

Assignment 1

by James Bunyan

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2019

Electrical Machines

ASSIGNMENT 1

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Abstract

In this assignment we have been given a problem to find out the magnetic flux within a DC Motor. We must design the motor on FEMM 4.2 and then conduct tests to determine the total flux and the max useful flux of the motor.



This assignment has taught me basic knowledge on magnetism and magnetic flux, and how it works within a motor.

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Introduction

In this assignment a simulation of a DC motor stator circuit will be designed and then tested for the magnetic flux being created in the circuit, the flux leakage factor of the design and the flux cutting the rotor coil as a function of the coil angle. FEMM 4.2 is the software that is being used to design the stator circuit.

The problem that is given to us is to calculate the magnetic flux in the stator circuit, the flux leakage factor for the design and the flux cutting the rotor coil.

DC Motors

DC motors consist of two main parts, the stator and rotor. The motor contains permanent magnets or electromagnetic windings on the stator which is on the outside of the motor. The rotor is located on the inside of the motor, it contains the coil windings that are powered by the DC current. When the windings are powered, a magnetic field is created that causes rotor to rotate. This is because one side of the rotor is attracted by the magnetic field in the stator and the other side is repelled. [1]

The rotation continues due to the commutator, this also manages the flow of current (direction of magnetic field). The rotor turns due to the attraction and repulsion of the magnetic fields, but when the rotor becomes horizontally aligned in a brushed DC motor, both brushes will make contact with the opposite side of the commutator, which reverses the current through the rotor. [1]

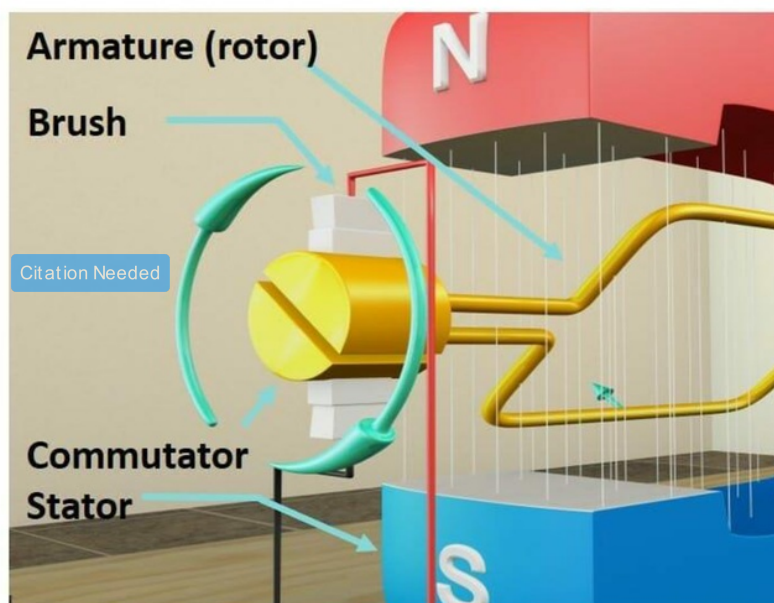


Figure 1 - Brushed DC Motor

Magnetism

Magnetism is the attraction and repulsion phenomenon produced by moving electrical charges. The affected region around the moving electrical charges consist of both electric field and a magnetic field. Any moving electric charge generates a magnetic field perpendicular to it. [2]

"In addition to current traveling through a wire, magnetism is produced by the spin magnetic moments of elementary particles, such as electrons. Thus, all matter is magnetic to some degree because electrons orbiting an atomic nucleus produce a magnetic field. In the presence of an electric field, atoms and molecules form electric dipoles, with positive-charged nuclei moving a tiny bit in the direction of the field and negative-charged electrons moving the other way." [2]

With magnets the opposite attract, and the same poles repel each other.

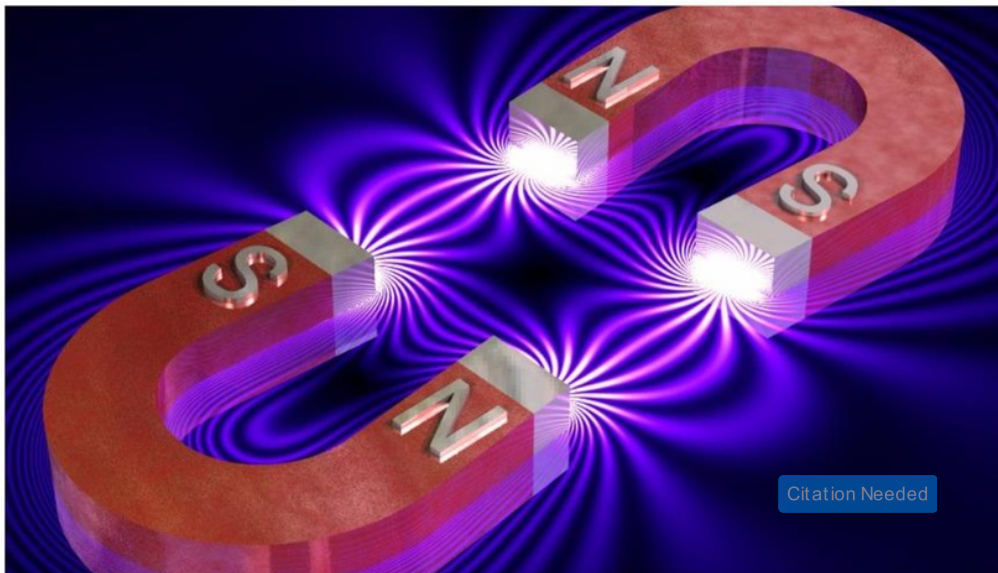


Figure 2 - Magnets

Finite Element Method

FEM was developed by engineers, to address structural mechanics problems related to aerospace and civil engineering. FM is a numerical method that is used for solving problems of mathematical and engineering physics. It can be used for various reasons, problems such as structural analysis, heat transfer, fluid flow and electromagnetic potential. The method uses mathematical equations to solve the problems that it is given, in the assignment we are given the dimensions of the stator of a DC motor, and the FEMM 4.2 software will help us calculate flux etc. [3] [4]



Above is an example of the stator that has been designed on FEMM. We can see the different nodes that have been used to create the motor, as would be used for any other problem.

Method

Using FEMM 4.2, a motor stator circuit is designed to be able to work out the magnetic flux, flux leakage factor and flux cutting the rotor coil. Various nodes are added which will place key points on the FEMM software that will eventually create the design of the motor. Each of the nodes are then joined together by a series of lines or curves to give the shape of the motor.

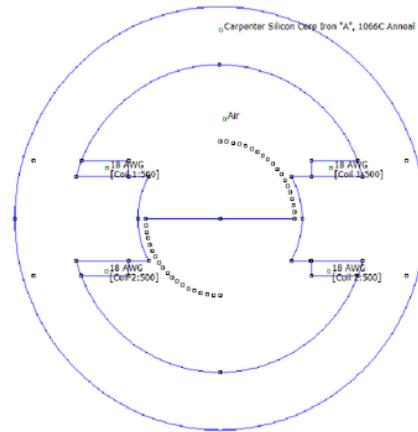


Figure 3 - Motor Design

Block labels are added to the design as seen above, to determine which materials and other problems that part of the motor is. The block regions used are air, Carpenter Silicon Core and 18 AWG. 18 AWG being the copper wire. Circuit properties are added to the coil region of the design.

A Boundary is also added to the design that accurately emulates the impedance of an unbounded domain.

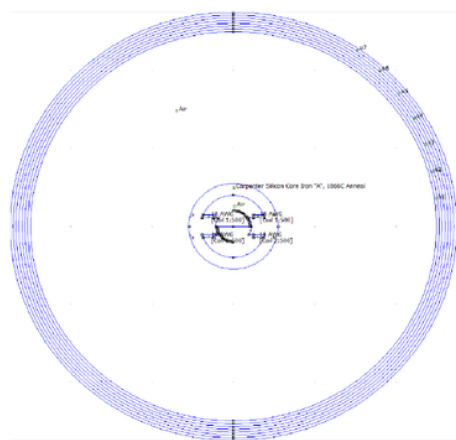


Figure 4 - Boundary

Once the design is completed, we mesh the design, that generates a triangular mesh for the problem. If the software manages to mesh the problem, we then 'turn the crank' that analyses the model before we can be able to see the results.

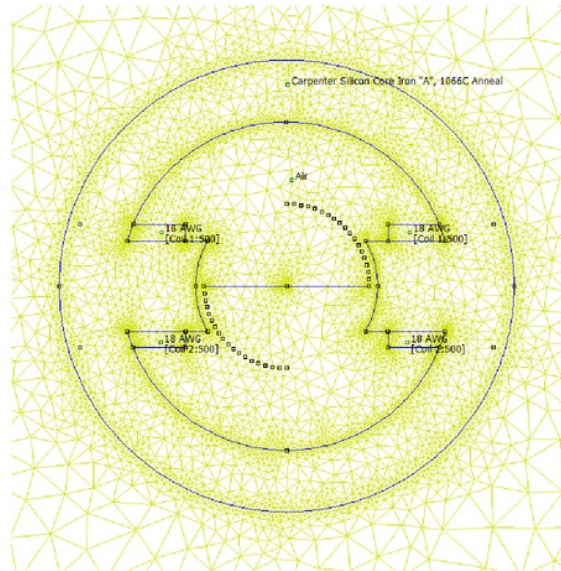


Figure 5 - Mesh

Once the mesh has been created, we can then see the results of the magnetic flux of the stator circuit. We can see the magnetic flux of the stator below, shown by the lines going across. This is the magnetic flux in the stator.

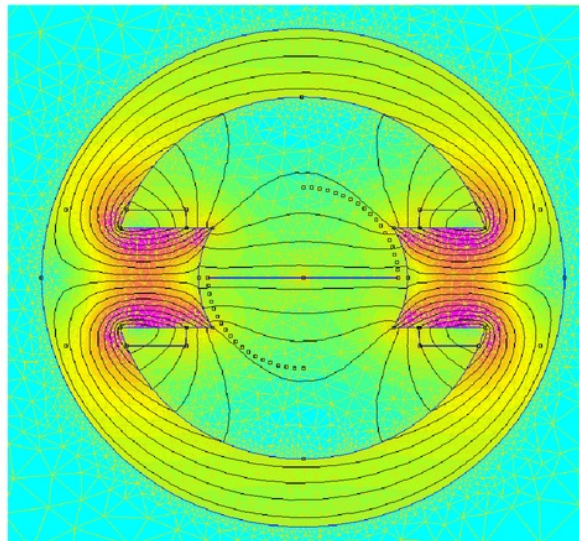


Figure 6 - Magnetic Flux

Now we have completed the design, we can calculate the total magnetic flux of the stator, the flux leakage factor of the design and the flux cutting the rotor coil as a function of the coil angle.

To determine the total flux, we must put a line across the width of one of the poles (armature), and click the equation button to give Total Flux of the stator.

To determine the flux cutting the rotor coil as a function of the coil angle, we would place nodes from 0 on the Y axis, placing a node every 5 degrees until the 90 degree angle. This would be done to calculate the flux across the rotor at each different angle.

To determine the total flux leakage, using the information already acquired the equation would be;

$$Total\ Flux\ Leakage = \frac{(Total\ Flux - Useful\ Flux)}{Total\ Flux}$$

Results

Total Flux

To calculate total flux, a line must be put across on of the armatures, and then the equation button must be pressed.

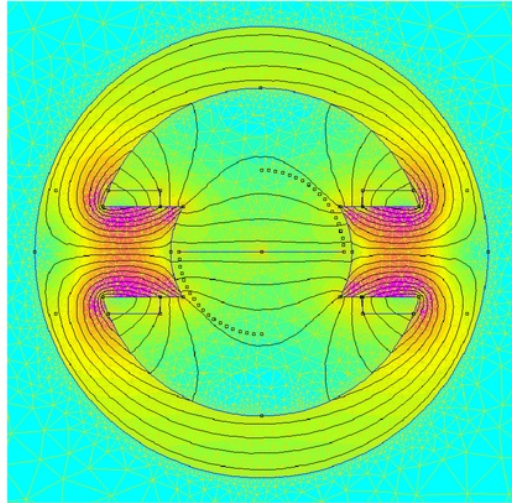


Figure 7 - Total Flux

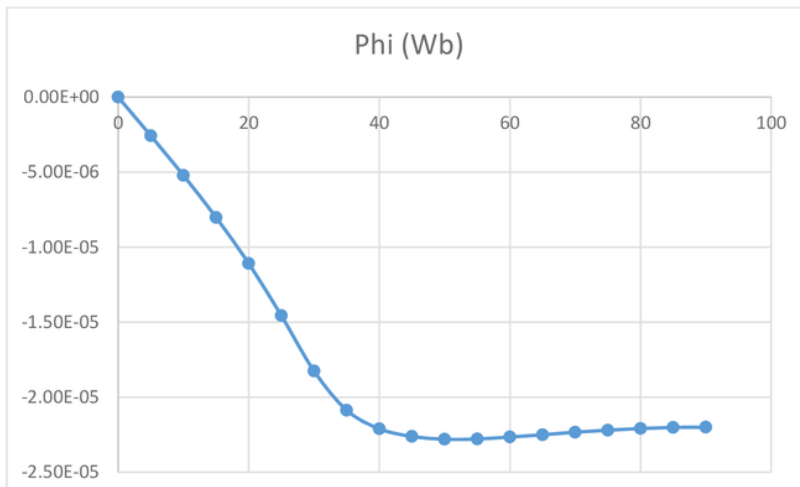
The flux calculated for the stator circuit = $6.45751\text{E-}05$



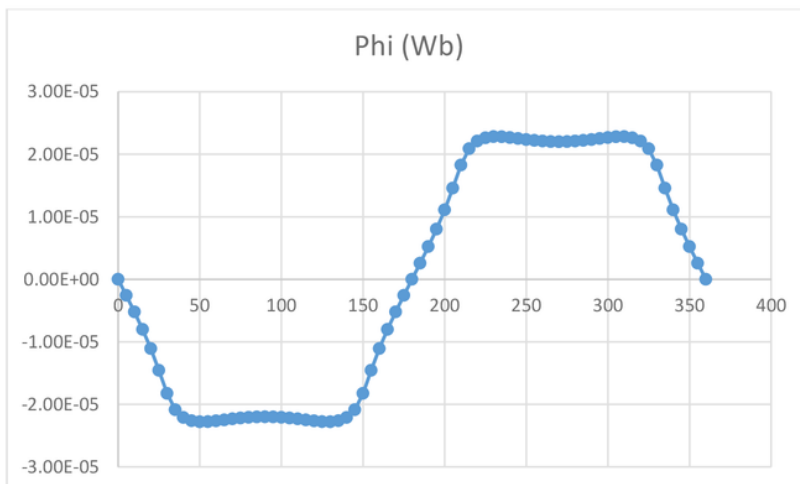
Flux Cutting the Rotor Coil

To determine the flux cutting the rotor coil as a function of the coil angle, we would place nodes from 0 on the Y axis, placing a node every 5 degrees until the 90 degree angle. This would be done to calculate the flux across the rotor at each different angle.

Above are the results that were found up to 90 degrees.



Here is a graph of the flux cutting the rotor coil.



Above is the full 360 degree results for the flux cutting the rotor coil. As we can see the closer the angle gets to the armature, the less flux there is.

Flux Leakage Factor

To calculate the flux leakage factor, the following equation must be used;

$$\text{Total Flux Leakage} = \frac{(\text{Total Flux} - \text{Useful Flux})}{\text{Total Flux}}$$

$$\text{Total Flux Leakage} = \frac{(6.45751\text{E} - 05 - 2.28037\text{E} - 05)}{6.45751\text{E} - 05}$$

$$\text{Total Flux Leakage} = 64.69 \%$$

64.69% flux leakage is extremely high, as there is only 34% of the flux being used, this wasn't expected to be so inefficient.

Discussion

5

In our results we can see that the total flux is $6.45751\text{E-}05$ from the first set of tests, but as we look at the results from the flux cutting the rotor coil the maximum useful flux is $2.28037\text{E-}05$. Comparing both results, there is 64% of flux being wasted, that isn't turned into useful flux.

6

By looking at the screenshots of the flux density, we can see that the maximum useful flux is at its highest when it's closer to one of the density lines, the further away it is the smaller the flux.

7

Surprisingly the flux is also smaller the closer to the armature it is also, we had or highest flux at around 55 degrees. The 360 degree graph shows that the flux is continuous and repetitive.

Conclusion



In this assignment, I have learnt about how magnetism and flux works within DC motors. It has surprised me with some of the results as they weren't expected, such as how much flux leakage that there is, and where the most useful flux is in the stator.

I have also learnt how to use the FEM programme. This was new to me and has given me confidence that I can use it again for other various problems that may arise in the future.

My knowledge in general has vastly improved with this assignment, realising how magnetism and magnetic flux works within a motor, also magnetism in general.

Bibliography

- [1] "DC MOTOR, HOW IT WORKS?," Magnetic Innovations, [Online]. Available:
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- [2] A. M. Helmenstine, "What Is Magnetism?," ThoughtCo., [Online]. Available:
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Assignment 1

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

63/100

PAGE 1

PAGE 2



Comment 1

This feels more like a reflection than an abstract. You should include information on what you are doing, why you are doing it, what you hope to find and a short summary of your results.

PAGE 3

PAGE 4

PAGE 5

QM

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PAGE 6

QM

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PAGE 7



Comment 2

Typo - FEM

PAGE 8



Comment 3

What does the mesh do? why is this important?



Comment 4

units?



Comment 5

Units?



Comment 6

Units?



Comment 7

Why is the flux cutting the line lower when it is closer to the armature?



Comment 8

This is more like a reflection on your personal feelings of the assignment, rather than a list of things you have found out by analysing the results from the simulations.



Comment 9

Wikipedia should not be used as a reference source as it can be edited by anyone. You should use more reputable sources such as peer reviewed journals, text books or other academic writing.

JAMES BUNYAN

63.30

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 extensive. Exhibits understanding of the breadth and depth of established views.

18.6

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. Ability to devise and sustain persuasive arguments. Ability to communicate ideas and evidence accurately and convincingly.

20.1

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 well, confidently and consistently in a suitable format. Work is coherent and fluent and is well structured and organised.

6.7