

Assignment 2

by Adrian Thomas

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Electical Machines

Assignment 2

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1 Abstract

The following report is designed to look at magnetic flux being used, created and leaked in a DC motor circuit using FMEE 4.2 simulation software. The aim is to establish flux leakage, then try and minimise the flux leaked by redesigning specific variables to try and establish a greater overall efficiency. The original design produced an efficiency of 35.83%. In order to establish what effects changes had made only one variable was altered at a time.

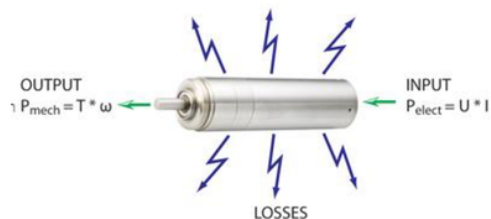
2 Introduction



The aim is to establish areas of inefficiency in a dc motor, then improve these inefficiencies by means of stator, armature redesign using the FMEE simulation software. The results will then be compared against each other to find the best solution to this problem

2.2 Motor Efficiency

The definition of motor efficiency is the ratio of mechanical output power vs electrical input power, in an ideal world this would be 100% but in reality this is highly unlikely to happen.



<https://www.portescap.com/motor-solution-1>

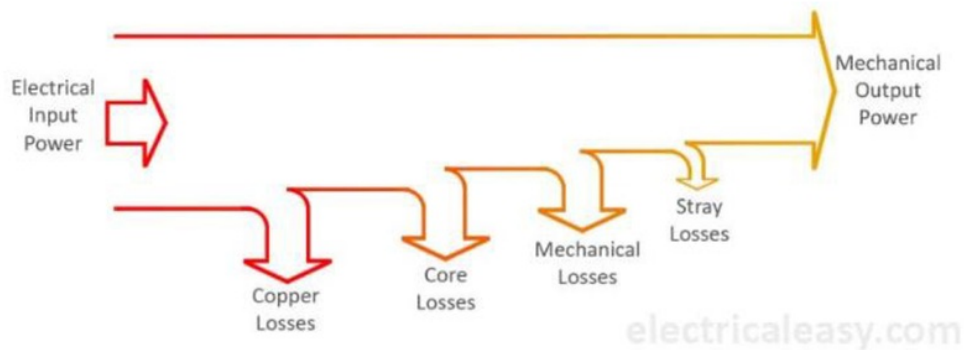
Mechanical power is based on the speed and the torque required to turn the load that is attached to the motor, the electrical input is calculated by VI i.e. voltage x current. During the conversion of electrical power (input) to mechanical power (output) losses occur which means in general motors are really only 80-80% efficient

[1]

2.3 Losses

There are 4 main categories of losses

Copper losses, Iron Losses, Mechanical losses, Stray losses



<https://www.electricaleasy.com/2014/01/11>

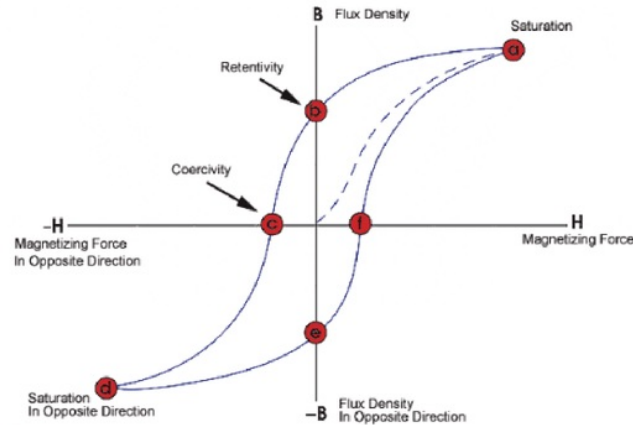
2.31 Copper losses

- Armature copper loss – Caused by resistance of copper winding in the armature
- Field copper loss - Caused by resistance of copper field winding
- Brush resistance loss – Caused by resistance of the brushes [2]

2.32 Iron Losses

- Hysteresis – Caused by changing polarity of the steel core
- Eddy current losses – Caused by circulating currents induced in the steel core by the changing polarity of the flux

2.33 Hysteresis



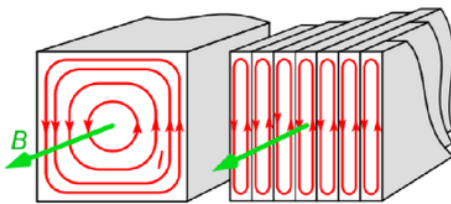
A hysteresis loop shows the relationship between the induced magnetic flux density (B) and the magnetizing force (H). It is often referred to as the B-H loop.

<https://www.motioncontroltips.com/hyster-1>

This occurs when the iron core gets magnetized and demagnetised flowing a reversal in polarity of the current. As current increases so does the magnetic flux, however when the current decreases the flux doesn't decrease at the same rate and in order to get the flux to return to zero the current (magnetic force) must go to a negative value. The area of the above loop represents the energy lost during this process. Above can be seen the magnetizing force (H) required to produced a given flux (B), losses occur at points B-C and E-F, these losses can be improved by selecting a material with a better B-H curve. [3]

2.34 Eddy current

These losses occur as a result of Faraday's Law which states *"Any change in the environment of a coil of wire will cause a voltage to be induced in the coil, regardless of how the magnetic change is produced"* [2]



Eddy currents in laminated cores (right) are smaller than those in solid cores (left).

Therefore when a rotor is rotated within a magnetic field a EMF is generated is induced into the coils, this EMF is known as Eddy currents and cause circulating currents to flow. The losses attributed to these are known as Eddy current losses.

To try and reduce these losses the core is made up from many pieces of laminated steel rather than a single piece as shown above. This is done because multiple laminates have a higher resistance than the single block and thus result in less eddy current losses. The laminates are insulated from each other by a varnish finishing . [3]

2.4 Mechanical

- Friction – these can be attributed to friction from bearings, bushes or brushes
- Windage - these can be attributed to turbulent air acting against the rotating rotor

Stray losses

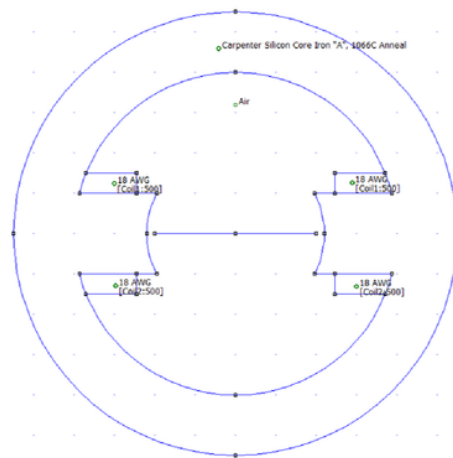
These are losses that don't fit into the above categories and are put it at the design stage as a safety factor, generally account for around 1%

2.4 Specific problem

The specific problem is to analyse a dc motor stator circuit more specifically how much total magnetic flux is being created in the stator and how the design could be improve in order to reduce these losses. To complete this task FEM software will be used specifically FEMM (Finite Element Method Magnetics) 4.2 software

3 Method

Using the FEMM 4.2 software a model was created with the same dimensions as assignment 1, then redesign the stator core to establish if a better design could be found. One dimension will be altered at a time so the effect can be seen



The Stator Dimensions and Parameters are as follows:

NB: When adding labels ensure that a mesh size of 1 is used.

Depth of Circuit: 100mm

Outside Stator Diameter: 110mm

Inside Stator Diameter: 80mm

Pole Face Radius: 22mm

Pole Widths: 20mm

Field Generating Coil Vertical Coordinates: $\pm 15\text{mm}$

Field Generating Coil Horizontal Internal Coordinates: $\pm 24.5\text{mm}$

Rotor Coil Width: 40mm

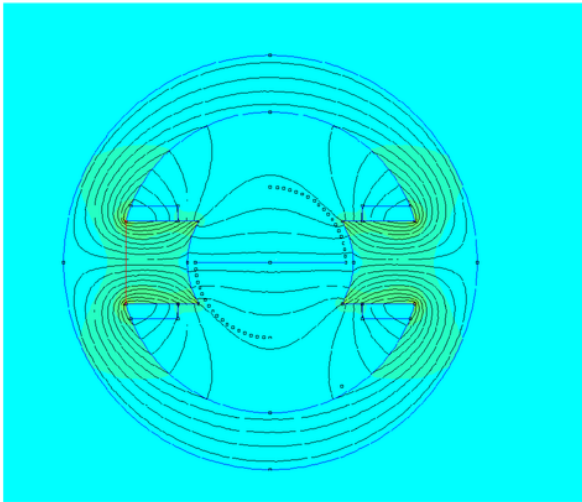
Field Generating Coil Current: $\pm 1\text{A}$ (indicates in and out of page)

Field Generating Coils Number of Turns: 500

4 Results

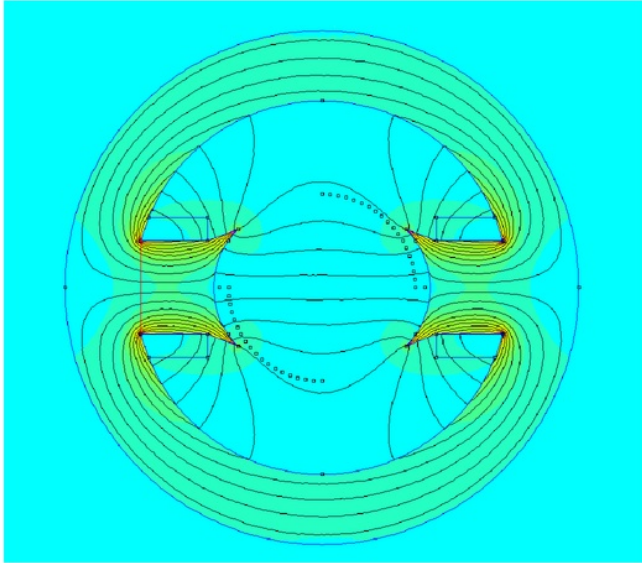
Original design

Unaltered value (20mm armature, 40mm stator no fishtail)



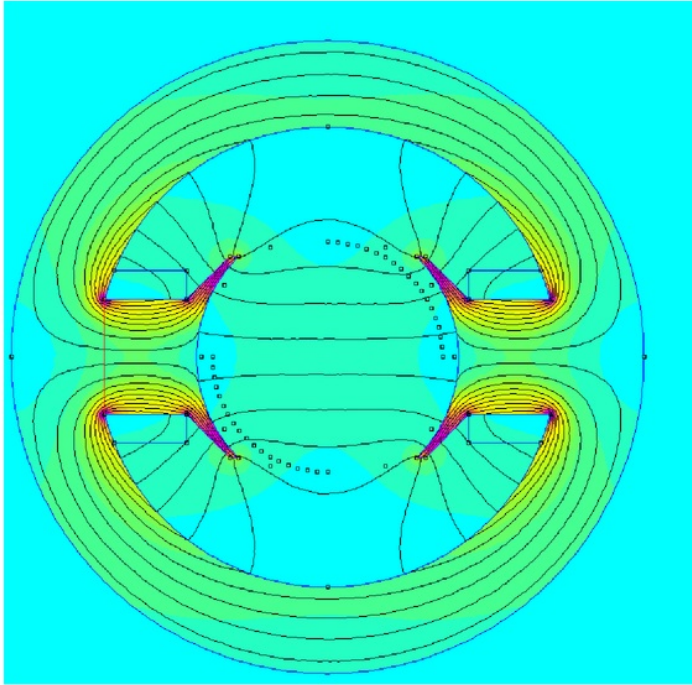
Angle	X	Y		Phi (Wb)
40	15.32089	12.85575		2.21E-05
50	12.85575	15.32089		2.28E-05
60	10	17.32051		2.26E-05
Total Flux	0.000348			
Useful flux	9.95E-05			
Used Flux	35.83%			
Flux lost	65.17%			

Original stator radius, original armature width, small fishtail (X17.5 , Y12.5)



Angle	X	Y	Phi (Wb)
40	15.32089	12.85575	9.09E-05
50	12.85575	15.32089	9.34E-05
60	10	17.32051	9.33E-05

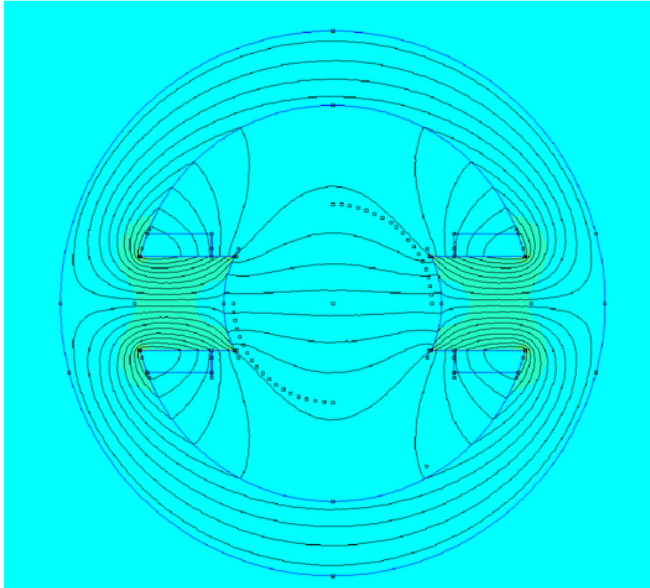
Total Flux	0.000266
Useful flux	9.34E-05
Used Flux	34.81%
Flux lost	65.19%

Original stator radius, original armature width, Large fishtail (X15.5 , Y17.5

Angle	X	Y		Phi (Wb)
40	15.32089	12.85575		7.59E-05
50	12.85575	15.32089		9.95E-05
60	10	17.32051		1.10E-04

Total Flux	0.000348
Useful flux	9.95E-05
Used Flux	28.61%

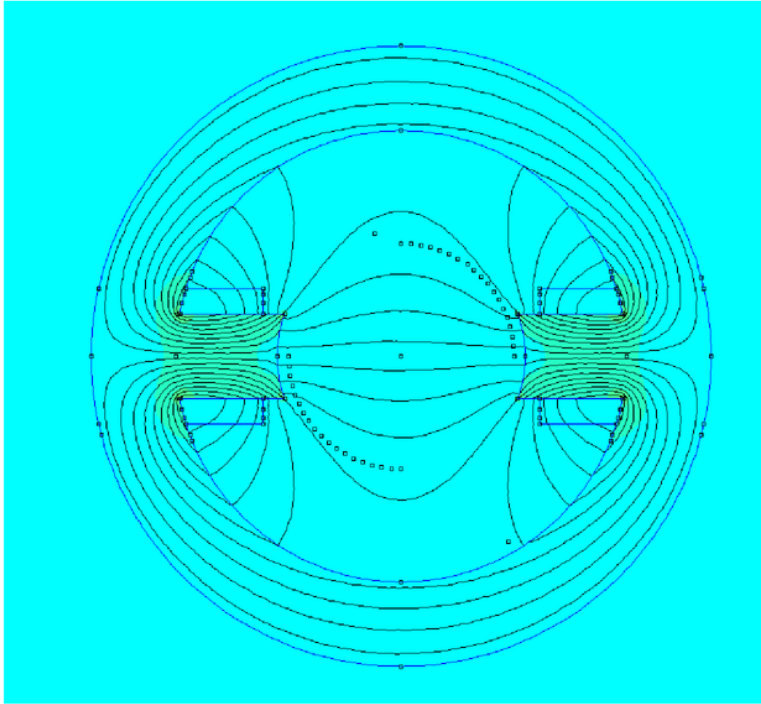
Original stator radius, Medium armature width, original fishtail (X39 , Y9.5), (X20,Y9.5)



Angle	X	Y		Phi (Wb)
40	15.32089	12.85575		2.06E-05
50	12.85575	15.32089		2.11E-05
60	10	17.32051		2.08E-05

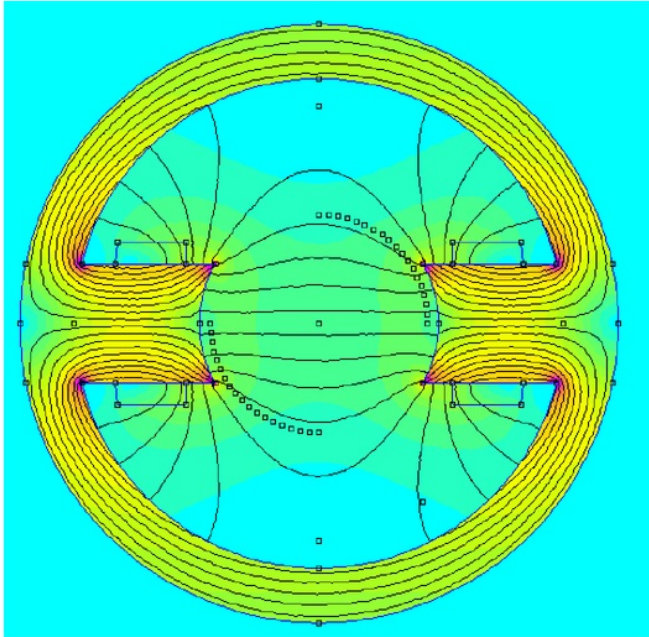
Total Flux	5.76E-05
Useful flux	2.11E-05
Used Flux	36.61%
Flux lost	63.39%

Original stator radius, Small armature width, original fishtail (X39.5 , Y7.5), (X20.5,Y7.5)



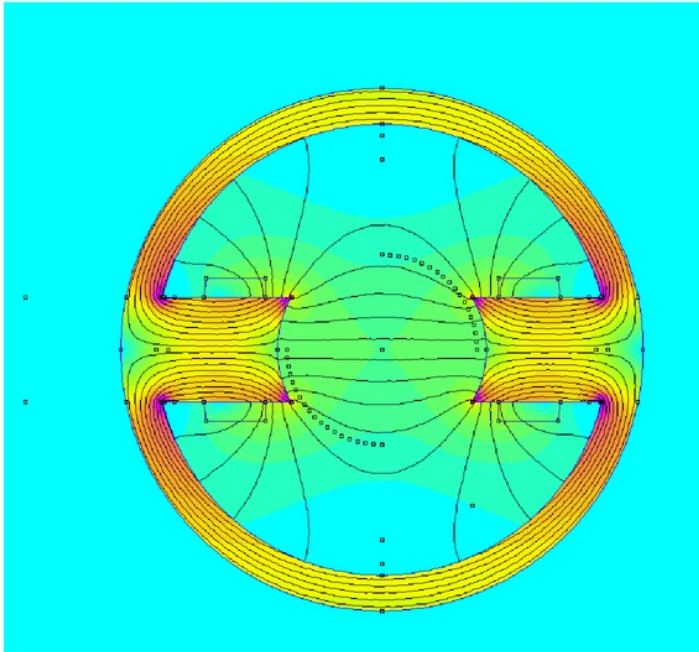
Angle	X	Y		Phi (Wb)
40	15.32089	12.85575		1.89E-05
50	12.85575	15.32089		1.88E-05
60	10	17.32051		1.84E-05

Total Flux	4.93E-05
Useful flux	1.89E-05
Used Flux	38.42%
Flux lost	61.58%

85mm stator Diameter, original armature width, original fishtail

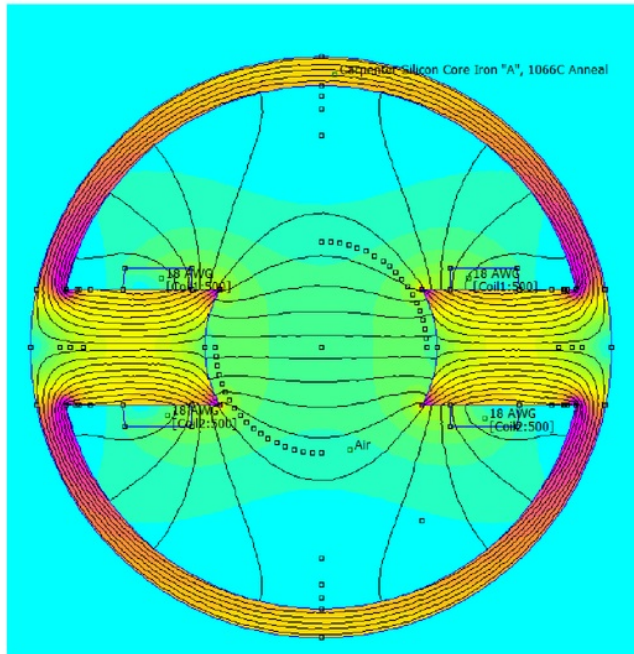
Angle	X	Y		Phi (Wb)
40	15.32089	12.85575		2.19E-05
50	12.85575	15.32089		2.28E-05
55	11.47153	16.38304		2.29E-05
60	10	17.32051		2.28E-05

Total Flux	5.41E-05
Useful flux	2.29E-05
Used Flux	42.38%
Flux lost	57.62%

90mm stator Diameter, original armature width, original fishtail

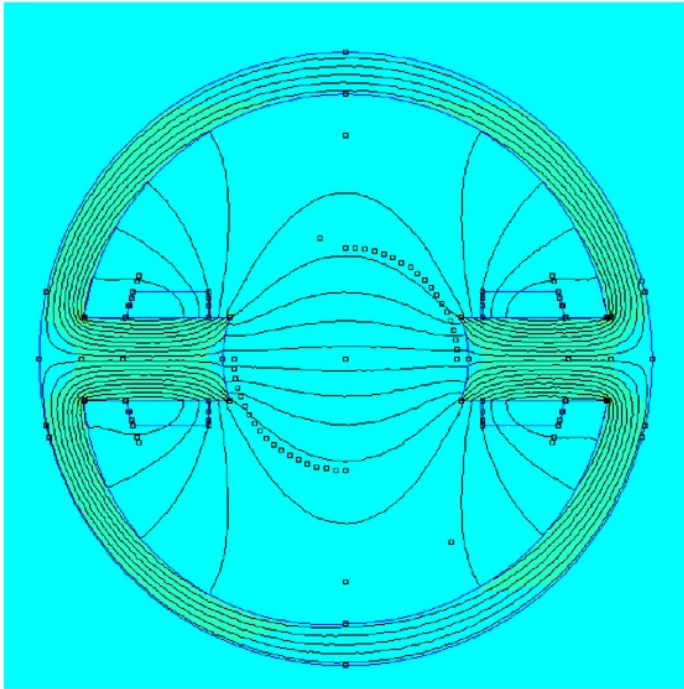
Angle	X	Y		Phi (Wb)
40	15.32089	12.85575		2.18E-05
50	12.85575	15.32089		2.27E-05
55	11.47153	16.38304		2.29E-05
60	10	17.32051		2.28E-05

Total Flux	5.15E-05
Useful flux	2.29E-05
Used Flux	44.53%
Flux lost	55.47%

100mm stator Diameter, original armature width, original fishtail

Angle	X	Y		Phi (Wb)
40	15.32089	12.85575		2.17E-05
50	12.85575	15.32089		2.27E-05
55	11.47153	16.38304		2.29E-05
60	10	17.32051		2.28E-05

Total Flux	4.98E-05
Useful flux	2.29E-05
Used Flux	45.96%
Flux lost	54.04%

90mm stator Diameter, Small armature width, original fishtail

Angle	X	Y		Phi (Wb)
40	15.32089	12.85575		1.88E-05
50	12.85575	15.32089		1.90E-05
55	11.47153	16.38304	-	1.90E-05
60	10	17.32051		1.88E-05

Total Flux	4.08E-05
Useful flux	1.90E-05
Used Flux	46.51%
Flux lost	53.49%

5 Discussion

	Original	Small fishtail	large fishtail	Medium armature	Small armature	90mm Stator
Total Flux	2.31E-04	0.000266	9.95E-05	5.76E-05	4.93E-05	5.41E-05
Flux used	35.83%	34.81%	28.61%	36.61%	38.42%	42.38%
Flux lost	64.17%	65.19%	71.39%	63.39%	61.58%	57.62%
Type	100mm Stator	small armature 90mm stator				
Total Flux	4.98E-05	4.08E-05				
Flux used	45.96%	46.51%				
Flux lost	54.04%	53.49%				

To complete the experiment one variable was selected at a time and the effect of the change monitored before commencing with another change. Below is a list of what could and couldn't be altered and which changes were made. The effect of the changes can be seen in the simulation screen shots where the lines of flux can be seen and also how they are directed through the rotor.

Could change

Stator inner diameter

Armature width

Armature pole face

Could not change

Any material

Turns or current of windings

Outer stator diameter

Rotor Properties

Changed in the experiment

- Pole body fish tail, no fish tail, medium fishtail and large fishtail
- Armature width standard, medium, small
- Stator inner diameter standard, medium, large
- Combination of the 2 best outcomes

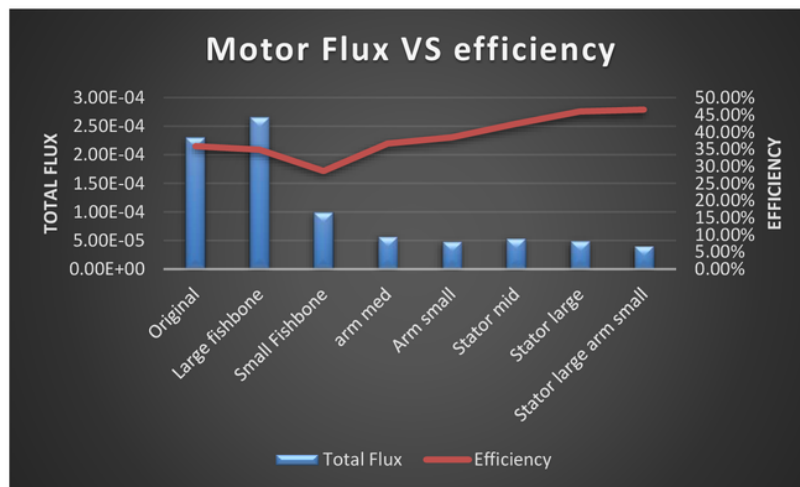
From the above table it can be noted that the original configuration produced nearly 35% efficiency when simulated. With both the small and large fish tails added it can be clearly seen that the efficiency got progressively worse which could be expected since the lines of flux of less concentrated on passing through the rotor

With the reduction in width of the armature the efficiency of the motor improved by nearly 3% of the original configuration again this may be expected since a large air gap has been created so there is now more reluctance between the armature and the stator therefore more flux will be direct into the rotor

Next, the stator inner diameter was increase and again the efficiency improved up to 45.96% which is just over a 10% gain in efficiency. The reason for the is the same as the decrease in armature width. Finally, the best two outcomes were combined i.e. 100m stator inner diameter and small armature width. With this combination the best efficiency was noted of 46.51 % this id due to the flux following the path of lese resistance (reluctance) through the rotor due to the large air gap created from the alterations. [5]

A word of caution must be applied however, even the efficiency of the motor increased the total flux available decreased but the flux that was available was obviously used more effectively.

While the stator inner diameter could be made smaller yet again there would be a point where 1) it would become mechanically weak due to the limited material and 2) would produce limited flux.



In the above graph it can be seen how the efficiency has improved but also in general how the total flux has decreased. The large fishbone experiment yielded an unexpected result and could be put down to an erroneous value from the simulation software as in general the results are in line with what would be expected.

6 Conclusion

Overall the experiment has been a successful one, knowledge has been gained into how the design of the machine can affect the way the flux is created, distributed and used. It has also been proven that great gains can be made to the efficiency with little adjustments to the size and shape of armature/stator and ultimately air gap in this experiment a gain of 10.68% was seen. With more time more experiments could have been carried out to give an even greater gain however with the time available the experiments chosen show just what effect each alteration has made.

References

- [1] Portescap, "<https://www.portescap.com/>," 21 03 2019. [Online]. Available: <https://www.portescap.com/motor-solutions/motor-efficiency>.
- [2] e. essay, "<https://www.electricaleasy.com/>," 03 2019. [Online]. Available: <https://www.electricaleasy.com/2014/01/losses-in-dc-machine.html>.
- [3] Unkown, "<https://www.motioncontroltips.com/>," 03 2019. [Online]. Available: <https://www.motioncontroltips.com/?s=hyster>.
- [4] D. Collins, 21 03 2029. [Online]. Available: <https://www.motioncontroltips.com/hysteresis-loss/>.
- [5] D. S. Prof P.Parthasaradhy, "<http://theijes.com/>," 03 2019. [Online]. Available: <http://theijes.com/papers/ICIEEE/K085093.pdf>.

Assignment 2

GRADEMARK REPORT

FINAL GRADE

GENERAL COMMENTS

Instructor

62/100

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Comment 1

Do you mean Finite Element Method for Magnetism (FEMM)?

You should introduce acronyms at first use.

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GRADING FORM: SMU GENERIC_SMOSEY

ADRIAN THOMAS

62.10

ENGAGEMENT WITH LITERATURE

including reading, referencing, academic conventions and academic honesty



References to a 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.

5.1

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; synthesis and evaluation. Ability to devise and sustain persuasive arguments. Sound, convincing conclusions.

18.6

PRACTICAL APPLICATION SKILLS

Different approaches to solving problems in particular contexts.



A very good application of a range of methods and techniques. Very good consideration of the context of the application, with perceptive use of examples, where relevant. Evidence of some innovation and creativity.

13

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.

6.8