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ELECTROMAGNETS ARRANGEMENT FOR ELECTROMAGNETIC WINDSHIELD WIPERS - PROPOSAL AND ANALYSIS

Shahryar Mushtaq and M. B. Baharom
Department of Mechanical Engineering, Universiti Teknologi PETRONAS, Malaysia
E-Mail: shary_mq@hotmail.com

ABSTRACT

The objective of this paper is to analyse the superior electromagnet placement to apply strong forces on the corresponding magnets used as automotive windshield wipers with different configuration as a replacement to conventional motors. The electromagnetics are engaged to observe the solenoids attraction and repulsive forces of the whole system with changing polarities. Main focus as pre-analysis is either side by side electromagnets or face to face electromagnets provides higher output force for this design. The observation is made based on flux along the moment arm and strength between the magnets. It was observed that face to face magnetic arrangement provides higher torque output on both of these parameters.

Keywords: electromagnetic strength, torque, solenoids, magnetic fields, automotive windshield wipers, electromagnets arrangements, magnets.

INTRODUCTION

The main purpose of a windshield wiper is to keep the windscreen clear during rainy weather. In general, the wipers move back and forth across the windshield in an oscillatory motion. The windshield wipers not only can be found on car windshields but also on some car headlights, airplanes and even on the space shuttle. The first windshield wipers were operated manually by the driver by moving a lever inside the car back and forth [1]. Nowadays, the windshield wipers are designed to be operated by electrical motors which are more reliable and convenient. The inventor of the electrical operated windshield wiper was Mary Anderson in 1903; the invention is still being used until now.

The main disadvantage of the current design is that it creates unwanted noise during heavy rain and requires high power output to overcome the resistance. The high power requirement is owing to the high sliding friction of wiper blades due to the lightly mist or completely dry windows [2]. In other words, the current design of windshield wiper may not be very efficient. One of the solutions is to provide a bigger motor but this is not economical. Research data has shown that ineffective windshield wipers can lead to road accidents both during clear and rainy weather [3]. In addition, most of the current motor designs make use permanent magnets. Outside the coil, the magnetic field is small but strong relative to permanent magnet [4, 5].

This research proposes an alternative design of windshield wipers driven by only electromagnets. The main reason for implementing solenoid is because it has advantages in term of packaging and also provides higher power output. The range of electromagnetic forces can be enhanced by varying the number of coils and the strength of electrical current. Solenoid provides a simple means to generate strong magnetic field which can be used to convert electric current into mechanical energy. Moreover, the polarities of the solenoids can be changed by reversing the flow of current and also they can also be turned on and off.

DESIGN PROPOSAL AND ANALYSIS

In this paper, the proposed design of the electromagnetic windshield is shown in Figure-1. The mechanism makes use of a four-bar mechanism similar to the conventional windshield wiper. However, for this design, the driver link is the rocker arm. The electromagnet is attached to the rocker arm and the main advantage is that the rocker arm can be made longer to increase the amount of torque or to lower the applied force. Hence, the system is expected to be more efficient due to the lower required energy.

In this paper, the main analysis to be done was to determine the orientation of the electromagnets. The analysis was carried using ANSOFT MAXWEL with 2D simulation models. Two different kinds of electromagnet designs were compared in order to determine the best configurations. The analysis is very important because it determines the optimum design of the solenoid systems.
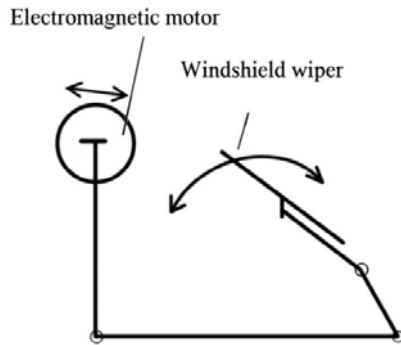
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Figure-1. Schematic diagram.

Two electromagnets (right and left) were considered as fixed whereas the central electromagnet will be oscillating with changing flux densities and forces applied as accordingly as shown in Figure-2.
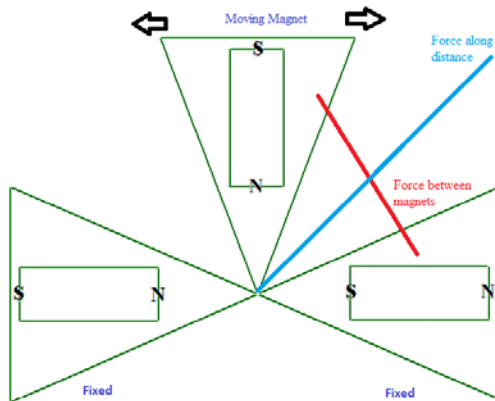

Figure-2. Electric motor replacement.

The polarities of the moving electrometric were changed as it reaches its extreme end either on right or left. So that one is repelling the moving magnet and the other one is attracting to keep the cycle. Also we know that

Torque = Force x Distance

Where,

Force = Force applied (Magnetic)

Distance = Perpendicular distance of force from the axis of rotation.

So either the force or higher the distance can result in higher torque. So, in this paper the magnetic arrangement will be analysed to acquire optimum configuration to acquire higher torque output.

RESULTS AND DISCUSSIONS

Different configurations of electromagnets are tested to establish strong force to keep it moving with high strength. Electromagnets are arranged as face to face & side by side which are shown in following figures.

Two kinds of forces is being observed, the force between each magnet and the force along the distance as shown in Figure-2.

MAGNETIC FIELD AND FLUX DENSITY WHEN MAGNETS ARE AT MAXIMUM DISTANCE
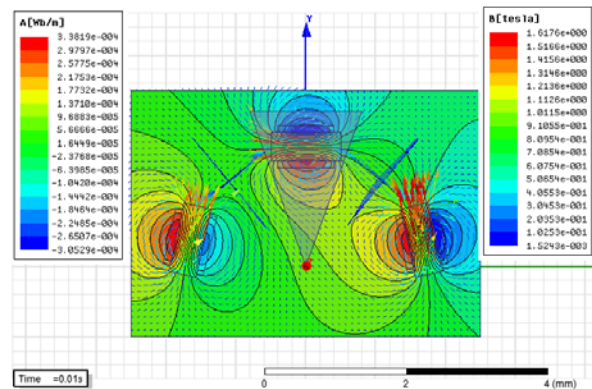
Face to face arrangement

Figure-3. Magnetic field and flux density for face to face magnetic arrangement at maximum distance.

Figure-3 shows the Magnetic Field and Flux Density for face to face magnetic arrangement. It can be clearly seen the middle magnet is attracted towards right and repelled by the left magnet making it to move to one of the ends.

The maximum magnetic flux between magnets in Figure-3 is 0.34 Tesla and it decreases in the middle with minimum value of 0.02Tesla in the middle of the graph as shown in Figure-4.
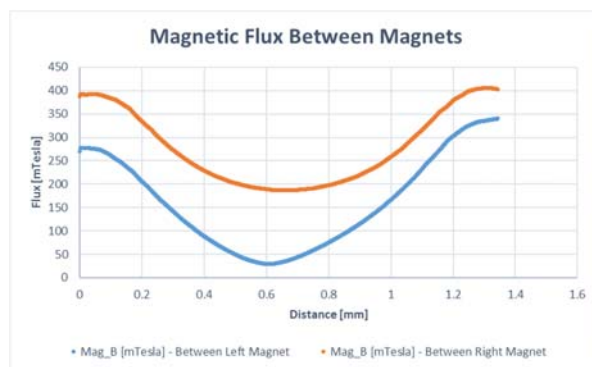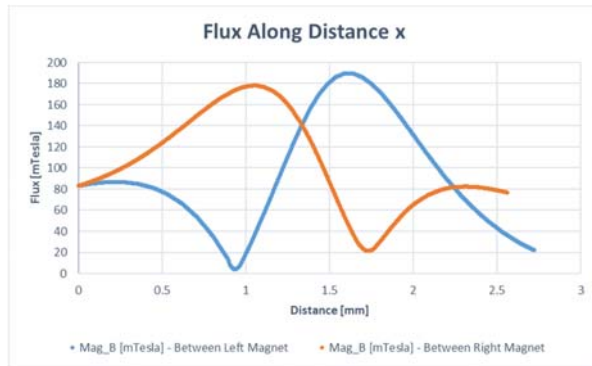

Figure-4. Magnetic flux between magnets Attraction: 0.34T, Repulsion: 0.40T.

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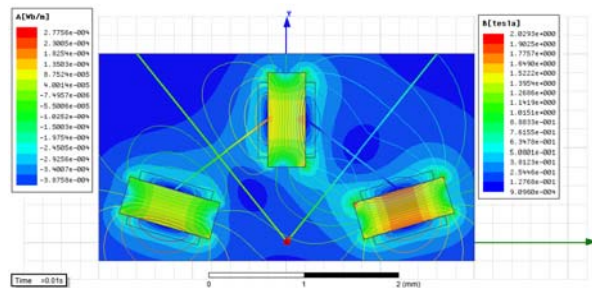
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In Figure-5 as we move along the line away from the centre the distance between the magnets are the same but the graph is inverse because of attraction and repulsion between the magnets.


Figure-5. Magnetic flux along moment arm.
Attraction: 0.18T, Repulsion: 0.17T.

**Side by side arrangement**

Figure-6. Magnetic field and flux density for side by side magnetic arrangement at maximum distance.

Figure-6 shows the magnetic field and flux density for side by side magnetic arrangement. It can be clearly seen the middle magnet is attracted towards right and repelled by the left magnet making it to move to one of the ends.
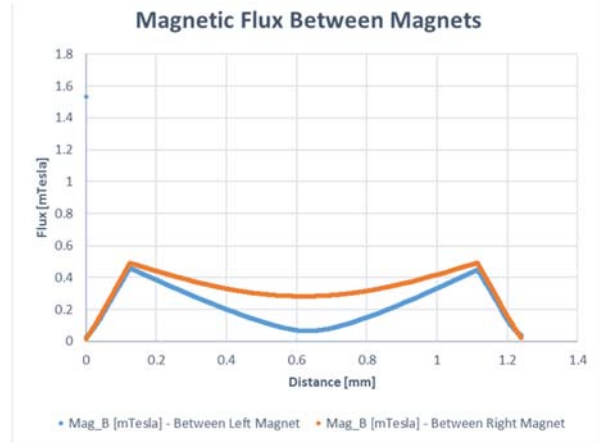
Figure-7. Magnetic flux between magnets.
Attraction: 0.015T, Repulsion: 0.004T.

The maximum magnetic flux between magnets in Figure-6 is 0.1Tesla and it tends to stay constant in the middle with minimum value of 0.18 Tesla as shown in Figure-7.
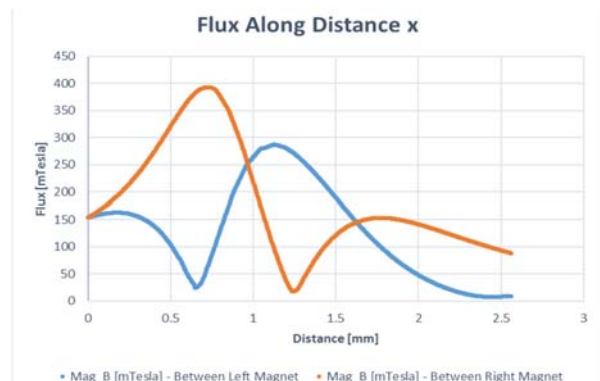
Figure-8. Magnetic flux along moment arm.
Attraction: 0.39T, Repulsion: 0.28T.

It can be observed in Figure 4 the flux between face to face magnetic arrangements is way higher than as observed in Figure-7 when the magnets are at maximum distance from each other.

Where as in Figure-8 the magnetic strength is comparatively higher then as shown in figure 5 but if we increase the moment arm face to face arrangement is a better option.
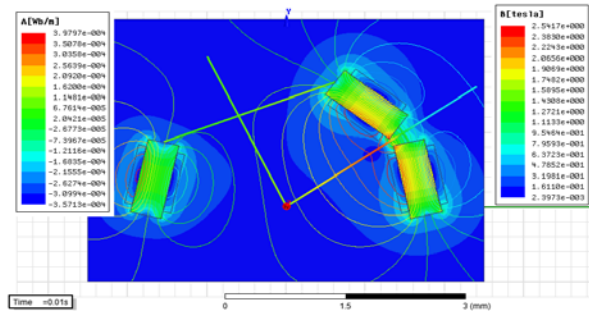
MAGNETIC FIELD AND FLUX DENSITY WHEN MAGNETS ARE AT MINIMUM DISTANCE

We already made a conclusion in the previous part about face to face magnetic arrangement when the magnets are at maximum distance and it provides us with higher force as compared to side by side arrangement.

Now let's observe the strength of the electromagnets when they are close to each other at any end of the magnet.
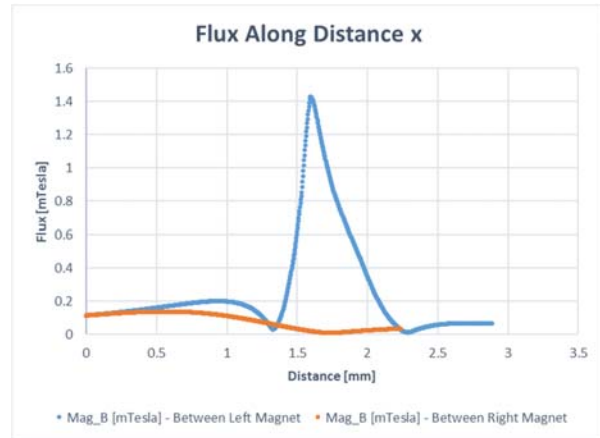
Face to face arrangement

Figure-9. Magnetic field and flux density for face to face magnetic arrangement at close distance.

The Figure-9 shows the Magnetic Field and Flux Density for face to face magnetic arrangement. It can be clearly seen the middle magnet which is in moving state is attracted towards right and repelled by the left magnet making it to move to one of the ends. And it goes vice versa.
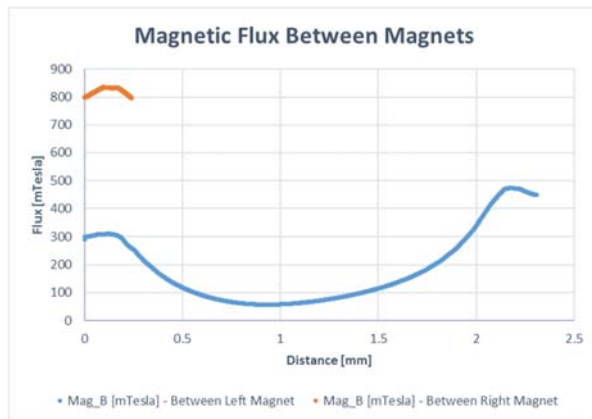
Figure-10. Magnetic flux between magnets
Attraction: 0.84T, Repulsion: 0.47T.

The maximum magnetic flux between magnets in Figure-9 is 0.84 Tesla. The plot is shown on an insignificant area because the moving magnet is very close to the right magnet. As it is really close to each other and they are being attracted before its polarity is being changed. After the change in polarity the moving middle magnet will be repelled with the same force it was attracted with and it goes on after the moving magnet reaches its extreme end. At the same time the other magnet is intended to attract the moving magnet when the other one is repelling with 0.47Tesla as shown in Figure-10.

Figure-11. Magnetic flux along moment arm.
Attraction: 1.4T, Repulsion: 0.13T.

The maximum magnetic flux between magnets in Figure-9 when they are really close to each other at one end is 1.4 Tesla at certain point but that certain point reaches with higher moment arm value means as a result it will provide with higher torque as shown in Figure-11.

Side by side arrangement
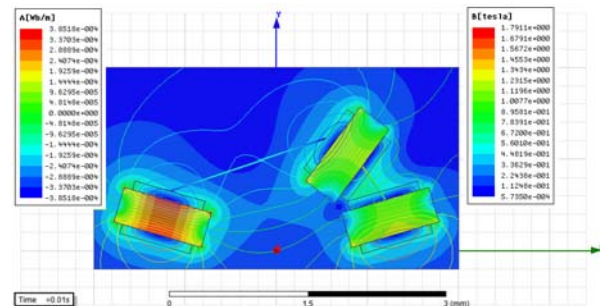
Figure-12. Magnetic field and flux density for side by side magnetic arrangement at close distance.

Figure-12 shows the Magnetic Field and Flux Density for side by side magnetic arrangement. It can be clearly seen the middle magnet which is in moving state is attracted towards right and repelled by the left magnet making it to move to one of the ends. And it goes vice versa.

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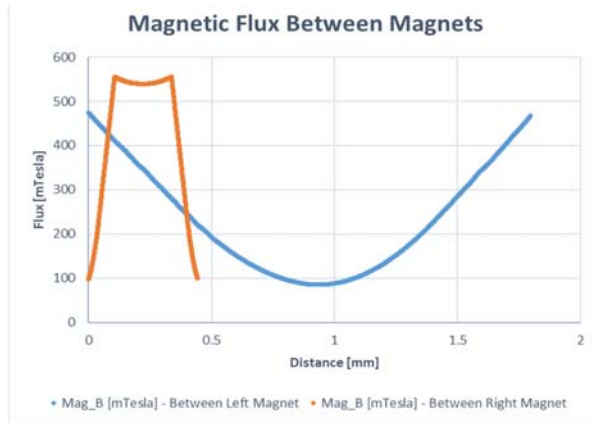
Figure-13. Magnetic flux between magnets
Attraction: 0.47T, Repulsion: 0.55T.

The maximum magnetic flux between magnets in Figure-12 is 0.47 Tesla. As it is really close to each other before its polarity is being changed. After the change in polarity the moving middle magnet will be repelled with the same force it was attracted with and it goes on after the moving magnet reaches its extreme end. At the same time the other magnet is intended to attract the moving magnet when the other one is repelling with 0.55T as shown in Figure-13.
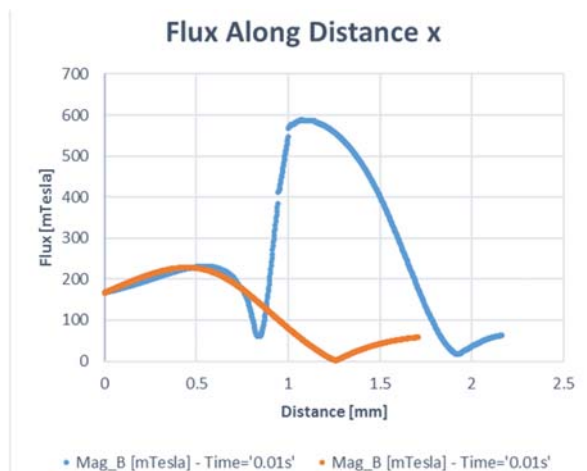
Figure-14. Magnetic flux along moment arm.
Attraction: 0.58T, Repulsion: 0.22T.

If we notice the values of attraction and repulsion from Figure-12. Face the face magnetic configuration was attracting with 1.4T and has higher moment arm as well. And just by increasing the arm the torque will be higher. Where as in Figure-14 for side by side magnetic arrangement not only the attraction and repulsion forces are lower it was gives maximum force at lesser moment arm.

CONCLUSIONS

It is concluded that for this design for electromagnetic windshield wipers, face to face arrangement of electromagnets have high strength as compared to side by side arrangement moreover if a curved solenoid was used with respect to its motion can provide even more strength and repulsive/attractive forces. It can provide higher torque by just increasing the moment arm with minimum chance of failure and less vibrations/sound. The observation is made based on flux along the moment arm and flux between the magnets. Face to face magnetic arrangement provides higher torque force on both parameters.

ACKNOWLEDGEMENT

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