University Physics II – Honors Project

Brushless DC Motor

Keaton Jaramillo

010586326

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Introduction:

An electric motor by definition is a device that converts electrical energy into mechanical energy. The term “brushless” describes how the device converts the energy. In the first motors built, electrons were transferred through physical contact, brushes, to produce electromotive force. Brushless generators and motors have many advantages over their “brushed” counterparts. Making use of a stationary armature and a rotating field, a direct current can be converted to mechanical energy. This is a brushless motor and will run on a low voltage power supply at high RPMs (Martin, 1891).

In a simple reed switch motor, the stationary armature is a single electromagnet; the rotating field is permanent magnets equally spaced around a rotating drum. If this were set up so that the magnetic field of the armature interacts with the rotating field, the motor would find an equilibrium position and stay there. In order to obtain continuous motion from the motor the magnetic field of the armature must be switched on and off. A reed switch is used to switch the field of the armature in place of more expensive and complicated electronic controllers. The components of the motor can be broken up and described individually.

Electromagnet:

An electromagnet is a device that uses current to produce a magnetic field. Electromagnets are generally constructed of insulated copper wire wrapped around an iron core shown in Figure 1. The copper windings are a solenoid, where the current carrying wire has a magnetic field that when wrapped in a cylindrical manner in the same direction, it creates a magnetic field down the middle of the solenoid. A solenoid, however, has little to no magnetic field outside of the solenoid. By filling the inside of the solenoid with a ferromagnetic material, generally iron, the magnetic field is increased substantially.

The iron core increases the magnetic field of the solenoid by the ferromagnetism effect. Where individual atoms in the material align their magnetic moment with the moments of surrounding atoms. Alignment happens because spins of outer electrons align with each other. These groups of aligned moments are called domains. The domains in a material are anti-aligned with each other. However, when a magnetic field is applied the domains align producing a large magnetization. Using this principle the magnetic field of a solenoid can be increased substantially (Stewart, 2012).

The electromagnet used in this project is constructed of 160 turns of insulated copper wire over 2cm of a steel nail. Where steel is generally over 97% iron, which is an excellent ferromagnetic material.

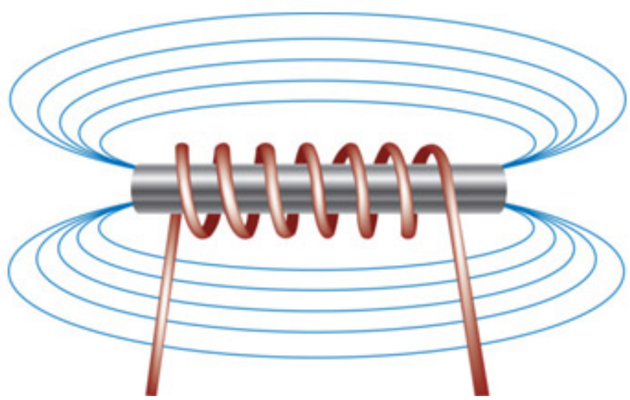

Figure 1

Rotating Field:

The rotating field constructed by affixing permanent magnets to a cylindrical object in an equally spaced manner. For this project four neodymium iron boron (NdFeB) magnets are tapped to the outside of an empty soda bottle, at equally spaced intervals of 90 degrees. Steel nails are punched through the center of each end of the bottle for the axis. The ends of the nails that protrude from the bottle are allowed to freely rotate in supports made of cardboard.

Reed Switch:

A reed switch is composed of two thin, ferrous, flexible strips that are separated from each other by a small gap. When a magnetic field is applied to the reed switch the strips are magnetized and attract to each other, which when used as a switch in a circuit, then completes the circuit. The strips are usually enclosed in a sealed glass tube to protect from environmental corrosion. The reed switches can also be made to be very sensitive to magnetic fields.

Figure 2

Combining all these components with a power source, a brushless motor can be constructed. The reed switch, electromagnet, and power source are all wired in series with a switch. The motor when completed had a total resistance of 0.4 Ohms and the power source supplying 1.54 Volts, with the max measured current of 3.4 Amps. A diagram of the constructed motor is shown in Figure 3. Special consideration needs to be taken in which direction the current is flowing through the electromagnet. The current needs to flow through the electromagnet so that the magnetic field produced has a magnetic dipole orientated opposite of the dipole of the permanent magnets. The opposing magnetic dipoles of the electromagnet and the permanent magnets are what provide the force necessary to turn the motor. When the dipoles are anti-aligned the magnets repel as shown in Figure 4 (Stewart, 2012).

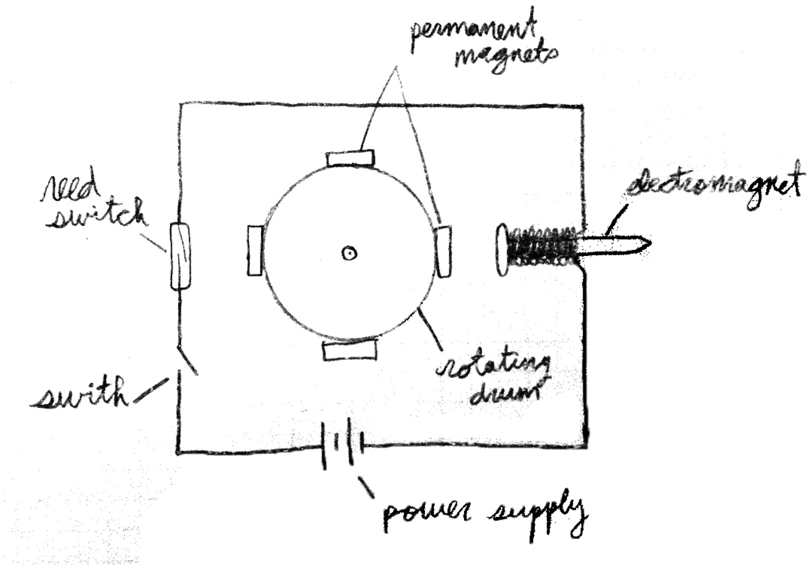

Figure 3

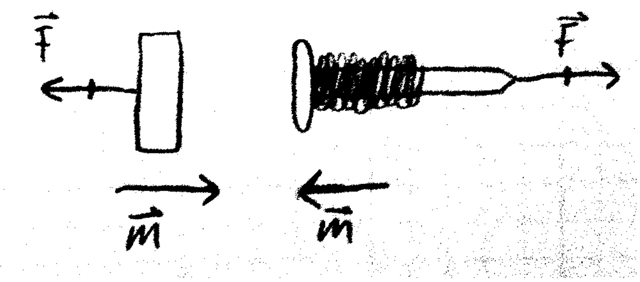

Figure 4

Conclusion:

The brushless motor works very well, however, various problems were encountered during the construction. A strong enough electromagnet needed to be made, first attempts resulted in the magnetic field of the permanent magnet would be much stronger than the field produced by the solenoid. The iron nail would magnetize in the permanent magnets favor and become attracted to it. The reed switch was also problematic; first they are very delicate the glass enclosure breaks easily. Also sparking occurs between the two thin strips, which if the contacts get hot enough the strips weld themselves together, ruining the switch. The sparking also represents loss energy. The electromagnet and the reed switch had to be aligned so that when the switch is closed the electromagnet is aligned with a magnet and this took some fine-tuning.

The motor can be improved by making various changes. By adding something such as a ZNR to absorb the spark, the motor becomes more reliable and a higher voltage can be used. A better rotating assembly with more magnets and less friction would make the motor more efficient. Also more stationary armatures can be added to produce more torque.

Bibliography

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