Motor Design Assignment 1

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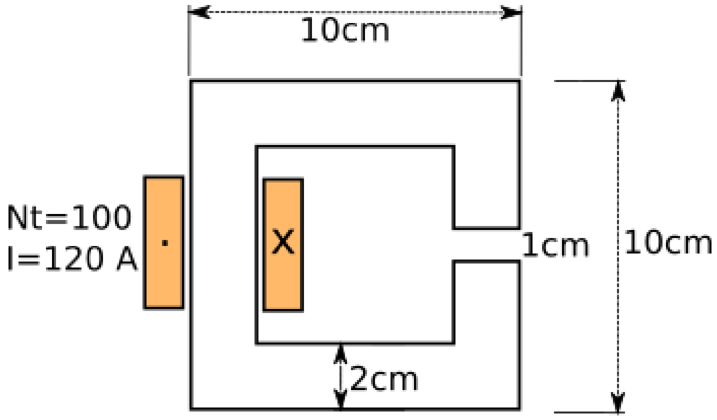

Figure 1: C- Core

I used Ansys Maxwell to simulate the given model. Before the simulations, the expected B_{gap}, namely the flux density in the air gap and the inductance are calculated analytically. In the calculations, the core is assumed to be infinitely permeable and the flux distribution is uniform.

$$NI = H_{core}.l_{core} + H_{gap}.l_{gap}$$

$$B_{gap} = \mu H_{gap}$$

$$B_{gap} = 1.5\ T$$

Therefore, we expect 1.5 T flux density in the air gap under the given assumptions. Neglecting the leakage and fringing, the inductance can be calculated as follows;

$$L = \frac{N^2}{R_{gap}} = \frac{\lambda}{I}$$

$$R_{gap} = \frac{l_{gap}}{\mu.Area_{gap}} = 3.9\ x\ 10^{-5}\ H^{-1}$$

$$L = 25\ mH$$

For the core material, Steel1010 having the B-H curve given in Figure 2 is selected. Figure 3 and 4 shows the flux density distribution and the flux lines respectively. Figure 5 shows the flux density in the air gap. As seen the flux density reaches 0.88 T in the middle of the air-gap. This is lower than the expected value, because the core saturates at the given excitation as seen in Figure 3. If modify the material so that the relative permeability is high and the B-H characteristic is linear, then we can have the expected flux density in the air gap (Figure 6). Modifying the material properties results in the flux density distribution given in Figure 7. As seen core does not saturates this time, flux density distribution is more uniform.

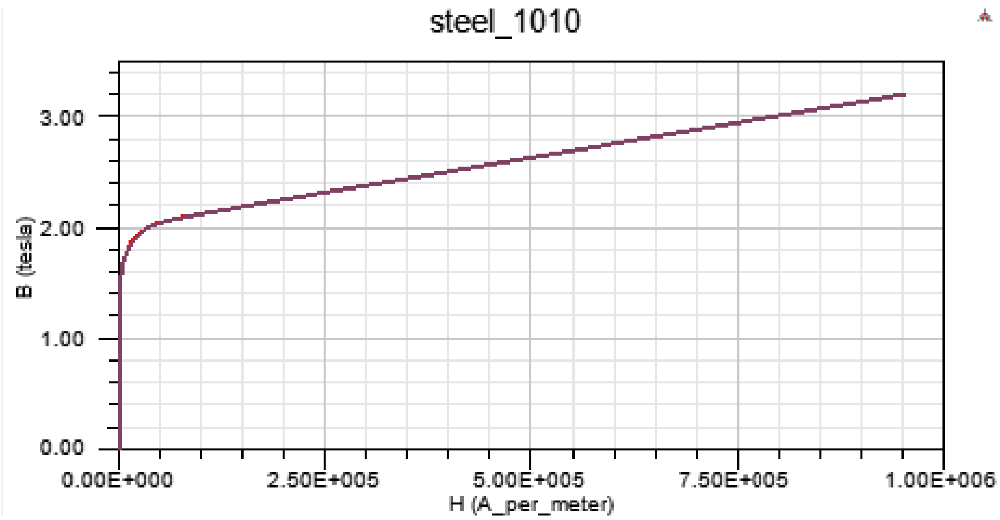

Figure 2: B-H curve of the selected material

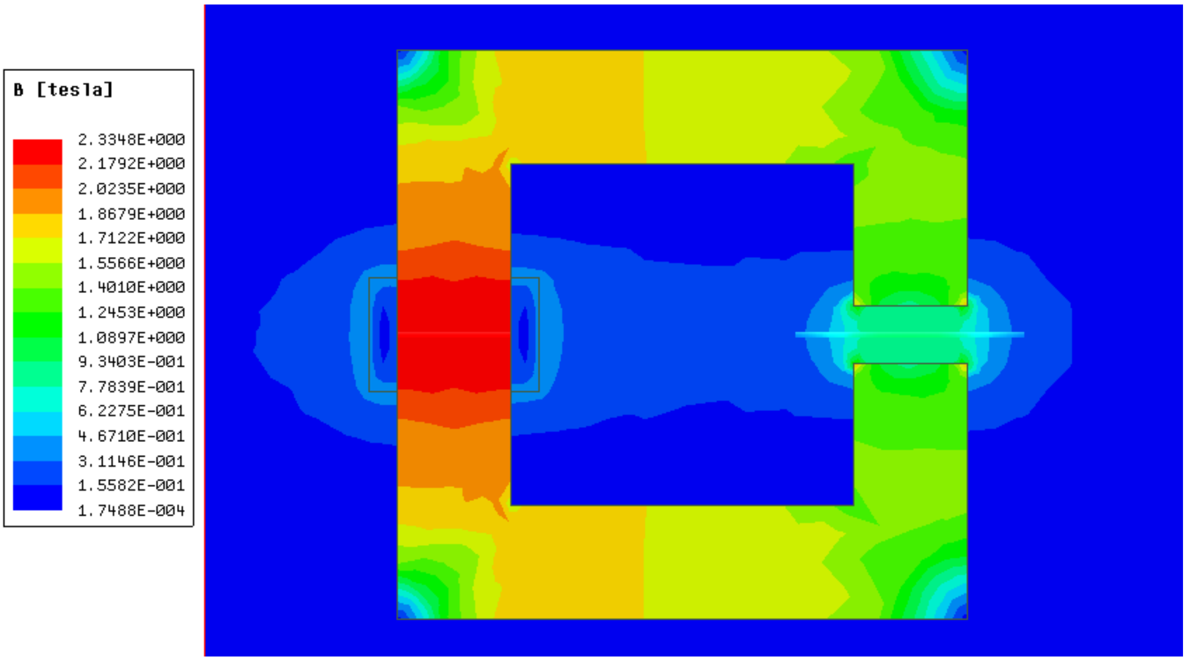

Figure 3: Flux density distribution with the given B-H curve

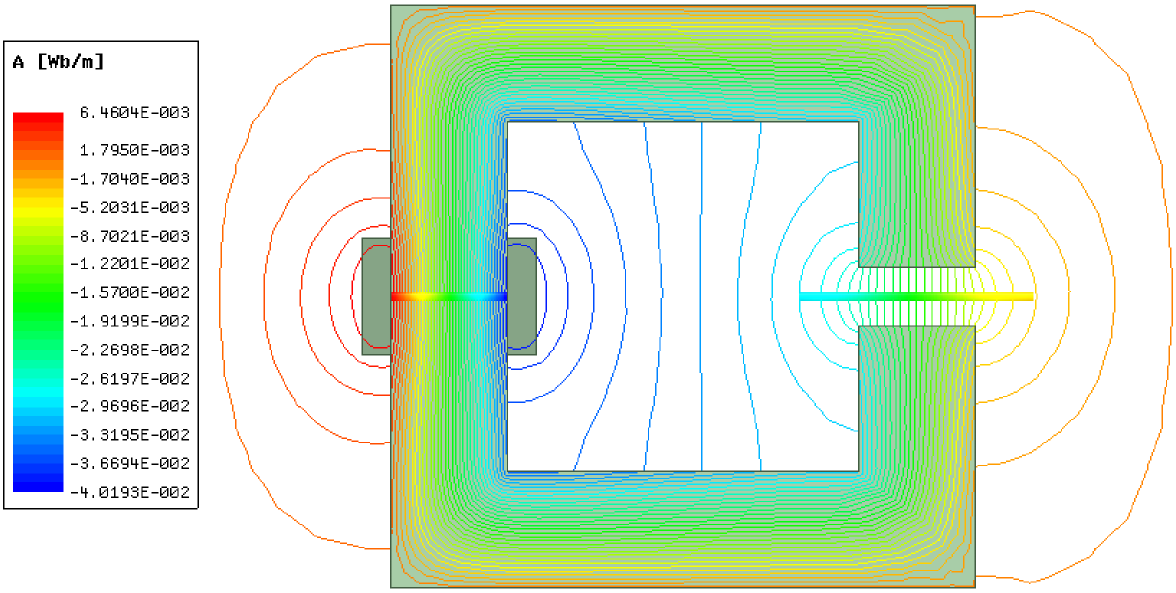

Figure 4: Flux lines

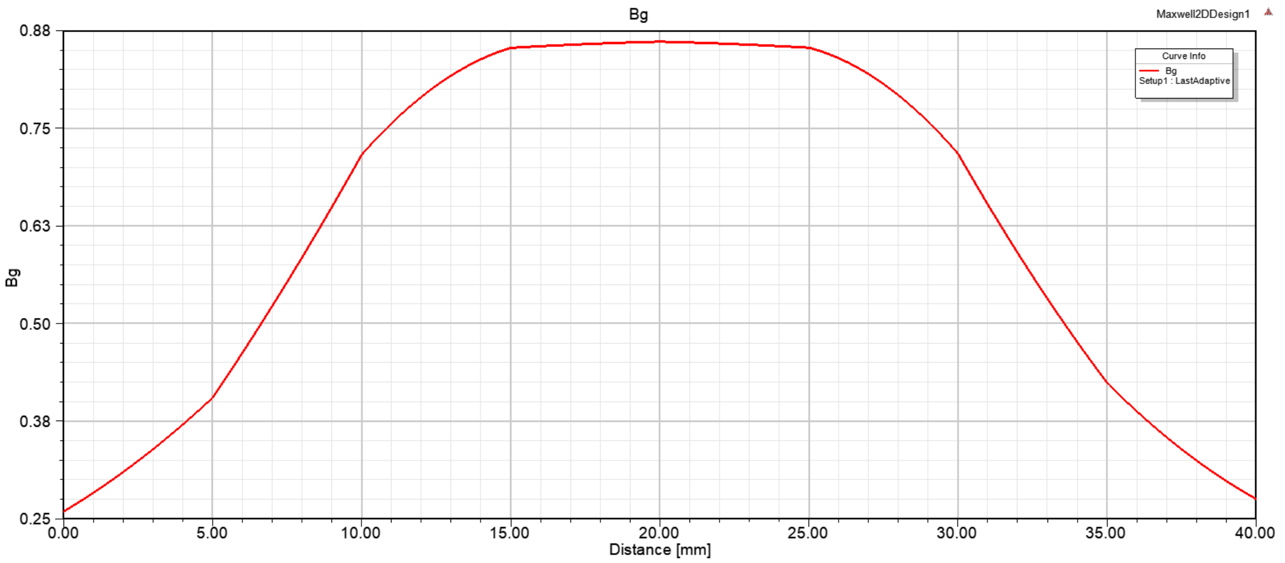

Figure 5: Flux density at the air-gap

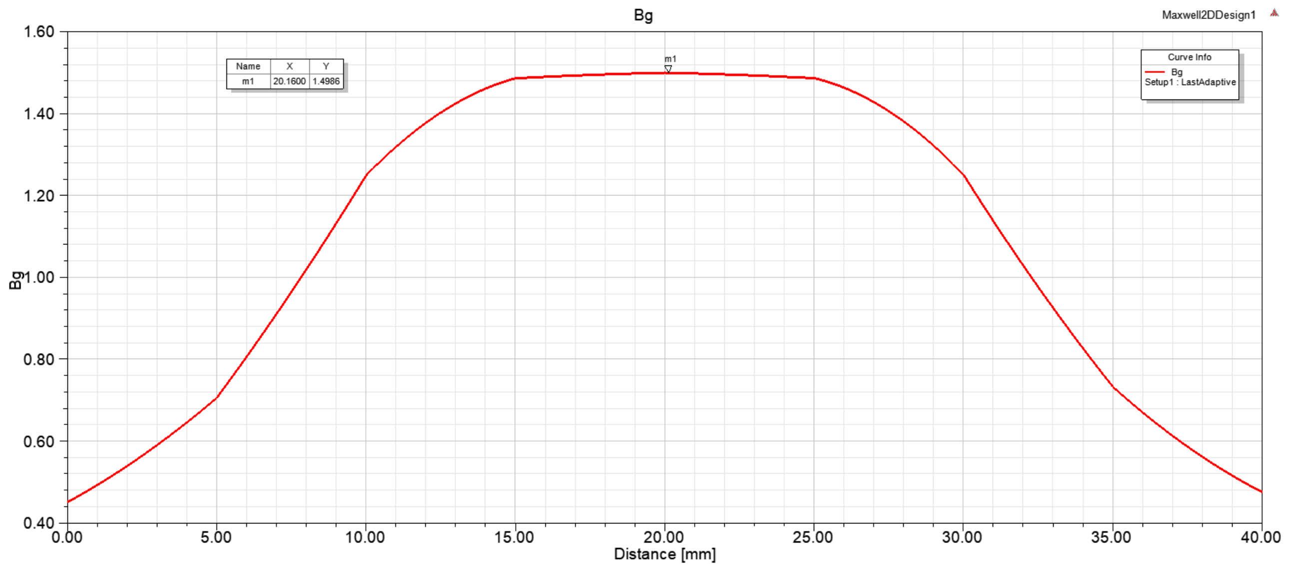

Figure 6: Flux density at the air gap with no saturation

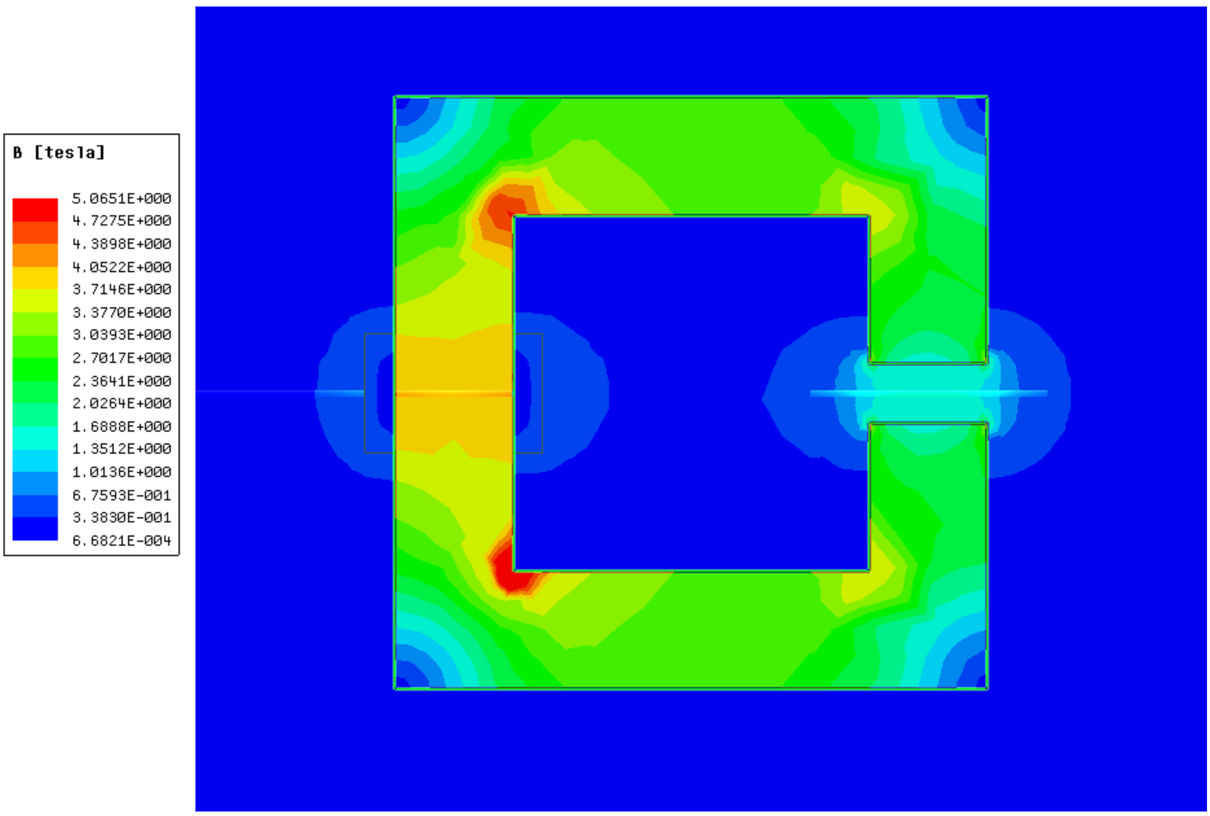

Figure 7: Flux density distribution with no saturation

There are several ways to calculate inductance using Maxwell. One way is to assign matrix parameter by adjusting the currents source and the return path. By this way, Maxwell estimates the corresponding inductance and it can be seen from results → solution data. The inductance is obtained as 64 mH. Note that this estimation is taken with the modified material so that the core does not saturate. To observe the effect of saturation on inductance and the inductance-current characteristics, I used the material with the original B-H curve. For different current values, the graph in the Figure 8 is obtained. The red line represents the mutual and the purple line represents the leakage inductance. The leakage inductance in measured to be 7 mH. This measurement are obtained by integrating the flux density in a given line and multiplying it with turns number and then dividing it to current. Notice that the unsaturated inductance is very close to the value Maxwell estimated.

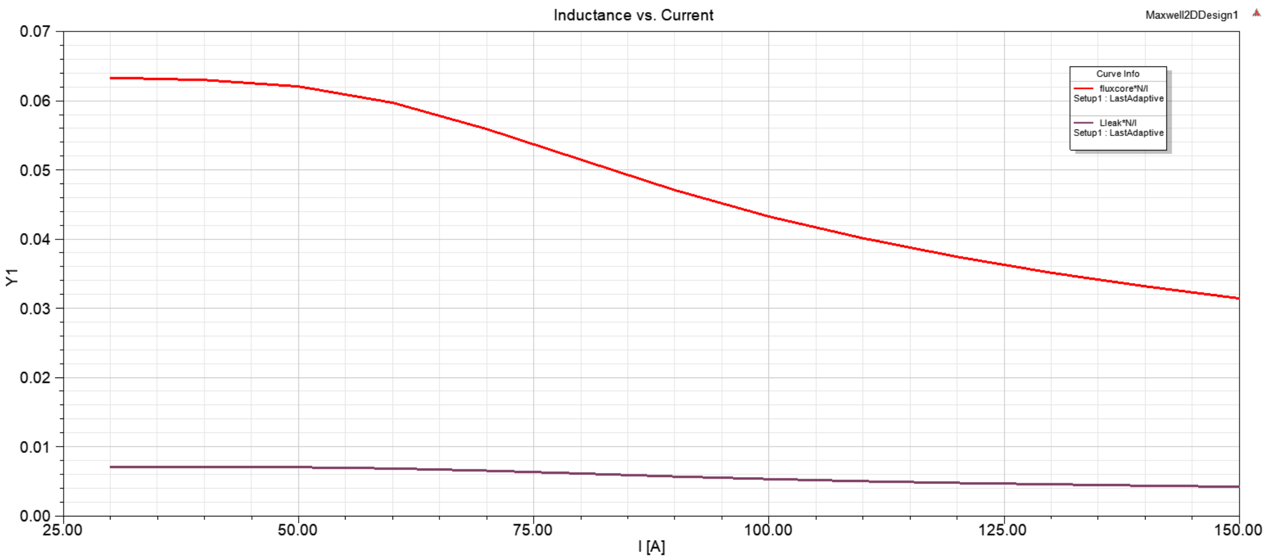

Figure 8: Total and leakage inductance with changing current

I calculated inductance as 25mH but the simulation results are very different. This may be due to the large air-gap resulting in excessive fringing. Fringing causes the effective air-gap area to be larger and the air gap reluctance to be lower and this increases the estimated inductance.