IASJ
المجلات الاكاديمية العراقية

Tikrit Journal of Pure Science

ISSN: 1813 – 1662 (Print) --- E-ISSN: 2415 – 1726 (Online)

Journal Homepage: http://tjps.tu.edu.iq/index.php/j

Effect of Outer Polepiece Shroud Geometry on Bipolar Lens and Studying its Properties

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https://doi.org/10.25130/tjps.v27i4.38

ARTICLE INFO.

Article history:

-Received: 31 / 5 / 2022

-Accepted: 21 / 7 / 2022

-Available online: / / 2022

Keywords: Shroud, bipolar lenses, properties of optics, chromatic aberration, spherical aberration, resolving power.

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ABSTRACT

In this paper, several innovative designs of axially symmetrical magnetic dipole lenses, which are bipolar lenses with different geometries, were designed, where the outer pole arm indicated by the symbol was changed (hp) with current density (σ = 6 A/mm^2) and after designing them, the engineering variables were studied in terms of magnetic properties, then the optical properties were studied in terms of aberrations, i.e. the coefficient of spherical aberration and the coefficient of chromatic aberration, where it was found that there were slight changes in the corresponding spherical aberration As for chromatic aberration and focal length, no noticeable changes occurred.

Introduction

Double polepiece magnetic lens: It is a large circular coil surrounded by an iron circle and in its axis are two iron poles of a magnetizing iron material with high magnetic permeability, separated by a vacuum gap of width S in which the magnetic field is concentrated. Surrounding the coil and the electrodes in the iron circuit prevents the magnetic flux from leaking out of the lens. The iron core penetrates an axial bore of diameter d along the axis of the coil to allow the beam of charged particles to pass through it into the air gap. The axial magnetic field generated by the passage of an electric current in the coil is confined within this vacuum gap to form the lens' breaking force for the charged particle beam. If the axial bore diameter is equal at both poles, then the magnetic lens is known as a symmetrical double polepiece lens. If the geometric structure of the lens around the plane of symmetry is the same, the location of the maximum end of the axial magnetic flux density B_{max} will be in the middle of the vacuum gap s.

The optical properties of this type of lens are expressed in terms of the s/d ratio. If the diameter of the axial aperture d for both poles is not equal, that is, d1≠d2, then the lens is called an asymmetrical double polepiece lens [1].

Aberrations of Magnetic Lenses the importance of aberration depends on the function of the magnetic lens. For example, spherical aberration and chromatic aberration are the two most important defects in objective lenses, because the limits of resolution in electronic optics are determined by the wavelength of electrons and spherical aberration.

To obtain a beam of electrons with a short wavelength λ, a high voltage is used to accelerate the electrons, as the kinetic energy of the electrons is given by the following relationship:

$$\frac{1}{2}mv^2 = eV_r \dots\dots\dots (1)$$

$$\lambda = h/mv \dots\dots (2)$$

And by connecting equation (1) with de Broglie equation (2) ؛We get a relationship in which the wavelength λ measured in nanometers is related to the acceleration voltage measured in volts, which is:

$$\lambda(nm) = \sqrt{1.5/V_r} \dots\dots\dots (3)$$

Spherical aberration is the most important image defect of the objective lens, which causes every point in the body image to appear as a disk in the image called a disk of confusion. The reason for the appearance of this aberration is due to the difference in the breaking strength of the lens of the electronic beam far from the lens axis from the one close to it as a result of the change in the curvature of the magnetic field lines with the distance from the optics axis of the lens. This results in an increase in the strength of the lens breaking the electronic beam.

Chromatic aberration it is one of the most important defects of the objective lens, and the effect of this aberration in the case of glass lenses is not the same as in the charged particle. The optimal choice of the type of glass used for the lens can correct this defect to an acceptable extent, while in electronic lenses there is no way to fix this defect, but it can only be reduced. It occurs due to the difference in the speed of the electrons or the change of the magnetic field as a result of the instability of the coil current of the magnetic lenses [2,3].

In 2017, Taleb Mohsen Abbas and Qutaiba Ahmed Sahi presented the characteristics of the proposed lenses in their research. They studied the objective focal characteristics of symmetric magnetic lenses, where the lens was bipolar, using a computer program for the disposal of explosive ordnance [4], Najwan Hussein Noman presented a study in 2018 on Some important geometric properties in lenses, such as bore diameter, air gap length, magnetic flux density, and focusing power. Magnification, spherical aberration, half width and minimum length, which increased the width of the air gap and diameter of the lens, also increased the ampere cycles. Also, a linear increase in magnetic alignment intensity [5]. Marwa Thamer Al-Shamma presented in 2019 two versions of magnetic lens geometry and non-equivalent subject [6].

The aims of present research is to study the characteristics of magnetic and optical properties of the proposed designs to obtain the best design among the proposed designs in terms of focal length , spherical and chromatic aberration using computer programs، Such as (EOD) [7] and finite element method (FEM). However, calculate the magnetic field distribution (CMFD-FEM) program has been used to calculate [8], were as Magnetic Electron Lens Optical Properties Program (MELOP) has been used to investigate the optical properties of suggested lenses [9].

The Practical Part

In this research, 5 designs of bipolar lenses were designed and the height of the outer pole arm was changed for the purpose of obtaining the best design among those designs in terms of studying the properties of magnetic lenses and their optical properties in terms of aberration coefficients, whether spherical aberration or chromatic aberration, as well as the focal length of innovative lenses.

Where it was studied using a graphical program to know the optical and magnetic properties of the innovative designs of bipolar lenses with a current density of (σ = 6 A/mm²). Its optical properties in terms of aberration (spherical aberration and chromatic aberration) and focal length.

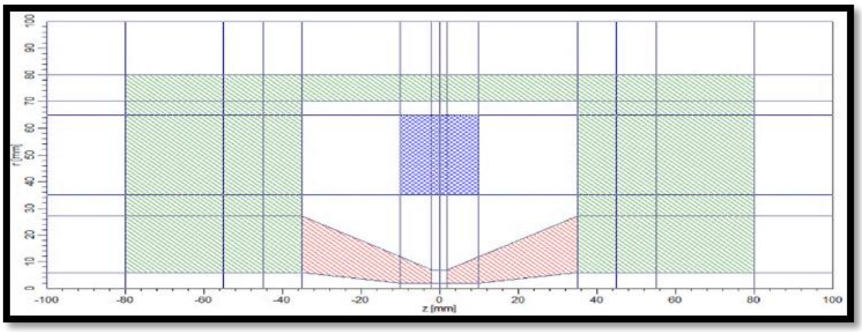

Fig. 1: Cross-section of magnetic bipolar lens prototype.

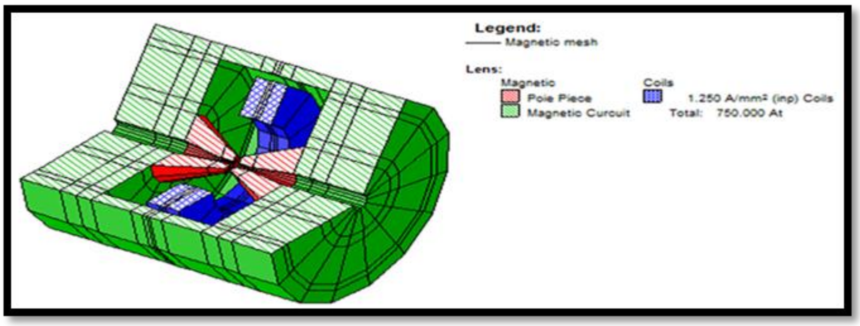

Fig. 2: 3-D magnetic bipolar prototype lens.

To calculate the magnetic flux density, you must know how to calculate the magnetic field through the equations for magnetic field strength and flux density mentioned below.

$$H = J + \frac{dp}{dt} \quad ....(4)$$

If the current is at rest, then the displacement current p is zero, then

$H = J$, $H = \frac{A}{m}$
flux density B
$H = \frac{B}{\mu}$ ……(5)
In the vacuum or in the air, $\mu = 0 \rightarrow H=B$ [10,11].

The figure (3) below shows the distribution of the axial magnetic flux density (Bz) as a function of the distance (Z) for lenses designed with a current density (σ = 6 A/mm^2).

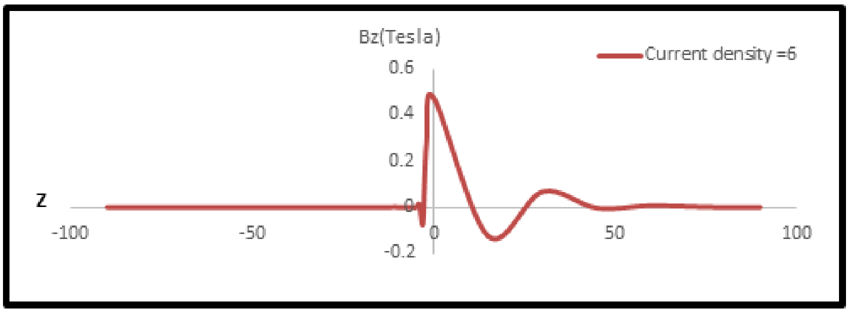

Fig. 3: Distribution of axial magnetic Flux (B_z) as a function of designed lens at current density of (σ = 6 A/mm^2).

Optical Properties
To calculate the optical properties of the proposed designs, where the aberration coefficient of spherical aberration was calculated, as well as the coefficient of chromatic aberration and the focal length as well. The drawings below show the knowledge and study of the optical properties of the proposed lenses, and this was done when using different current densities and (σ = 6 A/mm^2). Figure 4 shows the relationship between the rectified voltage V_r and the chromatic aberration C_c and its value in the table (1).

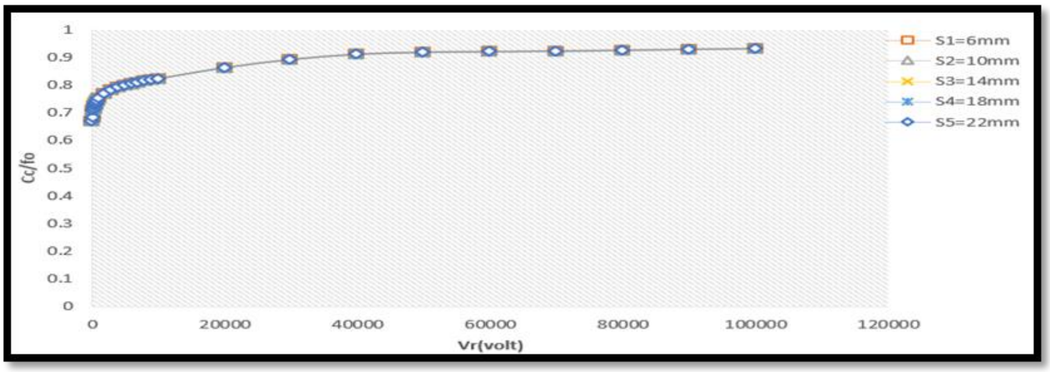

Fig. 4: Chromatic aberration relative to focal length as a function of relative corrected acceleration voltage V_r at a current density of (σ = 6 A/mm^2).

Figure 4 as well as table (1) show that there are no clear changes have been done during in a chromatic aberration and the resolving power investigated lenses, well spherical has been change.

Where Figure 5 shows the relationship between the rectified voltage V_r and the spherical aberration C_s and its value ... at current densities of (σ = 6 A/mm^2).

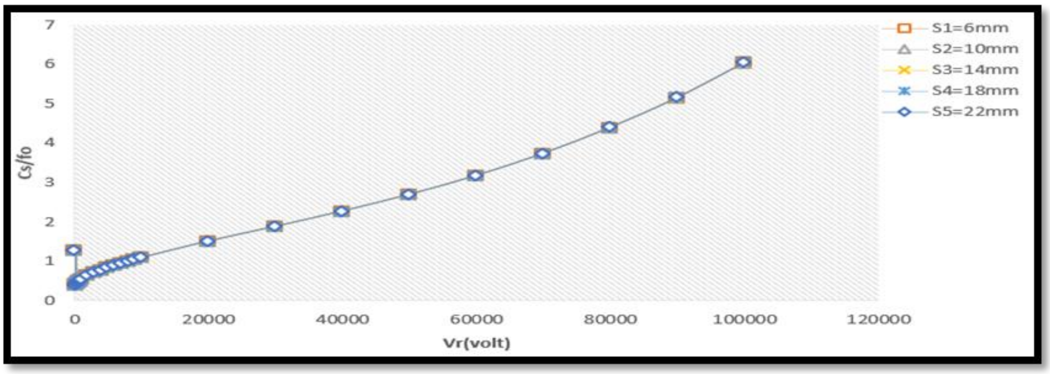

Fig. 5: Spherical aberration relative to focal length as a function of relative corrected acceleration voltage V_r at a current density of (σ = 6 A/mm^2).

Through the observation to Figure 5 as well as the table (1), it is clear that the relationship between the corrected voltage and spherical aberration is that there are slight changes as shown above, despite these slight changes, they mean a lot, because the spherical aberration has been reduced, and this decrease or decrease in aberration It means a lot, meaning that this change resulted from a decrease in spherical aberration and therefore the lens was improved.

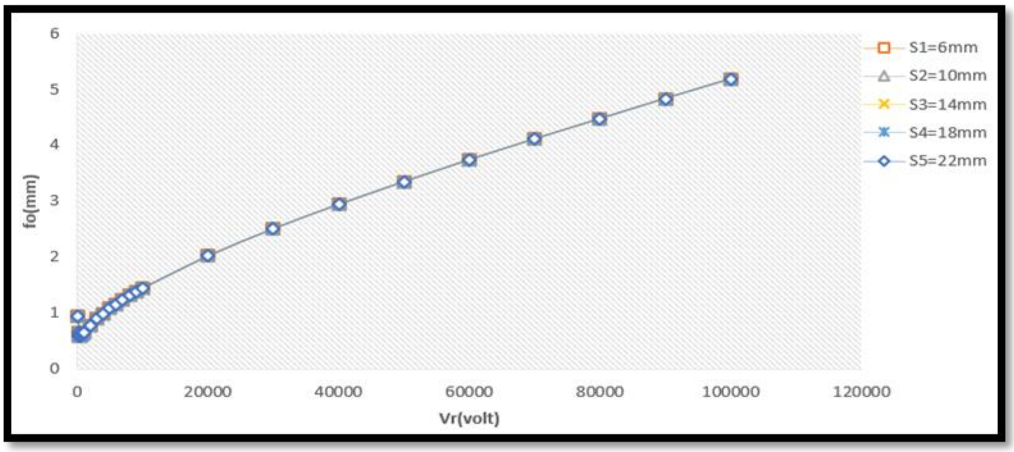

Fig. 6: Focal length as a function of relative corrected acceleration voltage V_r at a current density of (σ = 6 A/mm^2).

By noting Figure (6) as well as the table, it is clear that the relationship between the relatively corrected voltage and the focal length is that there are no changes.

Table 1: Comparison btween relatively corrected acceleration voltage with C_c/f_o, C_s/f_o and f_o at a current density of (σ = 6 A/mm^2).

hp	V_r (kv)	C_c/f_o (σ = 6 A/mm^2)	C_s/f_o (σ = 6 A/mm^2)	f_o (σ = 6 A/mm^2)
6	60	0.807487	3.179144	3.74
	70	0.815085	3.742092	4.11
	80	0.821029	4.400447	4.47
	90	0.824017	5.15735	4.83
	100	0.830116	6.044402	5.18
10	60	0.807487	3.179144	3.74
	70	0.815085	3.742092	4.11
	80	0.821029	4.39821	4.47
	90	0.824017	5.15528	4.83
	100	0.830116	6.042471	5.18
14	60	0.807487	3.179144	3.74
	70	0.815085	3.742092	4.11
	80	0.821029	4.400447	4.47
	90	0.824017	5.15735	4.83
	100	0.830116	6.042471	5.18
18	60	0.807487	3.181818	3.74
	70	0.815085	3.744526	4.11
	80	0.821029	4.400447	4.47
	90	0.824017	5.15942	4.83
	100	0.830116	6.046332	5.18
22	60	0.807487	3.181818	3.74
	70	0.815085	3.744526	4.11
	80	0.821029	4.402685	4.47
	90	0.824017	5.161491	4.83
	100	0.830116	6.048263	5.18

Conclusions

It is concluded from this work, that there is no noticeable changes in the proposed lens by changing the geometry of the outer shroud of the bipolar lens polepiece with a current density (σ = 6 A/mm^2). THIS RESALT ensures that there is no need to changing the geometry of the outer shroud of the bipolar lens polepiece in this studied dimension. Another dimensions should be studied in the future to make shore if there is an effect or not.

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تأثير الشكل الهندسي لذراع رأس القطب على العدسة ثنائية القطب ودراسة خواصها

حفصة يقظان إسماعيل ، رافع يونس جاسم الصالح ، هناء عيسى جاسم

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الملخص

في هذا البحث تم تصميم العديد من التصميم المبتكرة للعدسات المغناطيسية ثنائية القطب المتناظرة محوريا، وهي عدسة ثنائية القلب ذات أشكال هندسية مختلفة، حيث تم تغيير فراغ التعلم الخارجي المشار إليه بالرمز (hp) بكثافة تيار ($\sigma = 6$ A/mm^2) وبعد تصميمها تمت دراسة المتغيرات الهندسية من حيث الخواص المغناطيسية، ثم تمت دراسة الخواص البصرية من حيث الزيوغ، أي معامل الزيغ الكروي ومعامل الزيغ اللوني حيث تبين أنه حصل تغييرات طفيفة في الزيغ الكروي يقابله في الزيغ اللوني و البعد البؤري لم يحصل تغييرات ملحوظة.