Study of the Objective Focal Properties for Asymmetrical Double Polepiece Magnetic Lens

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Abstract

In this study the design of asymmetrical double polepiece magnetic lens and study their objective focal properties are presented by studying the effect of diameter of the axial air-gap on the magnetic field generated between lens polepieces is presented. The calculations were performed by using codes written with FORTRAN language to calculate the magnetic flux density and the optical properties for the double polepiece magnetic lenses.

Keywords: objective focal properties, Asymmetrical Double polepiece magnetic lens

1. Introduction

In the recent years the considerable computer power makes easy to design electromagnetic lenses in which this task was difficult for the designer previously to solve the mathematical functions numerically. The magnetic and electric flux distribution function can now easily and accurately generate by the aid of computer calculations before we start the practical design [1]. This advances in computer simulations helps to solve a lot of complicated designs which was impossible to implement previously.

Munro 1973, have used the finite element method (FEM) to write packages used to calculate the magnetic and electric field for symmetric rotational electromagnetic lenses[2].

The design of the electrmagnetic lenses previously depends on the hypothetical mathematical models for the field distribution like the Bell shaped model and on the experimental fields which have high percentage error.

The steps needed to design the electromagnetic lenses numerically are:[3]

1. The finite element method (FEM) used to calculate the axial magnetic flux distribution B_z for the proposed design.
2. Calculation of the axial ray tracing (trajectory) by solving the ray tracing equation numerically using (Runge-Kutta Method).
3. Calculation of the chromatic factors for the proposed model by using (Simpson method) for each value of the axial magnetic field distribution and axial ray tracing.

2. Test lens

Figure 1 shows a diagram and geometrical dimension for the test lens suggested in the present work. The lens consists of coil with sectional area of ($A=30\ cm^2$) and it had two magnetic polepieces the left pole have cylindrical shape with conic face, while the right pole for the lens takes the shape of plate in which axial bore with width (S=10mm) separate the two polepieces.

Penetrating the poles there is axial bore with diameter of (D=10 mm). The coil is surrounded with magnetic soft iron. Figure 2 shows the mesh on the upper half of the test lens, from this figure it is noticed that the mesh lines are very few at the edges of the lens, due to the unimportance of the magnetic field distribution in this region, while the distribution of these lines increase near to the poles and the region between them, due to the importance of this region in determination of the optical properties for the lens. This test lens studied at constant excitation parameter at (NI=500 A.t).

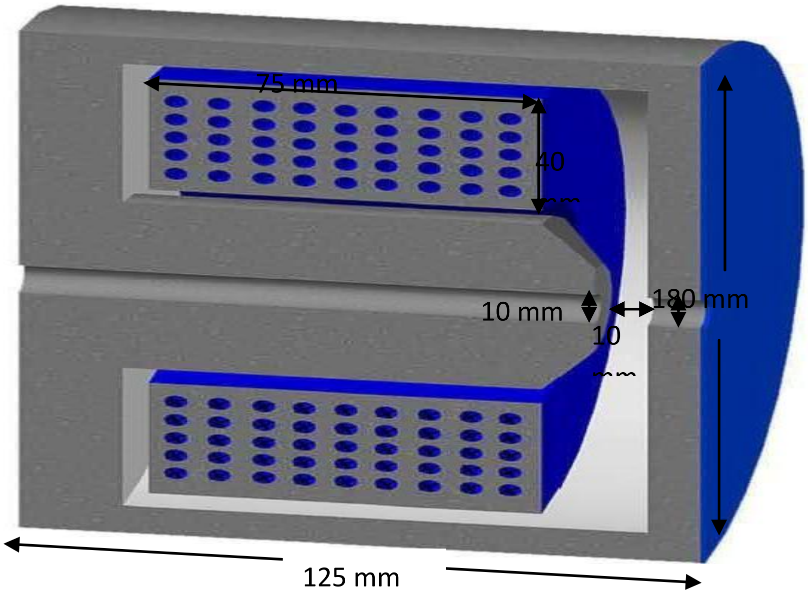

Fig.1: Asymmetrical double polepiece magnetic lens (test lens).

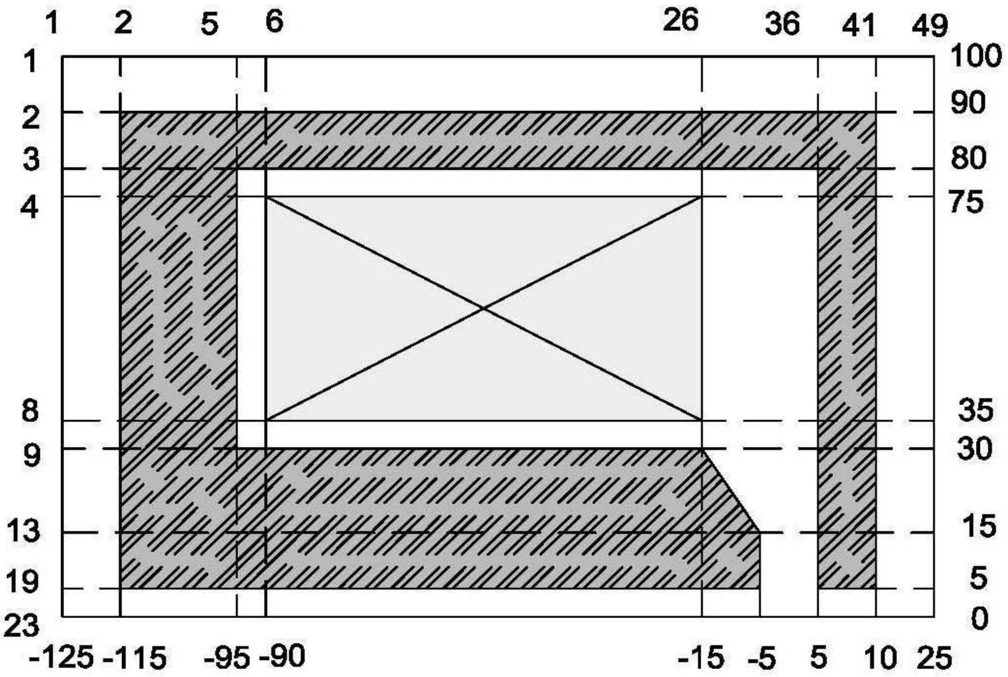

Fig.2: The line distribution of the mesh on the upper half of the asymmetrical double polepiece magnetic lens (test lens).

3. The effect of change of the axial bore diameter(D)

The effect of the diameter of the axial bore (D) on the test lens is studied and shown in figure (3) on the axially magnetic field and consequently on the objective optical properties where different values have been used in this study and they are (10, 15, 20 and 25 mm).

4. The distribution of the axially magnetic field (B_z)

Figure 3 presents the axially magnetic field distribution B_z for different values of the axial bore diameter (D), from the figure it is noticed that the increase of the axial bore diameter reduces the magnetic flux density in the air-gap and this leads to decrease of the maximum value of the magnetic field density B_{max} with the increase of the half-width (w) as shown in figures (4) and (5). This behavior can be explained that when axial bore diameter (D) increase leads to increase the region of the magnetic field distribution and therefore reduces the strength of the magnetic field in this region and the half-width increase.

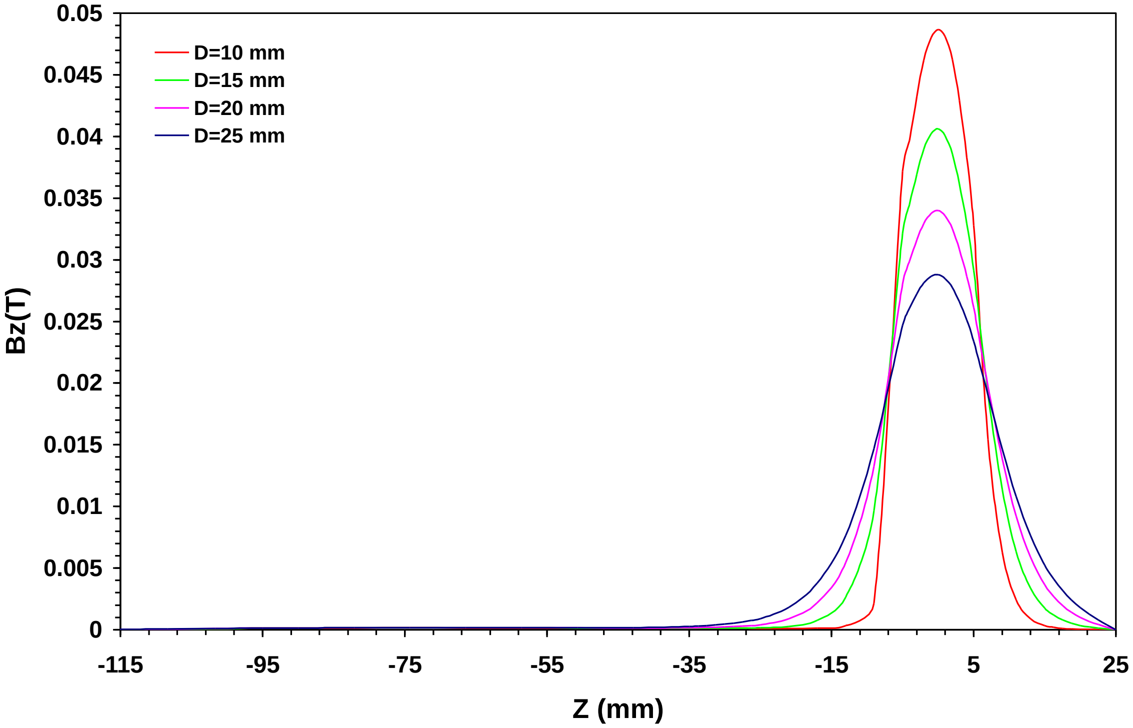

Fig.3: The axially magnetic field flux (B_z) for test lens for different values of axial bore diameter (D).

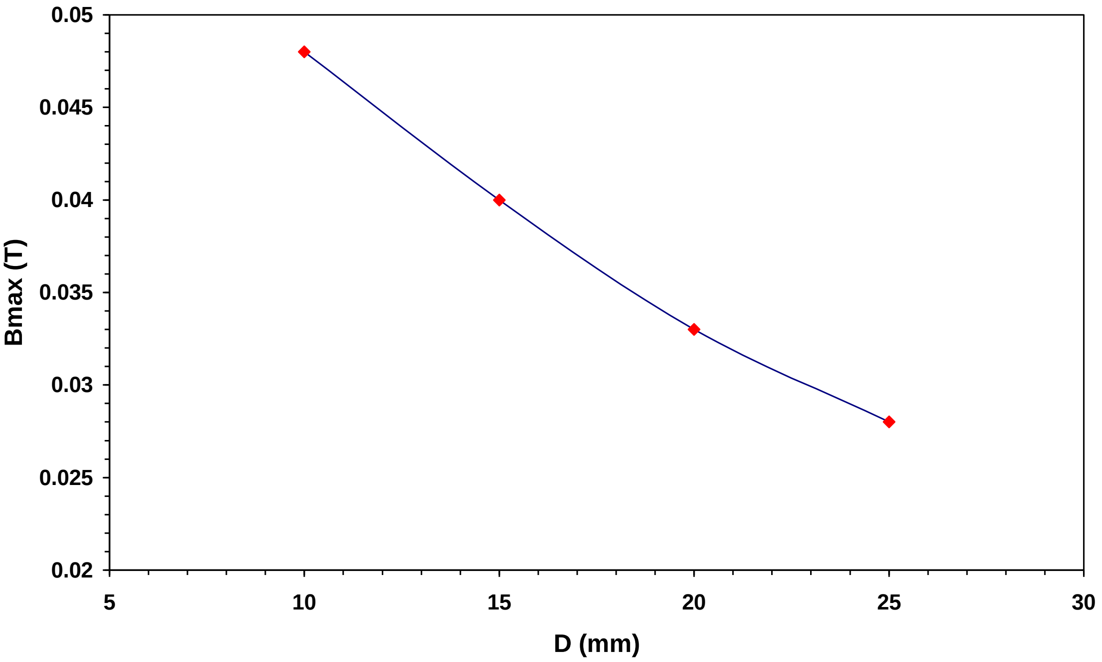

Fig.4: The variation of the maximum of the axially magnetic field flux (B_{max}) with the increase of axial bore diameter (D) for the test lens.

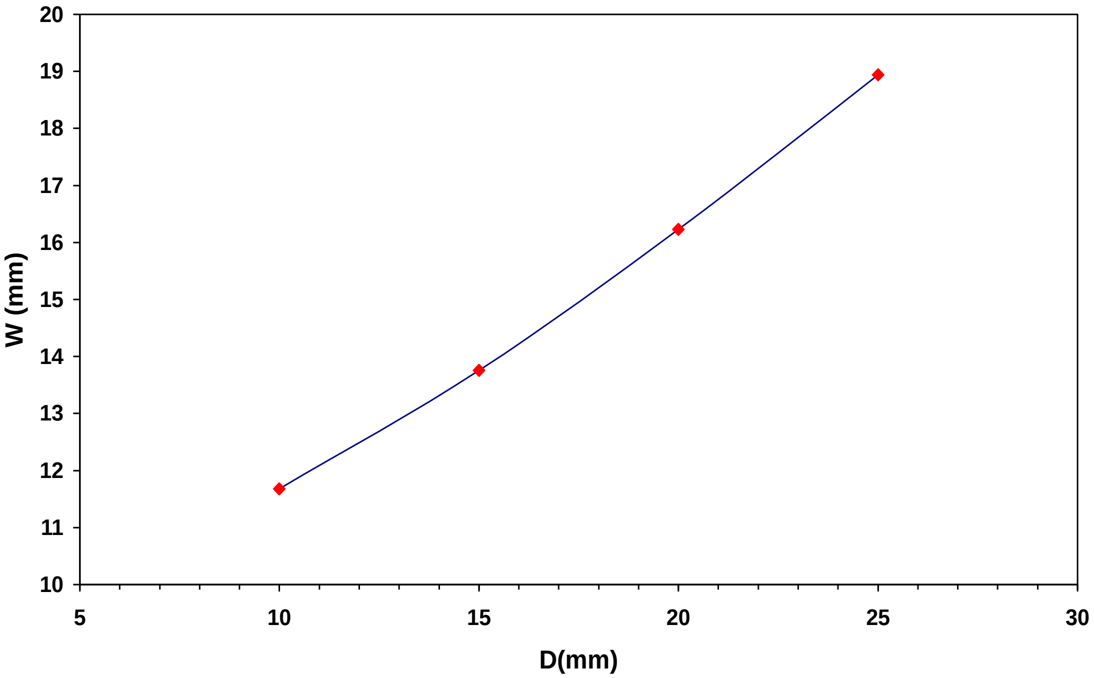

Fig.5: The variation of the half-width of the axially magnetic field with the increase of axial bore diameter (D) for the test lens.

5. Objective optical properties

Figures (6), (7) and (8) shows respectively, the variation of the objective focal length (fo), and spherical aberration parameter (Cs) and chromatic aberration parameter (Cc) as a function of the excitation parameter (NI/SQRT(Vr)) for different values of the axial bore diameter (D). From these figure we have noticed that all these parameters decrease with the increasing for he excitation parameter and also they increase by increasing the axial bore diameter (D) at constant value of the excitation parameter as shown in figures (9), (10) and (11), where it is shown that the increase of the axial bore diameter (D) at excitation parameter NI/SQRT(Vr)=20 leads to increase the values of the objective focal length fo, spherical aberration parameter Cs and chromatic aberration parameter Cc. This increase can be explained as the increase of the axial bore diameter (D) leads to increase the half-with of the magnetic field and this will in turn changes the electron beam trajectory in which its gradient along the axis will decrease with the increasing of the axial bore diameter (D) and will refract in different regions far from the lens.

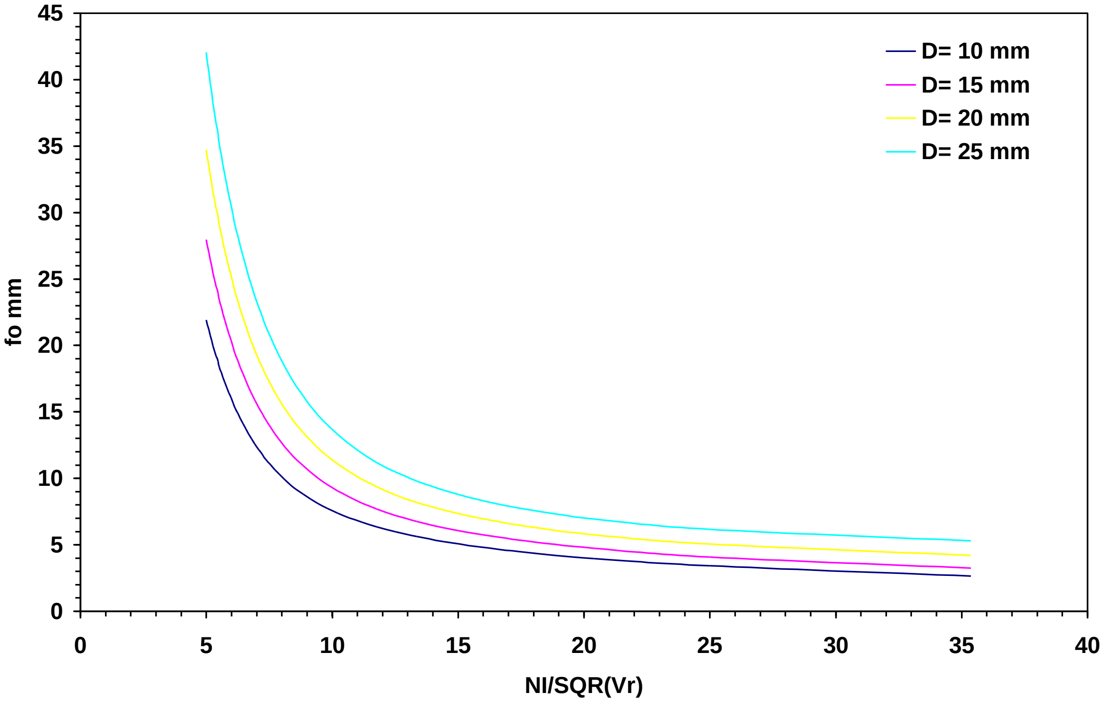

Fig.6: The variation of the objective focal length (fo) with the excitation parameter (NI/SQRT(Vr)) for different values of axial bore diameter (D).

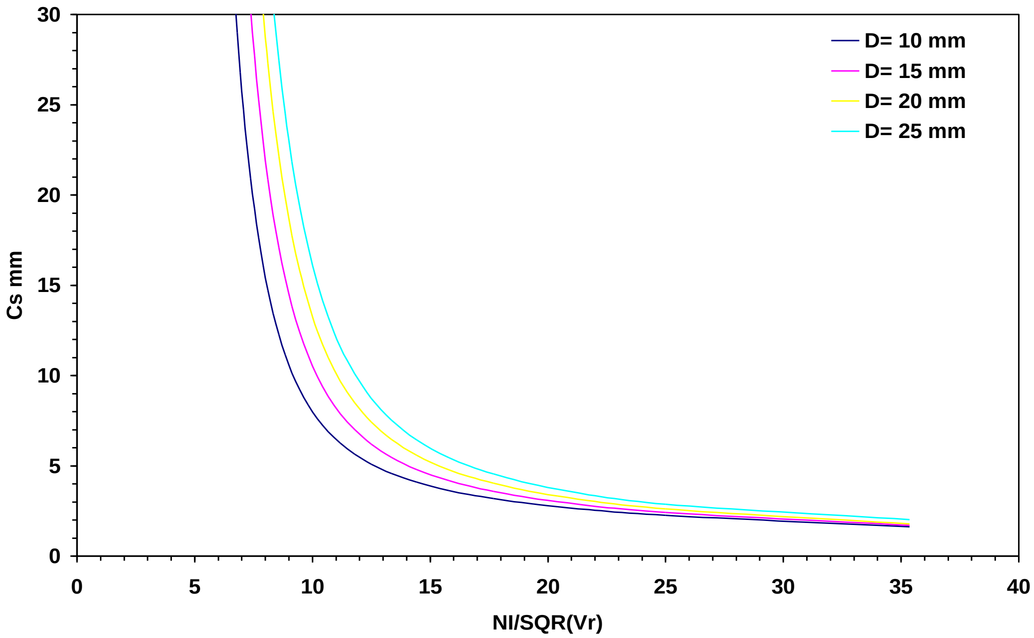

Fig.7: The variation of the spherical aberration parameter (Cs)with the excitation parameter (NI/SQRT(Vr)) for different values of axial bore diameter (D).

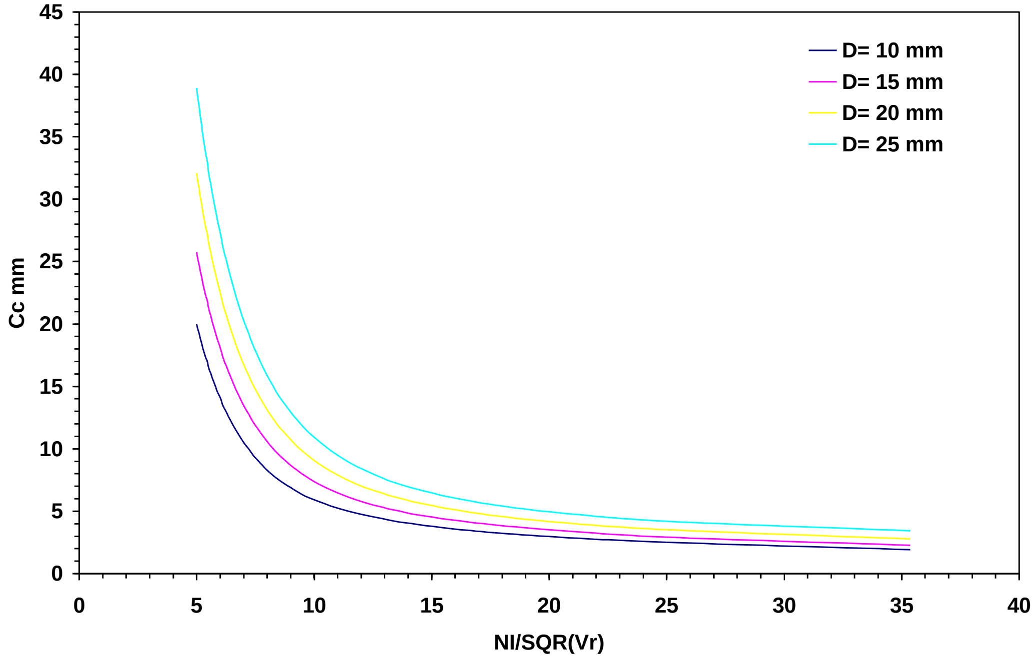

Fig.7: The variation of the spherical aberration parameter (Cs)with the excitation parameter (NI/SQRT(Vr)) for different values of axial bore diameter (D).

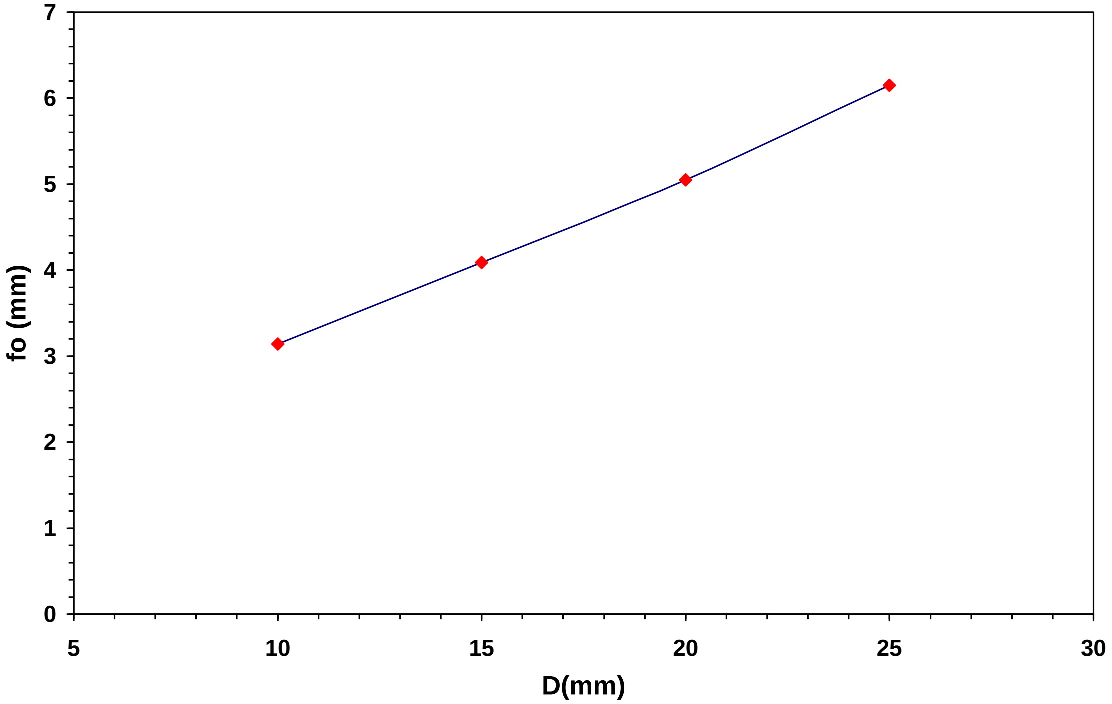

Fig.9 : The variation of the objective focal length (fo) with the axial bore diameter (D) at fixed value of the excitation parameter (NI/SQRT(Vr))=20

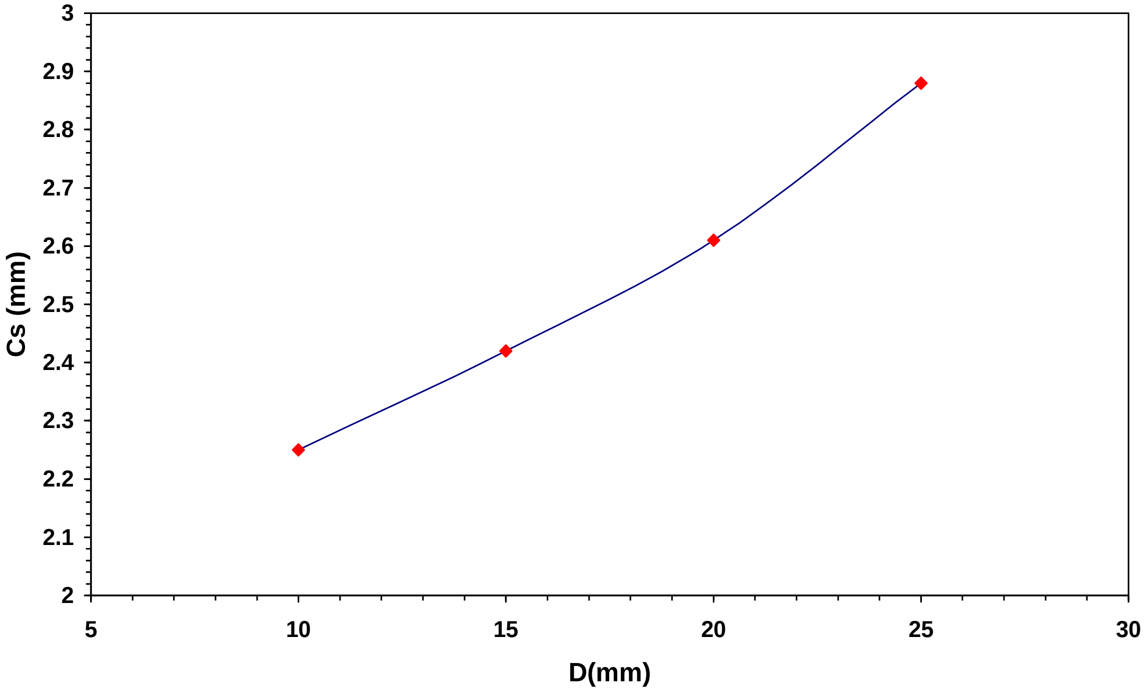

Fig.10 : The variation of the spherical aberration parameter (Cs) with the axial bore diameter (D) at fixed value of the excitation parameter (NI/SQRT(Vr))=20

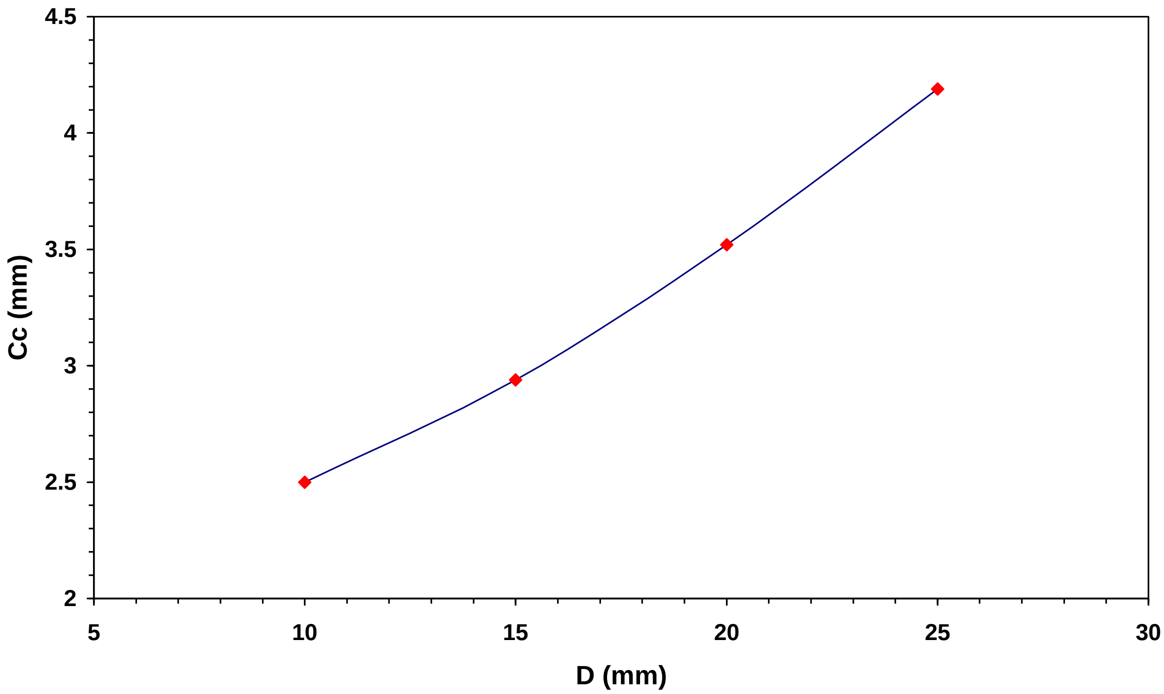

Fig.11 : The variation of the chromatic aberration parameter (Cc) with the axial bore diameter (D) at fixed value of the excitation parameter (NI/SQRT(Vr))=20

6. Conclusions

The most important conclusions were drawn from this study can be summarized as follows:

1. Decreasing of the maximum value of the axial magnetic field (B_{max}) as the value of the axial bore diameter (D) increase for the lens and is accompanied with increase of the half-width of the magnetic field and vice versa.
2. The values of the objective foal length (f_o), spherical aberration parameter (C_s) and chromatic aberration parameter (C_c) with the increase of the excitation parameter.
3. **3.** At constant excitation parameter the aberration parameters increase by increasing the value of the axial bore diameter and this due to the increase of the half-width for the magnetic field which in turn reduces the gradient of the electron beam inside the lens.

References

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