Chad Meadowcroft
2016

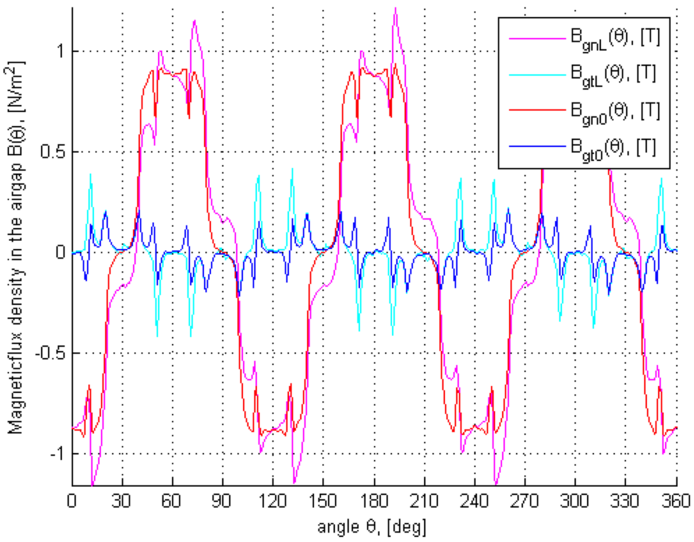
# EIEN20 Assignment 4

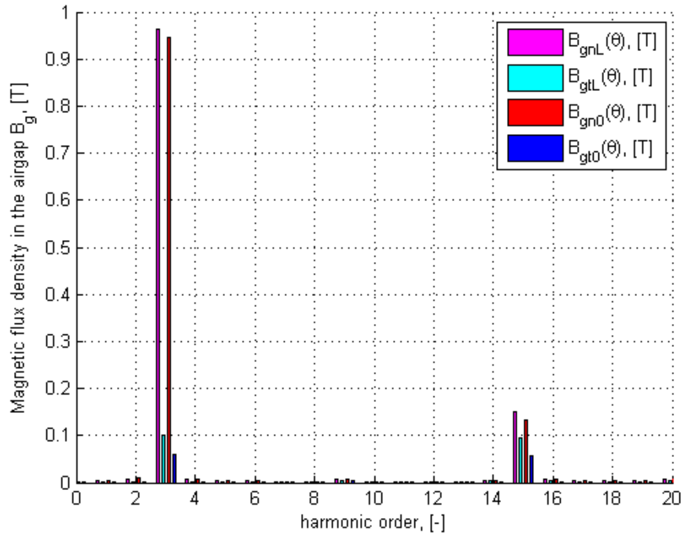
## Introduction

I will be using the same parameters as from assignment 3, simulation 4:

| *Motor frame size* | *Outer/Inner diameter Do/Di [mm]* | *Stack length lr [mm]* | *No. of poles N_p* | *Slotting factor K_s* | *Stator core inner radius [m]* |
|---|---|---|---|---|---|
| 115 | 105/25 | 50 | 6 | 0.3 | ro-(ro-ri)*0.7 |

## 1.)

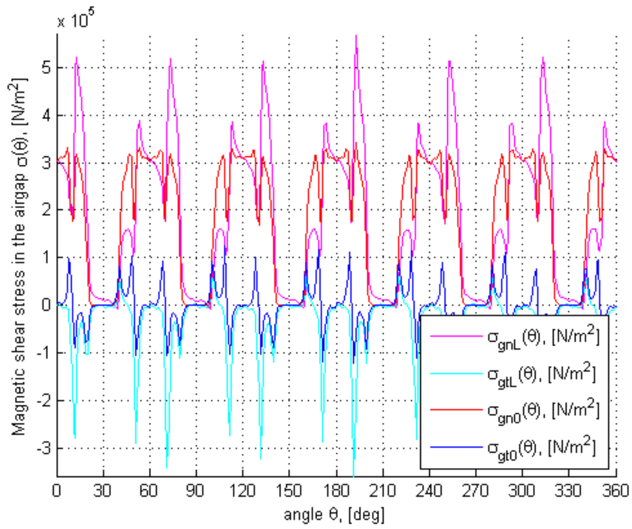



These graphs generated by Matlab show that the normal gap flux density BgnL & Bgn0 is larger and in the opposite direction to the tangential flux density BgtL & Bgt0.
The peak gap density is around 1.2 T, which occurs at a harmonic order of 3. This corresponds to the peak gap flux density for this motor from assignment 3 of 0.8919 T. There are differences here because of the calculation method.

## 2.)

This graph of air gap magnetic sheer stress gives 4 separate outcomes. σgnL & σgn0 represent tensile or 'normal' stress. σgtL & σgt0 represent the shear stress that is experiences at parallel to the rotor. From intuition we can tell that the loaded motor will have higher stress forces acting upon it. Therefore I conclude that σgnL & σgtL are the tensile and shear stresses for the loaded motor and σgn0 & σgt0 are unloaded.



$$t_{n(max)} = 5.691 \cdot 10^{5}$$
$$t_{t(max)} = -3.594 \cdot 10^{5}$$

$$r_{stator(inner)} = ro - (ro - ri) \cdot 0.7 = 0.0525 - (0.0525 - 0.0125) \cdot 0.7$$
$$r_{gap} = 0.00875 - (4 \cdot 10^{-4}) = 0.00835 m$$
$$t_t = \sigma_{shear} = \frac{T}{2\pi r l_r}$$
$$T = t_t \cdot 2\pi r l_r = 3.594 \cdot 10^{5} \cdot 2\pi \cdot 0.00835 \cdot 50 \cdot 10^{-3}$$
$$T = 942.79 Nm$$

This gives us a peak torque value for the peak shear stress value used when motor is loaded. The unloaded torque is 293.54Nm.

<u>3.)</u>
From Matlab:
Weighted Torque=6.81Nm
Integrated line Torque at r=0.0241Nm
Integrated line Torque at m=-6.97Nm

Expected Torque from A3=6.797Nm

The torque values from A3 and A4 are close, small differences can be attributed to calculation method etc. An interesting observation is that the integrated line torque in negative, this could be due to the symmetry of the line.

<u>4.)</u>

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$$\vec{\psi} = \psi_{\alpha} + j\psi_{\beta} = k(\psi_a + \psi_b e^{j\frac{2\pi}{3}} + \psi_c e^{j\frac{4\pi}{3}})$$

*Loaded*

$Phase\_Fluxes: fa = 2.16 \cdot 10^{3} Vs,\_ fb = 2.1 \cdot 10^{4} Vs,\_ fc = -2.38 \cdot 10^{3} Vs$

$Phase\_Linkages: \psi_a = 0.00216 Wb,\_ \psi_b = 0.00021 Wb,\_ \psi_c = -0.00238 Wb$

$$\vec{\psi}_s = \frac{1}{3}(0.00216 + 0.00021 e^{j\frac{2\pi}{3}} - 0.00238 e^{j\frac{4\pi}{3}})$$

$$\vec{\psi}_s = \frac{1}{3}(0.00216 + 0.00021(\cos(\frac{2\pi}{3}) + j\sin(\frac{2\pi}{3})) - 0.00238(\cos(\frac{4\pi}{3}) + i\sin(\frac{4\pi}{3}))$$

$$\vec{\psi}_s = (3.959 + j12.933) \cdot 10^{4} Wb$$

$$\theta = \tan^{-1}(\frac{12.933}{3.959}) = 1.2737 rad = 72.98 \deg$$

*Unloaded*

$Phase\_Fluxes: fa = 2.17 \cdot 10^{3} Vs,\_ fb = -1.08 \cdot 10^{3} Vs,\_ fc = -1.09 \cdot 10^{3} Vs$

$Phase\_Linkages: \psi_a = 0.00217 Wb,\_ \psi_b = -0.00108 Wb,\_ \psi_c = -0.00109 Wb$

$$\vec{\psi}_m = \frac{1}{3}(0.00217 - 0.00108 e^{j\frac{2\pi}{3}} - 0.00109 e^{j\frac{4\pi}{3}})$$

$$\vec{\psi}_m = \frac{1}{3}(0.00217 - 0.00010(8\cos(\frac{2\pi}{3}) + j\sin(\frac{2\pi}{3})) - 0.00109(\cos(\frac{4\pi}{3}) + i\sin(\frac{4\pi}{3}))$$

$$\vec{\psi}_m = (9.230 + j2.835) \cdot 10^{4} Wb$$

$$\theta = \tan^{-1}(\frac{2.835}{9.23}) = 0.298 rad = 17.07 \deg$$

$$\vec{I} = I_{\alpha} + jI_{\beta} = k(I_a + I_b e^{j\frac{2\pi}{3}} + I_c e^{j\frac{4\pi}{3}})$$

*Loaded*

$Phase\_Currents: ia = 0A,\_ ib = 5431A,\_ ic = -5431A$

$$\vec{I} = \frac{1}{3}(0 + 5431 e^{j\frac{2\pi}{3}} - 5431 e^{j\frac{4\pi}{3}}) = \frac{1}{3}(5431(\cos(\frac{2\pi}{3}) + j\sin(\frac{2\pi}{3})) - 5431(\cos\frac{4\pi}{3} + j\sin(\frac{4\pi}{3}))$$

$$\vec{I} = -1 + j9405 A$$

$$\theta = \tan^{-1}(\frac{9405}{-1}) = -1.57 rad = 89.94 \deg$$

*Unloaded*

$Phase\_Currents: ia = 0A,\_ ib = 0A,\_ ic = 0A$

$$\vec{I} = 0A$$

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Loaded flux linkage:

Unloaded flux linkage:

12.933*10^-4Wb (I)

2.835*10^-4Wb (I)

Loaded current:

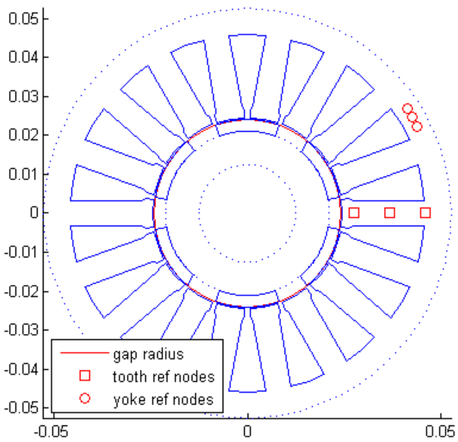
3.950*10^-4Wb

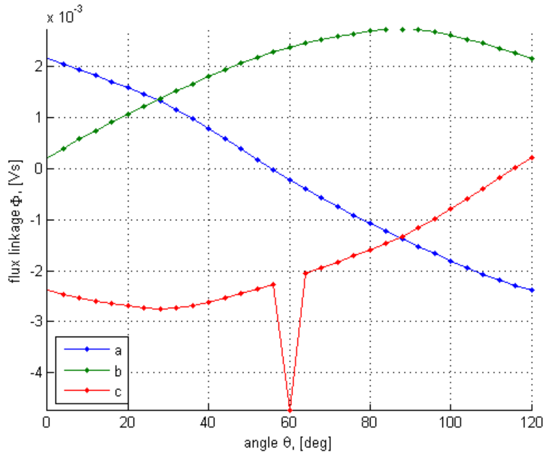
5.)

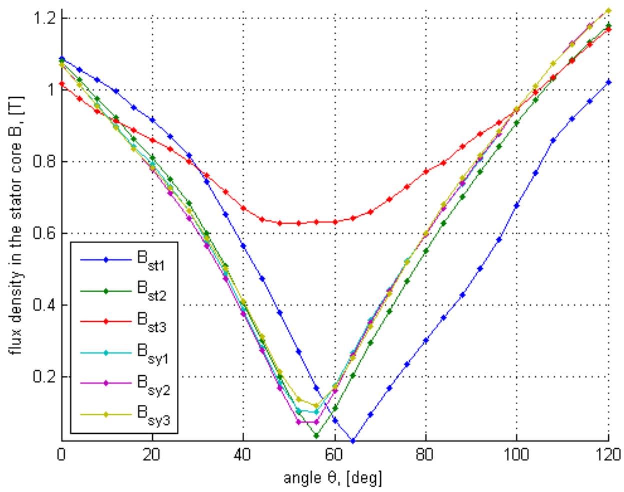
9.230*10^-4Wb R)

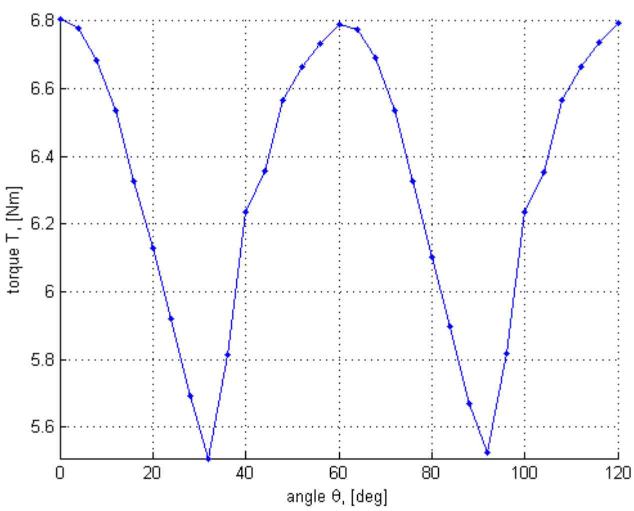
940.5A (I)

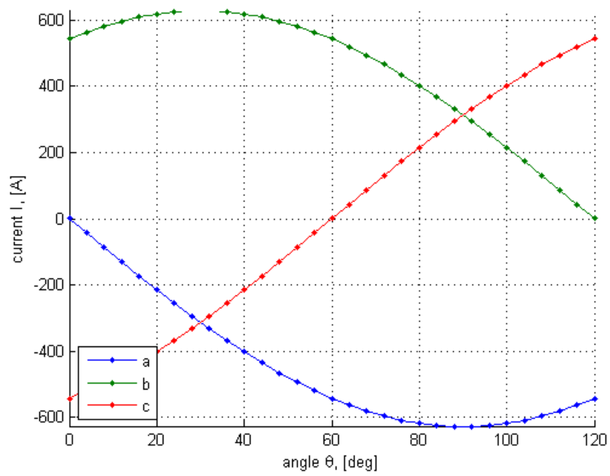
-1A (R)



$$\Delta\phi = 0.002742 - (-0.002743) = 0.005485 Vs$$
$$f = 50 Hz$$
$$\omega = 2\pi f = 100\pi rads^{-1}$$
$$t = 1/f = 0.02 s$$

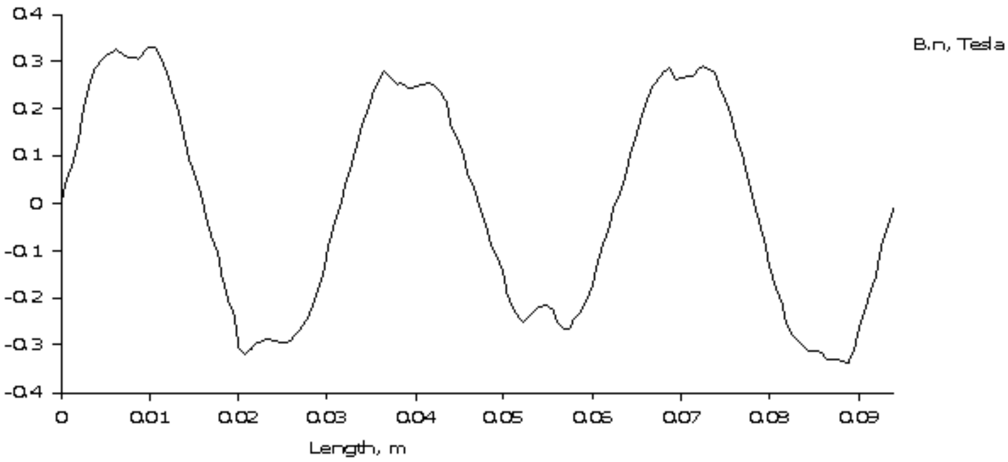
$$backemf = -\frac{d\phi}{dt} = -\frac{0.005485}{0.02} = 0.274 V$$

$$T = \vec{\psi}_{Load} \times \vec{I}_{Load} = |\vec{\psi}||\vec{I}|\sin\theta = 1.3525\cdot 10^{3}\cdot 9405\cdot\sin(8994 - 7298)$$
$$T = 0.371 Nm$$

4.3 - Femm hands on

7.)

$$\psi_A = 0.000732892 Wb$$
$$\psi_B = 1.26099\cdot 10^{-6} Wb$$
$$\psi_C = -0.000734457 Wb$$
$$\psi_m = \frac{1}{3}(0.000732892 + 1.26099\cdot 10^{-6}\cdot e^{j\frac{2\pi}{3}}) - 0.000734457 e^{j\frac{4\pi}{3}})$$
$$\psi_m = (0.5235 - j17.867)\cdot 10^{-6} Wb$$




10.)

At section 8, when modifying the winding currents the values that were present were the same as before but all moved to a new winding. For these winding currents the torque was 0.021045Nm.

I changed the currents back to the same windings as in the previous excersize and the torque was then 4.42922Nm.

The previous weighted torque value from Matlab is -6.97Nm, this roughly corresponds to my second result.

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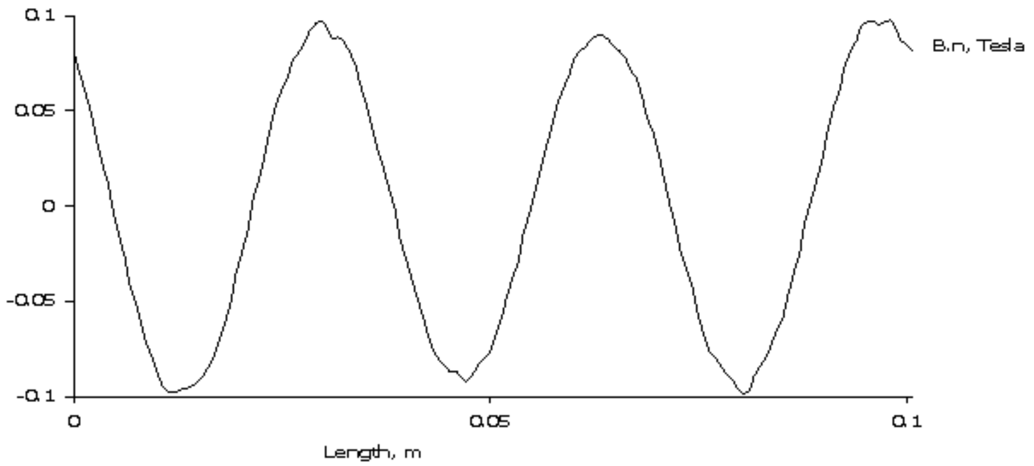
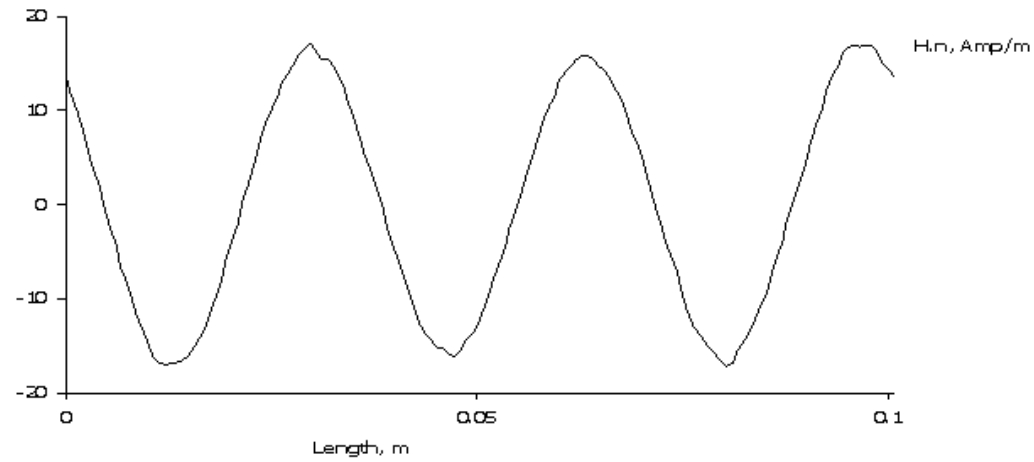
11.)

$$\psi_A = 0.001886 Wb$$
$$\psi_B = 0.001133 Wb$$
$$\psi_C = -0.003091 Wb$$
$$\psi_s = \frac{1}{3}(0.001886 + 0.001133 e^{j\frac{2\pi}{3}} - 0.003091 e^{j\frac{4\pi}{3}})$$
$$\psi_s = (-2.150 - j6.146) \cdot 10^{-5} Wb$$

14.)

$$\psi_A = 9.36 \cdot 10^{-6} Wb$$
$$\psi_B = 0.0013 Wb$$
$$\psi_C = -0.0013 Wb$$
$$Lsls = \frac{1}{3}(9.36 \cdot 10^{-6} + 0.00131 e^{j\frac{2\pi}{3}} - 0.00131 e^{j\frac{4\pi}{3}})$$
$$Lsls = (-3.9155 - j0.1594) \cdot 10^{-4} Wb$$



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Additions/Improvements

$$dAg = 2\pi \cdot rsi \cdot \frac{hm}{Length(BgnL)} = 2\pi \cdot 0.0285 \frac{0.05}{}$$