Luleå 2017-04-10

ANALYSIS OF A COIL

This assignment is about the influence of end effects on the inductance of a coil. Use Comsol to calculate the magnetic field of a coil of length l and radius a , winded with n current turns per unit length. Find the error of using the approximate inductance for an infinitely long coil $L = \mu_0 n^2 S\, l$.

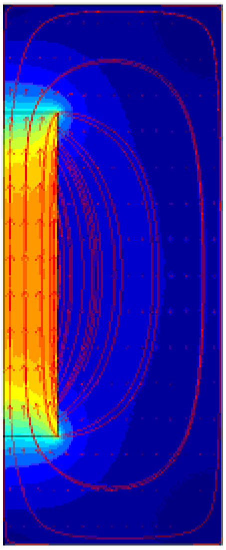
Instructions

1. Open Comsol Multiphysics 5.2 and click on model wizard. Choose axisymmetry(2D). Under *AC/DC* click Magnetic fields and add. Click on Study. Choose Stationary and click on done.
   A dotted symmetry axis with r=0 should appear in the geometry window.
2. Under Global Definitions choose parameters. Enter the radius of the coil a=0.2[m] and the surface current K= nI wher n is the number of current turns per unit length and I the current. Choose values for n and I, n=1000 turns/m [1/m] and l=0.1[m].
3. Right-click Geometry and choose Rectangle. Choose the width 2 and height 3. Place the left lower corner at r=0, z=-1.5. Press the buttons ”Build selected”. Right-click Rectangle and choose a new rectangle with width a and height l. Place the left lower corner at r=0, z=-*l*/2. Press”Build selected”.Right-click Geometry and choose Boolean operations and compose r1+r2. Press ”Build selected” and ”Build all”
4. Under Magnetic fields choose Amperes law. Look at equations to see the equations to be solved. Add the rectangles r1 and r2. Under relative permeability, choose user defined and put μ_r=1. Under conduction current choose user defined and enter conductivity equal to zero. Under Electric field choose user defined and put ε_r=1.
5. Right-click Magnetic fields and choose surface current. Select element 8 where the surface current flows and enter K in the phi-component of the surface current. Make sure that Axial symmetry is chosen along the r=0-axis. Right-click Magnetic fields and choose Magnetic potential. Select the boundaries 2,7,9 and as boundary condition put all components of the phi-component of the vector potential equal to zero.
6. Choose mesh and press”Build all”. Later vary the mesh and see how the result is modified.
7. Right-click Study and compute. Right-click Magnetic Flux Density and choose streamline with field components mf.Br and mf.Bz. Choose uniform density. Press plot.
8. To calculate the inductance of the coil L, the total magnetic flux of the coil should be calculated. So that

$$\psi_{total} = 2\pi a\, A_\varphi(a,0)\, n\, l = L\, I\,. \qquad (1)$$

The value of Aphi(a,0) may be found by plotting Aphi(r,0).
To make a plot of Aphi(r,0) right-click Data sets and choose Cut line 2D.
Choose point1 as (0,0) and point2 as (2,0) press plot. The plot-line should then appear in the geometry window. Right-click on Results and choose 1D plot group.
Right-click 1D Plot Group and choose Line Graph. Choose the phi-component of the vector potential. As data set choose Cut Line 2D and a line from (r,z)=(0,0) to (r,z)=(2,0). Plot the curve.

9. To compare the result from the numerical calculation and the analytical expression introduce the dimensionless number
$$\Pi_1 = \frac{L}{\mu_0 n^2 l^3} = \frac{2\pi A_\phi(a,0)a}{\mu_0 I\, n l^2} = f(\frac{a}{l})$$
and make a plot of this as a function of $\alpha = a/l$. Compare with the result using the approximate analytic expression $L = \mu_0 n^2 S\, l$. To plot the two dimensionless numbers as functions of α=*a/l* define a point probe under definitions and choose an"expression"corresponding to the two dimensionless numbers. Solve the problem using a parameter sweep in the parameter α.



Write a report about your results. The report about your results should include

- A physical problem formulation together with a mathematical formulation with the equations used together with the boundary conditions. Derive equation (1)
- Some words about how the mesh size modifies the result
- Plots showing the results together with comments