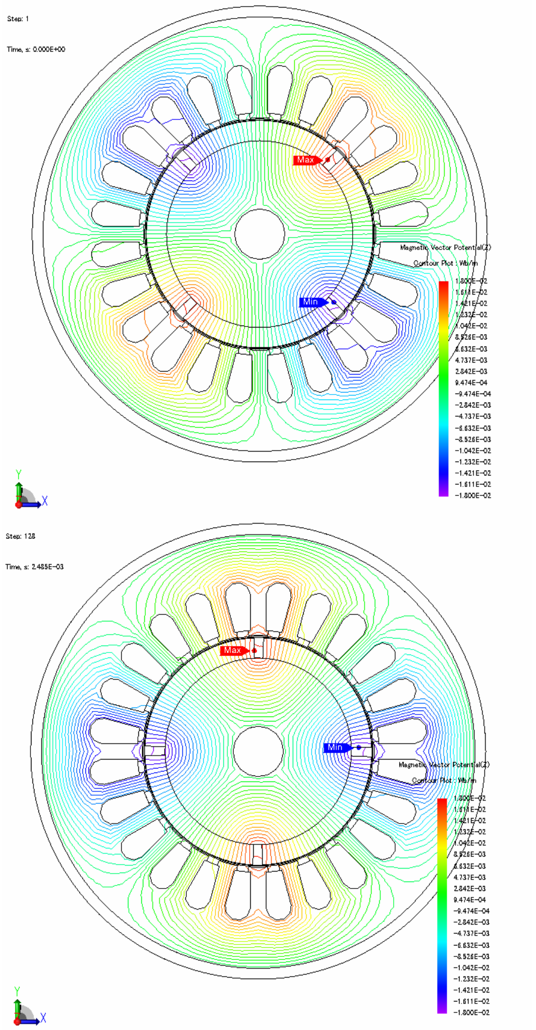

Figure 7. The plots of the flux lines for two rotor positions

In the figures the four magnetic poles generated by the PMs can be easily distinguished.

As in the design of electrical machines the saturation level in different regions are of maximum interest also the color maps of the flux densities for the same two positions are shown in Figures 8 and 9.

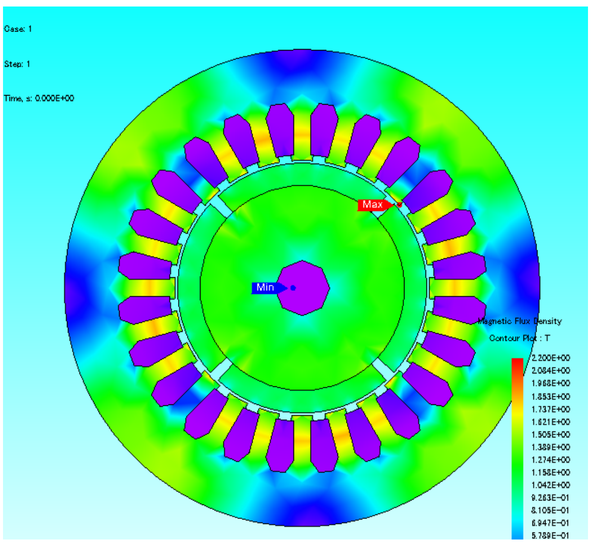

Figure 8. The color map of the flux density (position 1)

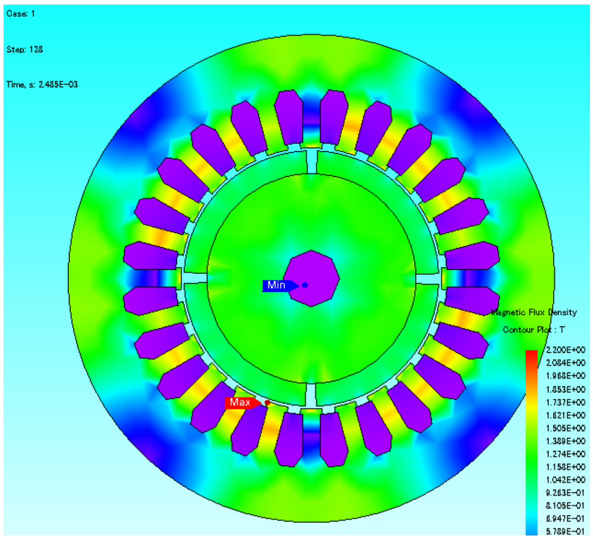

Figure 9. The color map of the flux density (position 2)

IV. CONCLUSIONS

A parameterized model of PMSM has been proposed. An interface for specifying geometric design parameters has been realized for low noise PMSMs, which are of real interest for automotive applications.

JMAG Designer software was used in order to perform the electromagnetic analysis. The purpose of this parameterized modeling was to link JMAG to other software, to create models of diverse construction variants in the shortest time possible and to optimize the studied model much easier.

ACKNOWLEDGMENT

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