

Assignment 1

by James Thomas

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Prifysgol Cymru
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University of Wales
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UWTSD

Electrical Machines (M6X00373)

Stator Modelling Part 1

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3-14-2019

Declaration

The work of this report completed under the supervision of Dr Steve Mosey declare that this report is the product of my own work and is not being submitted for any other degree etc.

Sign the declaration

James Thomas

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Abstract

This report will demonstrate an in depth understanding of the principles of operation and design of electrical machines. The electrical machine in this report is a DC motor. It will show the relationship between useful flux and the angle that the rotor cut through the flux in the motor. These result will be shown in table and a graph. This will calculate the flux leakage factor and show how efficient the DC motor is.



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1.0. Introduction

1.1. DC Motors

A DC motor has two main parts, the stator and the rotor. A DC motor has perpetual magnets or either has electromagnetic windings on the stator, and this is on the external part of the motor. Inside the motor the rotor is positioned. Inside the rotor it has coil windings that get powered (DC current). When the coils are powered with DC current, this will create a magnetic field around the rotor. The rotor rotates by the point that one side of it, gets attracted by the magnetic field in the stator and then the other side is being repelled. [1]

The rotation carry on because of the commutator. The commutator is there to manage the direction of the current flow and also the magnetic field direction. The rotor turns because of the attraction and repulsion, then the rotor come to be horizontally lined, both brushes will make interaction with the opposite side of the commutator. Because of this the current traveling through the rotor is then reversed. As a result of that, the magnetic field also gets reversed. This route repeats itself as long as power is supplied to the DC motor. [1]

1.2. Magnetic Field

A magnetic field is a vector field and this describes the magnetic influence of magnetized materials and electrical currents. Magnets are commonly used in everyday life, the properties of magnetic fields are often seen in permanent magnets, which attract to magnetic materials such as iron or repel other magnets. [2]

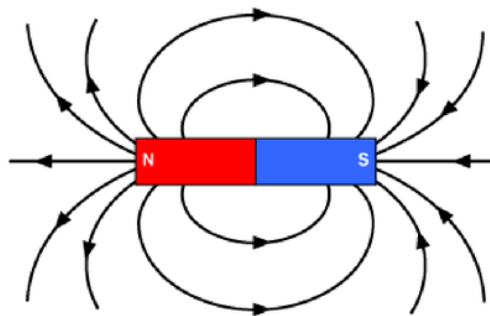


Figure 1 Magnetic Field [3]

1.3. Finite Element Method

4. The finite element method (FEM) is a numerical technique used to perform finite element analysis (FEA) of any given physical phenomenon.

It is necessary to use mathematics to comprehensively understand and quantify any physical phenomena, such as structural or fluid behaviour, thermal transport, wave propagation, and the growth of biological cells. Most of these processes are described using partial differential equations (PDEs). However, for a computer to solve these PDEs, numerical techniques have been developed over the last few decades and one of the most prominent today is the finite element method.” [4]

1.4. Task

This report will show a finite element simulation and analysis for the following DC Motor Stator circuit shown below. This report will show an estimate of the total magnetic flux being created in the stator circuit. Determine the flux leakage factor for the design. Provide an estimate of flux cutting the rotor coil as a function of the coil angle.



Figure 2 DC Motor Stator Circuit [5]

The Stator Dimensions and Parameters are as follows:

- Circuit Depth - 100mm
- Internal Stator Diameter - 80mm
- External Stator Diameter - 110mm
- Pole Thicknesses - 20mm
- Radius Pole Face - 22mm
- Field Coil Vertical Coordinates - $\pm 15\text{mm}$
- Field Coil Horizontal Internal Coordinates - $\pm 24.5\text{mm}$
- Rotor Coil Thickness - 40mm
- Field Coil Current - $\pm 1\text{A}$ (indicates in and out of page)
- Field Coils Number of Turns - 500 [5]

2.0. Method



Figure 3 DC Motor Stator Circuit

Using FEMM 4.2, DC Motor Stator Circuit was designed using materials specified in the introduction. When the design was completed an open boundary was added. The problem type is planar.

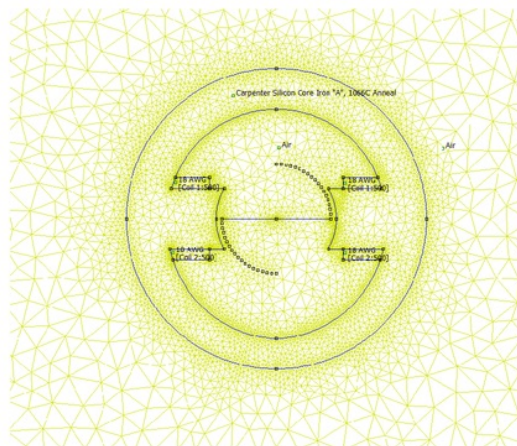


Figure 4 DC motor stator, mesh for the problem

The figure above show FEMM 4.2 program makes a mesh which is triangular for the problem.



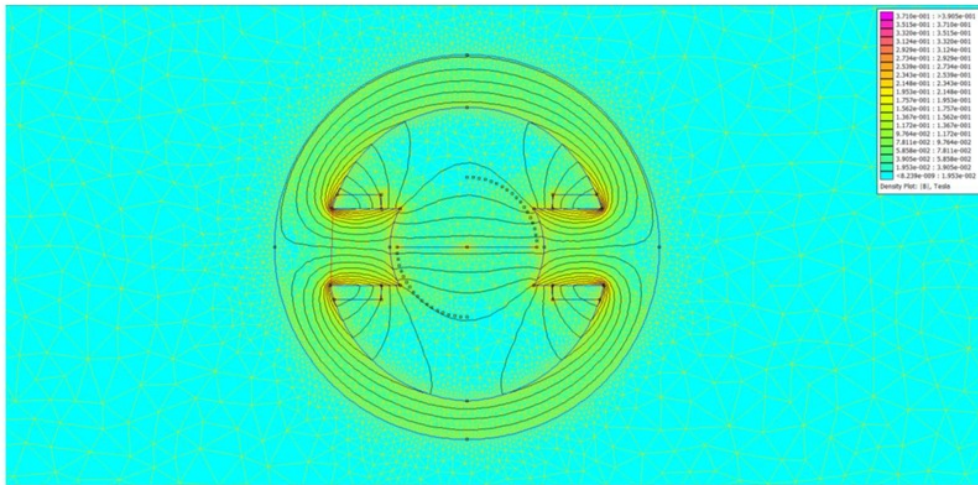


Figure 5 Flux Density in the DC Motor

Flux density has been schemed as a colour density plot as shown above. As shown from the figure above between the both poles, that's where the total flux can be measured form. As the above figure shows the rotor will only be cutting through 6 'flux lines' and missing 10 others, these suggest there will be a lot of flux leakage, over 50%.

3.0. Results

3.1. Total Flux

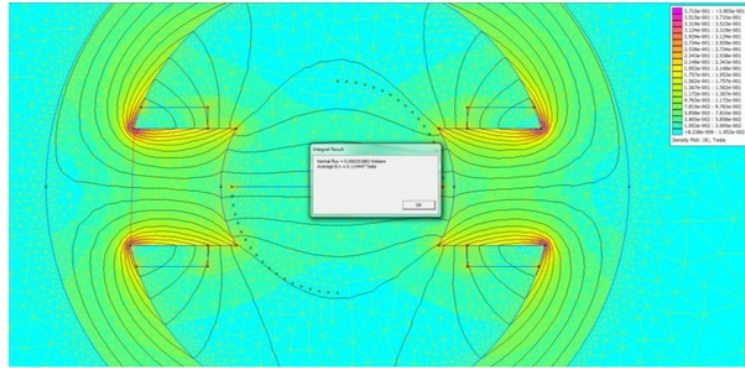


Figure 6 Total Flux Density being Measured in the DC Motor

The red line in the figure above is measuring the total flux across one of the poles. Total Flux = 0.000251912.

3.2. Flux Vs Angle

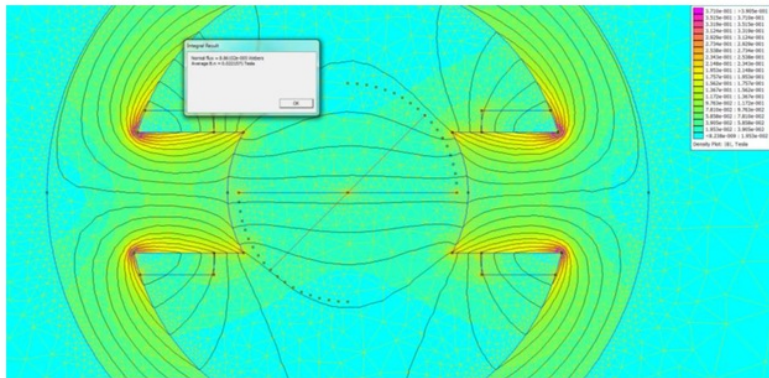


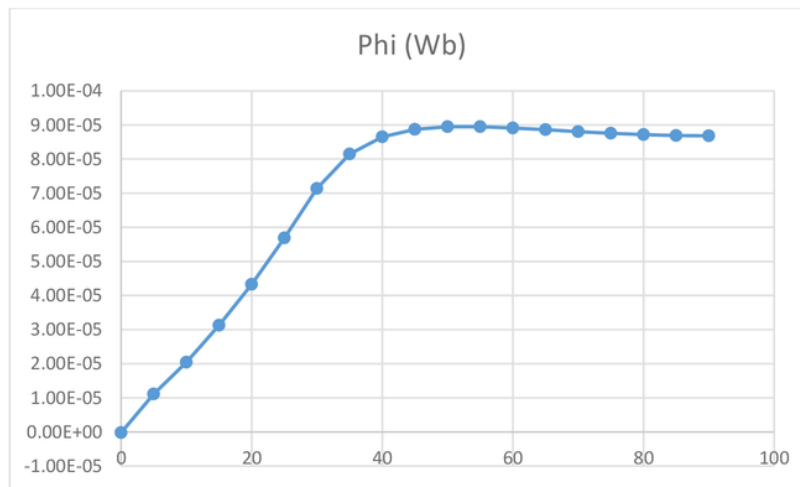
Figure 7 Measuring Flux Vs Angle Across the DC Motor

To calculate the FLE, firstly the useful flux will need to be found. This can be found by plotting points around the inside stator and measuring the flux across it, as show above. To find the points needed for the X coordinates, it can be found be using the equation, $R \cdot \cos(\theta) = X$. To find the points needed for the Y coordinates, it can be found be using the equation, $R \cdot \sin(\theta) = Y$. $R = 20$. As these table below shows it was done through 90° of the cycle.

Angle (°)	X	Y	Phi (Wb)
0	20.00	0.00	-2.17E-07
5	19.92	1.74	1.11E-05
10	19.70	3.47	2.04E-05
15	19.32	5.18	3.13E-05
20	18.79	6.84	4.33E-05
25	18.13	8.45	5.68E-05
30	17.32	10.00	7.14E-05
35	16.38	11.47	8.15E-05
40	15.32	12.86	8.65E-05
45	14.14	14.14	8.87E-05
50	12.86	15.32	8.95E-05
55	11.47	16.38	8.95E-05
60	10.00	17.32	8.91E-05
65	8.45	18.13	8.86E-05
70	6.84	18.79	8.80E-05
75	5.18	19.32	8.76E-05
80	3.47	19.70	8.72E-05
85	1.74	19.92	8.69E-05
90	0.00	20.00	8.68E-05

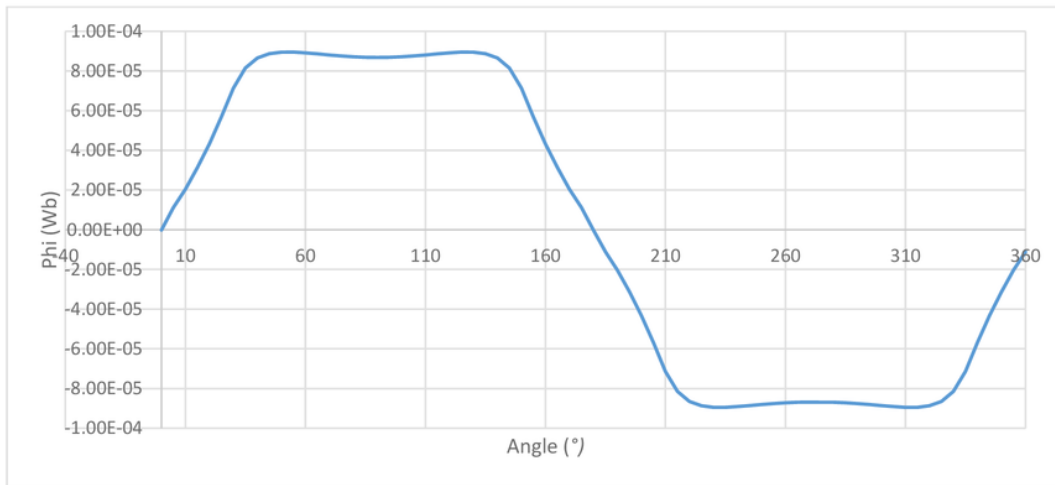
Table 1 Flux Vs Angle

The table above shows the flux against angle and the highest useful flux is around 50/55°, this is due to the rotor cutting through more flux at these points, also show in figure 7.



Graph 1 1/4 Cycle of Flux Vs Angle

From Table 1 the graph above show the relationship between Flux and angle.



Graph 2 Full Cycle of Flux Vs Angle

After seeing the results for 90° by assuming the results will follow the same pattern, the graph above was produce for the full 360°.

3.3. Flux Leakage Factor

The Flux leakage factor is amount of useful flux against the total flux.

Total Flux = 0.000251912

Useful flux = 8.95E-05

$$FLF = 1 - \frac{\text{Useful Flux}}{\text{Total Flux}}$$

$$FLF = 1 - \frac{8.95E-05}{0.000251912}$$

$$FLF = 0.6447 \times 100\%$$

$$FLF = 64.47\%$$

The Flux leakage factor is what was suggest under Figure 8 earlier on in this report, being over 50% FLF. This shows how inefficient this method is.

4.0. Conclusion

This report shows the most useful flux will be around 50/55° and this is due to the rotor cutting through more flux at these points. The Flux will take the easiest route and will try to avoid going through the air than the metal due to the air having a higher resistance, hence why the FLF is over 60%, showing how efficient this method is. From the result, there can be improvements made to lower this, like making the stator smaller or even moving the coils closer together?

References

- [1] Magnetic Innovations, "DC MOTOR, HOW IT WORKS?," [Online]. Available: <https://www.magneticinnovations.com/dc-motor-how-it-works/>. [Accessed 11 03 2019].
-  [2] Wikipedia, "Magnetic field," [Online]. Available: https://en.wikipedia.org/wiki/Magnetic_field. [Accessed 11 03 2019].
- [3] Magic of Magnetism, "Magnetism Basics," [Online]. Available: <https://www.ece.neu.edu/fac-ece/nian/mom/work.html>. [Accessed 11 03 2019].
- [4] Simscale, "Finite Element Method – What Is It? FEM and FEA Explained," [Online]. Available: <https://www.simscale.com/blog/2016/10/what-is-finite-element-method/>. [Accessed 11 03 2019].
- [5] S. Mosey. [Online]. Available: M6X00373_Sem2_CW1_2018_19_ElectricalMachines . [Accessed 11 03 2019].

Assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

57 / 100

PAGE 1

PAGE 2

PAGE 3

PAGE 4



Comment 1

You should include a short statement of results in your abstract

PAGE 5

PAGE 6



Comment 2

permanent magnets



Comment 3

This sentence seems to be saying too much. A sentence should say one thing. Also it would have been nice for you to define a stator and rotor before discussing them.

PAGE 7



Comment 4

You should paraphrase information you take from sources as this allows your understanding to be assessed.

A quote should not be longer than a line or two at the most. Quoting an entire paragraph is not good practice.



Comment 5

What does the mesh do?

Why is this important?



Comment 6

Red line is very difficult to see in image



Comment 7

units?



Comment 8

You should define an acronym at first use. So your previous statement on page 6 should have said "Flux Leakage Factor (FLF)"



Comment 9

Wikipedia should not be used as a reference source as it can be edited by anyone and is not regarded as a reputable source.

GRADING FORM: SMU GENERIC_SMOSEY

JAMES THOMAS

57.30

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



You have included a range of sources, but you should try to use more reputable sources such as peer reviewed articles, text books or other academic writing. Referencing conventions consistently applied.

5.5

KNOWLEDGE & UNDERSTANDING

Knowledge of the basic underlying concepts and principles of a subject.



Knowledge is accurate with a good understanding of the field of study.

17.4

COGNITIVE & INTELLECTUAL

Evaluate underlying concepts and principles of a subject and interpret qualitative and quantitative data in order to develop lines of argument and make sound judgements.



Sound, logical, analytical thinking; synthesis and evaluation. Ability to devise persuasive arguments. Sound, convincing conclusions.

18

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A very good application of a range of methods and techniques. Evidence of some innovation and creativity.

12.4

TRANSFERABLE SKILLS

Communicate the results of their study/work accurately and reliably, and with structured and coherent arguments; the qualities needed for employment requiring the exercise of some personal responsibility within a structured and managed environment.



Can communicate in a suitable format but with room for improvement. Work lacks coherence in places.

4