

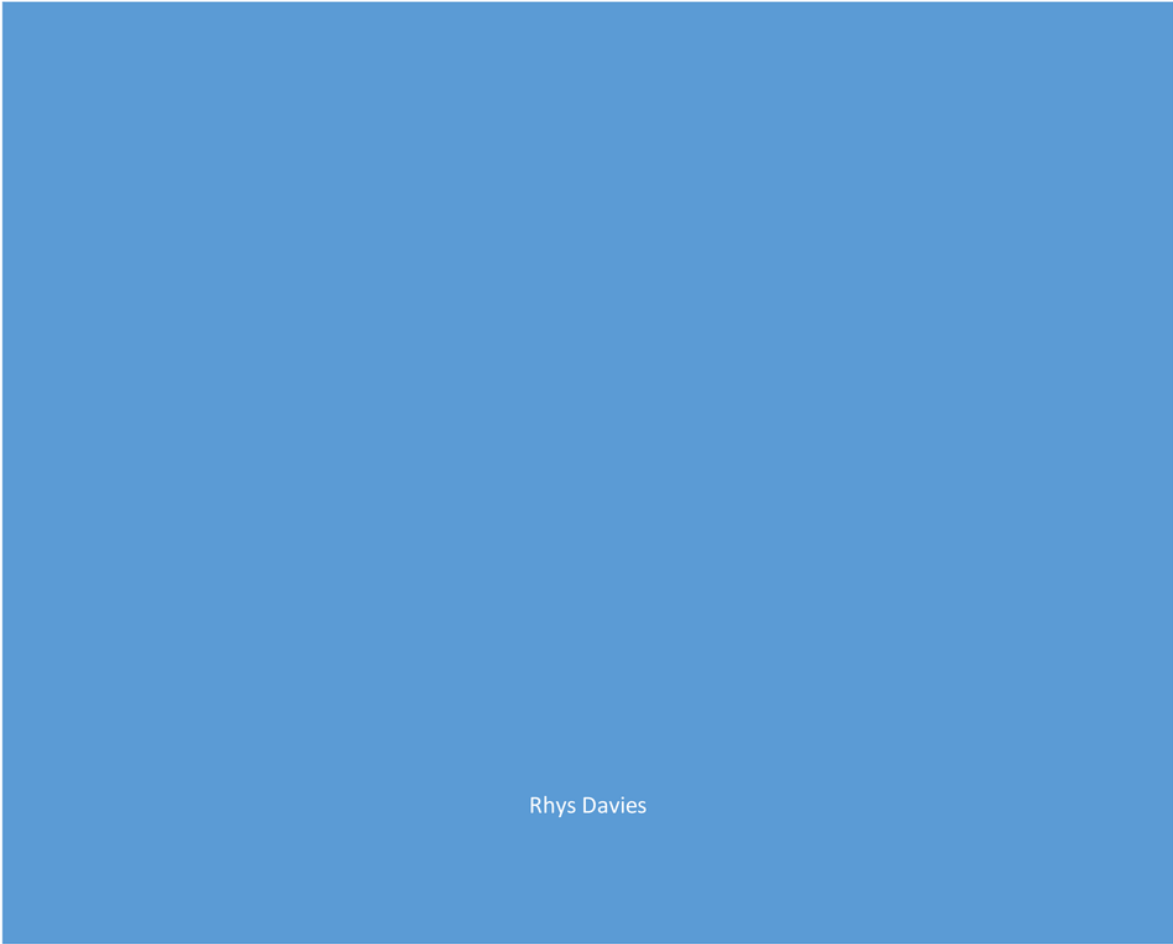
Rhys Davies - Assignment 2

by Rhys Davies

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STATOR DESIGN ASSIGNMENT 2



Rhys Davies

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Abstract



By creating and comparing 9 different DC motor designs using FEMM4.2 software the efficiency of the motor can be determined. This is done by adjusting only 3 parts which are the armature width, stator width and placing different sized fishtails. By then collecting certain measurements such as total flux and useful flux an efficiency percentage can be derived. I discovered that the efficiency of the motor increased by 10% all depending on the different adjustments made.

Introduction

The objective is to enhance the assessment of the areas of inefficiencies in DC motors and then to improve the performance of a DC motor model generated within FEMM software. Relevant aspects of the model will be created in order to obtain the best energy efficiency, the multiple adjustments will all be compared.

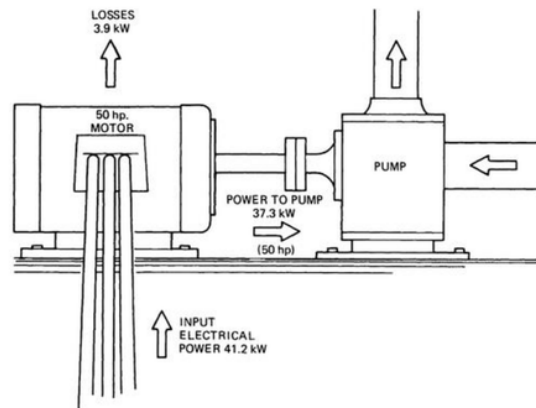
Chapter 1 - Flux Leakage Factor and Methods of Improvements

The objective is to greatly increase the overall efficiency of the system. Efficiency is defined as the energy output comparison with the energy input in a given system, is represented as the percentage ratio of the energy output of the energy input [1].

The formula for measuring efficiency is shown below.

$$\text{Efficiency} = \frac{\text{Energy Out}}{\text{Energy In}} \times 100\% [1]$$

In regards to a DC motor the ratio of mechanical power to electrical power is motor efficiency. With factors such as RPM and torque representing mechanical power, current and voltage symbolize electrical power. The energy supplied to the system in a DC motor is by electrical current in the coils heightened by the stator. Percentage mechanical output power is always slightly lower than the electrical input power due many factors.



[2]

Figure 1 - DC Motor Efficiency Losses

As shown in figure 1 41.2kW of electrical power is supplied to the motor and only 37.3kW of power is transferred to the pump. With 3.9kW of energy being lost majority through heat and sound via the mechanical operation of the motor by friction between parts. Using the formula

$\text{Efficiency} = \frac{37.3}{41.2} \times 100$ the efficiency is worked out to be 90.5% meaning that 3.9kW loss is equivalent to 9.5% energy loss [2].

Many losses are established within the armature core which is made from iron. These losses are made up of eddy current loss and hysteresis loss. In a DC motor the armature spins within a magnetic field carrying a current through the magnetic field which then creates a force which could then be used to turn a machine.

1.1 - Hysteresis Losses

When exposed to a magnetic field, the core of the armature endures a magnetic inversion rotation. The part of the armature under the South Pole, after the half electric rotation, would then be the same part under the North Pole and the magnetic lines are reversed to overthrow the magnetism from within the core [3].

The material of the armature core and volume totally depend on the size of the hysteresis losses [3].

Figure 2 is the hysteresis curve is to display the lagging of magnetization of a ferromagnetic material behind the magnetizing force.

Ferromagnetic materials are materials that magnetic [4].

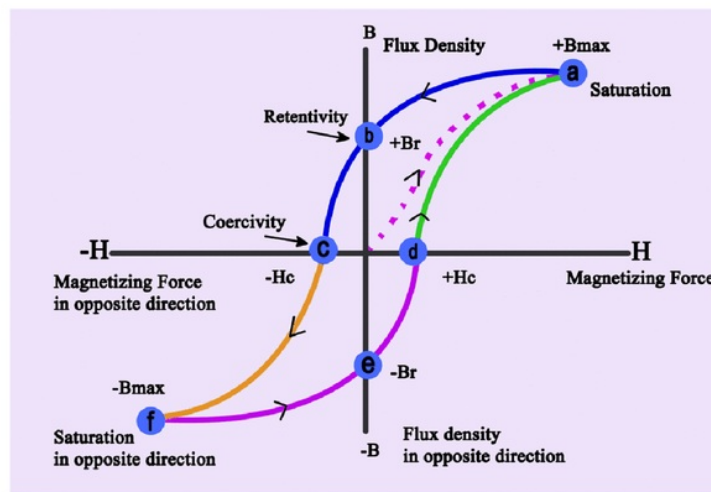


Figure 2 - Hysteresis Loop

As d increases towards the saturation value by increasing the current the magnetization of the ferromagnetic material begins to increase as shown to its saturation value in segment da. When the current is reversed at point C the flux Density (B value) is equal to 0. The value of which the magnetizing force (H value) reads when B is equal to 0 is called coercivity. As the reversed current is increased the B value saturates in the opposite direction at point f and switching the current to 0 at point e, lastly to complete the loop the current is increased to saturation at point d. The path abcdefa represents the magnetisation of a ferromagnetic material. Motor losses are formed between points b to c and e to d due to a small portion of coercive force is needed to change the polarity of the flux within the material.

1.2 – Eddy Current Losses

To get Eddy current losses Faraday's Law is used. Michael Faraday in 1831 created this law by a series of experiments which involved moving a closed loop in a magnet's magnetic field or by moving the magnet while the loop remained fixed as a current passed through the loop. The current was induced within the loop due to the change in magnetic flux. [5]

"The current observed by Faraday is due to an induced voltage in the loop." [5]

The stator core is made from a conductive material so with the constantly changing flux a voltage is created resulting in currents forming within the stator which are known as Eddy currents and as stated above the current changes depending on the rate of change of the magnetic flux using the path with the least resistance. This loss of energy is either through noise and heat. There are a number of ways which eddy currents can be reduced such as laminating each individual iron lamination within the core of the stator which would result in an increased resistance. [6]

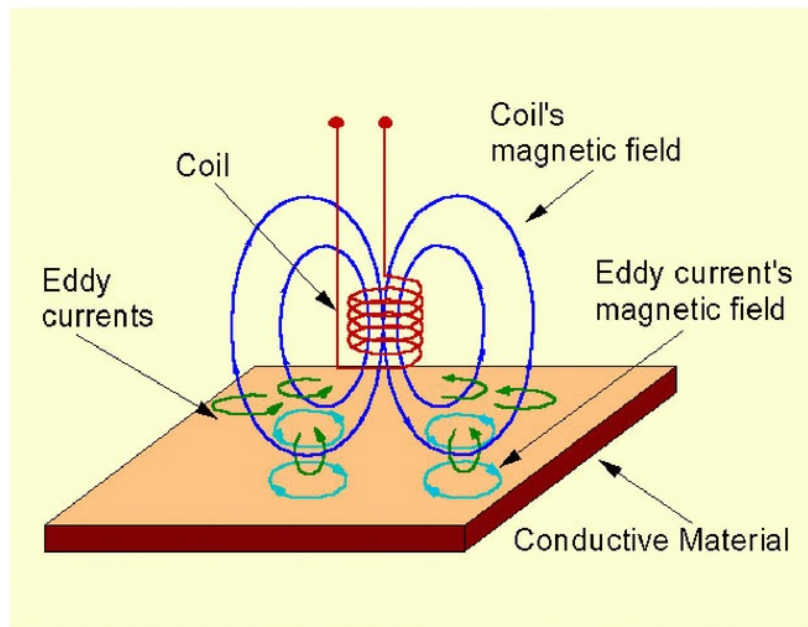


Figure 3 - Eddy Currents Explained

Chapter 2 – Method

In assignment 1 a DC motor was created using FEMM4.2 software which contained 2 500 turn coils that are placed around the stator arms. The coils are 20mm thick and are positioned away from the rotor by roughly 2mm as shown below.

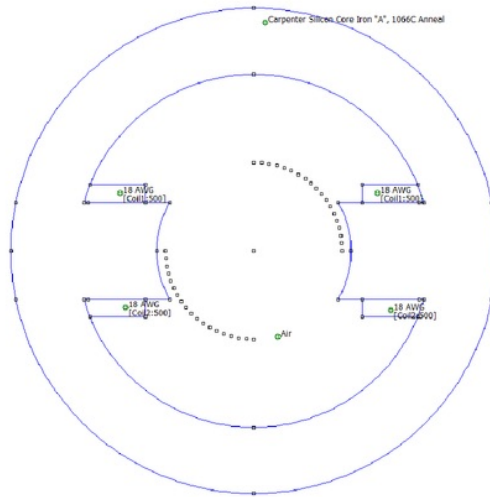


Figure 4 - DC Motor Model Using FEMM4.2

With the mesh created and the model cranked the results of the flux density is shown in figure 4. The more lines of magnetic flux passing through the centre of the rotor the more efficient the motor becomes.

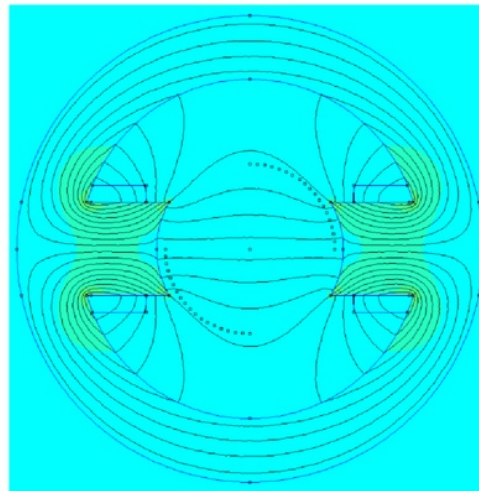


Figure 5 - DC Motor showing Flux Density

2.1 – Efficiency Improvements

Listed below are the properties of the motor than can and can't be altered.

Motor adjustments that can be changed.

- Armature Face
- Winding Position
- Stator Inner Radius
- Armature Dimensions

Motor adjustments that can't be changed.

- Material Properties
- Outer Radius
- Amount of Turns in The Coils
- Rotor Dimensions

To make it easier to understand the adjustments that were made are shown in table 1.

	Stator Radius	Armature Width	Fishtail Size
1	40mm	20mm	None
2	45mm	15mm	Small
3	48mm	10mm	Big
4	50mm	25mm	
5		35mm	

Table 1 - Potential Adjustments Table

Table 1 shows a range of potential adjustments that could be made when carrying out the experiments.

Experiment No.	Stator Radius	Armature Width	Fishtail Size
1	1	1	1
2	1	4	3
3	1	5	1
4	1	2	2
5	4	1	2
6	3	1	2
7	2	3	2
8	2	2	3
9	4	3	1

Table 2 - Range of Experiments Performed

Table 2 identifies the experiments 1 to 9 containing the different adjustments made to the motor.

Chapter 3 – Results

3.1 – Experiment 1

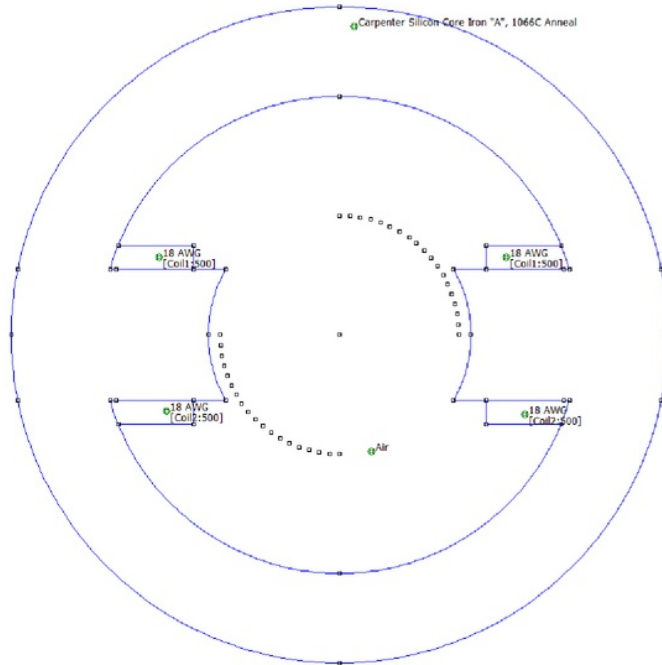


Figure 6 – Experiment Simulation 1

Angle	X	Y	Normal Flux
0	20.00	0.00	2.74E-10
5	19.92	1.74	2.56E-06
10	19.70	3.47	5.19E-06
15	19.32	5.18	7.99E-06
20	18.79	6.84	1.11E-05
25	18.13	8.45	1.45E-05
30	17.32	10.00	1.82E-05
35	16.38	11.47	2.08E-05
40	15.32	12.86	2.21E-05
45	14.14	14.14	2.26E-05
50	12.86	15.32	2.28E-05
55	11.47	16.38	2.28E-05
60	10.00	17.32	2.26E-05
65	8.45	18.13	2.25E-05
70	6.84	18.79	2.23E-05
75	5.18	19.32	2.22E-05
80	3.47	19.70	2.21E-05
85	1.74	19.92	2.20E-05
90	0.00	20.00	2.20E-05
Total Flux Wb			6.48E-05
Useful Flux Wb			2.28E-05
Flux Wasted			64.70%

Table 3 - Experiment 1 Results

3.2 – Experiment 2

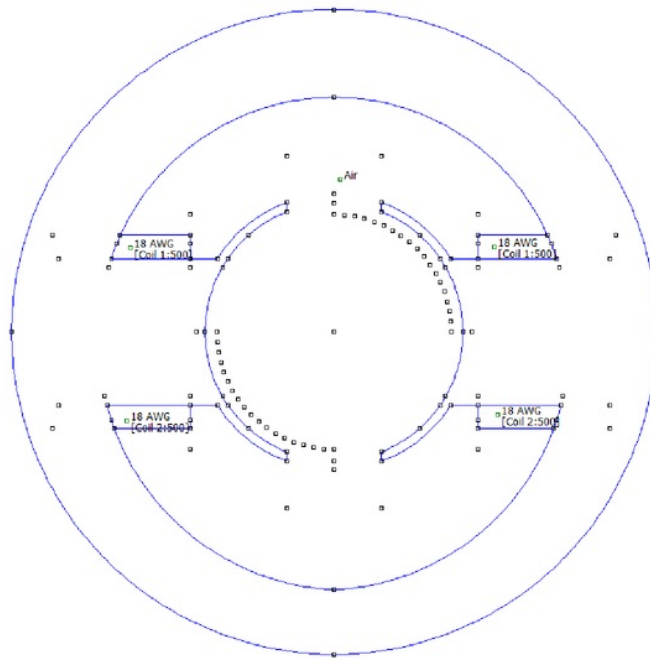


Figure 7 - Experiment 2 Simulation

Angle	X	Y	Normal Flux
0	20.00	0.00	4.29E-09
5	19.92	1.74	7.14E-06
10	19.70	3.47	1.44E-05
15	19.32	5.18	2.19E-05
20	18.79	6.84	2.95E-05
25	18.13	8.45	3.73E-05
30	17.32	10.00	4.56E-05
35	16.38	11.47	5.43E-05
40	15.32	12.86	6.35E-05
45	14.14	14.14	7.36E-05
50	12.86	15.32	8.46E-05
55	11.47	16.38	9.74E-05
60	10.00	17.32	0.000112
65	8.45	18.13	0.000130
70	6.84	18.79	0.000149
75	5.18	19.32	0.000162
80	3.47	19.70	0.000169
85	1.74	19.92	0.000172
90	0.00	20.00	0.000172
Total Flux Wb		0.000501	
Useful Flux Wb		0.000172	
Flux Wasted		65.57%	

Table 4 - Experiment 2 Results

3.3 - Experiment 3

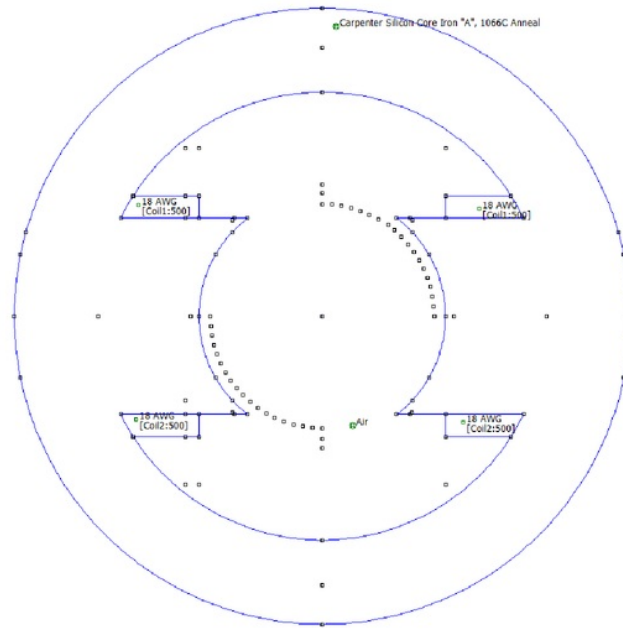


Figure 8 - Experiment 3 Simulation

Angle	X	Y	Normal Flux
0	20.00	0.00	4.06E-10
5	19.92	1.74	1.98E-06
10	19.70	3.47	3.98E-06
15	19.32	5.18	6.04E-06
20	18.79	6.84	8.16E-06
25	18.13	8.45	1.04E-05
30	17.32	10.00	1.28E-05
35	16.38	11.47	1.54E-05
40	15.32	12.86	1.84E-05
45	14.14	14.14	2.18E-05
50	12.86	15.32	2.58E-05
55	11.47	16.38	2.94E-05
60	10.00	17.32	3.13E-05
65	8.45	18.13	3.21E-05
70	6.84	18.79	3.25E-05
75	5.18	19.32	3.26E-05
80	3.47	19.70	3.26E-05
85	1.74	19.92	3.26E-05
90	0.00	20.00	3.26E-05
Total Flux Wb	8.95E-05		
Useful Flux Wb	3.26E-05		
Flux Wasted	63.52%		

Table 5 - Experiment 3 Results

3.4 - Experiment 4

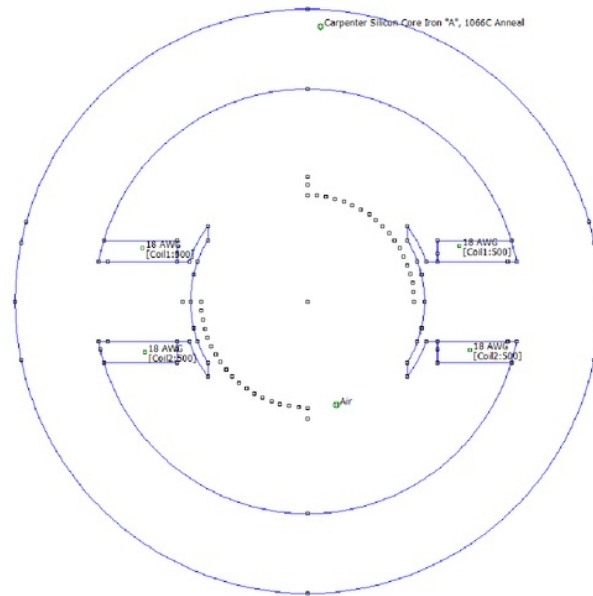


Figure 9 - Experiment 4 Simulation

Angle	X	Y	Normal Flux
0	20.00	0.00	1.39E-05
5	19.92	1.74	2.38E-06
10	19.70	3.47	4.81E-06
15	19.32	5.18	7.37E-06
20	18.79	6.84	1.01E-05
25	18.13	8.45	1.31E-05
30	17.32	10.00	1.66E-05
35	16.38	11.47	2.00E-05
40	15.32	12.86	2.26E-05
45	14.14	14.14	2.39E-05
50	12.86	15.32	2.45E-05
55	11.47	16.38	2.47E-05
60	10.00	17.32	2.46E-05
65	8.45	18.13	2.45E-05
70	6.84	18.79	2.43E-05
75	5.18	19.32	2.42E-05
80	3.47	19.70	2.41E-05
85	1.74	19.92	2.40E-05
90	0.00	20.00	2.40E-05
Total Flux Wb		7.36E-05	
Useful Flux Wb		2.47E-05	
Flux Wasted		66.39%	

Table 6 - Experiment 4 Results

3.5 - Experiment 5

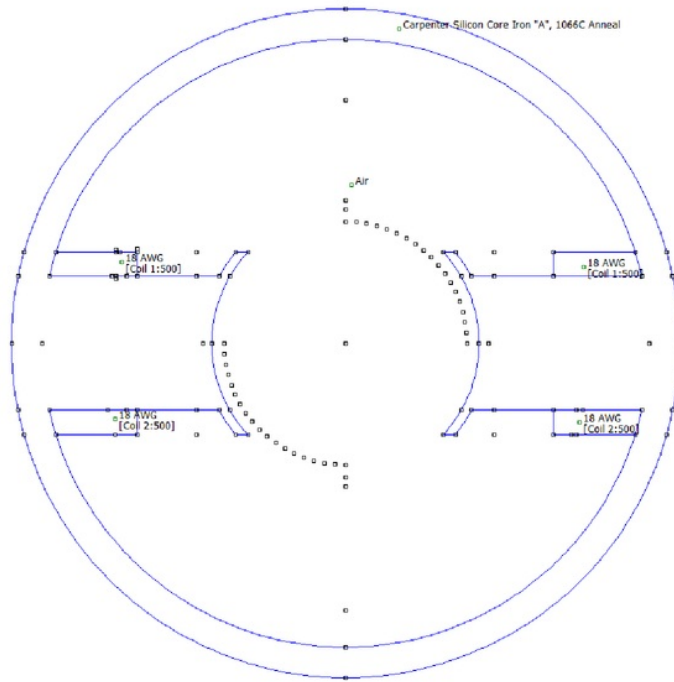


Figure 10 - Experiment 5 Simulation

Angle	X	Y	Normal Flux
0	20.00	0.00	5.08E-08
5	19.92	1.74	8.42E-06
10	19.70	3.47	1.71E-05
15	19.32	5.18	2.60E-05
20	18.79	6.84	3.54E-05
25	18.13	8.45	4.53E-05
30	17.32	10.00	5.63E-05
35	16.38	11.47	6.89E-05
40	15.32	12.86	8.34E-05
45	14.14	14.14	9.70E-05
50	12.86	15.32	1.05E-04
55	11.47	16.38	1.08E-04
60	10.00	17.32	1.09E-04
65	8.45	18.13	1.10E-04
70	6.84	18.79	1.10E-04
75	5.18	19.32	1.11E-04
80	3.47	19.70	1.11E-04
85	1.74	19.92	1.10E-04
90	0.00	20.00	1.10E-04
Total Flux Wb		2.46E-04	
Useful Flux Wb		1.11E-04	
Flux Wasted		55.08%	

Table 7 - Experiment 5 Results

3.6 – Experiment 6

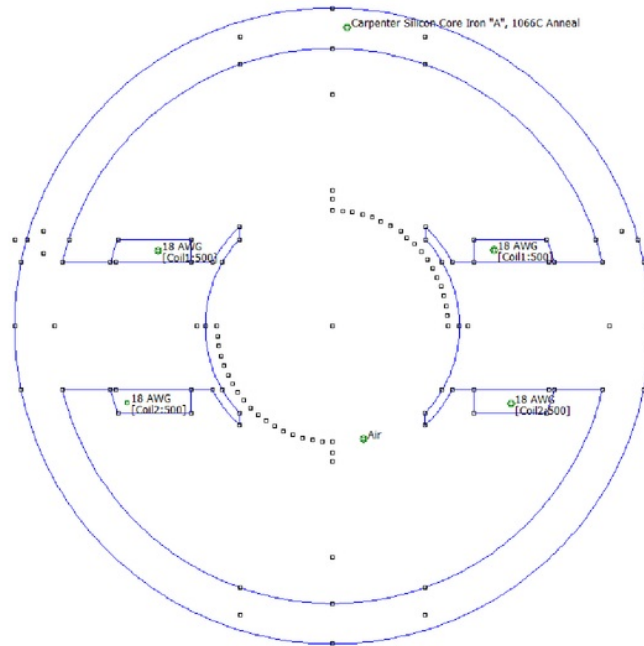


Figure 11 – Experiment 6 Simulation

Angle	X	Y	Normal Flux
0	20.00	0.00	7.68E-10
5	19.92	1.74	2.08E-06
10	19.70	3.47	4.19E-06
15	19.32	5.18	6.37E-06
20	18.79	6.84	8.64E-06
25	18.13	8.45	1.11E-05
30	17.32	10.00	1.37E-05
35	16.38	11.47	1.67E-05
40	15.32	12.86	2.01E-05
45	14.14	14.14	2.37E-05
50	12.86	15.32	2.64E-05
55	11.47	16.38	2.80E-05
60	10.00	17.32	2.87E-05
65	8.45	18.13	2.91E-05
70	6.84	18.79	2.92E-05
75	5.18	19.32	2.93E-05
80	3.47	19.70	2.93E-05
85	1.74	19.92	2.93E-05
90	0.00	20.00	2.93E-05
Total Flux Wb		6.88E-05	
Useful Flux Wb		2.93376E-05	
Flux Wasted		57.36%	

Table 8 - Experiment 6 Results

3.7 – Experiment 7

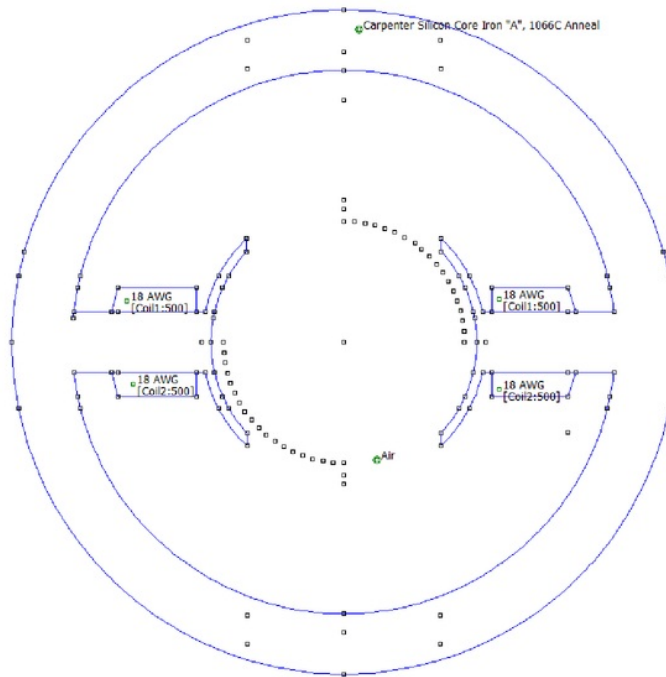


Figure 12 - Experiment 7 Simulation

Angle	X	Y	Normal Flux
0	20.00	0.00	1.59E-10
5	19.92	1.74	2.09E-06
10	19.70	3.47	4.22E-06
15	19.32	5.18	6.41E-06
20	18.79	6.84	8.67E-06
25	18.13	8.45	1.11E-05
30	17.32	10.00	1.37E-05
35	16.38	11.47	1.67E-05
40	15.32	12.86	2.01E-05
45	14.14	14.14	2.37E-05
50	12.86	15.32	2.64E-05
55	11.47	16.38	2.80E-05
60	10.00	17.32	2.86E-05
65	8.45	18.13	2.89E-05
70	6.84	18.79	2.90E-05
75	5.18	19.32	2.90E-05
80	3.47	19.70	2.90E-05
85	1.74	19.92	2.90E-05
90	0.00	20.00	2.90E-05
Total Flux Wb		7.61E-05	
Useful Flux Wb		2.89853E-05	
Flux Wasted		61.89%	

Table 9 - Experiment 7 Results

3.8 – Experiment 8

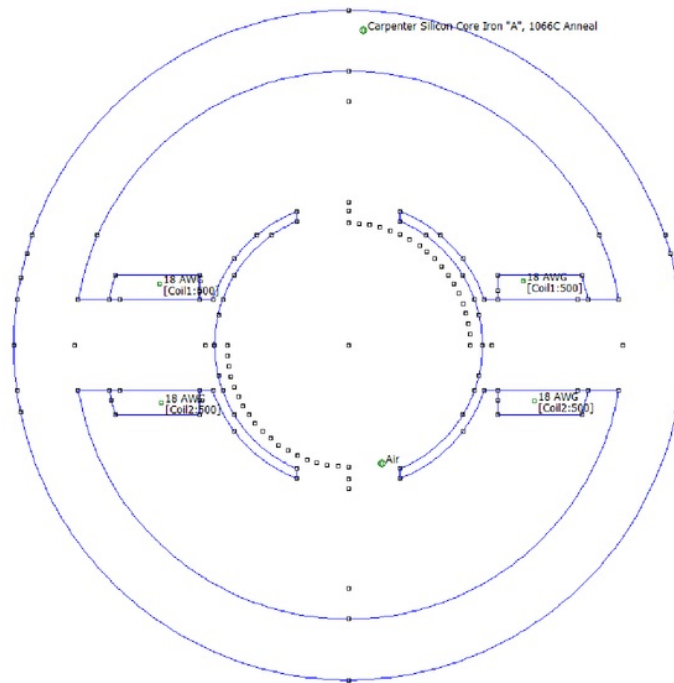


Figure 13 - Experiment 8 Simulation

Angle	X	Y	Normal Flux
0	20.00	0.00	8.04E-10
5	19.92	1.74	1.82E-06
10	19.70	3.47	3.67E-06
15	19.32	5.18	5.55E-06
20	18.79	6.84	7.46E-06
25	18.13	8.45	9.43E-06
30	17.32	10.00	1.15E-05
35	16.38	11.47	1.37E-05
40	15.32	12.86	1.60E-05
45	14.14	14.14	1.85E-05
50	12.86	15.32	2.13E-05
55	11.47	16.38	2.44E-05
60	10.00	17.32	2.83E-05
65	8.45	18.13	3.29E-05
70	6.84	18.79	3.72E-05
75	5.18	19.32	4.00E-05
80	3.47	19.70	4.13E-05
85	1.74	19.92	4.19E-05
90	0.00	20.00	4.20E-05
Total Flux Wb			1.13E-04
Useful Flux Wb			4.20E-05
Flux Wasted			62.74%

Table 10 - Experiment 8 Results

3.9 – Experiment 9

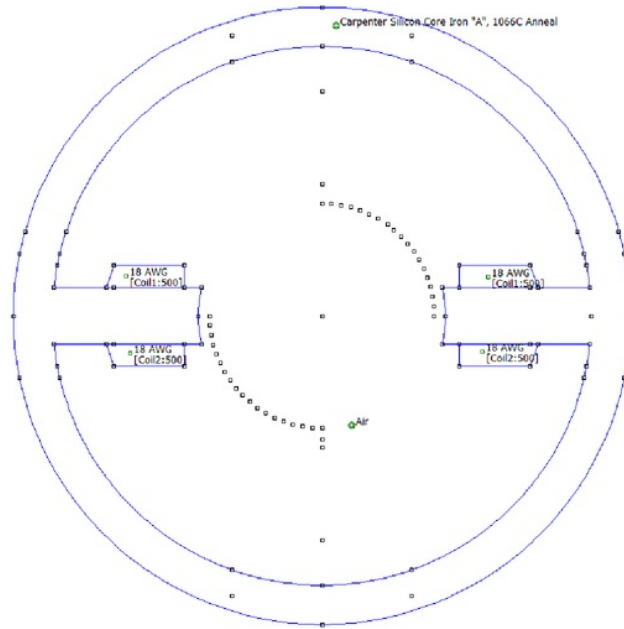


Figure 14 - Experiment 9 Simulation

Angle	X	Y	Normal Flux
0	20.00	0.00	1.88E-09
5	19.92	1.74	3.84E-06
10	19.70	3.47	7.88E-06
15	19.32	5.18	1.17E-05
20	18.79	6.84	1.40E-05
25	18.13	8.45	1.53E-05
30	17.32	10.00	1.59E-05
35	16.38	11.47	1.62E-05
40	15.32	12.86	1.63E-05
45	14.14	14.14	1.62E-05
50	12.86	15.32	1.62E-05
55	11.47	16.38	1.61E-05
60	10.00	17.32	1.60E-05
65	8.45	18.13	1.59E-05
70	6.84	18.79	1.58E-05
75	5.18	19.32	1.57E-05
80	3.47	19.70	1.56E-05
85	1.74	19.92	1.56E-05
90	0.00	20.00	1.56E-05
Total Flux Wb		3.68E-05	
Useful Flux Wb		1.63E-05	
Flux Wasted		55.79%	

Table 11 - Experiment 9 Results

Experiment	Total Flux Wb	Max Useful Flux Wb	Fluk Wasted
1	6.48E-05	2.28288E-05	64.70%
2	5.01E-04	1.72E-04	65.57%
3	8.95E-05	3.26E-05	63.52%
4	7.36E-05	2.47E-05	66.39%
5	2.46E-04	1.11E-04	55.08%
6	6.88E-05	2.93376E-05	57.36%
7	7.61E-05	2.89853E-05	61.89%
8	1.13E-04	4.20E-05	62.74%
9	3.68E-05	1.63E-05	55.79%

Table 12 - Overall Results of 1 to 9 Experiments

Chapter 4 – Discussion

With 9 different experiments completed and results gathered by comparing the results it shows that experiment 5 and 9 had the best efficiency with the least flux leakage. Experiment 5 had 55.08% flux leakage which is a drastic improvement from the original motor design experiment 1 which had a flux leakage of 64.7%.

In experiment 5 and 9 the stator radius was set to 50mm which was resulting in a much less flux leakage percentage. By changing the stator radius the magnetic reluctance within the motor has changed therefore the flux flows via a different path.

By increasing the armature width and the size of the fishbone the total flux increased in some areas of the motor but due to the magnetic reluctance being low the flux would travel via the path with least resistance therefore not directed through the rotor. By decreasing the armature width more flux is directed towards the rotor which overall improves efficiency as shown in experiment 9 which was combined with a larger stator width.

By adding larger fishtails to the designs a greater flux density was created but didn't aid with directing the lines of flux through the rotor so the efficiency of the motor decreased, as shown in experiments 4 and 8.

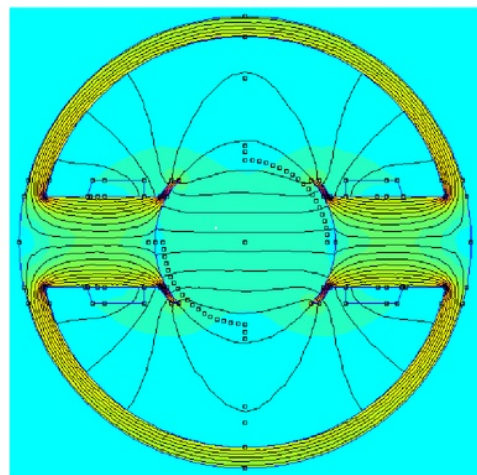


Figure 15 - Experiment 5 with the Flux Density Shown

2

With experiment 5 being the most efficient simulation, figure 14 shows the direction of the flux and the flux density. As can be seen a lot more lines pass through the rotor compared with other models which means that the reluctance between the armature and the inner of the stator is greater due to a much greater air gap.

Conclusion

By creating 9 different experiments a range of DC motor designs were created therefore providing a wide range of results which deliver a clear idea of what type of motor design is needed to get the best efficiency. With the tests being a success the best flux wasted percentage was 55.08% compared to the first experiment a reduction of 9.62% has been achieved.

3

To achieve a better motor efficiency a larger stator width is needed as well as a smaller armature width to direct the travel of flux through the motor.

Having to perform research into hysteresis losses and eddy currents a greater understanding has been gained.

Having not used FEMM4.2 software much previously before this assignment I felt like I have gained a lot of knowledge by creating these experiments which should give me confidence in building DC motor designs in the future.

Bibliography

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Rhys Davies - Assignment 2

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

58/100

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Comment 1

You can determine it with one simulation. Do you mean improve?

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Comment 2

figure 15



Comment 3

Are you sure? Do you mean a larger air gap, or thinner stator and larger armature?

GRADING FORM: SMU GENERIC_SMOSEY

RHYS DAVIES

57.90

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



References to a limited range of material. The material you reference should be from more reputable sources such as peer reviewed journals, theses submitted to universities, textbooks and other academic writing. Referencing conventions adhered to throughout report.

4.8

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

19.5

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A good and appropriate application of standard methods and techniques. Good appreciation of the context of the application.

10.2

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.

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