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Article

Comparative Analysis of Magnetic Field Distribution in Electromagnetic lenses Using the Glaser and Gaussian models

Ashrf Abdulrahman M.Taher[1]

[1] *Collage of Nursing, University of Telafer, Nainawa Iraq*

ashrf.m.taher@uotelafer.edu.iq

Abstract: Electromagnetic lenses are dependent upon a specific rely on a specific procedure of magnetic fields which focus on beams of charged particles and make their plan technically tedious and demanding efficient numerical models. This specific study attempts to assess the efficiency of dual prominent models for the depiction of magnetic field within lenses, the Gaussian model and the Glaser model, to determine which of the models is suitable for high-sensitivity scientific usages. MATLAB was used to carry out quantitative simulations of each model and analyse the axial magnetic domain spread in a good electromagnetic lens. The outcomes displayed that the assumed Gaussian model produces a clear and balanced field spreading, to render it suitable for accuracy usages. The Glaser framework shows improved adaptability to depict non-balance distributions, which makes it appropriate for difficult experimentation conditions.This comparison exemplifies that the choice of a mathematical model should be dependent on the features of the usage and the plan specifications. This study suggests the application of Gaussian model for schemes that are proportioned around a distinct axis and the Glaser framework that need appropriate domain adjustments with the potential of integrating both models in an advanced simulation for great adjustments and the need to provide accuracy and efficacy.

Keywords: Electromagnetic lenses, Gaussian model, axial magnetic field, Glaser model, numerical simulation, MATLAB, charged particle beam focusing, lens design, magnetic field modeling, applications in electron microscopy.

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Introduction

In Electromagnetic lenses are critical items in several modern physical resources, which include electron microscopes as well as particle accelerators. These potential lenses can control the streams of charged elements to produce a squarely engineered axial magnetic domain. The plan of these lenses forces a detailed understanding of the magnetic field dispersal, which is important for achieving precise and reducing optical deviations [1, 2].

Electromagnetic lenses are applied in different areas that need precise beam which focus on nano imaging systems, systems and spectrometers that use electron beams. The achievement of beam steadiness in these systems is essentially affected by the lens plan and formation of the magnetic domain within it [3, 4].

Numerous mathematical models occur to describe the behaviour of the magnetic field in the lenses, differentiating the structure, applicability and accuracy. The Gaussian model is distinguished for its capability to show a clear and normal spread of the magnetic field around the specific center, which makes it appropriate for systems the need accurate symmetry. Similarly, the present Glaser model provides notable flexibility by allowing the parameters to conform to experimental information for dispersal [5, 6].

The Gaussian model uses a dedicative Gaussian role to represent a seamless depiction of its behaviour. This concept is regularly used in lenses which necessitate a symmetric field dispersal. The Glaser model uses a dynamic measured formula that consents for better control over the field at the edges, which makes it appropriate for lenses applied in less-than perfect conditions or adjustable applications.

This study seeks to conduct a numerical and narrative comparison of the two distinct models to assess their efficiency that occurs within the magnetic domain within a standard is to do a quantitative and qualitative comparison electromagnetic lens. The assessment will comprise the identification of accurate model that will represent magnetic field. In consonance with the axis and how perfect the model can adapt to various operating situations.

A quantitative simulation approach will be applied to use both models to a typical electromagnetic lens, considering the results of the comparable axial field dispersal and how it transforms in space. By comparing the digital findings from each model. The study will come up with scientific recommendations in different practical situations.

This work attempts to offer a detailed comparison of two different mathematical framework that can reflect the magnetic field in a predictable electromagnetic lens: the Glaser framework and the Gaussian model. Each of the models can be assessed based on the representation precision, computing efficacy, field distribution smoothness, and applicability to various contexts. This work seeks to furnish empirical information to assist designers and researchers in selecting the best -suited model based on application requirements [13, 14].

2. The Theoretical Treatment

Numerous mathematical models can depict the axial magnetic field. The way the magnetic field is arranged along the axis for a magnetic lens can be described using Glaser's model, Gaussian models, the fourth exponential model, the exponential model, and the electron's wavelength based on potential.

a- The Glaser's model:

Glaser's mathematical model describes the distribution of axial magnetic flux density for an asymmetric magnetic lens, given by the equation [15].

$$B(z) = \frac{B_m}{1+(z/a)^2} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where:

B_m= represents the maximum value for the distribution of axial magnetic flux density.

a = one-half of the half-width of the distribution is evaluated at $B_z = \frac{B_m}{2}$.

Observe that the (B_m) is contingent upon the excitation lens and (a) determined by the configuration of polarization and saturation.
The curve representing the model's distribution is closely aligned with the center of the lens but exhibits reduced accuracy toward the extremes of the distribution. The Glaser model is fitted to provide the axial magnetic flux density distribution for a magnetic lens near saturation [16].

b- Gaussian model:

The magnetic flux density distribution in this model is described by the following equation [17].

$$B(z) = B_m \, Exp\left[-\left(Z/a\right)^2 \ln 2\right] \ldots\ldots\ldots\ldots (2)$$

Where :

B_m= represents the maximum value for the distribution of axial magnetic flux density.

a = represents half of the half-width of the distribution, measured at $B_z = \frac{B_m}{2}$.

The distribution of this model is identical to that of the magnetic flux density in a non-saturated lens. This model illustrates the dispersion within the thin lens[17].

3.Results and Discussions:

I-The Glaser's model :

The magnetic field distribution relative to the optical axis for Glaser's model and a constant lens axial pore, with varying maximum values for magnetic distribution, is illustrated in Figure (1).

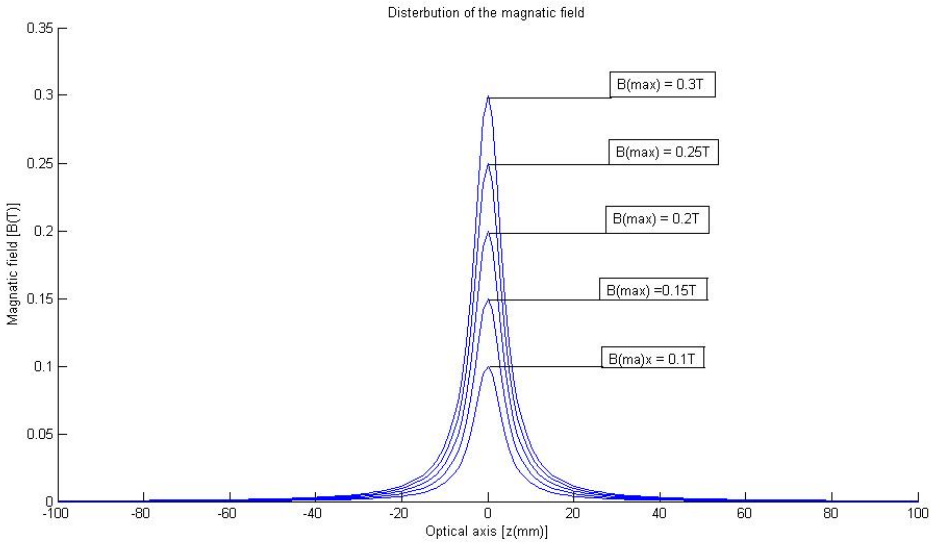

Fig. (1): distribution of the magnetic field by using the Glaser's model.

The impact of the magnetic field diminishes as the maximum value distribution decreases.

II - The Gaussian Models:

For the maximum value [(0.1, 0.15, 0.2, 0.25, 0.3) T], which may not alter the area under the curve that diminishes with varying effects for the lens. Which center can exhibit analogous behavior to the Gaussian model in the distribution of the magnetic field depicted in Figure (2)

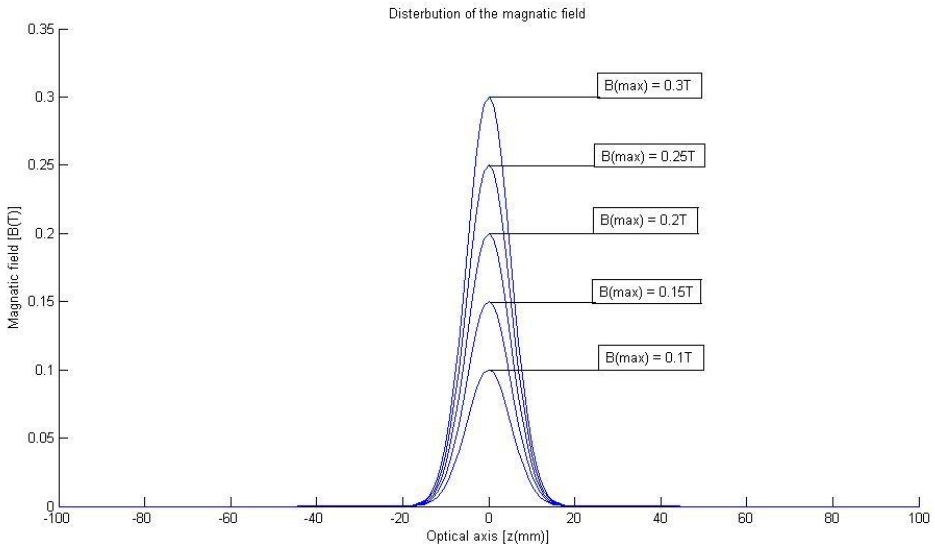

Fig.(2): distribution of the magnetic field by using the Gaussian model.

The three figures show how the three models are improved and how they can create different forces to direct the electron beam and produce adjustable images for scanning electron microscopy and transmission electron microscopy.

III - The Glaser and Gaussian Models:

Figure (3) shows how the magnetic field is spread out along the optical axis, with different values along the way but keeping the strongest magnetic field at 0.2 T. It also shows that the area under the curve gets bigger, which improves how well the magnetic field works. This model is linked to Glaser's model. It demonstrates an increase in the area under the curve, which enhances the efficacy of the magnetic field. This field model is associated with Glaser's model.

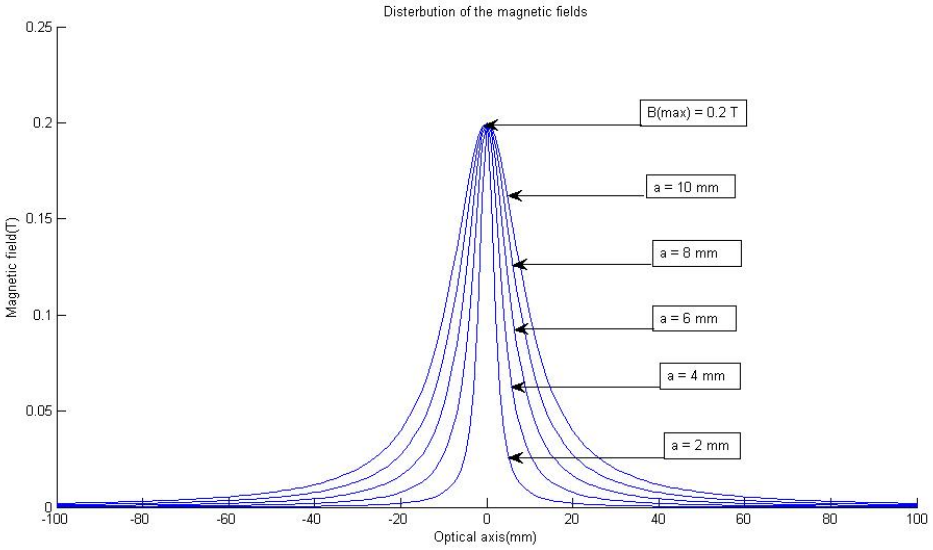

Fig.(3): distribution of the magnetic field by using the Glaser's model.

Some speech for figure (4):

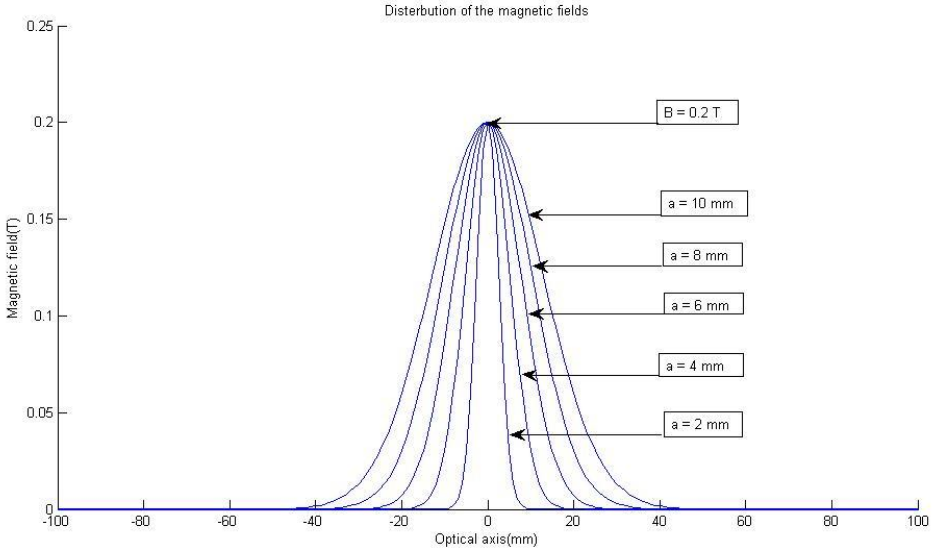

Fig.(4) : distribution of the magnetic field by using the Gaussian model.

Which belong to the Gaussian framework which can see various areas for this specific model larger than Glaser model.

4. Conclusion:

The findings of this study show that both the specific Gaussian and Glaser models to offer different benefits that can render suitable and particular usages in the construction of electromagnetic lenses. The Gaussian prototypical item was very efficient to describe a stable magnetic field. This makes it essential for precise symmetry and steady optics, such as high-resolution electron microscopes. Similarly, the Glaser model is much better to indicate complex modifications in the domain that can adjust well to less-than-perfect situations that serves as the best choice to stimulate difficult practical conditions. The mathematical comparison exposed that the Gaussian model surpasses in simplicity and computation efficacy, while the Glaser model offers superior adjustment and control over the field configuration. Accordingly, the selection of an appropriate model must be determined by the usages, features, precision demands and present computation constraints. This present study helps designers and researchers in the selection of suitable mathematical model to achieve optimum function for electromagnetic lenses.

5. Recommendation:

1- The Gaussian model is far better for states conditions that demand symmetry while making calculations speeding up replication time.
2- Future research needs to incorporate more urbane measured models as well as machine learning approaches to improve the prediction of magnetic field and dynamics within the lenses.
3- The research supports the expansion for involvement of 3D models and flexible particle replications in the lens to improve practical perception and increase the reliability of genuine plans.

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