Optimizing Inductor Winding Geometry for Lowest DC-Resistance Using COMSOL Multiphysics® with LiveLink™ for MATLAB®

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Abstract

Introduction: An optimization routine is presented to optimize the shape of a foil winding of a toroid inductor in terms of the DC resistance [1,2]. MATLAB® is used to create a graphical user interface (GUI) enabling control of the winding geometry [3]. COMSOL Multiphysics® was used to import the geometry and create a 2D finite element model [4]. The feedback from COMSOL in terms of DC resistance was used to find the optimal winding geometry.

The parameters that were altered during the optimization routine is shown in Figure 1. The winding has "N" number of turns and a specific clearance between each turn which was fixed. A single turns has 4 segments "F1-F4" each having an angle and a thickness which can be varied.

Use of COMSOL Multiphysics: The challenge was to set up communication between COMSOL and MATLAB® using the LiveLink™ functionality [5]. The following steps were implemented in the MATLAB code in order to automate the calculation of the DC resistance with changing winding geometry:

• Creating a MATLAB GUI - See Figure 2

• Creating the winding geometry
o The geometry of a single turn is created based on the parameters set by the GUI for the winding such as size of the core, clearance, thickness of the foil and the angle of each segment in a turn. The coordinates positions are translated from 3D to 2D by unfolding the turn and saved.
o A for loop creates the desired turns by copying the coordinates of the single turn by rotating them in a polar coordinate system. Every section of a turn is created as a polygon and the coordinates is saved for later selection of domains and boundaries.

• Selecting the boundaries.
o The saved positions are used by the function "mphselectbox" to select the relevant boundaries.

• The material setup
o A material is assigned to every section with a resistivity determined by the thickness of the section.

• The Physics setup
o The terminations are selected by the relevant boundaries.
o A for loop connects the turns in the winding via "PeriodicCondition". - See Figure 3

• The Mesh setup
o A default mesh is used

• The Study Setup
o Stationary and default solver settings are used.

• Results
o A global variable is used to calculate the DC resistance seen from the terminals.
o The current density is plotted using the function "mphplot".

Results: The result of the optimization routine is shown in Figure 4. The plot shows the simulated resistance for a given number of solutions where the previously mentioned variables were altered. The difference in DC-resistance between the solution where F1 to F3 goes straight over the core and F4 is angled 100% and the optimum solution is 31% for a given core with 10 turns.

Conclusion: A GUI has been created and for a given setup of the core and the thickness of of each segment in a turn the optimum winding geometry can be found leading to an improved DC-resistance.

Reference

H. Schneider, T. Andersen, A. Knott and M. A. E. Andersen, “Hybrid winding concept for toroids”, ECCE Asia 2013.

H. Schneider, T. Andersen, A. Knott and M. A. E. Andersen, “Optimizing DC-Resistance of a Foil Wounded Toroidal Inductor Combining Matlab and Comsol”

Guide to GUI in Matlab, http://www.mathworks.com/discovery/matlab-gui.html

"Introduction to AC/DC Module", COMSOL, Application note, www.comsol.com.

"LiveLink™ for MATLAB", COMSOL, Presentation, www.comsol.com.

Figures used in the abstract

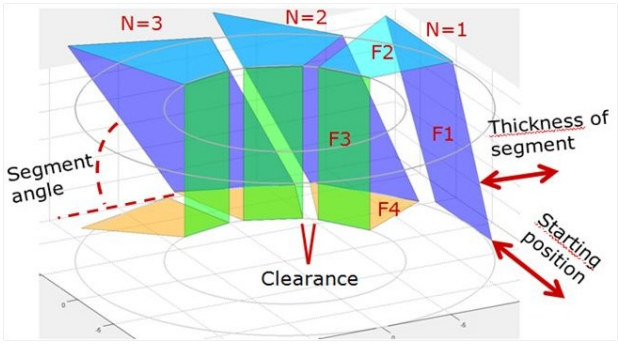

Figure 1

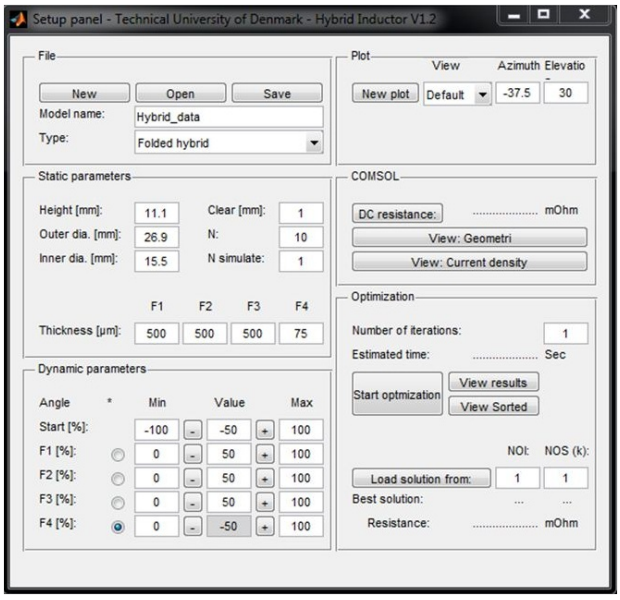

Figure 2

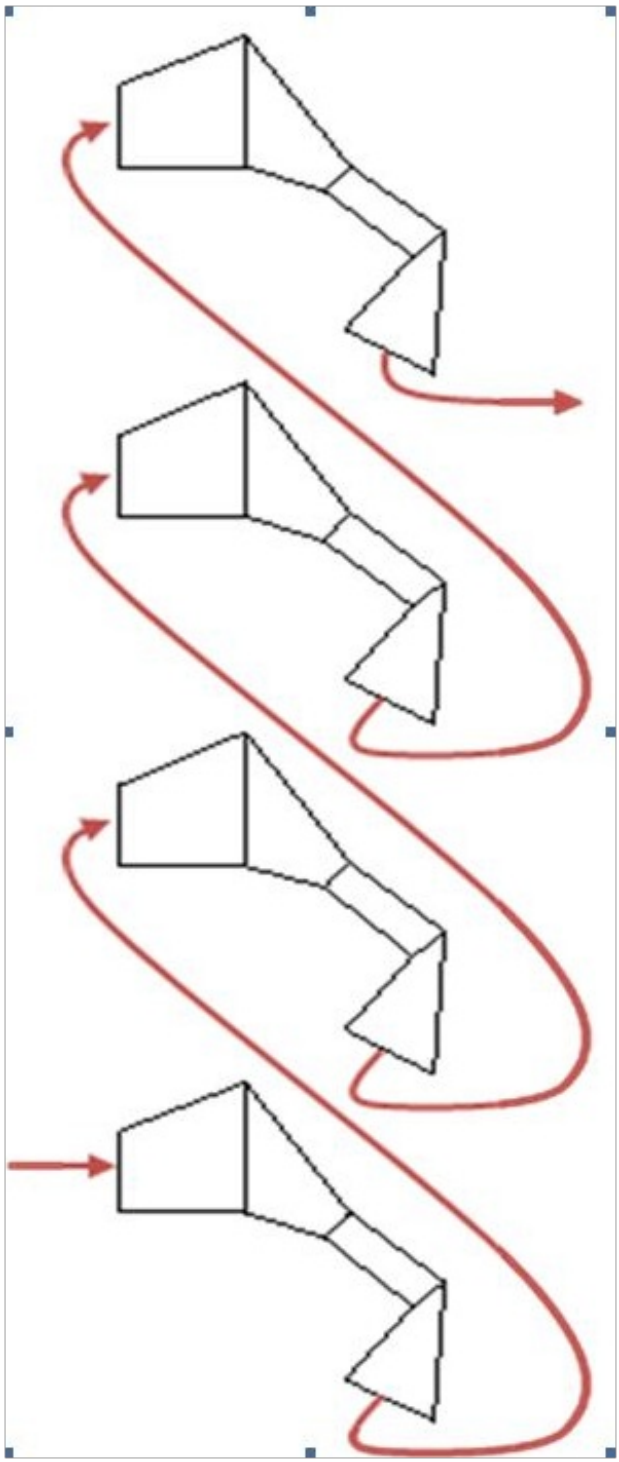

Figure 3

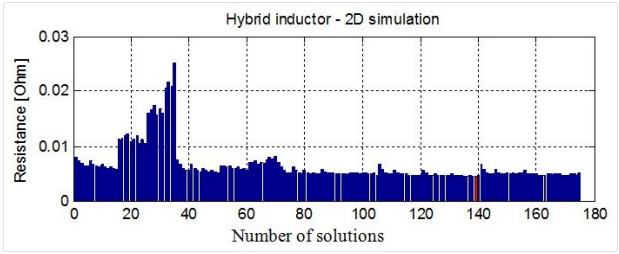
Hybrid inductor - 2D simulation
Resistance [Ohm]
0.03
0.02
0.01
0
0
20
40
60
80
100
120
140
160
180
Number of solutions

Figure 4