Prototyping and Series Production of a Claw Pole Machine Using 3D Modeling

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Abstract

Introduction: To meet the growing demand for small electrical vehicles, prototyping an effective and/or power dense electrical motor with low material cost is of interest. The step from prototype to production should be as simple as possible. For a small electrical vehicle an electrical machine with high torque per volume is preferred as it assures a compact solution. With this in mind, a machine with a high number of pole pairs and high frequency control signals would be suitable. To withstand the increased eddy current due to the high frequency control signals, the material should have a high electrical resistance. Some sort of soft magnetic core material is preferred, since such materials generally have lower losses at higher frequencies compared to laminated steel.

A claw pole machine can, if designed for it, have a high torque per volume ratio due to the possibility of a high frequency control signal. This would allow a higher number of pole pairs for a given mechanical speed. Additionally, the brittle powder material allows for easy recyclability by crushing the machine and separating the materials [1].

Use of COMSOL Multiphysics®: Since the flux in the claw pole machine is three-dimensional and the conventional simulation tools for electrical machinery is based in a 2D space, a more advanced simulation environment which can handle a complex 3D geometry is needed. To be able to verify the geometry of the claw pole machine, a COMSOL Multiphysics® simulation with the Magnetic Field Interface (found under the AC/DC Module) was used. This, together with the LiveLink™ for SolidWorks®, made it possible to iterate the geometry. Since the geometry was created in SolidWorks®, the effort to transfer the design to manufacturing will be small. As the geometry was set to have a relatively even distribution of the magnetic flux density, it became necessary to calculate the back EMF. This was done by stepping the rotor an electrical turn and calculating the inductance of the winding for the given rotor angle. The equation L=2*Wn/I^2 was used, where L represents the inductance, Wm the magnetic energy density and I the current in the coil. An FFT of the resulting back EMF was used to find the standardized values of the harmonics, a graph of the FFT can be found in figure 2.

Conclusion: A claw pole machine with a machinable iron powder core would give the possibility to go from a single machine to a series production, without a big design change or high costs. The Höganäs Somaloy Prototyping Material fits the specification for a low cost prototyping material with the possibility for a transfer to larger production series by changing the production

method to a powder metallurgy method [2].

Calculations will hopefully show the torque/weight ratio of the prototype machine. A rotating machinery simulation should validate the back EMF calculations. Building a prototype should validate the accuracy of the simulations and the usefulness of the material in question.

Reference

[1] Lundmark, S. K. (2005). Application of 3-D Computation of Magnetic Fields to the Design of claw pole motors. Göteborg: Chalmers University of Technology.

[2] Höganäs (2014). Höganäs Somaloy: http://www.hoganas.com/en/Segments/Somaloy-Technology/Home/

Figures used in the abstract

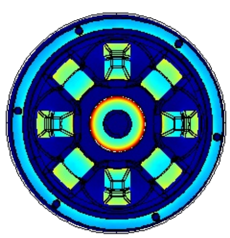

Figure 1: Magnetic flux density normal, a slice from the iterative process of designing the geometry. When an irregularity is found the geometry will be changed.

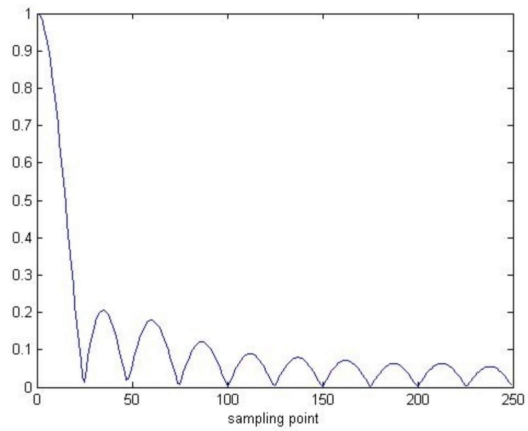

Figure 2: Normalized back EMF

Electrical degrees	Inductance [mH]
0	0.1948
18	0.1884
36	0.1750
54	0.1633
72	0.1503
90	0.1469
108	0.1514
126	0.1648
144	0.1718
162	0.1781
180	0.1838
188	0.1785
206	0.1777
224	0.1606
242	0.1548
260	0.1483
278	0.1568
296	0.1638
324	0.1802
342	0.1940

Figure 3: Inductance of machine dependent on rotor angle.