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Automation Control Magnetic Fields Simulation

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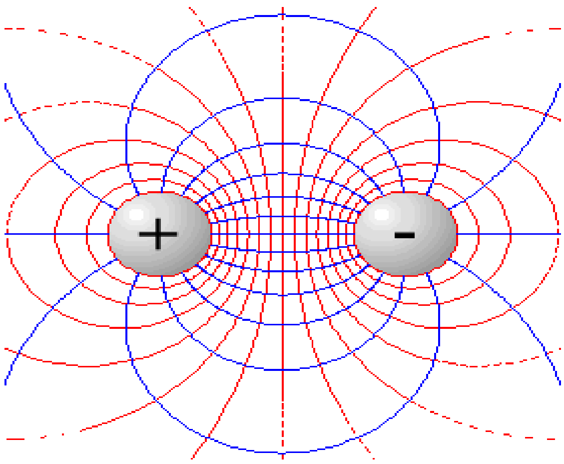
Abstract: ***In this paper, firstly, we have attempted to introduce magnetic field and its history and earlier contributions. Secondly, it describes to evaluate magnetic field of current-loop under Biot-Savart Law. Moreover, our main purpose is to simulate the data into a suitable for computer-aided analysis which is the MATLAB software. The primary duty of a computer programming is to develop computer programs and another specific goal is to perform monitoring tasks. Magnets are essential in today's electronic technology. Magnetic field is useful to learning and the science of magnetism is tied to the modern science of electricity. The modern science already has reached tremendous achievements but it is still a little mysterious as well as attraction for scientists.***

Keywords: Magnetic Field, Current-Loop

1. Introduction

A magnetic field is a vector field that describes the magnetic influence of electric charges in relative motion [1][2] and magnetized materials. The effects of magnetic fields are commonly seen in permanent magnets, which pull on magnetic materials (such as iron) and attract or repel other magnets. Magnetic fields surround and are created by magnetized material and by moving electric charges (electric currents) such as those used in electromagnets. They exert forces on nearby moving electrical charges and torques on nearby magnets. In addition, a magnetic field that varies with location exerts a force on magnetic materials. Both the strength and direction of a magnetic field vary with location. As such, it is described mathematically as a vector field.In electromagnetic, the term "magnetic field" is used for two distinct but closely related fields denoted by the symbols B and H. In the International System of Units, H, magnetic field strength, is measured in the SI base units of ampere per meter.[3] B, magnetic flux density, is measured in tesla [4] which is equivalent to Newton per meter per ampere. Magnetic fields are produced by moving electric charges and the intrinsic magnetic moments of elementary particles associated with a fundamental quantum property, their spin.[5][6] Magnetic fields and electric fields are interrelated, and are both components of the electromagnetic force, one of the four fundamental forces of nature.

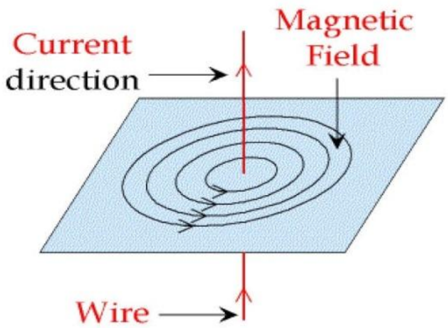


Magnetic Field

Magnetic fields are widely used throughout modern technology, particularly in electrical engineering and electro mechanics. Rotating magnetic fields are used in both electric motors and generators. The interaction of magnetic fields in electric devices such as transformers is studied in the discipline of magnetic circuits. Magnetic forces give information about the charge carriers in a material through the Hall Effect. The Earth produces its own magnetic field, which shields the Earth's ozone layer from the solar wind and is important in navigation using a compass.

2. History of Electromagnetic Theory

Although magnets and magnetism were studied much earlier, the research of magnetic fields began in 1269 when French scholar PetrusPeregrinus de Maricourt mapped out the magnetic field on the surface of a spherical magnet using iron needles. Noting that the resulting field lines crossed at two points he named those points "poles" in analogy to Earth's poles. He also clearly articulated the principle that magnets always have both a north and South Pole, no matter how finely one slices them. Almost three centuries later, William Gilbert of Colchester replicated PetrusPeregrinus's work and was the first to state explicitly that Earth is a magnet.[7] Published in 1600, Gilbert's work, De Magnete, helped to establish magnetism as a science.In 1750, John Michelle stated that magnetic poles attract and repel in accordance with an inverse square law.[7] Charles-Augustin de Coulomb experimentally verified this in 1785 and stated explicitly that the north and south poles cannot be separated.[7] Building on this force between poles, Siméon Denis Poisson (1781–1840) created the first successful model of the magnetic field, which he presented in 1824.[7] In this model, a magnetic H-field is produced by "magnetic poles" and magnetism is due to small pairs of north/south magnetic poles.



Extending these experiments, Ampère published his own successful model of magnetism in 1825. He showed the equivalence of electrical currents to magnets [7] and proposed that magnetism is due to perpetually flowing loops of current instead of the dipoles of magnetic charge in Poisson's model. This has the additional benefit of explaining why magnetic charge cannot be isolated. Further, Ampère derived both Ampère's force law describing the force between two currents and Ampère's law, which, like the Biot–Savart law, correctly described the magnetic field generated by a steady current. Also in this work, Ampère introduced the term electrodynamics to describe the relationship between electricity and magnetism.

In 1831, Michael Faraday discovered electromagnetic induction when he found that a changing magnetic field generates an encircling electric field. He described this phenomenon in what is known as Faraday's law of induction. Later, Franz Ernst Neumann proved that, for a moving conductor in a magnetic field, induction is a consequence of Ampère's force law. [7] In the process, he introduced the magnetic vector potential, which was later shown to be equivalent to the underlying mechanism proposed by Faraday.

The twentieth century extended electrodynamics to include relativity and quantum mechanics. Albert Einstein, in his paper of 1905 that established relativity, showed that both the electric and magnetic fields are part of the same phenomena viewed from different reference frames. Finally, the emergent field of quantum mechanics was merged with electrodynamics to form quantum electrodynamics (QED).

3. Magnetic Field Centre of A Circular Loop

A current i is maintained in a thin, tightly would coil of N turns, with a radius, R.

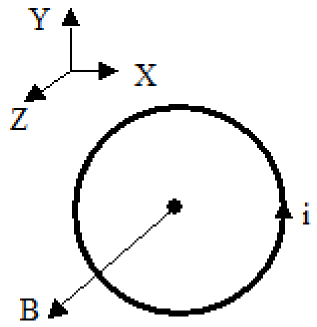
The magnetic field at the centre of a coil of radius R with one turn is found from the Biot-Savart Law:

$$d\vec{B} = \frac{\mu_o\, i}{4\pi}\frac{d\vec{L}\times\vec{R}}{R^3} \quad \Rightarrow \quad dB = \frac{\mu_o\, i\, dL}{4\pi\, R^2}$$

Since $d\vec{L}$ and $\vec{R}$ are at right angles to each other. For N turns and integrating dB

$$B = N\int dB = N\frac{\mu_o\, i}{4\pi R^2}\int dL = N\frac{\mu_o\, i}{4\pi R^2}\left(2\pi\, R\right) = \frac{\mu_o\, N\, i}{2\, R}$$

Direction of B in Z-direction, if current anticlockwise in XY plane (Right Hand Screw Rule)



4. Subject and Method

The Biot-Savart law can be used to calculate the magnetic field from any current configuration.

$$d\vec{B} = \frac{\mu_o}{4\pi}\frac{i\, d\vec{l}\times\vec{r}}{r^3}$$

Although this equation looks difficult to perform calculations with, using Matlab it is relatively easy. We will consider a very important type of current configuration: a ***current loop*** of radius a, centered at the origin and in the xy plane. We will calculate the magnitude of the magnetic field B surrounding the current loop in the xz plane.

To simplify the programming, the magnetic field is calculated in arbitrary units with a = 1. The limits of the region where the magnetic field is calculated is given in terms of the radius of the current loop a. We sum the contribution from each current element dB at each detector point (x_p, y_p, z_p).

$$d\vec{B} = \frac{d\vec{l}\times\vec{r}}{r^3}$$

4.1. Steps in the calculation using current-loop

- Divide the circumference into N elements of length L. The center of each element (x_c, y_c, z_c) and its (L_x, L_y, L_z).= 0) components are specified by the radius of the circle a, and an angle θ which is measured anticlockwise with respect to the x axis.
- Set up a two dimension grid for the detector points $(x_p, y_p{=}\,0 z_p)$. at which the magnetic field is calculated.
- For each element calculate
  The displacement r (r_x, r_y, r_z) from the center of each element (x_c, y_c, z_c) to each detector point $P(x_p, y_p, z_p)$.
  The cross product

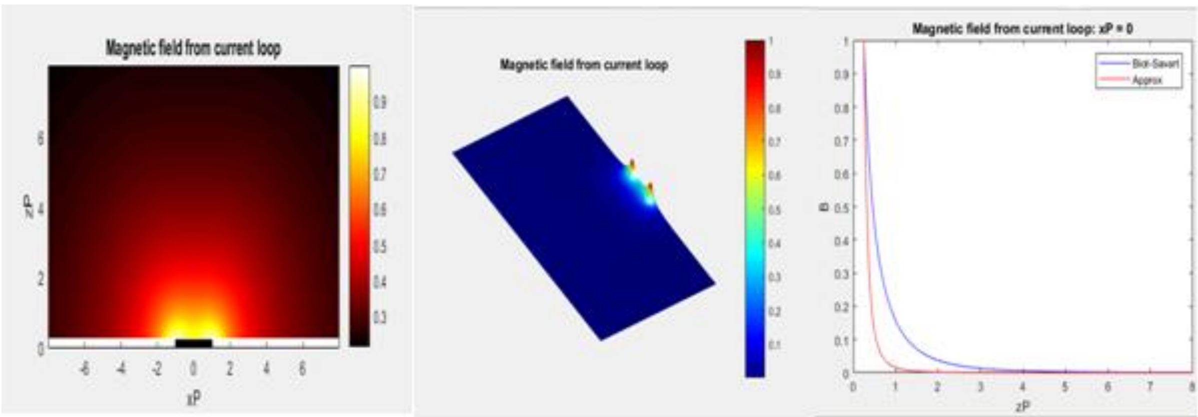
$$d\vec{l}\times\vec{r} = \begin{pmatrix} \vec{i} & \vec{j} & \vec{k} \\ L_x & L_y & L_z \\ r_x & r_y & r_z \end{pmatrix} = \begin{pmatrix} \vec{i} & \vec{j} & \vec{k} \\ L_x & L_y & 0 \\ r_x & 0 & r_z \end{pmatrix}$$

$$d\vec{l}\times\vec{r} = \vec{i}\left(L_y\, r_z\right) - \vec{j}\left(L_x\, r_z\right) + \vec{k}\left(r_x\, L_y\right)$$

- Sum the contribution of the magnetic field from each element.
- Plotting the magnetic field.

This code to plot the magnetic field in an xy plane just above the current loop

```
% current loop ==================
a = 1 ;% radius of current loop
N = 115;            % number of elements in current loop
theta = zeros(1,N);    % angle of current loop element
xC = zeros(1,N);          % xyz coordinates for point current
lop element
yC = zeros(1,N);
zC = zeros(1,N);
dtheta = 360/N;
theta(1) = dtheta/2;
theta(end) = 360-dtheta/2;
for c = 2 : N-1
theta(c) = (c-1)*dtheta+theta(1);
end
xC = a.*cosd(theta); yC = a.*sind(theta);
L = 2*pi*a/N;                    % length of each current loop
element
Lx = L.*cosd(90+theta); Ly = L.*sind(90+theta);
cleartheta
% Detector space (xP, yP, zP) where B is calculated ==
NP = 217               % Detector points NP x N
xPmax = 8*a;              % Dimensions of detector space
zPmin = 1*a/4; zPmax = 8*a;
xP = linspace(-xPmax,xPmax,NP);
zP = linspace(zPmin,zPmax,NP);
[xxPzzP] = meshgrid(xP,zP);
Bx = zeros(NP,NP);By = Bx; Bz = Bx;
% Calculation of magnetic field B: sum over each current
element
for c = 1 : N
rx= xxP - xC(c);
rz = zzP - zC(c);
ry = yC(c);
   r = sqrt(rx.^2 + ry.^2 + rz.^2);
   r3 = r.^3;
Bx = Bx + Ly(c).*rz./r3;
   By = By - Lx(c).*rz./r3;
Bz = Bz + Ly(c).*rx./r3;
end
B = sqrt(Bx.^2 + By.^2 + Bz.^2);
B = B./max(max(B));          % normalize B to 1
% GRAPHICS =====================
figure(1)
pcolor(xxP,zzP,B.^0.2);
colormap(hot)
shadinginterp;
axisequal;
axis([-xPmaxxPmax 0 zPmax]);
xlabel('xP');ylabel('zP');
set(gca,'XTick',[-6:2:6]);
set(gca,'YTick',[0:2:6]);
rectangle('Position',[-1 0 2 0.2],'FaceColor','k');
title('Magnetic field from current loop')
colorbar
figure(2);
surf(xxP,zzP,B,'FaceColor','interp',...
'EdgeColor','none',...
'FaceLighting','phong')
daspect([1 1 1])
axistight
view(-122,36)
camlightleft
colormap(jet)
gridoff
axisoff
colorbar
title('Magnetic field from current loop')
% B along z-axis: Biot-Savart& approx.
B_theory = abs(1./zP.^3);
B_theory = B_theory./max(B_theory);
figure(3)
index=find(B(1,:)==1);
plot(zP,B(:,index),'b');
holdon
plot(zP,B_theory,'r');
xlabel('zP'); ylabel('B');
legend('Biot-Savart','Approx');
title('Magnetic field from current loop: xP = 0')
```



4.2. Result and Discussion

From our magnetic field calculated in the xz plane, we can plot the magnetic field along the z axis. An expression for the magnetic field along the z axis when $r >> a$ is $B = \frac{\mu_o}{4\pi}\frac{2 i a^2}{r^3}$ or in our arbitrary units $B = \frac{1}{{z_P}^3}$.

Here, we can compare the two, one from the using the Biot-Savart Law and another one is using the approximation. Moreover, the plotting figures show that how the results agree with the default values. By increasing the range for z values so that $r >> a$ by increasing both $zPmin\ and\ zPmax$.

5. Conclusions

This paper provided thatan alternative approach of computing magnetic field provides one with easier and quicker way to compute magnetic field usingcurrent-loop. It is equally true for the computation of magnetic field distribution of electromagnet. It provides an easier path for the calculation of field each current element. With the existing formula we can monitor and control magnetic field using current-loop. Moreover, magnetic field due to different geometry electromagnet or permanent magnets such as solid cylinder, hollow cylinder and ring can also be figured out by using area with this technique. An improved simulation integrates an electromagnetic field model simulation to predict approximately situation and it is useful to use realistic magnetic fields.

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