MAGNETIC ANALYSIS OF THE SYNCHRONOUS MACHINE AND THE SUPPORTING STRUCTURE

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Abstract: This paper deals with simulation possibilities of the electromagnetic field in electrical machines. A finite element method was used for calculation. The content of this thesis is a model creation and electromagnetic field calculation of synchronous machine. The stator and rotor pack of the synchronous machine and part of the supporting structure (pressure fingers) are analyzed by finite element method in ANSOFT MAXWELL program.

Keywords: Synchronous Machine, Ansoft Maxwell, Adaptive Meshing, Finite Element Method, Supporting Structure (Pressure Finger)

1. INTRODUCTION

The supporting structure (pressure fingers) constricts stator packet and avoids stator vibration. This supporting structure is nearby the stator packet and the stator winding. The magnetic flux flows from the air gap into the fingers directly, and additional losses are generated.

This paper deals with inception and decrease of magnetic field in the supporting structure. Ansoft Maxwell is used for the simulation of magnetic field and subserves to simulation of the electrical machines. Decrease of magnetic field is done by the air gap between supporting structure and stator packet. The size of this air gap is 20mm.

2. FINITE ELEMENT METHOD (FEM)

Finite element method (hereinafter referred to as FEM) is numerical method suitable to solve mechanical deformations, heat convention, flow and electromagnetic fields [5]. The principle is in discretization of continuous continuum into certain, finite number of elements, while nodal points determine required parameters. The proceeding of this method has been known for a long time, but only with modern computer science it has come to use.

The main problem is to solve electromagnetic field to determine electrodynamic forces. Analytical solution is very complicated in this case. Maxwell equations are the basic mechanics to solve numerically these problems using computer technology. The result of the solution is not only one value of physical variable (electromagnetic induction and intensity), but electromagnetic field distribution on the whole model.

Finite element method is suitable to solve complicated components, where more detailed MESH is created in complicated parts of the model.

3. PARAMETERS OF THE SYNCHRONOUS MACHINE

The basic parameters are at Tab. 1. Simulation model is the synchronous machine with the non salient rotor. The power is 15MVA and no-load rotor current is 140A.

	STATOR		ROTOR
SHEETS			
Inside diameter [mm]	1700		1050
Outside diameter [mm]	1080		560
Air gap [mm]		15	
Core lenght [mm]	780		760
Radial ducts [number x mm]	15 x 8		15 x 8
Packet lenght [mm]	900		880
Sheet quality [-]	M530-65A		M530-65A
Number of slots [-]	72		40(dividing 1/60)
Turning [-]	(1/72)		
WINDINGS			
Number of parallel branch	4		1
Winding	Two-layer		One-layer
Turns	12		20
Number of Phases, Connection	3, Y		1
Step	z 1. do 17		
Shortening step	16/18, 89%		
SUPPORTING STRUCTURE (PRESSURE FINGER)			
Material	Fe		

Tab. 1: Parameters of the synchronous machine.

3.1. MATERIAL PROPERTIES

Two BH curves of prime magnetization are important to enter in this model. The first curve conforms to the sheets material and the second curve conforms to the supporting structure, shaft and short circuiting ring materials. BH curves of prime magnetization are at Fig. 1.

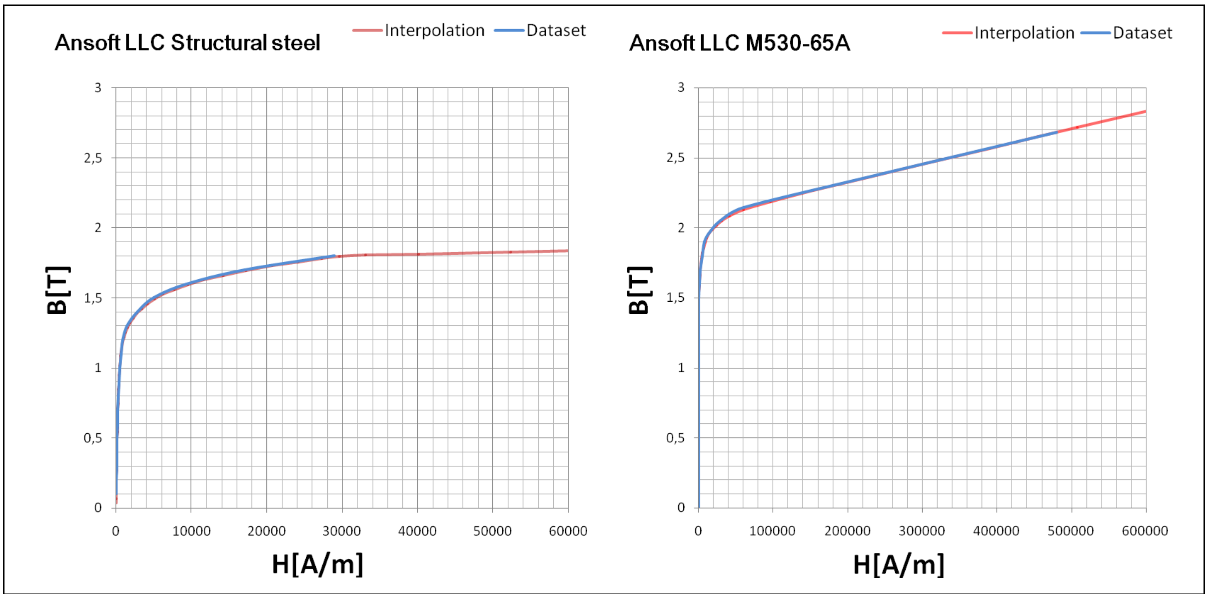


Fig. 1: Initial magnetization BH curves of structural steel and M530-65A sheets.

4. ADAPTIVE MESCHING OF THE ANSOFT MAXWELL PROGRAM

Maxwell is the premier electromagnetic field simulation software for engineers tasked with designing and analyzing 3-D and 2-D electromagnetic and electromechanical devices such as motors, actuators, transformers, sensors and coils. Maxwell uses the finite element method to solve static, frequency-domain and time-varying electromagnetic and electric fields. A key benefit of Maxwell is its automated solution process where users are only required to specify geometry, material properties and the desired output. From this point, Maxwell will automatically generate an appropriate, efficient and accurate mesh for solving the problem [1], [2]. Maxwell includes automatic adaptive meshing techniques. This robust meshing algorithm automatically creates and refines the finite element mesh as the solution converges, streamlining the solution process and making the software very easy-to-use. The meshing process uses a highly robust volumetric meshing (TAU) technique and includes multi-threading capability. The meshing technique results in more efficient and higher-quality meshes that reduce the amount of memory used and speeds the simulation time.

5. SIMULATIONS

The mesh creation is eliminated from adaptive meshing reason. This fact leads to faster model creation and model setting for self-simulation. Only no-load simulation of this machine is done due to difficult computation reason. The setups of analysis are at Tab. 2. We can see a dependence of used memory on number of elements in solution at Tab. 3

GENERAL SETUP1/SETUP2		
Maximum number of passes	10	10
Percent error	1	0.1
CONVERGENCE SETUP		
Refinement per pass	10	30
Minimum number of passes	2	2
Minimum converged passes	1	1

Tab. 2: Analysis setup.

5.1 STATEMENT OF CONVERGENCE PROFILE

Solution setup: Setup1 (from Pass3)		
Task ----	Memory ------	Information (number of elements)
Adaptive Pass 3 adapt	 4.58 GB	 1037241 tetrahedra
Adaptive Pass 4 adapt	 5.92 GB	 1343297 tetrahedra
Adaptive Pass 5 adapt	 7.66 GB	 1740759 tetrahedra
Adaptive Pass 6 adapt	 9.66 GB	 2257052 tetrahedra
Adaptive Pass 7 adapt	 14.03 GB	 2894742 tetrahedra
Solution Process Error Process 'hnl3d' terminated abnormally. It may have run out of memory.		

a)

Solution setup: Setup2 (from Pass 5)		
Task ----	Memory ------	Information (number of elements)
Adaptive Pass 5 adapt	 3.91 GB	 881652 tetrahedra
Adaptive Pass 6 adapt	 4.29 GB	 968061 tetrahedra
Adaptive Pass 7 adapt	 4.72 GB	 1063102 tetrahedra
Adaptive Pass 8 adapt	 5.19 GB	 1167817 tetrahedra
Adaptive Pass 9 adapt	 5.71 GB	 1283259 tetrahedra
Adaptive Pass 10 adapt Adaptive Passes Done	 6.28 GB	 1410861 tetrahedra

b)

Tab. 3: Statement convergence profile, a- model without air gap between packet and supporting structure, b- model with air gap between packet and supporting structure.

6. THE RESULTS

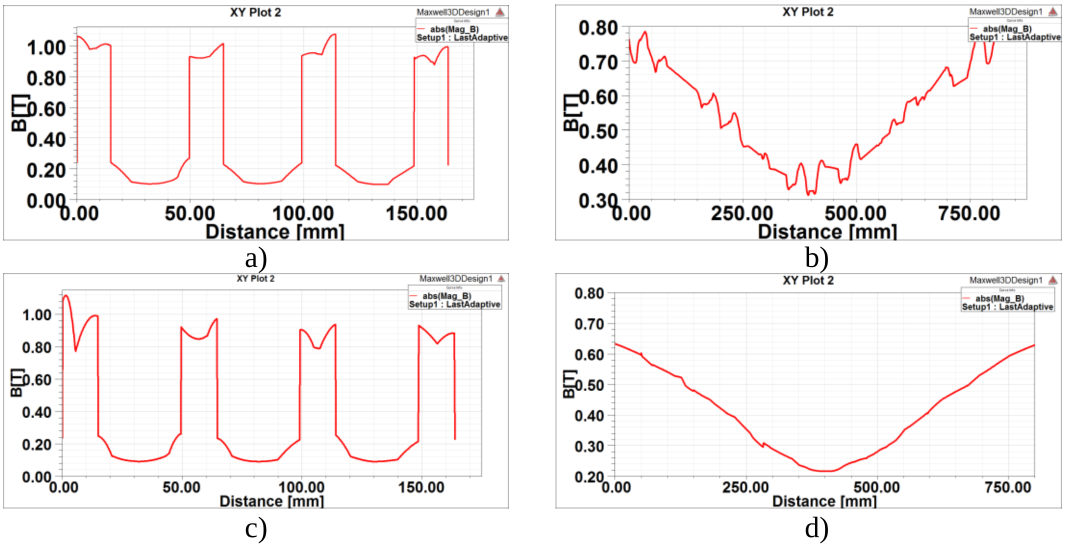


Fig. 2: Graph of magnetic flux density, a- through the supporting structure without air gap in radius distance R=570mm from center, b- through the supporting structure without air gap in radius distance R=710mm from center, c- through the supporting structure with air gap in radius distance R=570mm from center, d- through the supporting structure with air gap in radius distance R=710mm from center.

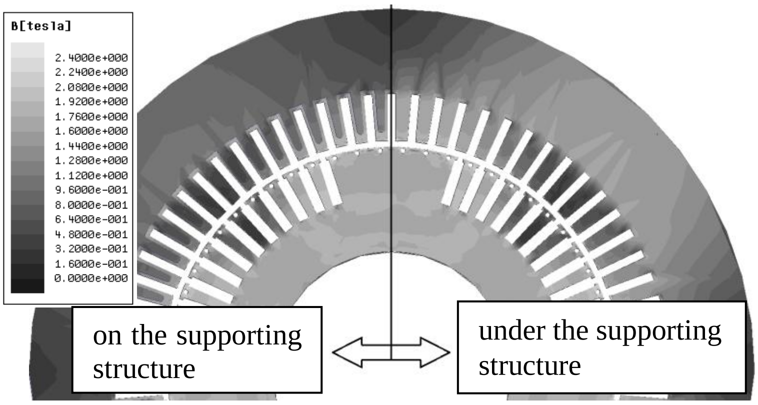


Fig. 3: Magnetic field of the synchronous machine without air gap between the packet and supporting structure.

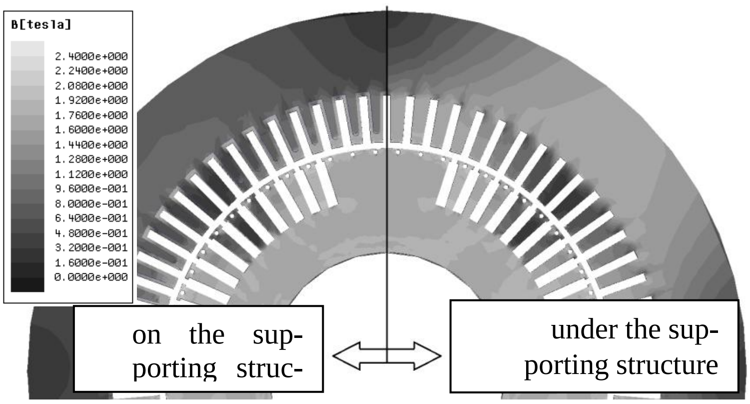
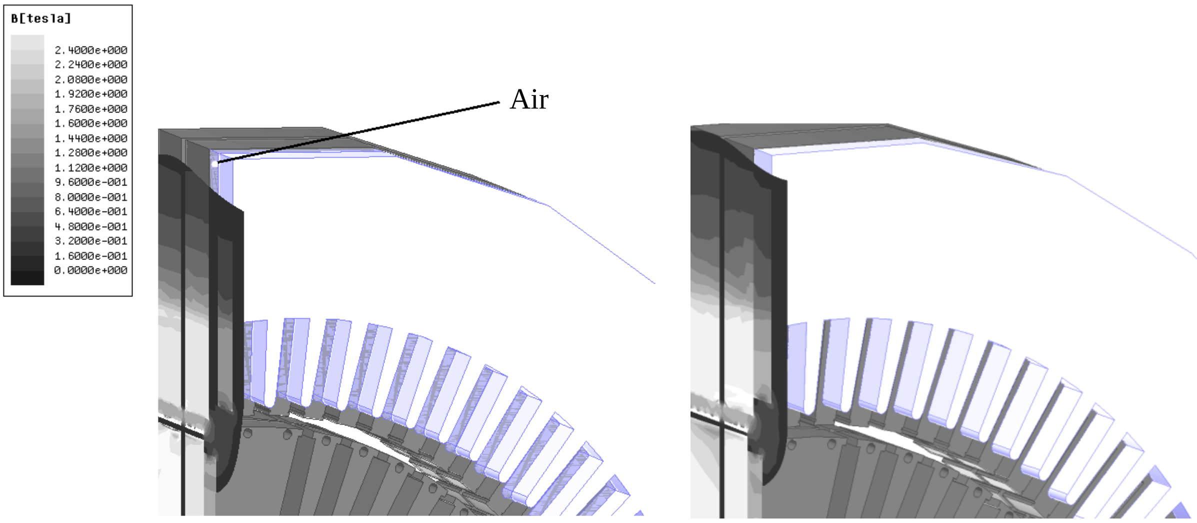


Fig. 4: Magnetic field of the synchronous machine with air gap between the packet and supporting structure.



a b

Fig. 5: Axial cross-section of magnetic field, a-with air gap between packet and supporting structure, b-model without air gap between packet and supporting structure.

7. CONCLUSION

How we can see at Fig.2, so magnetic flux density decreases with air gap between supporting structure and stator packet. Magnetic flux density is not decreased too much in the fingers directly (Fig. 2 a) and c)), but it is decreased up to 0,1T in the upper area of the fingers (Fig. 2 b) and d)). The reduction of additional losses and the machine heating is the result of air gap between stator packet and the fingers. How we can see at Fig. 5, most of the magnetic flux flows from the air gap into the fingers directly. We can see at Fig. 3 and Fig. 4 the distribution of magnetic flux density under the supporting structure.

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REFERENCES

[1] Help Ansofts Maxwell®, Copyright© 2010, Ansys, Inc.

[2] SVSFEM, Inc., www pages, Available from URL: <:http://www.svsfem.cz:>

[3] MICHAILIDIS, Petr Analysis of the stator and rotor pack termination effect on the sychronous machine by FEM. Brno University of Technology, Faculty of Electrical Engineering and Communication, 2010. 94 p. Supervisor Prof. Č. Ondrůšek.

[4] MICHAILIDIS, P.: Problems of the komplex 3D models creation in ANSYS program. LVEM 2010 – Internationl Conference on Low Voltage Electrical Machines, 2010. 62-63p. ISBN: 978-80-214-4178-1

[5] GÉRARD M.: The Finite Element Method for Electromagnetic Modeling. Great Britain, Chippenham, 2008, vol. 602, ISBN: 978-1-84821-030-1