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2016

EIEN20 Assignment 3

Introduction

In this assignment our aim is to analyse a three-phase machine using Matlab and FEMM. There are many factors to take into account for a machine like this as the electro magnetization and magnetic flows can affect every other moving part around it.

1.)

I chose the following parameters for my initial simulations and changed the values in the Matlab code:

Motor frame size	*Outer/inner diameter Do/Di [mm]*	*Stack length lr [mm]*
115	105/25	50

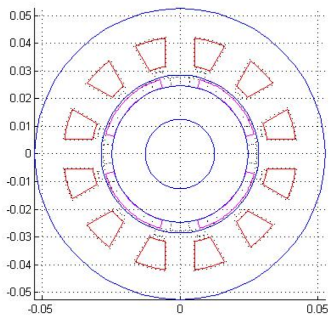
2.)

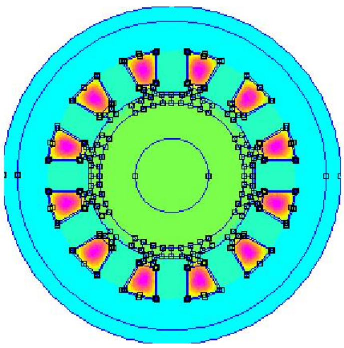
Simulation 1:

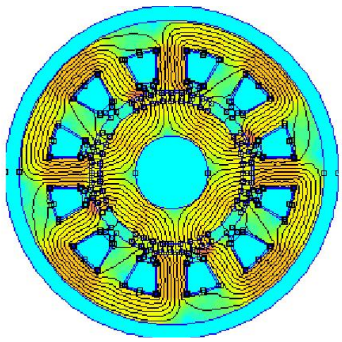
This simulation was run without any changes to the code other than those expressed above.

N_p=4   K_s=0.4   rsi=ro-(ro-ri)*0.6

Torque: 5.32 Nm
Max temp: 119.77 c (wslot)
Max loss: 166.32 W (wend)





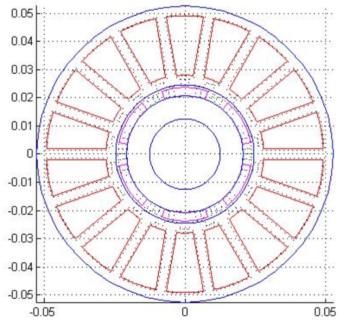


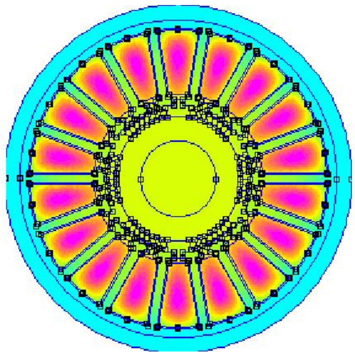
Simulation 2:

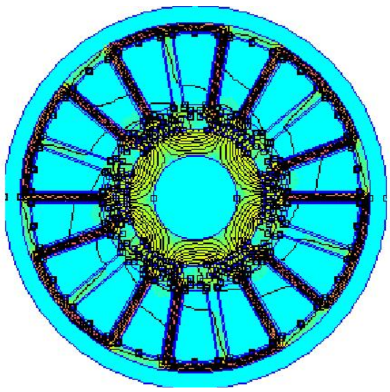
For this simulation I will aim to increase torque as much as possible without worrying about the temperature. To achieve this I will raise the number of poles, raise the relative slot width and increase the stator radius. I hope this will increase volume and therefore torque although I accept that power losses should also increase.

N_p=6   K_s=0.7   rsi=ro-(ro-ri)*0.7

Torque: 8.4368 Nm
Max temp: 119.77 c (wslot)
Max loss: 211.34 W (wend)







Simulation 3:

The previous simulation had the desired effect; I managed to increase torque by around 50%. As predicted, the losses also increased but, unexpectedly, the wslot temperature stayed exactly the same. This time I will keep the poles and slotting factor the same but decrease the inner radius of stator core to 0.5.

N_p=6   K_s=0.7   rsi=ro-(ro-ri)*0.5

Torque: 6.8996 Nm
Max temp: 119.78 c (wslot)
Max loss: 167.20 W (wend)

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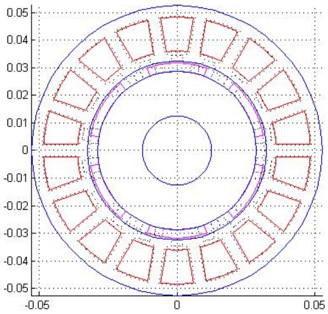
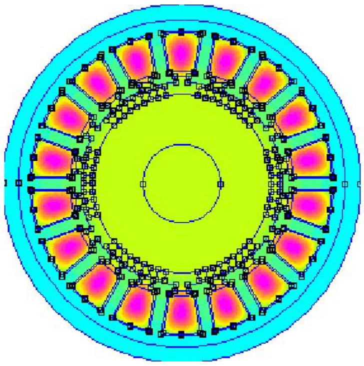
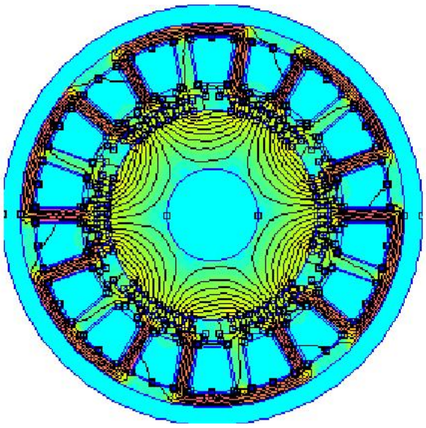




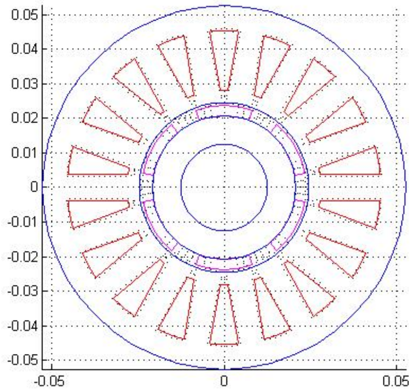


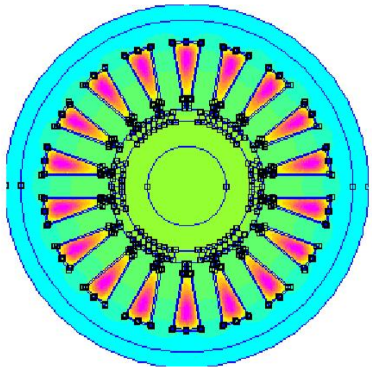
Simulation 4:

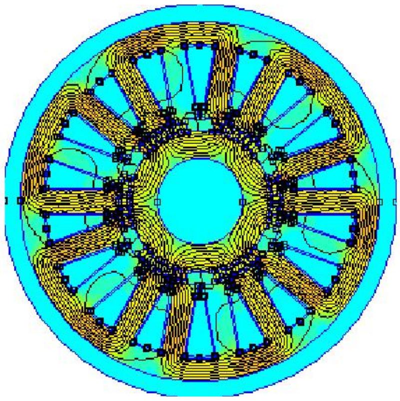
My torque dropped with the decrease in the stator radius value, as did the power losses. For the last simulation I will take the stator radius up to its highest value and instead reduce the relative slot width. By this point I can see that the temperature in the motor is fairly steadt so I can concentrate on achieving the high torque of simulation 2 with the low losses of simulation 4.

N_p=6   K_s=0.3   rsi=ro-(ro-ri)*0.7

Torque: 6.7970 Nm
Max temp: 119.77 c (wslot)
Max loss: 161.07 W (wend)







It is clear to see that the torque and losses have both decreased further with this change. The ‘best’ simulation really depends on the power supply in the situation. Simulation 2 shows us that we can achieve a high torque if we are willing to take a power loss with it.

<u>3.)</u>
The heat transfer diagrams clearly show the difference in temperature between the core and the cooling area. The cooling effect of the stator teeth is shown also by the green shade removing heat from the coils. The differences in calculation method between FEMM and the thermal ECM are significant so any visual difference is understandable.

<u>4.)</u>
The electromagnetic diagram from FEMM displays vastly different results when the torque is changed. The field lines become much more dense as torque increases, even for a seemingly small change in torque such as that from simulation 3 to 4 (only 0.1026Nm). This is not too surprising as we know flux density is directly related to torque by the $T = \frac{1}{2} B_m J_m A_e A_m$ equation. Relating power, current density and sheer stress indirectly as well.

<u>5.)</u>
I will use the results from simulation 4 to complete the required calculations.

J=1.4336 x 10^7 A/m^2
B=[0.8919 1.1193 1.1193 0.915] T (gap sth syk ryk)

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Ploss=[138.72 161.07 1.19 0.959] W (wslot wend sth syk)
Temp=[98.06 119.77 104.59 113.85] DegC (rot wslot syk wend)
T=6.797 Nm
F=50Hz (Supplied)

$$V_{Active} = \frac{\pi}{4}(Do^2 - Di^2)l_r = \frac{\pi}{4}(105-25)\cdot 50\,10^{6}$$

$$V_{Active} = 3.14\,10^{3} m^3$$

$$A_{Cooling} = \pi Do l_r = \pi \cdot 105\,10^{3} \cdot 50\,10^{3}$$

$$A_{Cooling} = 0.016 m^2$$

$$P = T\omega = 6.797\,2\pi \cdot 50$$

$$P = 2135.3 W$$

$$P_{loss} = 138.72 + 161.07 + 1.19 + 0.959 = 301.94 W$$

$$\eta = \frac{P}{P + P_{loss}} = \frac{2135.3}{2135.3 + 301.94}$$

$$\eta = 0.876 = 87.6\%$$

$$\sigma_{shear} = \frac{T}{2\pi r l_r} = \frac{6.797}{2\pi \cdot 125\cdot 10^{3} \cdot 50\,10^{3}}$$

$$\sigma_{shear} = 17308.4 \, {}^{Nm}/_{m^3}$$

$$\frac{T}{V_r} = 2\sigma_{shear} = B_m K_m$$

$$K_m = \frac{2\sigma_{shear}}{B_m} = \frac{2\cdot 17308.4}{1.1193}$$

$$K_m = 30927.2 \, {}^{A}/_{m}$$

To compare my results with an appropriate real life motor I must convert the power in Watts to a horsepower value used by Baldor.
1hp=745.699872W
2135.3W=2.86hp

The CEM5448 motor [http://www.baldor.com/catalog/CEM3558#tab=%22performance%22] has an output of 2hp which is close enough for my rough comparison.

The efficiency achieved is around 86% depending on the load.
The torque is measure in pound-foot by Baldor, 1 lb-ft=1.355818 Nm so my achieved torque is 6.797*1/1.355818 = 5.01 lb-ft. The CEM5448 toque varies from 15.9 to

24.9 lb-ft depending on the situation. Here we can see obvious discrepancies between the simulation results and the real motor. The most likely explanation is firstly the difference in output power and secondly the difference in applied voltage.