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Magnetic Coils Alignment System Generates Uniformed Bio-Magnetic Field

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Abstract: A uniform and homogeneous magnetic field is widely explored in the area of bio-electric and bio-magnetic materials. The values of magnetic flux density vary from 2.513×10^{6} to 2.513×10^{5} tesla in which the current flows throughout a designed winding coil. The experimental design consists of involved coil geometrical setup in which the coil is used for magnetic winding stimulation at certain numbers of winding series (1000N) within the steel plate with the thickness of 3mm. The structured iron frame is in a rectangular structure form, and the magnetic coil is winded on an iron plate which is installed at the middle of the structured frame. The density of the circular flux that flows within the designed body ranges from 7.5384×10^{6} to 1.7592×10^{5} tesla, but most of the surrounding magnetic field is defined 2.513×10^{6} tesla.

Keywords: magnetic flux, bio-electric, bio-magnetic, uniform magnetic field, circular flux

1. Introduction

This paper aims to generate a uniformed circular magnetic field by inducing a magnetic field (MF) in a coil alignment system that can be applied in bio-magnetic cell activities. A uniformed and homogeneous MF is widely explored in the field of bio-electric and bio-magnetic materials (Ahrendsen et al., 2020). A biological substance such as molecule and cell activities are affected and influenced by a uniformed MF to gain at optimum level.

Geometrical coil is designed to generate a uniform MF for numerous applications. It is widely applied in bio-magnetic field testing especially for sensing calibration at different frequency. The setup is established from the utilization of invented *Maxwell equation* into *Bio-Savart law*. The experimental set-up consists of permanent magnets or air-core winding coils with geometrical shapes which are circular, square and rectangular (Saqib & others, 2020)(Wang et al., 2020)with different distances amongst each other. As referred to the Bio-Savart law, the circular and square coils are widely implemented geometrically in building systems to generate uniformed MF due to the geometrical coordination as well as those geometrical are well defined in the literature(Ishii & Suzuki, 2020), in which the design of the coil is geometrically defined in both experimental and computational analysis. Further research is carried out by several scientist and scholar to improve the alignment of magnetic coil geometrically as introduced by A. F. Restapo as an equilateral triangular coil under Helmholtz configuration (Mustafa et al., 2020).

A co-relation is existing between side length and separation distance in the propose geometrical. Although the assumption is made via the result of simulation analysis but the is a significant outcome based on the magnetic flux arrangement in geometrical form (Kossowski & Szczupak, 2020).

Copper wires are coiled tightly around a geometrical which represents as cylinder, rectangular or other geometrical forms (Morin et al., 2020). A strong MF is generated within the coils whenever current is applied through the copper wire. The direction of the MF depends on the current flow. The magnetic field of the solenoid can be determined by the cross-sectional area of the wire loop as shown in Fig.1.

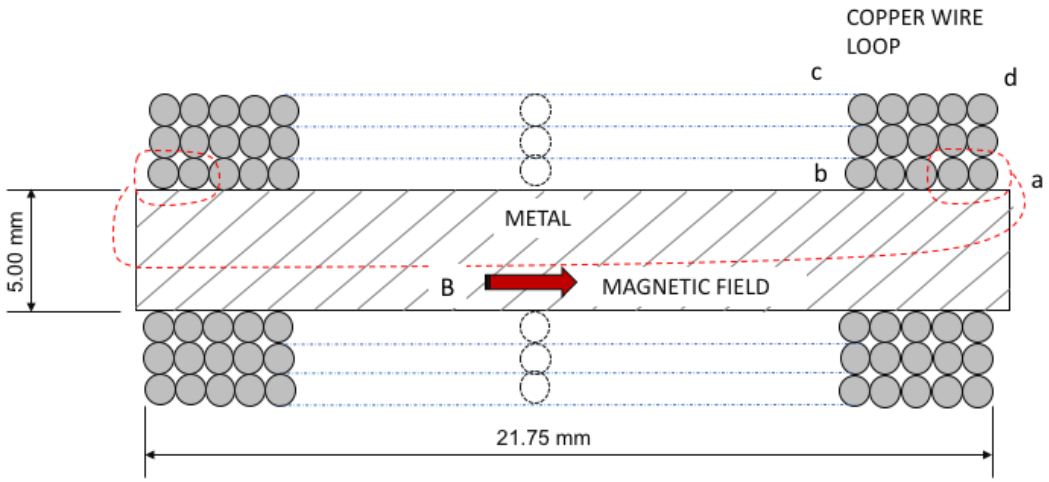

Fig. 1: The cross-section of the wire loop

The value of the MF within the solenoid is uniformed which is represented by value B, and external value of the coils is assumed zero (Jin et al., 2020), using the derivation of ampere law from the origin Maxwell formulation is written as follows,

$$\oint B.dl = \oint B.dI\,cos\theta = I\mu_0 \tag{1}$$

$$\oint B.dl = \int_a^b BdI + \int_d^c BdI + \int_d^a BdI \tag{2}$$

Since the vertical paths from *a* to *b*, *c* to *b*, and *a* to *d* is perpendicular to the direction of the MF, then its value is assumed zero, therefore Equation (2) can be written as follows,

$$\oint B.dl = \int_c^d B.dI = BI \tag{3}$$

If *I* represents the current in the solenoid wire, the enclosed *I* is given by *NI*, where *N* represents the number of wire loop, the equation can be written as follows,

$$\oint B.dl = I\mu_0 \tag{4}$$

Then, the equation above can be solved as follows,

$$Bl = \mu_0 NI \quad (4)$$

$$B = \mu_0 {}^{NI}/_{l} \quad (5)$$

2. Experimental Design

The iron metal frame which is coiled with copper wire as shown in Fig. 2(a) is geometrically positioned as shown in Fig. 2(b). The copper wire as shown in Fig. 2(c) is coiled longitudinally for the purposed of generating magnetic stimulation within the centre of the 3-mm steel plate thickness.

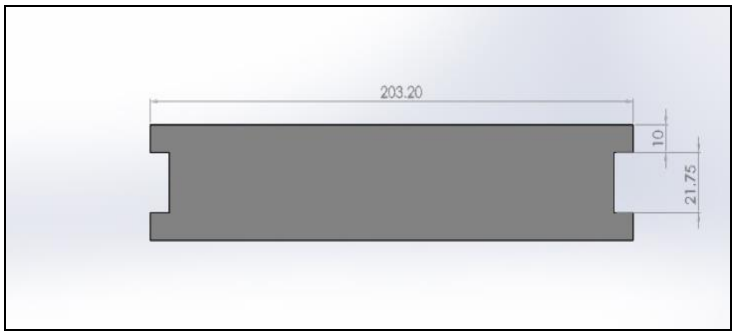

Fig. 2(a): Iron plate

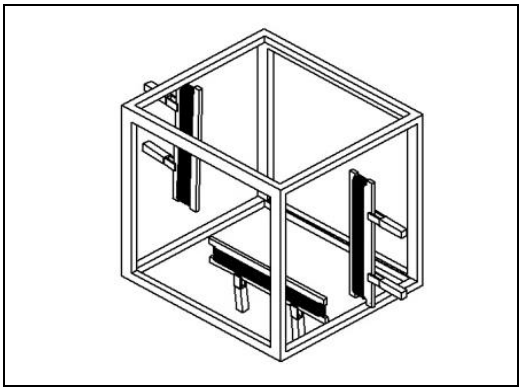

Fig. 2(b): Iron structural frame setup

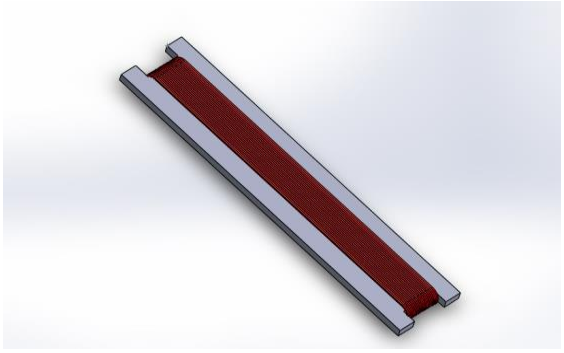

Fig. 2(c): The coils of copper wire

A mesh grid is geometrically designed and simulated using EMS Solidworks. A MF and flux are generated and displayed that normalize those values up to 1Tesla at the center of the measurement area. The results are 0.5%, 1% and 2% deviation from which the area of homogeneity is determined. The simulation results are demonstrated in Fig. 2(d) and (e).

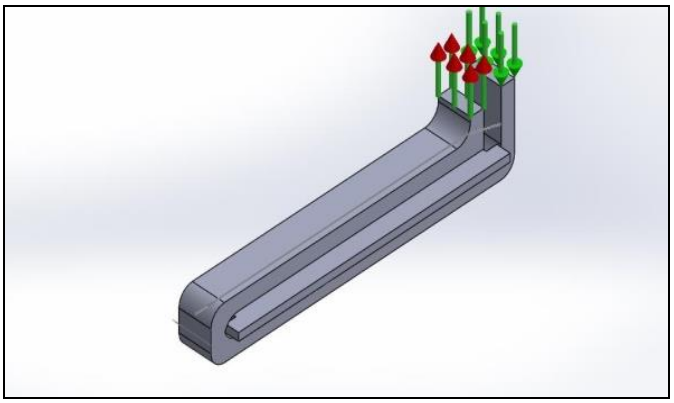

Fig. 2(d): The simulation result of the magnetic field from the isometric view

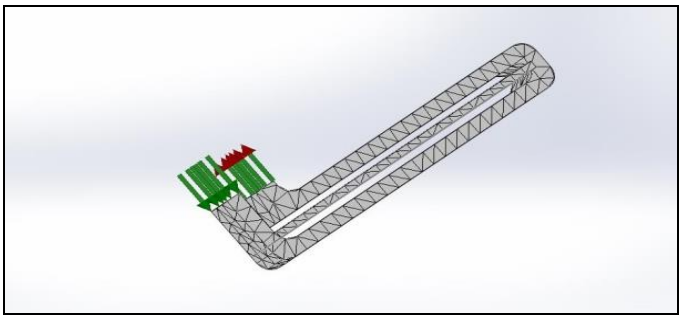

Fig. 2(e): The simulation result of the magnetic field from the side view

3. Simulation Results

The meshing parameter of an element with the diameter of 21.3 mm as shown in Table 1(a) is simulated by using EMS application software generates difference conductivity and relative permeability values as shown in Table 2(b).

Table 1(a): The simulation result of the meshing parameter

Nodes Number	Elements Number	Size of Element (mm)	Tolerance (mm)
6765	31148	21.331684	0.021332

Table 1(b): The conductivity & relative permeability

	Conductivity [Mho/m]	Relative permeability
Copper	$57.0x10^6$	1
Iron	$1.1x10^6$	200,000
Air	0	1

Current value of 2.5mA is supplied to generate a distribution of consistance current density along with the copper coil as the result is shown in **Figure 4(a)**. It demonstrates that the magnetic flux distribution of the design coil winding is consistance.

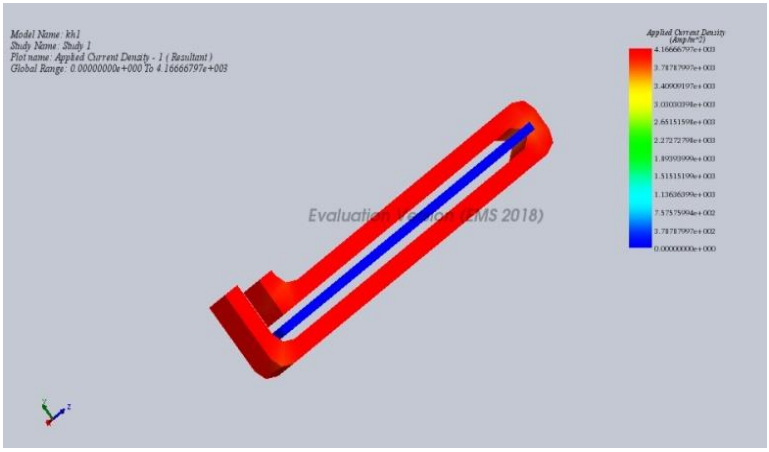

Fig. 4(a): Current Density

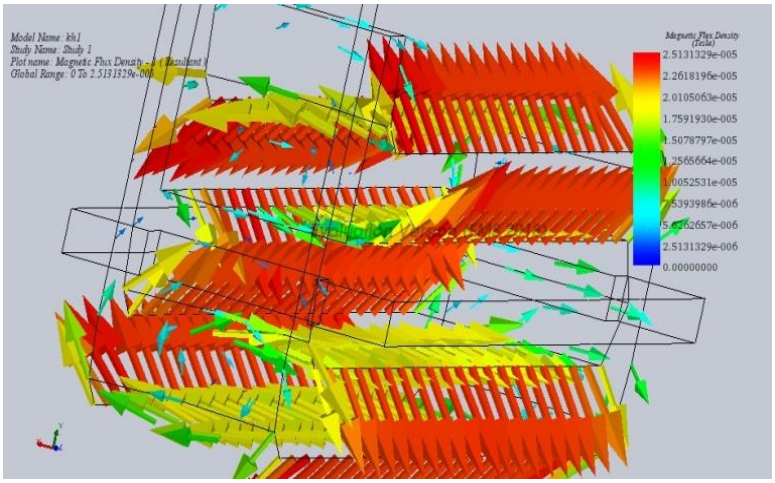

Fig. 4(b): Magnetic Flux Density

Figure 4(b) shows the values of magnetic flux density vary from $2.513x10^{-6}$ to $2.513x10^{-5}$ Tesla as the current flow through the winding coil. The circular flux density that flows within the body design ranges from $7.5384x10^{-6}$ e-tesla to $1.7592x10^{-5}$, as compared to the value of $2.513x10^{-6}$ Tesla of the surrounding MF is produced constantly.

4. Conclusion

The measured MF in the design experiment is influenced by the natural variations of the magnetic flux with consistence with single direction due to the changes of the geometry. This system is designed negates the effects of these MF as a certain direction of magnetic flux. It can be navigated to achieve a desired result. The research work on designing a geometrical solenoid at a certain degree of complexity can be improved higher efficiency towards exposing the biological substance against the magnetic flux in a certain targeted direction.

5. Acknowledgments

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