CHAPTER FOUR

PROTOTYPE DESIGN AND EXPERIMENTAL RESULTS

4.1. System Practical Model

System practical model is consists of three general parts; prime mover, free rotating disks and magnets.

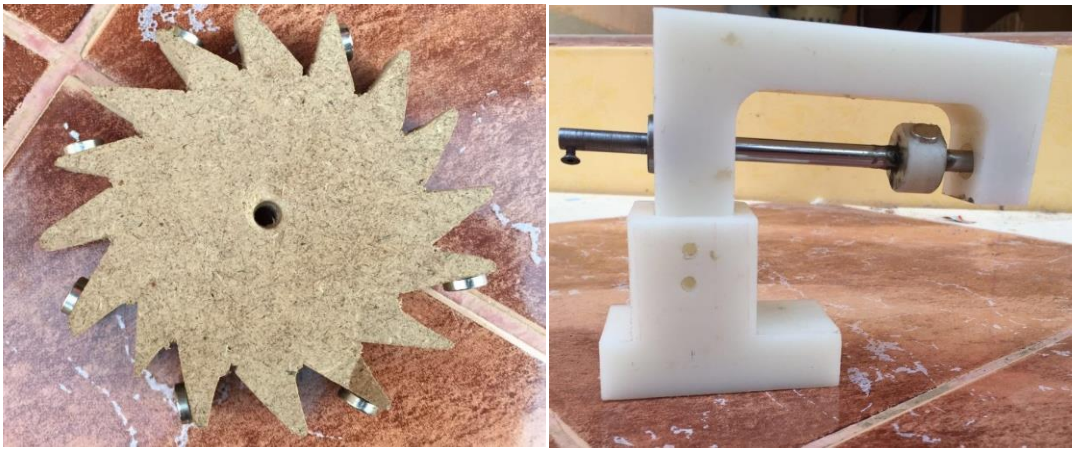
4.1.1. Prime Mover

We use prime mover in this design just to illustrate the other half of energy source used. The main idea of the prime mover is providing a way to produce alternating magnetic field. In our experiments, we used single Phase synchronous motor with low speed to see the effect on alternating magnetic field.

Figure (4.1): Single-phase synchronous motor.

4.1.2. Free Rotating Disks

There are two disks were used, one connected to the prime mover shaft which made of wood as shown in figure (4.2) (a) or Teflon (wheel shape) as shown in figure (4.2) (b). There is a separated base made of Teflon material with one bearing embedded on top of it. The base connected with the other disk, which also made of Teflon through a shaft to provide smooth and free disk rotation as shown in figure (4.3). In addition, the other disk has a 24 hole used to install the magnets.



(a) (b)

Figure (4.2): (a) wooden rotating disk. (b) Wheel shape Teflon disk.

Figure (4.3): Free and smooth rotating disk.

4.1.3. The Magnets

Neodymium magnets as shown in figure (4.4) below used in the prototype has a thick of 3mm and a diameter of 10mm. The magnets were fixed on the disks described above.

Figure (4.4): Neodymium magnets.

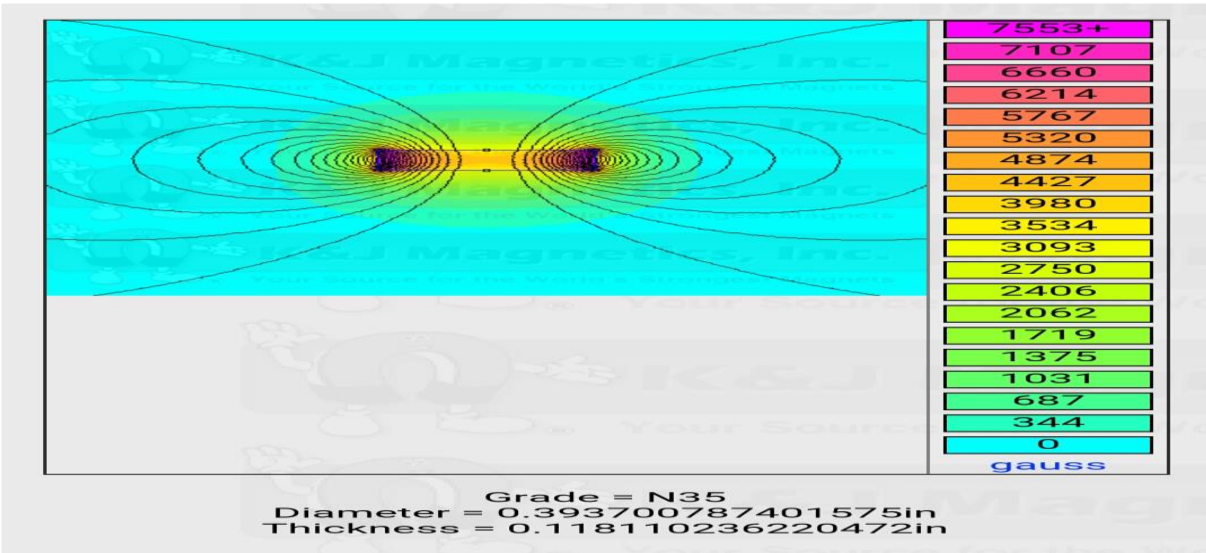


Figure (4.5): Magnetic field visualization of single magnet in free space.

[Note: 1 Tesla= 10000 gauss].

4.2. Principles of Operation

Principles of operation based on the attraction or repulsion between magnetic poles. There are a number of magnets fixed on wooden disk referred as stator (rotatable stator) and magnets poles on the Teflon disk referred as rotor. When the stator is adjacent to the rotor, interaction occur between magnetic fields of stator and rotor. The process start when the stator begins to rotate by a prime mover, a magnetic poles of stator attracts or repel the closest permanent magnets of the rotor which in turn cause rotor rotate. After this, the next magnet in the stator enter the area of magnetic interaction and depend to the rotor magnet position and its pole (N or S).

4.2.1. Conditions

There are several arrangements of magnets on the stator or rotor, which yields, to the following conditions:

4.2.1.1. Condition One

For stator: the disk take the shape of wheel and magnets on its periphery. The axis of rotation of stator is vertical to the rotor.

For rotor: we embedded the magnets on the rotor surface as far as much from the rotor center in holes as in figure (4.5).

(a) (b)

Figure (4.6): Rotor and stator position of condition one

Depend on magnetic pole direction the following is experimented

- Repulsion mode: the magnetic interaction between rotor and stator magnets are repel each other.
- Attraction mode: the magnetic interaction between rotor and stator are attract each other.
- Repel-repel-attract mode: the sequence of magnetic pattern is as follow (all magnets poles of stator is united (same pole)), rotors poles are set to be repel-repel-attract in sequence.

4.2.1.2. Condition Two

For stator: the magnets are set so that magnet axis is perpendicular to the disk axis (magnet stand with its thickness outwards at the far end of the disk) as shown in figure (4.6)

Figure (4.7): Rotor and stator position of condition two

For rotor: same as the stator.

Depend on magnetic pole direction the repel-repel-attract mode is experimented.

4.2.1.3. Condition Three

For stator: same as second condition with specific angle deviation, the angle is achieved by salient poles looks like saw teeth (magnet thickness is no longer outward) as shown in figure(4.7).

Figure (4.8): Rotor and stator position of condition three

For rotor: same as stator but without salient poles (the magnets fixed on the disk surface at a far end).

Depend on magnetic pole direction the repulsion mode is experimented.

4.3. Motion description and Results

The motion description of the above conditions as follow:

4.3.1. Condition One

The stator placed close to the rotor, the magnetic field of both rotor and stator start to interact with each other,

- Repulsion mode: in case(primary de-energies), the rotor and stator stand steady in position where the stator's magnet exist in position between two rotor magnets(adjacent to each other). Any external force move the rotor or stator to another situation the magnetic fields interaction produce a force tend to give the steady state position. The magnetic field of this mode applied a force in alignment with rotor shaft axis and perpendicular to the stator shaft. When the prime mover energized and start to rotate, the stator's magnet actuate the disk(rotor) by repelling first magnet (forward magnet) and attract the second (backward magnet). After that, the rotor rotates until the stator's magnet become again in the interaction area with the rotor. There are two possibilities, the one that on the stator's magnet gives positive torque (in the same rotation direction) and the other possibility is to produce a negative torque (reverse the rotation direction). The positive torque accelerated rotation speed and the negative torque de-accelerate the rotation speed or may even cause sudden stop (known as cogging torque).

- Attraction mode: The same de-energize condition for repulsion mode the only difference is that the direction of the net force on the shafts is reversed. When the prime mover energized and start to rotate, the stator's magnet actuate the disk (rotor) by moving the opposite magnet in the rotor with its motion direction. Next, when the stator's magnet enter the interaction magnetic area there are two types of torque, the positive (interact happened between two rotor magnets and stator's magnet) and the negative (interact happened between one rotor's magnet and stator's magnet) which causing very high cogging torque.
- Repel-Repel-Attract mode: When the stator de-energized the stator's magnet stop steady against the attracted one in the rotor (stator's magnet and rotor's magnet have different polarities faces each other), the main features in this mode that the starting torque is not high. There are different power affected on the shafts due to continuous alternate between repulsion and attraction. When the prime mover energized and start to rotate, the stator's magnet actuate the disk(rotor) by the movement of the attracted magnet (related to stator's magnet move) and repulsion between the stator's magnet and

repelling one in the rotor (which is next to the attracted one). The positive torque in this mode is very high compared to the other modes, which overcome on some of the cogging torque, producing smoother rotation more than repulsion and attraction modes.

Figure (4.9) below show the magnetic field strength between two neodymium magnets separated by a gap of 4 mm. Magnetic field strength at the center is 3478 gauss = 0.3478 Tesla.

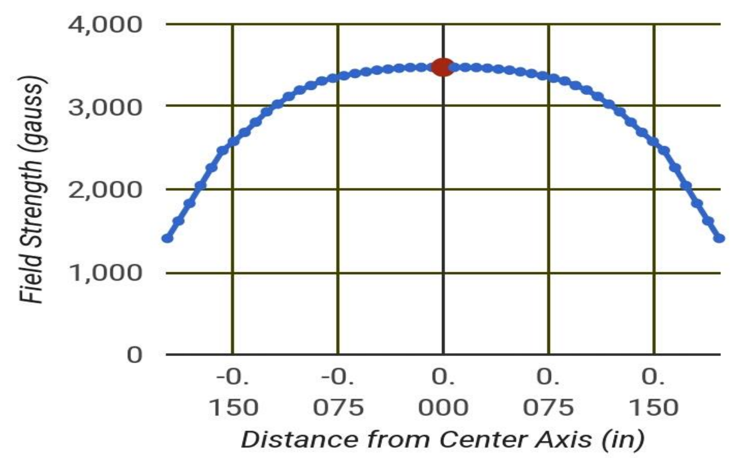


Figure (4.9): Magnetic field strength for condition one in vertical direction.

The graph above show the magnetic field strength in the vertical direction, along a line equidistant between the two magnets, as shown below in figure (4.10).

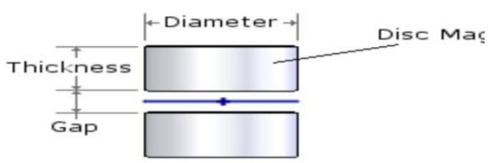


Figure (4.10): Two neodymium magnets separated by a small gap.

4.3.2. Condition Two

Same as repel-repel-attract in condition one, the only difference is that the interaction magnetic area is reduced which in turn the cogging torque reduced, in general this connection produce smooth rotation but lesser torque.

Figure (4.11) below show the magnetic field strength between two neodymium magnets separated by a gap of 5 mm. Magnetic field strength at the center is 3356 gauss = 0.3356 Tesla.

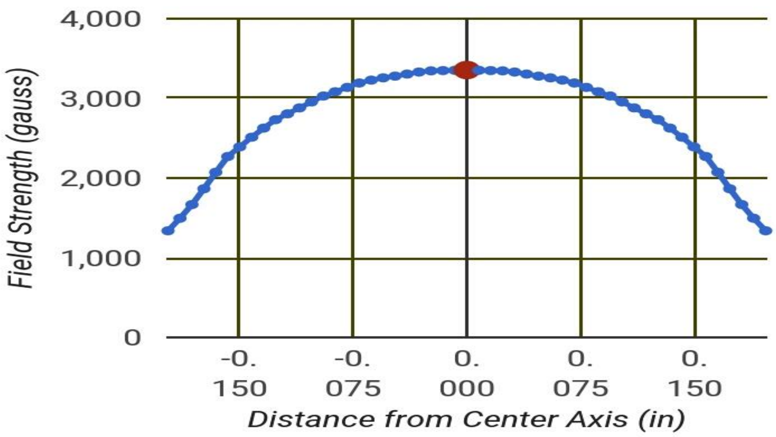


Figure (4.11): Magnetic field strength for condition two in vertical direction.

4.3.3. Condition Three

In this connection, the intensity of the magnetic fields between the rotor and stator is increased and the cogging is overcame as much as possible and has the smoothest rotation in specific speeds.

Figure (4.12) below show the magnetic field strength between two neodymium magnets separated by a gap of 21 mm. Magnetic field strength at the center is 406 gauss = 0.0406 Tesla.

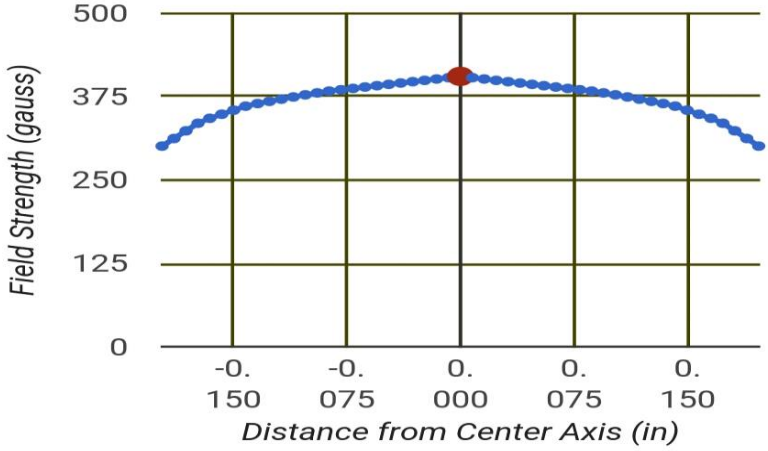


Figure (4.12): Magnetic field strength for condition three in vertical direction.

The table below shown the summary of three previous conditions

Table 4.1: Summary of three previous conditions

Conditions	**Air gap distance (mm)**	**Flux density (B) in Tesla**	**Notes**
One	4	0.3478	Noticed here that the flux density is very high , yet the torque developed in the disk is low and irregular
Two	5	0.3356	The flux is lesser than the previous condition due to increased distance and the torque is approximately the same as cond.1
Three	21	0.0406	Here the flux density is very low due to very large distance between two magnets, but the torque produced is very high and unidirectional and more regular