Effect of pole piece shape on properties of the symmetrical objective magnetic lenses

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Abstract:

A theoretical computational study has been carried out to describe the optimization for the symmetrical double pole piece magnetic lenses, under the absence of magnetic saturation by analysis. The study depends on design of pole piece shape for double pole piece magnetic lenses. By study the variation of the parameters air-gap width(S), axial bore diameter (D) and lens excitation (NI) for the tapered cylindrical, the tapered spherical and conical double pole piece magnetic lenses. The magnetic field distribution has been used to study the objective focal properties. Double pole piece magnetic lens with tapered spherical pole piece has shown the most favorable objective properties among the three unsaturated lenses.

الخلاصة

تم إجراء دراسة نظرية حاسوبية تصف الامثلية للعدسات المغناطيسية ثنائية القطب المتناظرة ، غير المشبعة مغناطيسيا بطريقة التحليل.وقد اعتمدت هذه الدراسة على تصميم شكل القطب للعدسات المغناطيسية ثنائية القطب ،وبواسطة تغير كل من عرض الفجوة الهوائية وقطر الفتحة المحورية والتهيج للعدسة ثنائية القطب الاسطواني الناقص والكروي الناقص والمخروطي .ولقد استخدمت توزيعات المجال المغناطيسي لحساب الخواص البؤرية الشيئية .وقد تبين آن أفضل الخواص الشيئية للعدسات غير المشبعة الثلاثة هي العدسة المغناطيسية ثنائية القطب الكروي.

1-Introduction

To improve properties of the objective magnetic electron lenses, it is necessary to reduce the most important of objective magnetic electron lenses defects (the spherical and chromatic aberration). Design of pole piece shape to deduce on high maximum flux density distribution (B_{max}), low half width in order to be used evaluation the objective optical properties where the spherical aberration is chief defect in the objective lens. The integral of the spherical aberration coefficient of axially symmetric magnetic lens is given by the formula [Munro, 1975].

$$C_s = \frac{\eta}{128 V_r} \int_{z_o}^{z_i} \left[\left(\frac{3\eta}{V_r} \right) + B_z^4 \, r_\alpha^4 + 8 \, B_z'^2 \, r_\alpha^4 - 8 \, B_z^2 \, r_\alpha^2 \, r_\alpha' \right] dz \quad \ldots\ldots(1)$$

where η is the charge-to-mass quotient, V_r is the relativistically corrected accelerating voltage, B_z is the axial magnetic field, r_α is the solution of the paraxial ray equation and zi, zo are the object and image planes. Chromatic aberration is the result of any variation in the wavelength of an accelerated electron beam forming an image, and is given by [Crivet,1972]

$$C_c = \frac{\eta}{8 V_r} \int_{z_o}^{z_i} B_z^2 \; r_\alpha^2 \; dz \quad \ldots\ldots\ldots\ldots\ldots\ldots(2)$$

There are several attempts to minimize the spherical and chromatic aberration of the objective magnetic lenses for example

[Liebman , 1951] , [Riecke and Ruske ,1966] , [Al-Nakeshli et at, 1983] ,[Kamel,1989], [Al-saady, 1990], [AL-Shafi'I,2001]

[Al-Bahrani, 2004] has been studied four the symmetrical double pole piece magnetic lenses. The pole piece of different geometries, namely, the cylindrical, tapered cylindrical, the spherical, and the tapered spherical. The aim of present work, is to deals with the optical properties of the tapered cylindrical and the tapered spherical pole piece magnetic lenses that proposed by [Al-Bahrani, 2004]

and companion with that of a conical pole piece magnetic lenses that proposed by [Munro,1975].

2-Test lenses

In the present investigation, the symmetrical double pole piece magnetic lenses: conical, the tapered cylindrical and the tapered spherical as shown in fig (1). Where the axial bore diameter (D1=D2=10mm) , air-gap width(S=10mm) and lens excitation (NI=500 A.t) are tested .

3- Calculation and Discussion

In order to study the axial magnetic flux density distribution and the objective focal properties for example objective focal length (fo), spherical aberration coefficient (cs) and chromatic aberration coefficient (cc) as a function for excitation parameter ($NI/V_r^{\frac{1}{2}}$) For different parameters.

3-1 The conical pole piece

A - Effect of air-gap width (S) on an objective optical properties

The optical properties are investigated by giving air-gap widths

S = 6, 8, 10, 12, 14 mm keeping the other parameters constant D=10mm and NI =500A.t.

Figure (2-a) shown decreasing of air-gap width (S) effect increase maximum flux density distribution (Bmax) and decrease of objective focal length (fo), spherical aberration coefficient (cs)and chromatic aberration coefficient (cc) as a function at excitation parameter($NI/V_r^{\frac{1}{2}}$) as shown in fig (5-a),(6-a),(7-a) respectively .

Table (1) shown the effect of air-gap width (S) on maximum flux density distribution (Bmax) and objective focal properties for test lens at excitation parameter $NI/V_r^{\frac{1}{2}}$=20 A.t. that increasing air-gap width (S) effect decrease maximum flux density distribution (Bmax) and increase objective focal length (fo), spherical aberration coefficient (cs)and chromatic aberration coefficient (cc) .

B - Effect of axial bore diameter (D) on an objective optical properties

The effect of axial pore diameter (D) has been investigated for various Values D=6 ,8 ,10 ,12 ,14 mm keeping the other parameters constant S=10mm and NI =500A-t .

Figure(2-b) shown decreasing of axial pore diameter (D) effect increase maximum flux density distribution (Bmax) and decrease of objective focal properties (objective focal length (fo),spherical aberration coefficient (cs) and chromatic aberration coefficient(cc)) as a function at excitation parameter $NI/V_r^{\frac{1}{2}}$ as shown in figure (5-a),(6-a),(7-a) respectively .

Table (2)shown the effect of axial bore diameter (D) on maximum flux density distribution Bmax and objective focal properties for tast lens at excitation parameter $NI/V_r^{\frac{1}{2}}$ = 20 A.t. That decreasing axial bore diameter effect increase maximum flux density distribution (Bmax) and decrease objective focal length (fo), spherical aberration coefficient (cs) and chromatic aberration coefficient (cc).

C- Effect of lens excitation (NI) on an objective optical properties

The excitation lens (NI) is giving the following values NI=400,500 ,600 ,700 ,800 A.t to investigate its effect on the flux density distribution and optical properties , by maintaining to other parameters constant S=10mm and D =10 mm. the results show the lens excitation not effect on maximum flux density distribution Bmax and objective focal properties.

3-2 The tapered cylindrical and tapered spherical pole piece

The tapered cylindrical and tapered spherical pole piece have same changes that explain in conical pole piece Figures(3-a),(3-b),(4-a),(4-b) are shown decreasing (S),(D) effect increase (Bmax) respectively . decrease of objective focal properties as

function for $NI/V_r^{\frac{1}{2}}$ are shown in figures (5-b),(6-b),(7-b),(5-c),(6-c),(7-c) respectively.

Tables (3), (4), (5), (6) shown effect (S)and (D) on Bmax and objective focal properties for test lens at excitation parameter $NI/V_r^{\frac{1}{2}}$ = 20 A.t. That decreasing axial bore diameter and air-gap width effect increase maximum flux density distribution (Bmax) and decrease objective focal length (fo), spherical aberration coefficient (cs) and chromatic aberration coefficient (cc).

4- Conclusion

In the present investigation , the tapered spherical pole piece can be using to assign the magnetic field for object magnetic lenses favorable properties in comparison with other pole piece Because if has reduce objective focal length (fo) , spherical aberration coefficient (Cs) and chromatic aberration coefficient(Cc).

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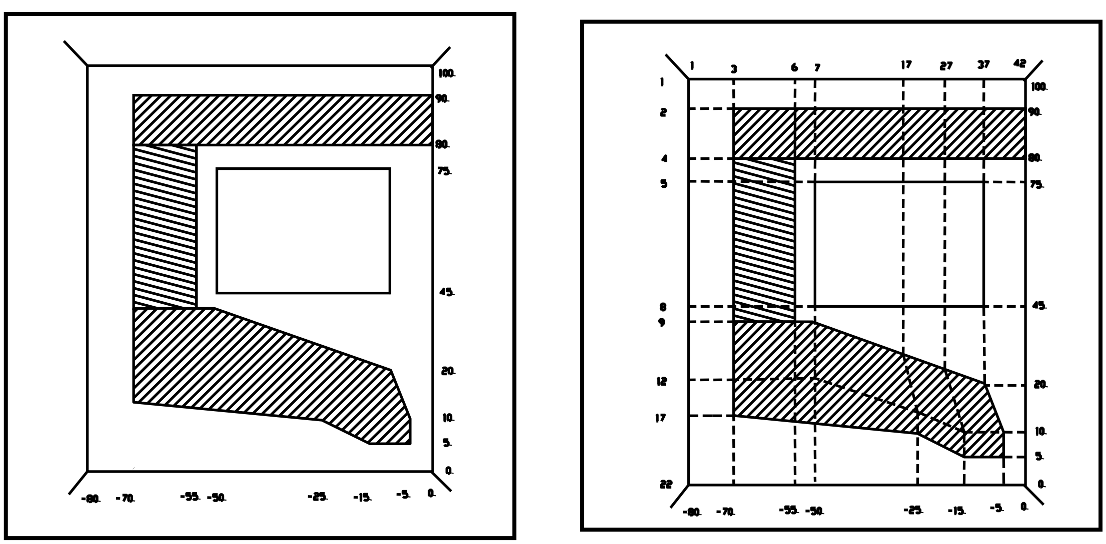

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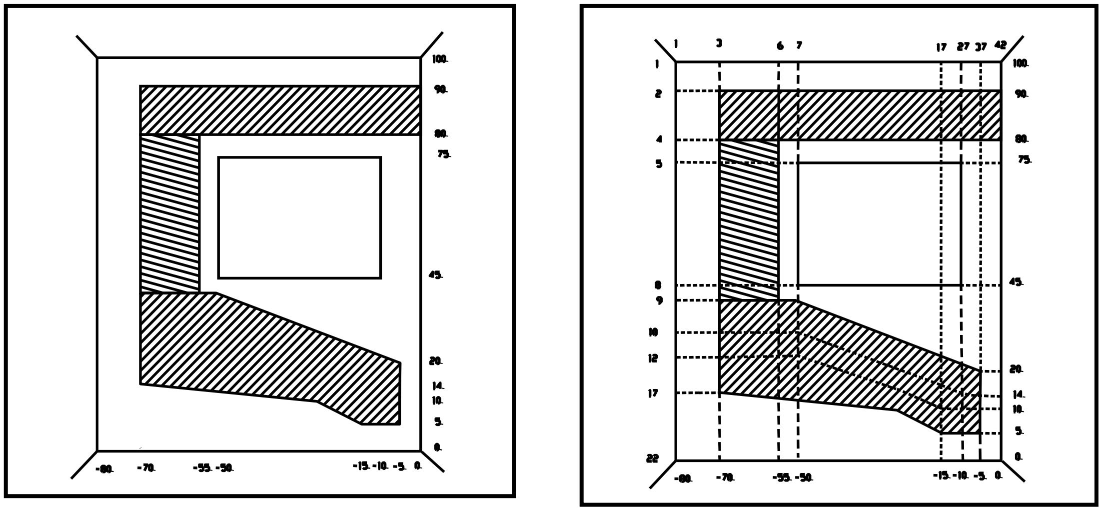

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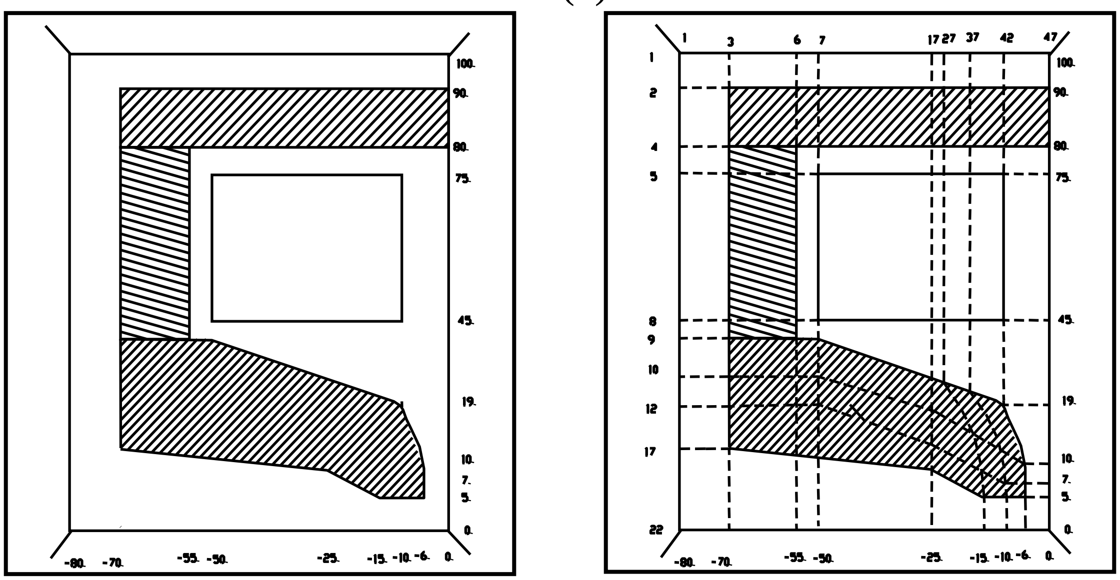
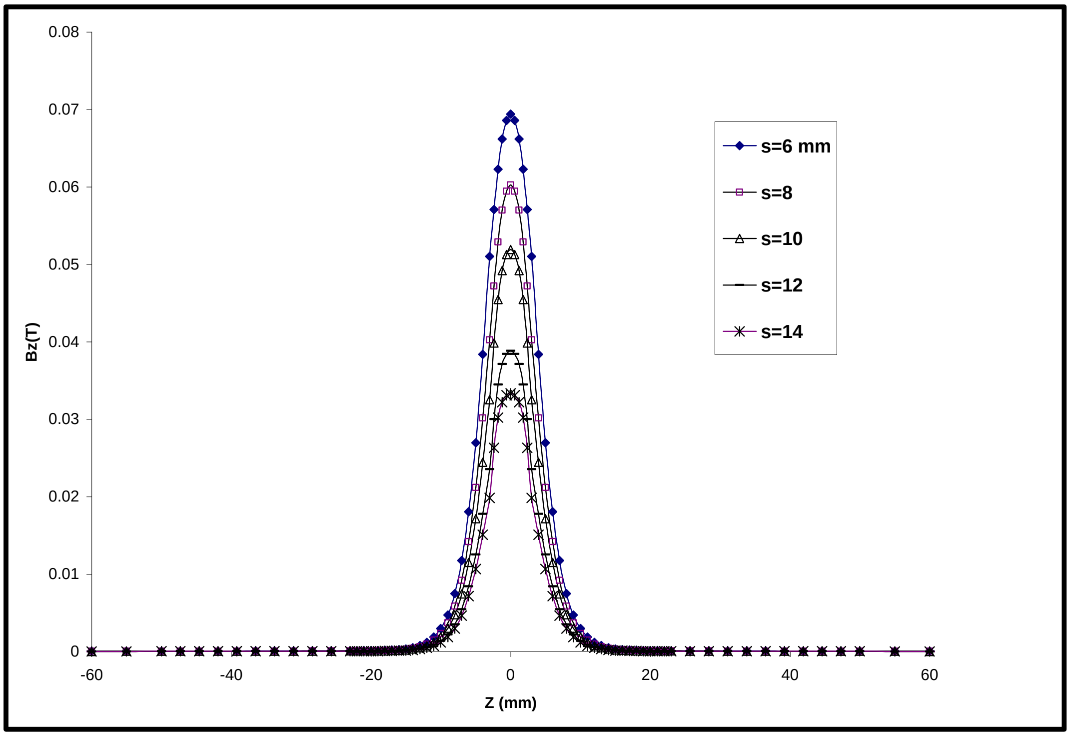


(c)

Figure (1) The left higher quarter with symmetrical double pole piece magnetic lenses: (a) conical, (b) the tapered cylindrical, (c) the tapered spherical [Al-Bahrani, 2004].



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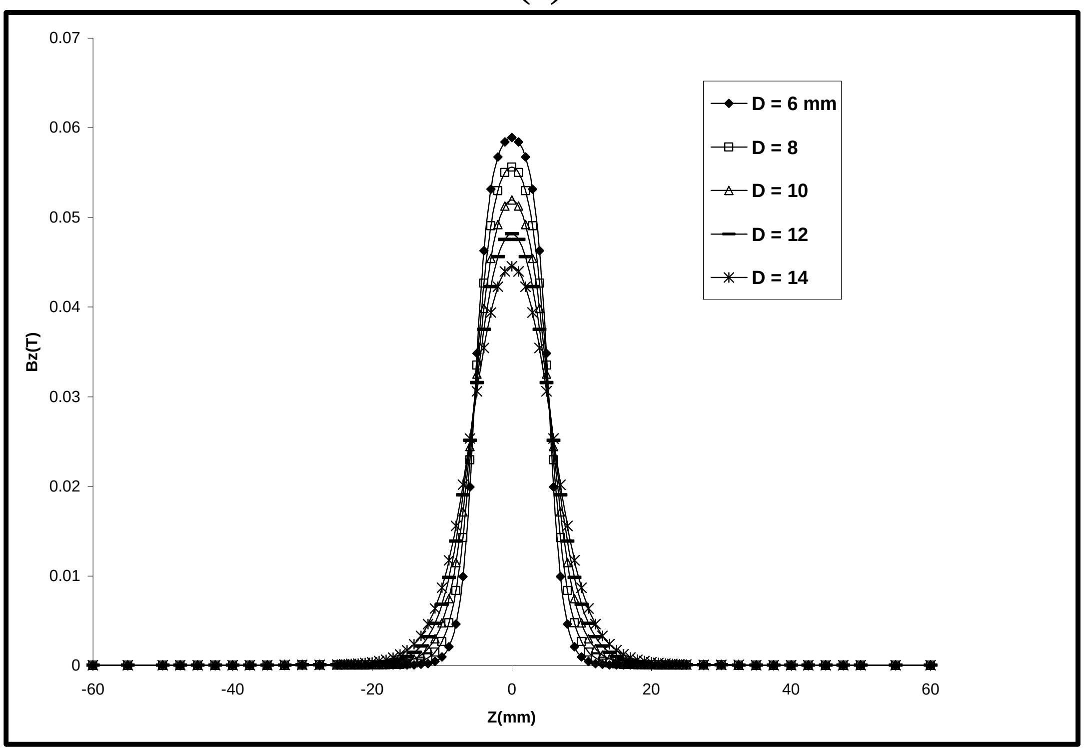
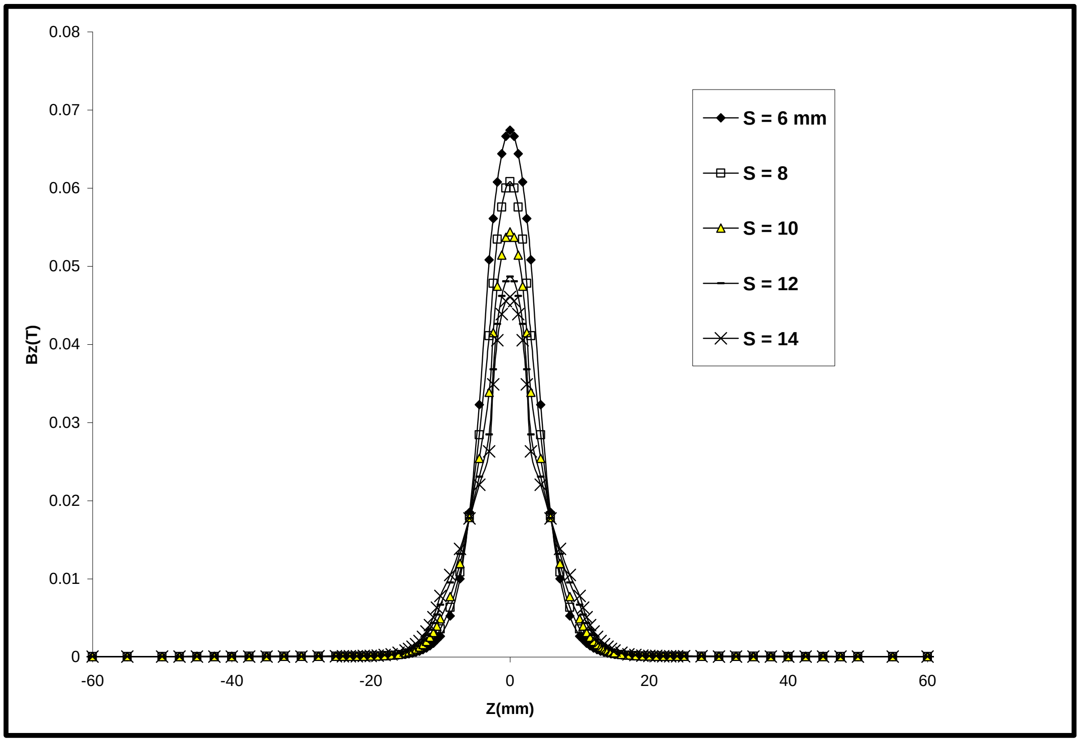


(b)

Figure (2) the axial flux density distribution Bz for various values (a) S, (b) D for a conical pole piece magnetic lens.



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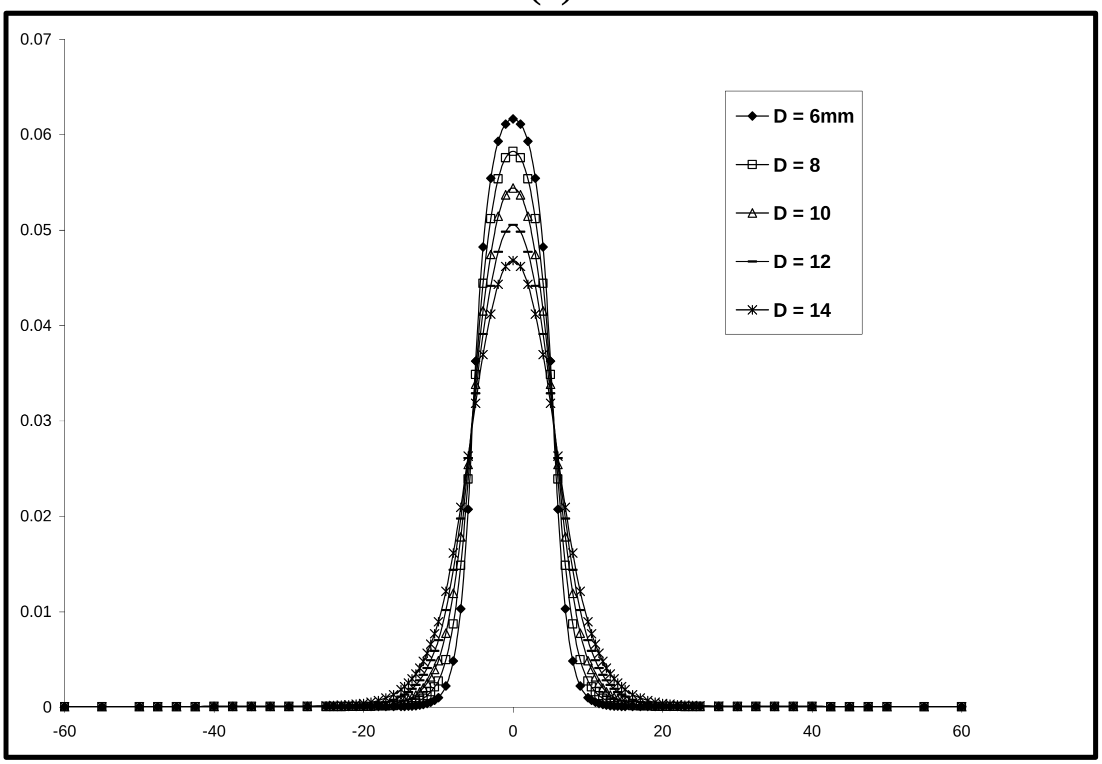

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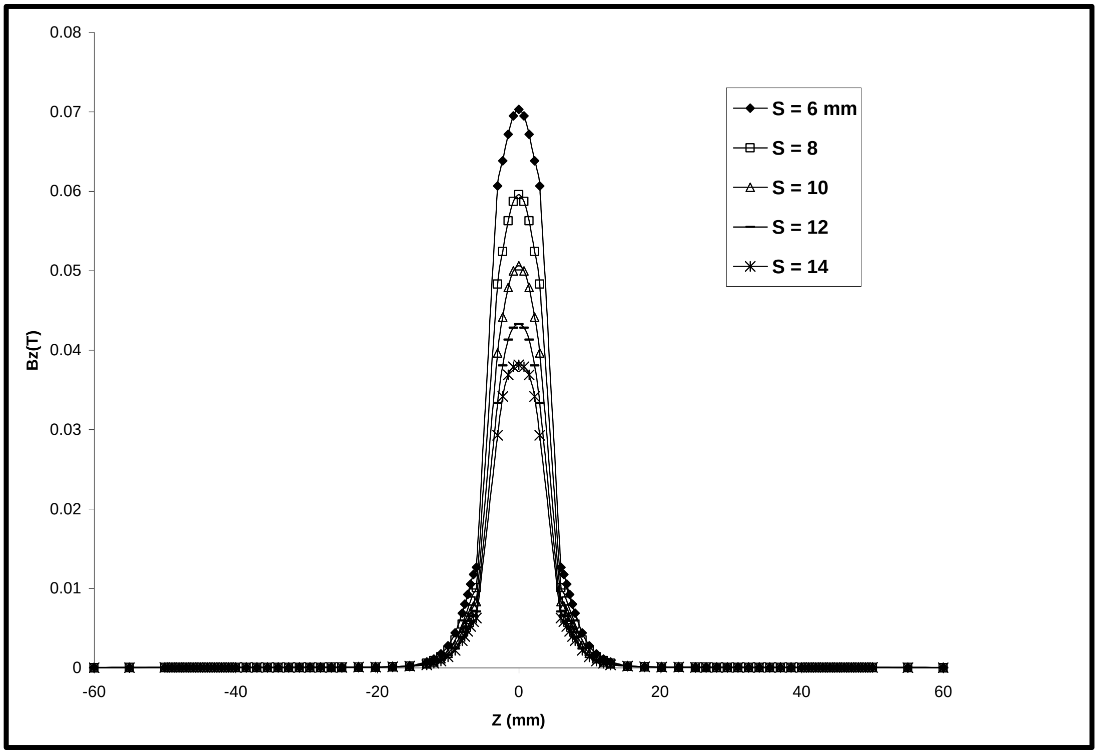
Figure (3) The axial flux density distribution Bz for various values (a) S , (b) D for the tapered cylindrical pole piece magnetic lens.



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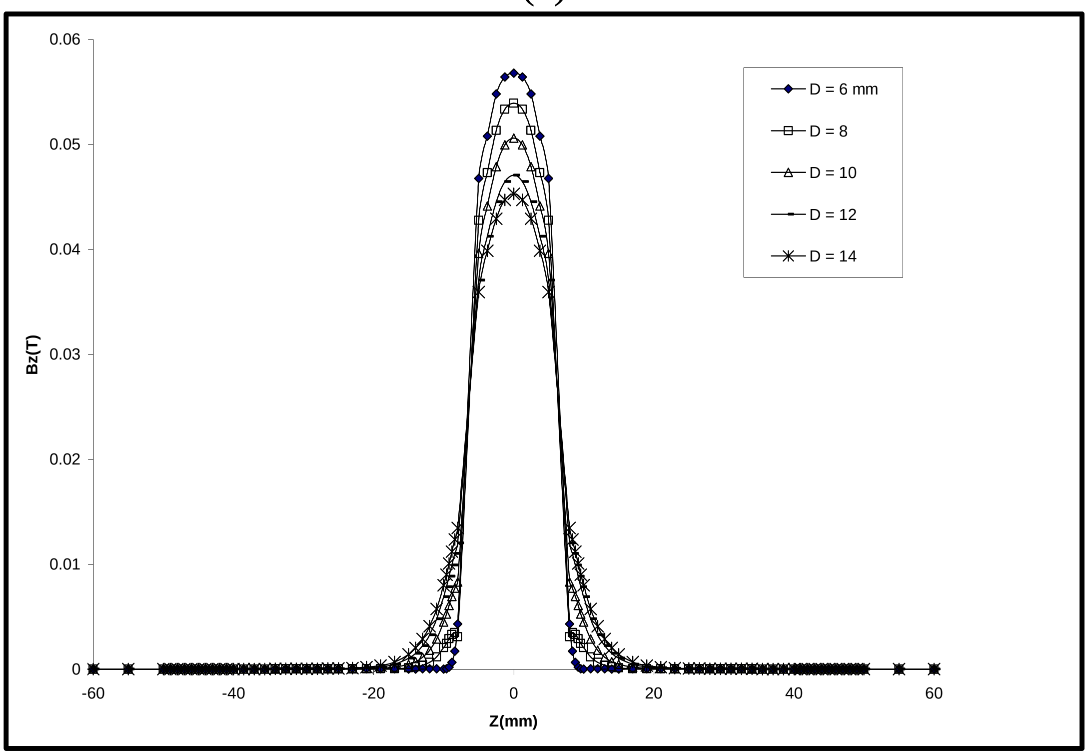


(b)

Figure (4) The axial flux density distribution Bz for various values (a) S , (b) D for the tapered spherical pole piece magnetic lens

Table (1) Effect of air-gap width (S) on Bmax and objective focal Properties for a conical pole piece at $NI/V^{\frac{1}{2}}$ =20 A.t.

S(mm)	$B_m(T)$ $(NI = 500A.t)$	f_o(mm) at B_m	Cs(mm) at B_m	Cc(mm) at B_m
6	0.069404	3.55	2.14	2.56
8	0.060225	4.03	2.57	2.93
10	0.051923	4.59	3.12	3.37
12	0.03883	5.92	4.75	4.45
14	0.033326	6.8	5.89	5.14

Table (2) Effect of axial bore diameter (D)on Bmax and objective focal properties for a conical pole piece at $NI/V^{\frac{1}{2}}$ =20 A.t .

D(mm)	$B_m(T)$ $(NI = 500A.t)$	f_o(mm) at B_m	Cs(mm) at B_m	Cc(mm) at B_m
6	0.058885	3.91	2.24	2.93
8	0.055608	4.22	3.1	3.13
10	0.051923	4.59	3.12	3.37
12	0.048168	5.01	3.25	3.65
14	0.044550	5.46	3.42	3.96

Table (3) Effect of air-gap width (S) on Bmax and objective focal properties for the tapered spherical pole piece at $NI/V^{\frac{1}{2}}$ =20 A.t.

S(mm)	$B_m(T)$ $(NI = 500A.t)$	f_o(mm) at B_m	Cs(mm) at B_m	Cc(mm) at B_m
6	0.070276	3.36	2.18	2.49
8	0.059533	3.95	2.67	2.94
10	0.050603	4.59	3.34	3.44
12	0.043234	5.29	4.16	3.99
14	0.038131	5.93	5.02	4.5

Table (4) Effect of axial bore diameter (D)on Bmax and objective focal properties for the tapered spherical pole piece at $NI/V^{\frac{1}{2}}$ =20 A.t .

D(mm)	$B_m(T)$ $(NI = 500A.t)$	f_o(mm) at B_m	Cs(mm) at B_m	Cc(mm) at B_m
6	0.069404	3.99	3.3	3.04
8	0.060225	4.25	3.28	3.22
10	0.050603	4.59	3.34	3.44
12	0.03883	4.99	3.45	3.7
14	0.033326	5.45	3.62	4.02

Table (5) Effect of air-gap width (S) on Bmax and objective focal properties for the tapered cylindrical pole piece at $NI/V^{\frac{1}{2}}$ =20 A.

S(mm)	$B_m(T)$ $(NI = 500A.t)$	f_o(mm) at B_m	Cs(mm) at B_m	Cc(mm) at B_m
6	0.06739	3.61	2.29	2.62
8	0.060808	3.99	2.56	2.9
10	0.054402	4.43	2.92	3.24
12	0.048645	4.9	3.37	3.6
14	0.046053	5.41	3.87	4

Table (6) Effect of axial bore diameter (D)on Bmax and objective focal properties for the tapered cylindrical pole piece at $NI/V^{\frac{1}{2}}$ =20 A.t .

D(mm)	$B_m(T)$ $(NI = 500A.t)$	f_o(mm) at B_m	Cs(mm) at B_m	Cc(mm) at B_m
6	0.061644	3.76	3.03	2.82
8	0.05823	4.07	2.9	3.01
10	0.054402	4.43	2.92	3.24
12	0.050518	4.83	3.03	3.5
14	0.046801	5.26	3.18	3.79

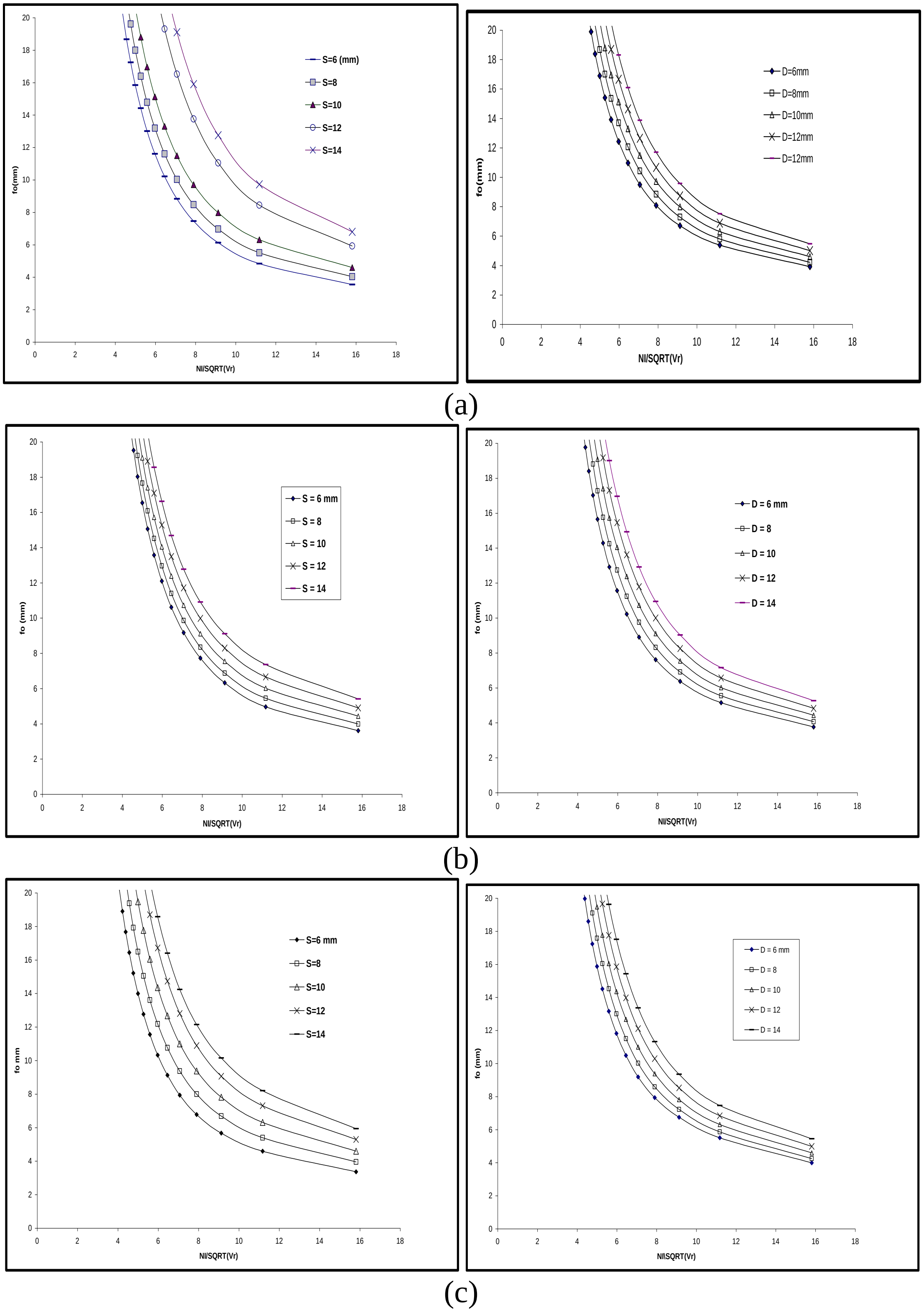
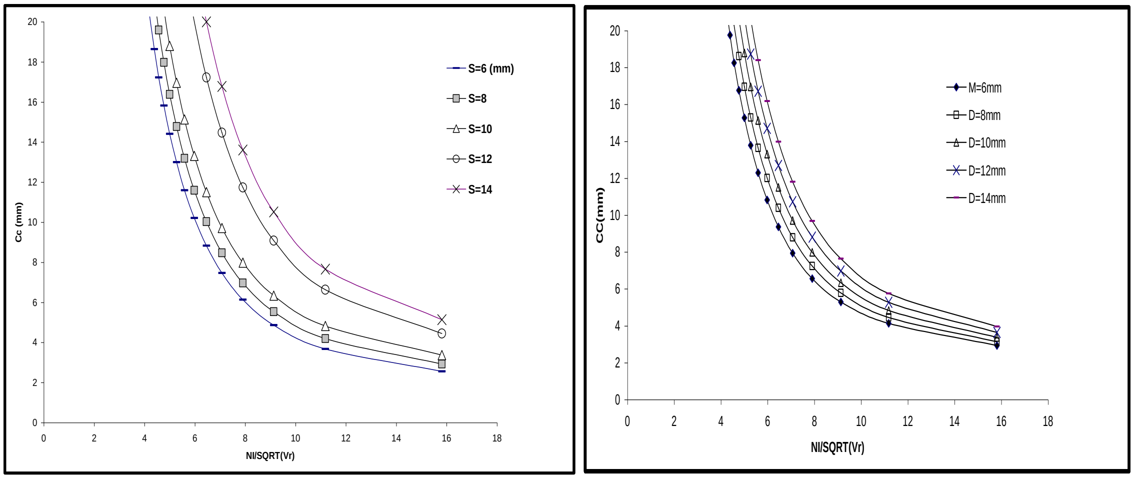


Figure (5) variation of the objective focal length of with S , D for (a) a conical pole piece magnetic lens .(b) the tapered cylindrical pole piece magnetic lens.(c) the tapered spherical pole piece magnetic lens



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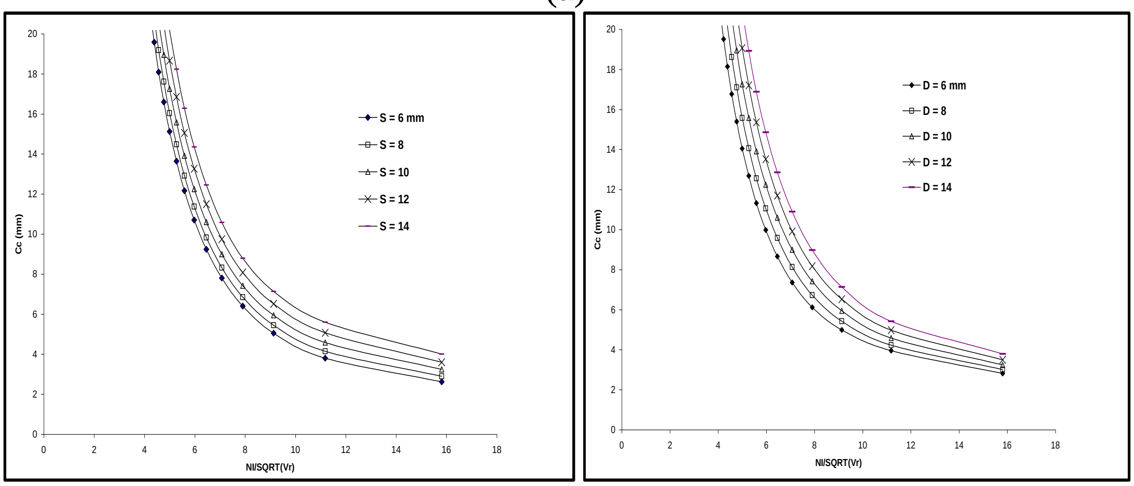

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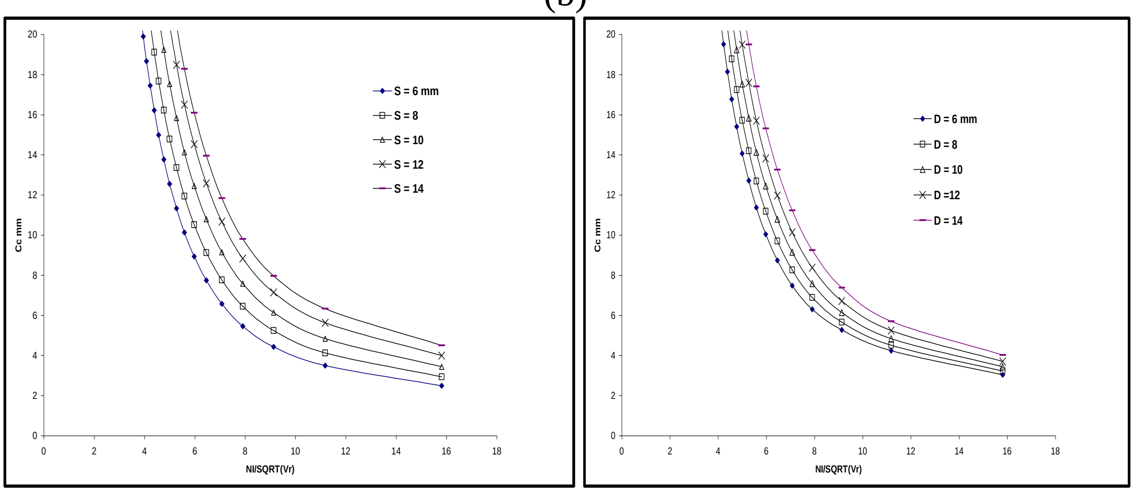
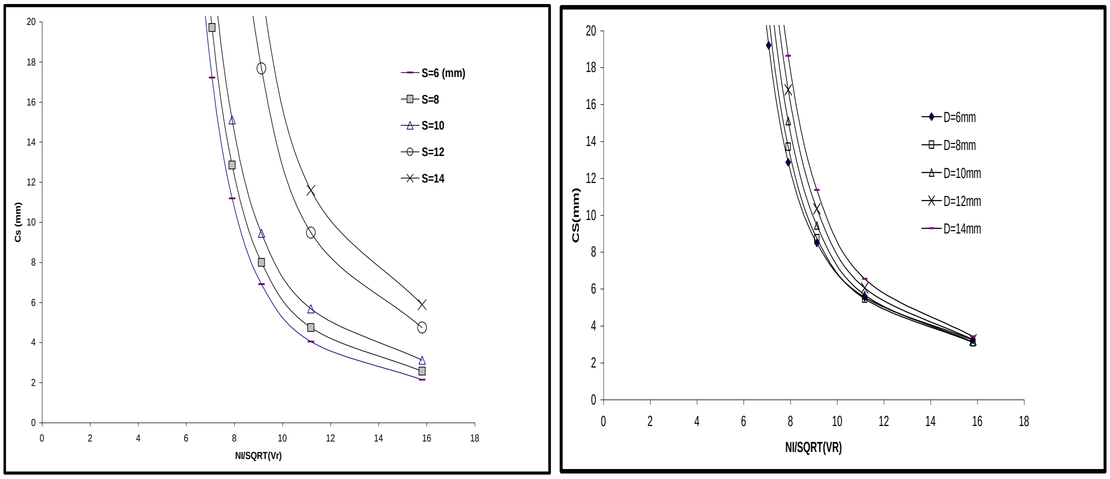


(c)

Figure (6) variation of the chromatic aberration coefficient (C_c)of with S , D for (a) a conical pole piece magnetic lens .(b) the tapered cylindrical pole piece magnetic lens (c) the tapered spherical pole piece magnetic lens



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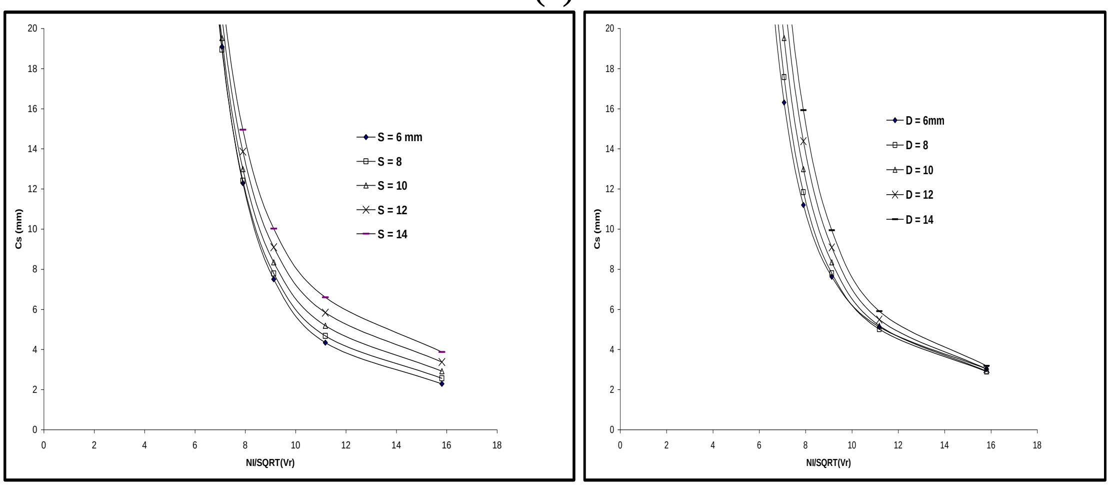

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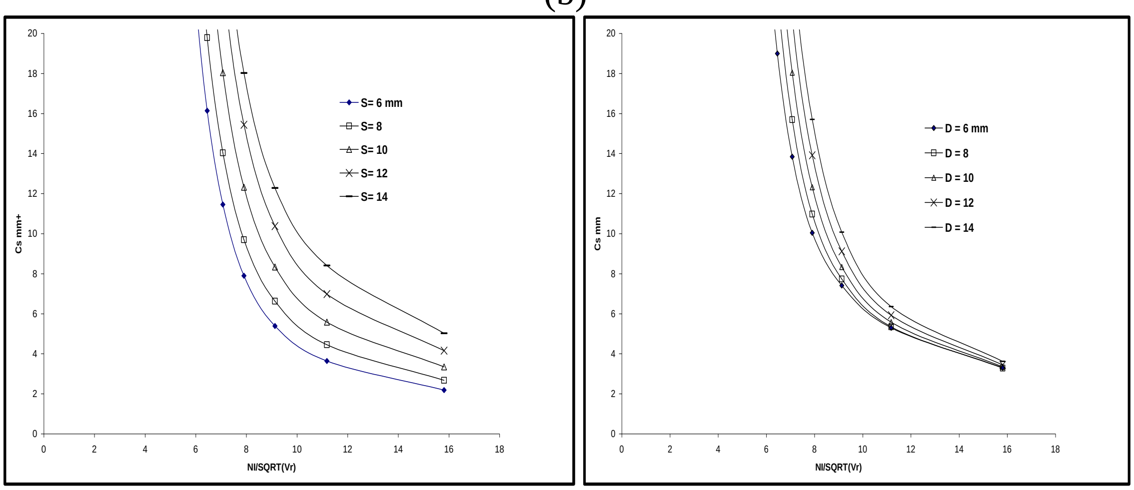

(c)

Figure (7) variation of the spherical aberration coefficient(C_s) of with S , D for (a) a conical pole piece magnetic lens .(b) the tapered cylindrical pole piece magnetic lens (c) the tapered spherical pole piece magnetic lens