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2016

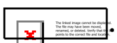
EIEN20 Assignment 2

Introduction:
Assignment 2 is a continuation of Assignment 1, this time we are using different ECM and FEM models to gain insight of how a transformer operates. For this assignment I will be using the same transformer parameters as Assignment 1:

Lamination type	*Length Ltr [mm]*	*Width Wtr [mm]*	*Stack Height Hc [mm]*
EI-96	*96*	*80*	*65*

The results from the FEMM computation are as follows:

	DC	AC (No load)	AC (4.18 Ohm)	AC (0.42 Ohm)
Freq	0	50	50	50
Flux	0.002097			
Bcr	1.3441			
iar	0.2058	0.2058	2.33135	19.28249
iai		0	-0.11697	-1.978758
ibr	0	0	-13.305	-110.33358
ibi		0	0.1522	10.9027
var	0.31053	16.00977	325.41423	325.22388
vbr	0	2.74316	55.61206	46.08786
far	0.995758	1.2232	0.000689	0.0097864
fbr	0.173902	0.21364	-0.002024	-0.01605
vai		384.281295	0.040057	0.08895
vbi		67.11853	-0.62887	-4.53945
fai		-0.04997	-1.0246	-0.9426
fbi		-0.00873	-0.17897	-0.16288
R1	1.508892128	77.79285714	139.581886	16.86628024
R2	0.046070949	2.375246506	4.2618487	0.514977527
L1	4.838474247	5.943634597	0.000295537	0.000507528
L2	0.14773265	0.181476401	9.0236E-06	1.54963E-05
M12	0.845004859	1.038095238	-0.000868167	-0.000832361

1.)
Flux and Permeability are bound by the relation .
Here we can see the relationship, the maximum permeability comes for a flux density of around 0.4T. The permeability increases with increase in flux until it becomes magnetically saturated (at 0.4T), the permeability then reverses and decreases to ~0 at 1.5T.

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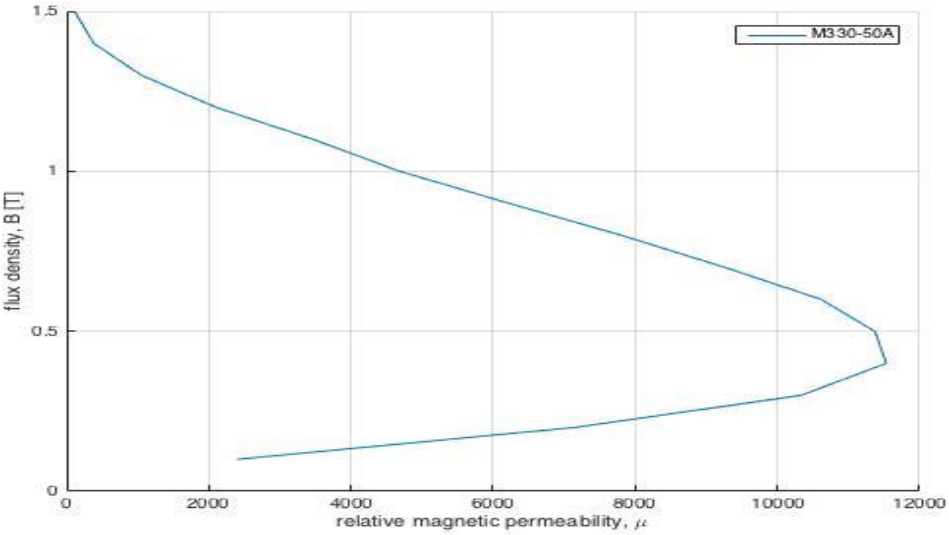
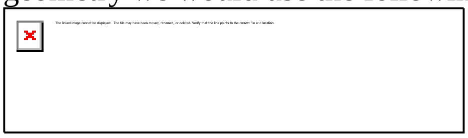


The data in this graph is for a 0.5mm sheet of steel; an iron transformer core will have a higher saturation rate so 1.4T would be a more suitable choice for that metal.
A lower flux would be more power conservative but generally the higher the permeability of the core, the more efficient the transformer is.

<u>2.)</u>
I selected the measurements shown above, the proportion of electrical to magnetic circuit (ks) is set to 0.5. If we're given a specific output voltage and transformer geometry we would use the following equations:



- Inductance, Mutual Coupling and Secondary Resistance can be found from transformer specifications.
- N1, N2, i1 & i2 should be found by use of a simultaneous equation to find the most effective turns ratio for the given output voltage.
- All these values can then be used to find input voltage etc.

Matlab give the turns for this transformer as N1=475, N2=83. This gives a turns ratio of n=N2/N1=0.175.
So if ideal, every 1V and 1A in would output 0.175V & 5.72A.

<u>3.)</u>
I expected the values for the AC simulation to be closer to the Matlab values than those of the DC simulation. The magnetisation currents decrease as the load increases which coincides with my expectations.

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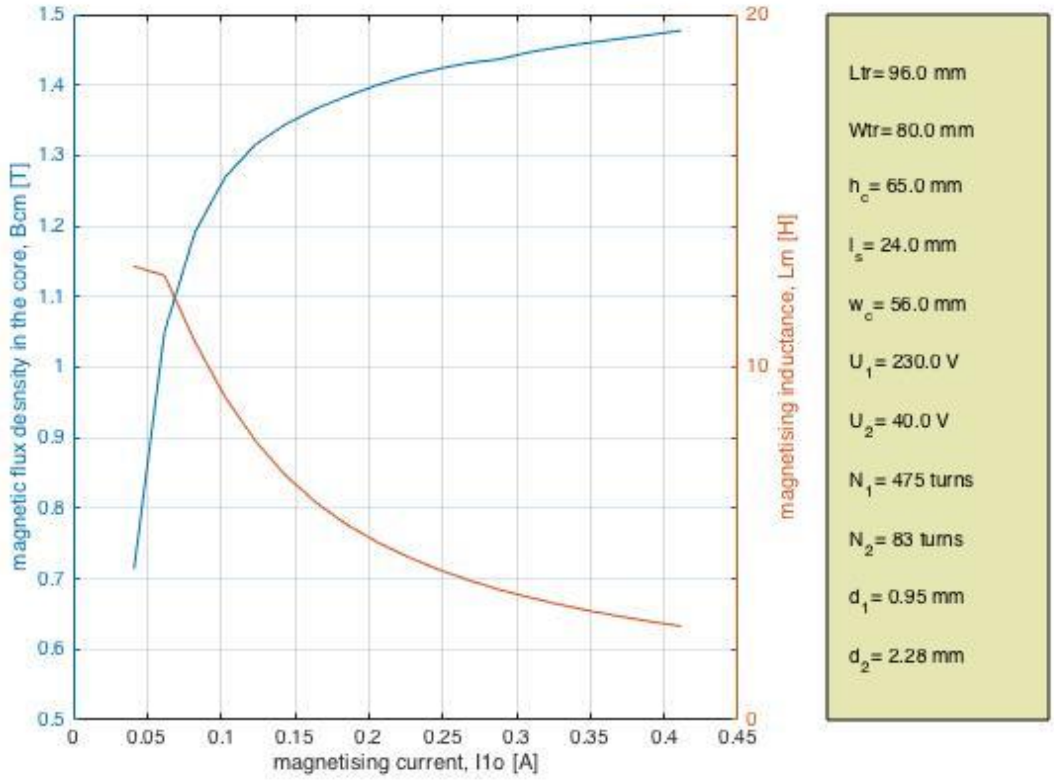
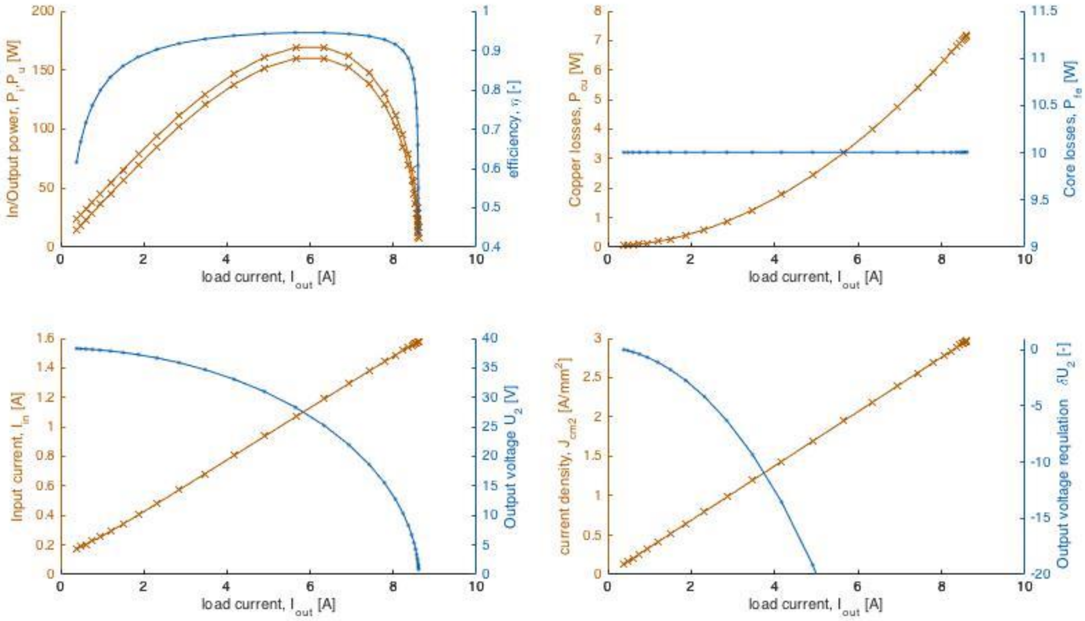
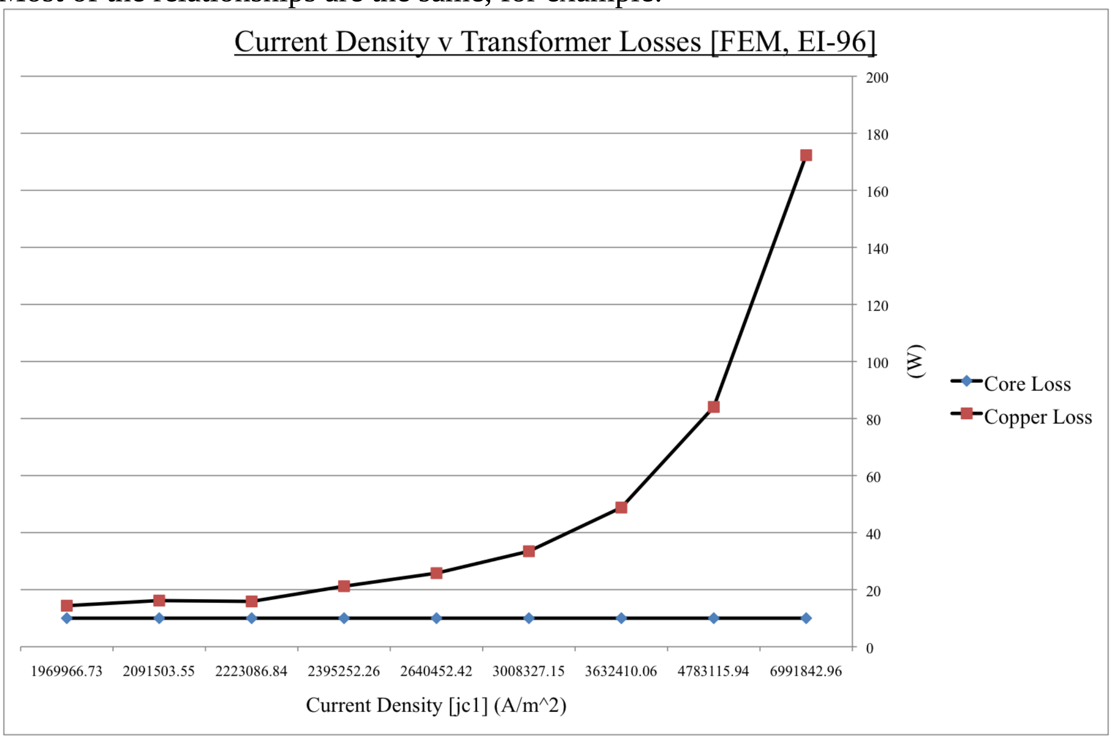


	Analytic expression	DC FEMM (0Hz)	AC FEMM (50Hz)
Magnetizing current [A]	0.2	0.206	0.206
Primary flux linkage	0.000478	0.996	
Secondary flux linkage	0.000476	0.174	
Primary voltage [V]	230	230	230
Secondary voltage [V]	40	40	40
Primary inductance [H]	5.279	4.838	5.944
Secondary resistance [Ω]	0.05	0.046	2.375
Active power [W]	34.707	47.4	63.5
Apparent power [VA]	46	47.4	47.4

4.)



These graphs show performance standards for the transformer with a changing load current. During the first assignment we were changing the proportion ks, as this ks increased the current density (jc1) decreased. This current density is roughly proportional to the load current so we can compare data from assignment 1.
Most of the relationships are the same, for example:



This graph should be equivalent to the top right graph in fig 3 produced by Matlab. The efficiency however does not follow the same relation. This comparison is inadequate as the changing current density in simulation 1 was due to a change in geometric proportions that doesn't occur here. That proportion is a significant variable so it's likely it will be responsible for discrepancies between results.
FEMM

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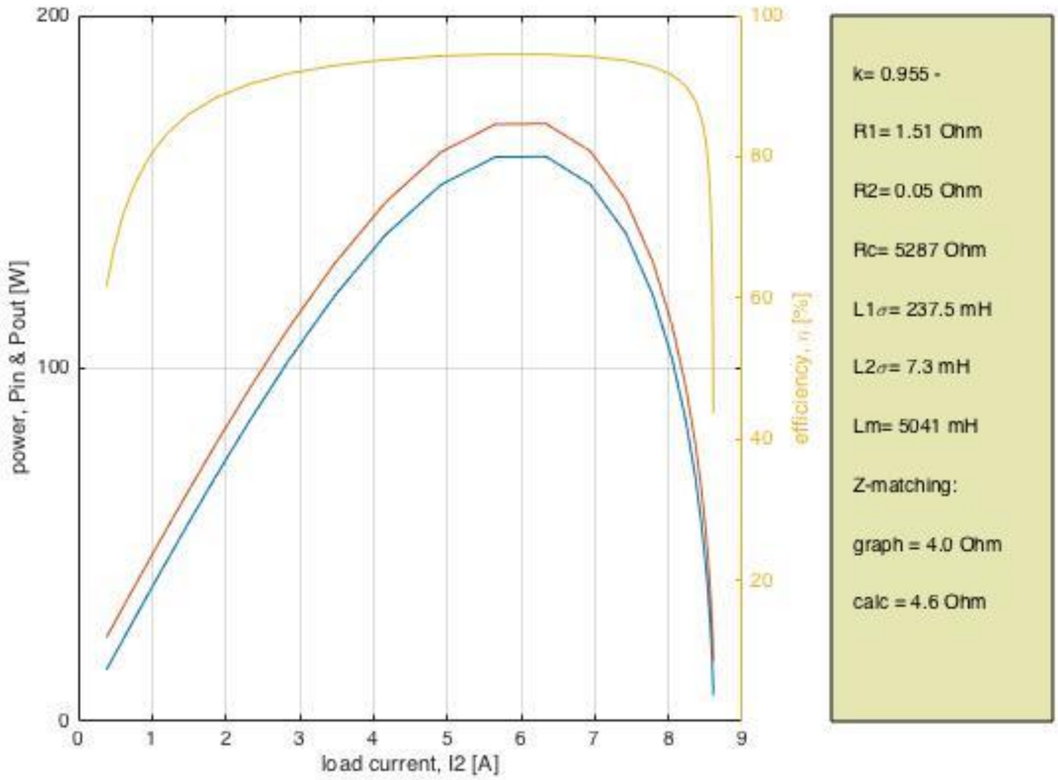
5.)
The transformer parameters can be found from FEMM through calculation. The values given at output by FEMM are used to find actual transformer parameters. The geometry of the transformer can be found by calculations involving size such as the flux to flux density relation.



I simulated a short-circuited load in FEMM and observed the results. The simulation for AC took far longer to compute than with the load intact and the images produced showed much higher heat concentration around the transformer.
The first image is DC heat map, the second is AC:

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