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RESEARCH ARTICLE

MEASUREMENT AND ANALYSIS OF MAGNETIC FLUX DENSITY USING 3 AXIS BOT

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ABSTRACT

Electromagnets play a very important role in the working of electric and electromechanical devices. Flux distribution is of paramount importance to calculate magnetic force which helps in optimal utilization of power which can be done by changing the position of object to be magnetized or attracted, these types of applications can be seen in MR fluids, Magnetic levitations, Particle accelerators. Failure of these machines may cause a lot of loss so it's very necessary to study the various ways to increase their reliability and efficiency. These electromechanical devices are mainly built on the principle of electromagnets and hence this literature review is aimed at studying the distribution of magnetic flux between the two poles of strong electromagnets along different planes. So, to analyze the flux density distribution a robot with a probe was designed and programmed to move along Y-Z plane and the flux density recorded in each plane is graphically represented.

INTRODUCTION

Magnetic Flux

The concept of flux is generally used to characterize the transmission rate of a conservative quantity through a surface. The flux through a surface is equal to the conservative quantity that passes through the surface per unit of time. Similarly, the flux is expressed by the surface-integral of a quantity also called flux density, and characterizes the transmission rate of the quantity through the surface under consideration. In physics, magnetic flux is the amount of magnetic lines of force passing through the surface normally. The experimental study of magnetic properties of materials requires (a) a means of producing the field which will magnetize the material, and (b) a means of measuring the resulting effect on the material. We will therefore first consider ways of producing magnetic fields, by solenoids, by electromagnets, or by permanent magnets.

Electromagnet

In the ordinary laboratory, the need for fields larger than those obtainable from conventional solenoids is met with electromagnets. Electromagnet is a type of magnet which produces magnetic field with the help of electric current. Unlike permanent magnets the very presence of magnetic field produced depends on the electric current in the coil.

Electromagnets have two advantages over permanent magnets in lab-on-a-chip systems:

1. They can be switched on off rapidly using electrical signals,
2. The strength of their magnetic field can be adjusted.

Electromagnets consists of coils of insulated wire (solenoid) which are often wound around a magnetic core (plunger) made of ferromagnetic /ferrimagnetic materials. The used magnetic core concentrates the magnetic flux thus making it a more powerful magnet. When electric current is passed through the coil, magnetic field is setup in the core.

Details of the apparatus used

The 3-axis bot

The 3-axis bot is made use for the movement of the gauss meter pen in the field between the electromagnets. The probe that is attached to the arm of the bot is driven by programmed stepper motors, belt mechanisms for movement and screw rods for support. The Arduino board is programmed in such a way that when the input coordinate values are given, it runs the stepper motors at prescribed rpm and as a result the probe is moved to the given input coordinate in the space between the electromagnets.A stepper motor is a brushless DC electric motor that divides a full rotation into a number of equal steps.

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Sufficient time delay for each stop of the stepper motor is programmed. The motor's position can then be commanded to move and hold at one of these steps without any position sensor for feedback, as long as the motor is carefully sized to the application in respect to torque and speed. The movement of the probe in the y-axis is achieved with the help of 2 stepper motors that are programmed to run at 1000rpm. Two Bearings of 5mm diameter are provided for the sake of smooth movement in Y axis direction. The movement in the z-axis is achieved with the help of a stepper motor and belt mechanism which is programmed to run at 700rpm. The x-axis movement is achieved through manual movement of the rod to various holes in the 3-D printed model. 3-D printed models are used for the robot to give supports and as a housing for the bearings. The probe is driven by programmed stepper motors, belt mechanisms for movement and screw rods for supports

Table 1 Specifications of the bot

Features	specifications
Diameter of the larger rod	16mm
Diameter of the screw rod	8mm
Distance between the centers of two rods	17.03mm
Height of the center of the rods from the platform.	28.5mm
Carbon rod length	55cm
Weight of the gauss meter pen	0.022Kg
Weight of the carbon rod	0.022Kg
Weight of the carbon rod with Gauss meter pen	.044Kg

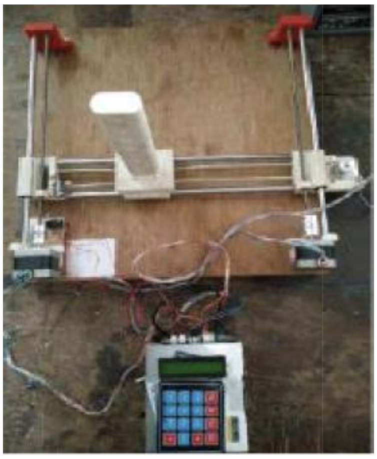

Figure 1 The 3-Axis bot

Gauss meter

To measure the magnetic flux density along different planes through static measurement a gauss meter which is a type of magnetometer is used. A magneto meter is an instrument that measures magnetization of magnetic material, or direction strength or relative change of magnetic field at a particular location. Gauss meter is usually used for those measurements which are greater than 1MT.The gauss meter used for the measurement is DGM-204.

DGM-204 operates on the principle of hall effect in semiconductors [2.2.1]. Hall effect gauss meters are designed to amplify and condition these low-level signals and provide a result that is calibrated in terms of gauss. Often the Hall generator is mounted inside a protective tube, or stem, made of aluminum, fiber glass or other nonmagnetic material. The wires are connected internally to a flexible cable and the cable is terminated with a multi pin connector. This assembly, known as a *Hall probe*, is generally available in two configurations

- Traverse probes
- Axial probes.

The primary difference between the two is the axis in which flux lines are sensed. Transverse probes which are usually thin and flat are often used to make measurements between two poles of a magnet such as those found in audio speakers, electric motors, or MRI machines. Axial probes, usually shaped cylindrical can be used to measure the fields generated by coils or solenoids. Either type can be used where there are few physical constraints. Some probes contain several Hall generators arranged orthogonally to allow simultaneous measurements in different axes. Some gauss meters use heavy filtering, modulation techniques, and sophisticated averaging in an attempt to provide better resolution. The signal can be enhanced by placing the Hall sensor near one or two pieces of iron or other ferrous material. These pieces, called concentrators, bend the local flux pattern so that more lines pass through the sensor. Because of the local flux distortion and the size of the concentrators, this type of probe is normally used to make volumetric measurements such as in geomagnetic surveys, electrical interference studies, or preflight package inspections. A millivoltmeter is connected at the output of the amplifier(concentrators). It is calibrated to give an output in terms of magnetic field unit (gauss).

Figure 2 Gauss meter

Hall Effect

According to Hall effect, a semiconductor carrying current develops an electromotive force, when placed in a magnetic field, in a direction perpendicular to the direction of both electric current and magnetic field. The magnitude of this EMF is proportional to the field intensity if the current is kept constant. This EMF is called the Hall Voltage. The Hall effect is generally considered as having a maximum resolution of 1 mG (100 nT).Below this level, electrical noise and thermal effects swamp the usable signal.

Table 2 Specifications of the gauss meter

Features	specifications
Resolution	0.1 gauss at 0.1 kilogauss range
Range	200KG,2KG,20KG and 40KG
Accuracy	±0.5%, ±1⁄2 digit at 1KG to 20KG range ±1%; ±1 digit at 0.1KG range
Temperature	Up to 50°C
Power	220V ±10%, 50Hz
Transducer	Hall Probe-InAs
Weight	3Kg

Testing

Preliminary testing

Several tests were conducted on the bot before the actual experiment, to minimize errors and obtain accurate values of flux density. Sufficient time delay programmed for each stop of the stepper motor helps in tabulating stabilized flux density values from the gauss meter. To get the basic idea on division of space several Dry runs were conducted in the space between electromagnets without magnetizing it.

Main Testing

After the preliminary testing, the main test was carried out. This test mainly consists of a device which produce magnetic flux using electro- magnet, gauss meter which measures the intensity of the flux produced and the bot which was designed, fabricated and programmed to move in Y,Z direction and manual movement along the X direction.

When the electric current is passed through the coils of the electromagnets, electric flux is produced and is distributed in the space between the electromagnets. To trace the distribution of these flux lines, it is necessary to find the magnitude of the field between the magnets. Therefore, the space between the two electro magnets was considered as a cuboid of dimension 14*9*14 (cm) and the same was divided further into 7 planes in x axis direction. The rectangular grid thus obtained was considered as reference and flux density at each point in the grid was tabulated.

Factors Effecting the Flux intensity

1. The material of the core used in the electromagnet.
2. The magnet size and shape.
3. Working temperature and humidity.
4. Presence of any external magnetic field near the electromagnets.
5. The circuit delivering current to the electromagnet.

Procedure

1. Initially when the gauss meter was switched on, it was ensured that there was no external magnetic field and then the reading in the gauss meter was calibrated to zero.
2. The gauss meter pen was attached to the carbon rod of the bot which moves in the experimental space between the electromagnets.
3. The probe along with the gauss meter pen was aligned to the left extreme corner of the bottom rectangular grid.
4. The electro magnet was switched on and the input was regulated by the dimmer stat and regulator.
5. The power supply voltage was kept at a constant 70 V using the dimmer stat.
6. The electromagnets were magnetized at a constant DC voltage of -24V and a direct current of magnitude -2.3A.
7. The corresponding input voltage and current values were noted. The apparatus could magnetize the electromagnets and simultaneously coordinate values.
8. As the probe moved in the plane to corresponding the coordinates, the values of flux density were recorded at each point.
9. After completion of each plane the probe was brought back to its initial/home position. The power source to the electromagnet was switched off to demagnetize the electromagnet.
10. To tabulate the values in the next plane, the probe was raised upward by manually fixing the carbon rod to the upper slot provided. The power source was switched on. Electromagnets were magnetized and the readings were noted as described earlier.
11. The values were tabulated for all the planes and respective graphs of flux distribution were plotted.

Review

Overview

The variations recorded were tabulated taking into consideration planes as shown in the figure.

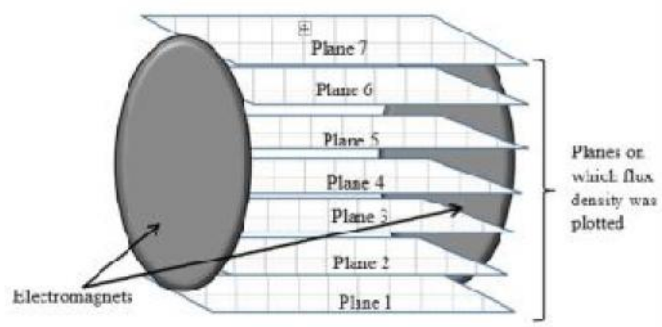

Figure 3 planes considered for plotting flux density distribution

The reading obtained are in gauss(g)(1 Tesla = 10000 gauss).Flux variation in units of gauss is noted and the results are tabulated as follows

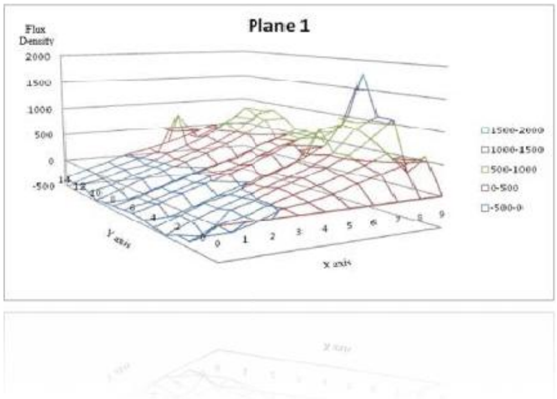

Figure 4 Flux density distribution in first plane

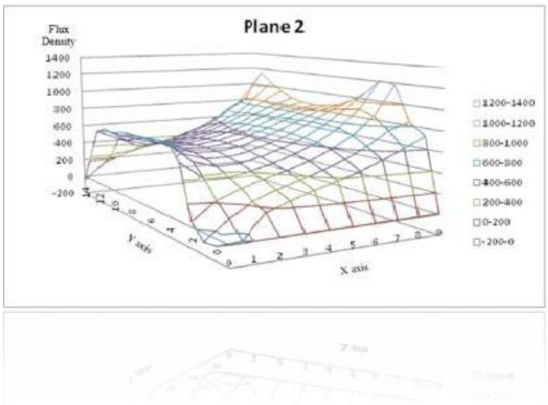

Figure 5 Flux density distribution in second plane

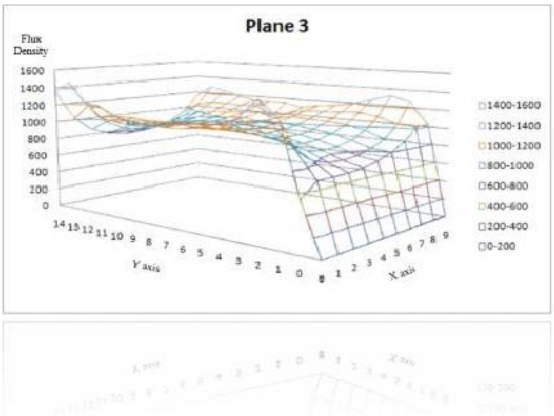

Figure 6 Flux density distribution in third plane

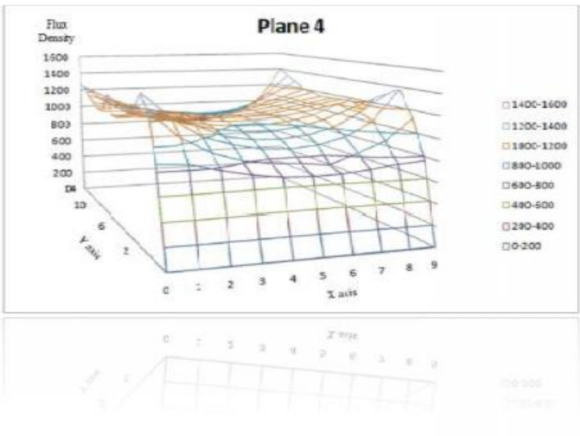

Figure 7 Flux density distribution in fourth plane

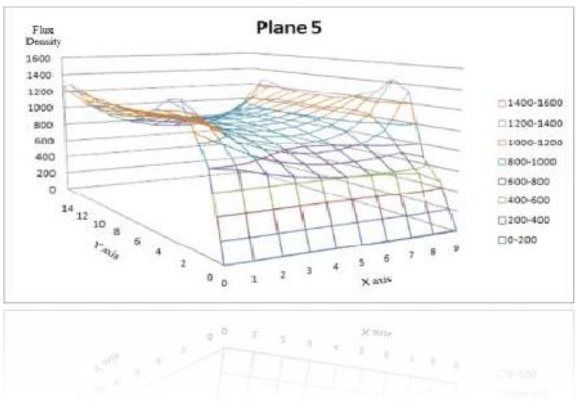

Figure 8 Flux density distribution in fifth plane

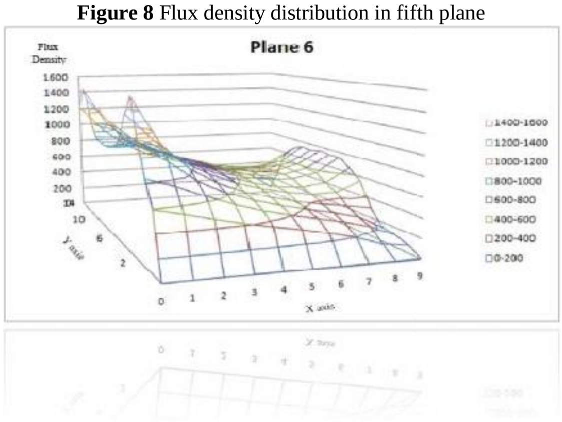

Figure 9 Flux density distribution in sixth plane

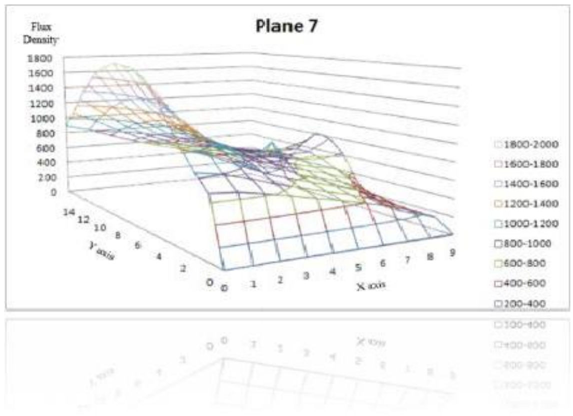

Figure 10 Flux density distribution in seventh plane

Comparative Review

The magnetic flux distribution is plotted for the experimental region along various planes in the space as shown in figures 4-10. The magnetic field is concentrated into a nearly uniform field in the center of the space which forms the region between the electromagnets. The field towards the edges is weak and divergent.

In the bottommost plane, the electromagnetic flux density is linearly varying from left magnet to right magnet. Across the plane of the magnet, the magnetic density is maximum in the beginning (inner edge), decreases to a minimum value at the center and again increases as we move to the outer edge.

In the mid plane, as we move along from left magnet to right magnet the flux density, is maximum at one end and decreases to a minimum value at the center and increases as it gets closer to another magnet. Across the plane of the magnet the magnetic density is maximum in the beginning (inner edge), decreases to a minimum value at the center and again increases as we move along the outer edge.

In the topmost plane, the electromagnetic flux density is maximum in the left magnet and decreases as moved towards right magnet. It reaches minimum value at the center and increases slightly as we move closer to right magnet. Across the plane of the magnet the magnetic density is maximum in the beginning (inner edge), decreases to a minimum value at the center and again increases as we move along the outer edge.

CONCLUSIONS

The concept of magnetic flux states magnetic flux through the surface is the surface integral of the normal component of the magnetic field B passing through that surface normally. The electromagnets which are used to produce magnetic flux instead of permanent magnets due the fact that they provide stable and desired output .The magnetic flux between the two magnets were measured with help of probe which was further attached to a gauss meter working on the principle of Hall Effect which was further mounted on to a three axis bot. The bot programmed with input coordinates, measured the magnetic flux along each plain and after repeated trails the graph was plotted for the recorded values. On comparison of the graphs plotted with respect to each plain it was found that all the graphs follow uniform pattern. In all the planes the magnetic flux density varied linearly from left to right and it was found that magnetic flux density was maximum in the beginning (inner edge) to minimum at the center and was again maximum at the outer edge.

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