DESIGN OF TRIPLE MAGNETIC LENS WITH DIFFERENT POLE PIECES

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Abstract :

In this research, A computational study for the possibility to produce a magnetic lens free from rotation and distortion. The triplet projector magnetic lens has been designed each consisting of two double pole piece lenses and one single pole piece lens. The suggested triplet projector lens can eliminate the radial and spiral distortions in the first and second maximum magnification region, after the magnetic field and optical properties has computed.

Key words: Electron Optics, Magnetic Lenses, Optimization , analysis , Aberrations.

الخلاصة :

في هذا البحث تم أجراء دراسة حاسوبية للحصول على عدسات مغناطيسية عديمة الدوران والتشويه. تم تصميم عدسة مغناطيسية مسقطيه ثلاثية تتكون من عدستين ثنائيتي القطب وواحدة أحادية القطب إذ حصل فيها انعدام التشويه ألشعاعي والحلزوني في نقطتي التكبير العظميين الأولى والثانية . بعد آن حسب المجال المغناطيسي ودراسة الخواص البصرية للعدسة.

Introduction:

In electron optical systems, there are three types from the magnetic lens according to the location in electron microscopes to condenser magnetic lens, objective magnetic lens and projector magnetic lens. Also three types from magnetic lenses depend on the number of poles are single pole piece lens, double pole piece lens and triple pole piece lens .

A projector lens suffer from the defects of most important the radial and spiral distortions. The radial distortion is take place because different strength to break the lens for the electronic bundle of toward the optical axis, increasing refraction of the lens for the electronic bundle of passed when is be more away from the optical axis, causing difference in focal lengths for the lens which results from a difference in the image magnification with distance from the axis, becomes the image distance from the axis formed then the image becomes distorted. The spiral distortion resulting from the rotation of the image about the optical axis, which leads to distortion the non-homogeneous for image of the electron microscope. Affect such defects in distorting the image with out affecting the ability of the microscope analysis [1].

In magnetic lens the important feature is the rotation of image about the optical axis as the [2]. The rotation angle is given Θ imaging electron beam passes through the lens magnetic field = 0.1863 (NI / $Vr^{1/2}$)[3] where V_r is the relativistically corrected acceleration voltage and NI is the number of ampere-turns. Here the direction of rotation depends on the direction of the current in the coil .

Juma and Chalab have attempted to theoretical and experimental study the design of [4-5]. Al-Saady[6] projector lenses in an attempt to correct the spiral and radial distortion designed the triplet projector magnetic lens consists of cylindrical pole pieces, obtained an images of rotation and distortion free in the low-lying areas of the magnification lens and high-magnetic. Al- Abedeen [7] get an image free from rotation and distortion on points of bones using trapilet projector magnetic lenses but with spherical pole pieces. This research aims to study the design of computer magnetic optical systems with a good focal properties that can be used as a system imaging in electron microscopes and force through the use of analysis method in the design of magnetic lenses.

Theory:

The triplet projector magnetic lens designed in this research were chosen based on the study carried out by Saadi [8], which represents a single lens with cylindrical pole piece. Either the double lens with tapered cylindrical pole with depending on the study carried out by Shafei [9].

Figure (1) shows cross-section of the upper half of the triplet magnetic lens consists of a single lens with cylindrical pole with the axial bore diameter (D=1) and two the double lenses with difference poles, one of the tapered cylindrical poles with the axial bore diameter(D=1) and air gap width (S=1mm) and other on a plate shape with the axial bore diameter (D=1) and air gap width (S=1mm) mounted back to back. It is consist three coils of each section area (A = 588 mm^2) provide by excitation NI = 1000A.t and excitation parameter of NI/SQRT(V_r) = 20A.t/V$^{1/2}$. Was surrounded the lens coils and the magnetic pole pieces by cover magnetizing iron to prevent leakage of magnetic flux outside the boundaries of the lens.

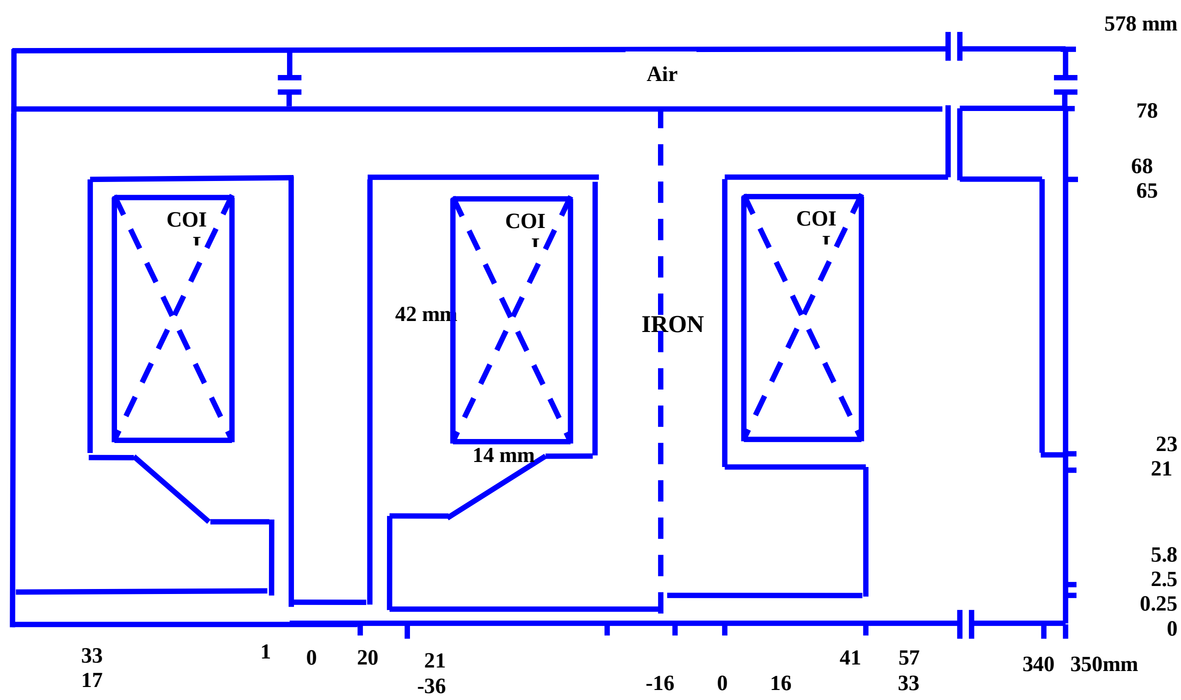

Figure (1) Cross section of the upper half of the triplet projector lens.

In the present paper, the magnetic flux density distribution of the triplet projector lens is computed by the aid of computer program [10] using the finite element method [11] and the

program in [12] to cal culate the projector focal properties of the doublet lens. The radial and spiral distortion coefficients can be calculated with the aid of the following formula [١٢]

$$D_r = \frac{3}{8 f_p^2} + \frac{e}{16 m V_r} \int_{-\infty}^{\infty} \left[B_Z'^2 + \frac{3eB_Z^4}{8mV_r} - B_Z^2 \left(\frac{\gamma_\alpha'}{\gamma_\alpha} \right) \right] r_\alpha^3 r_\gamma \, dz \text{...........(1)}$$

$$D_S = \frac{1}{16 V_r} \left(\frac{2e}{mV_r} \right)^{\frac{1}{2}} \int_{-\infty}^{\infty} B_Z \left[\frac{3eB_Z^2}{8m} + V_r \left(\frac{\gamma_\alpha'}{\gamma_\alpha} \right) \right] r_\alpha^2 \, dz \text{....................(2)}$$

where Dr and Ds are the radial and spiral distortion coefficients respectively , fp is the projective focal length, Vr is the relativistically corrected accelerating voltage , Bz is the axial flux density distribution,

rα and rγ are the independent solutions of the paraxial-ray equation , B'_Z **is first derivative of the axial flux density distribution , e and m are the charge and mass of the electron. The radial distortion and the spiral distortion of the following equations. [13]**

$$(\Delta\rho/\rho)_r = C_r (r/R)^2 = D_r r^2 \text{................(3)}$$

$$(\Delta\rho/\rho)_s = C_s (r/R)^2 = D_s r^2 \text{................(4)}$$

Where r is radial displacement of electron trajectory, ρ is gaussian image radius, R is axial bore radius of magnetic lens, Cr is radial distortion constant ,Dr is radial distortion coefficient, $(\Delta\rho/\rho)_r$ **is radial distortion, Cs is spiral distortion constant, Ds is spiral distortion coefficient and** $(\Delta\rho/\rho)_S$ **is Spiral distortion.**

Results and discussion:

Figure (2) shows distribution of axial magnetic field Bz in the first maximum magnification region for the first and second projector lenses when the ratio D1 = D2 = D3 = 11.6:0.5:0.5 and S1 = S2 = 1 mm and excitations NI = 1000, 1080 A.t. for the first and second lenses respectively.

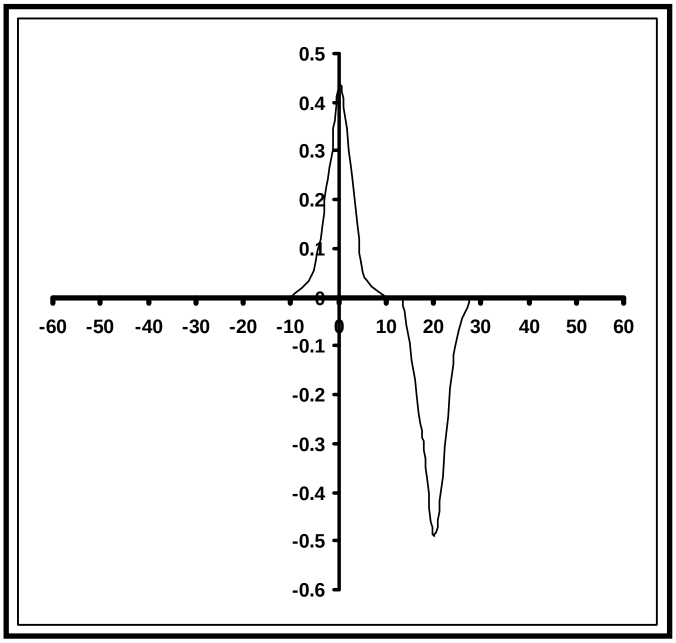

Figure (2) distribution of axial magnetic field in the first maximum magnification region

Notes from the figure (2) the two opposite magnetic fields value where the maximum face of the first lens pole. While the value of Bm for the second projector lens 0.511 T is located in the middle of air gap so as to correspond to magnetic flux density for the first projector lens (Bm =0.425T) and located 0.3mm from the homology magnetic field. Using the distribution of the axial magnetic field shown in the figure(2) to calculate the projector focal properties of the first and second lenses. As shown in Figure (3) relationship of projector focal length Fp, Dr radial distortion coefficient and coefficient of spiral distortion Ds with excitation parameter (NI / SQRT(Vr) in the first maximum magnification region. Where it is noted that the value minimum for the projector focal length (Fp)min is equal to 15.65mm and located at the excitation parameter NI / SQRTVr = 4.35 and intersects a curved radial distortion coefficient with curved spiral distortion coefficient when excitation parameter NI / SQRTVr = 4.35 which obtained the absence of distortion.

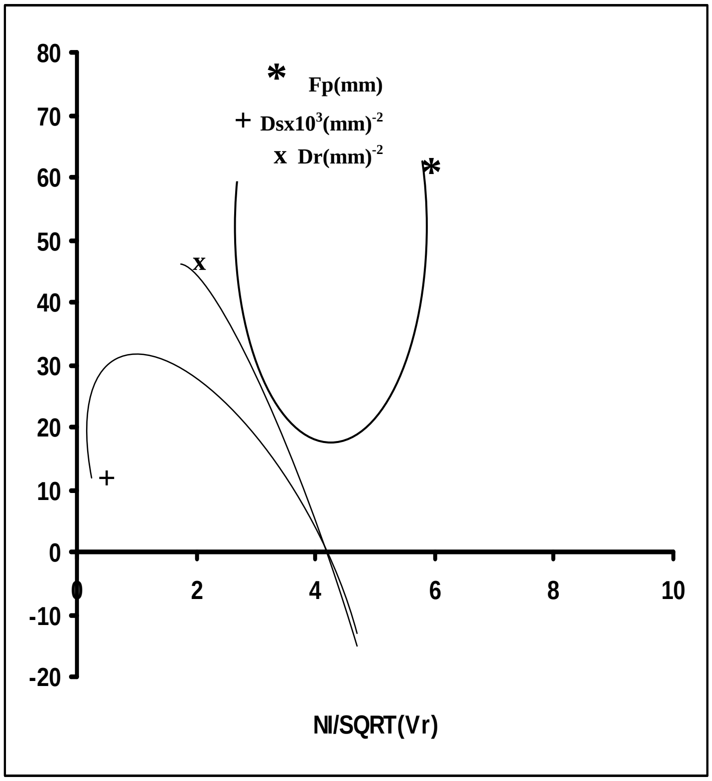

Figure (3) relationship of Fp, Dr and Ds with (NI / SQRT(Vr)
in the first maximum magnification region.

Figure (4) shows distribution of axial magnetic field Bz in the second maximum magnification region for projector lenses of the second and third when the ratio D2 = D3 = D4 = 0.5:0.5:5 and S2 = 1mm and excitation NI = 1000,1800 A.t. for the lenses of the second and third respectively. Figure (4) shows the maximum value of the Magnetic Flux density Bm the projector lens equal to 0.9 T and located in the middle of air gap so as to correspond to While the value of Bm of the projector lens 0.143 T and located at a distance of .magnetic field 4mm from the face of single pole lens. Use the distribution of axial magnetic field Bz as shown in Figure (4) to calculate the projector focal properties of second and third lenses.

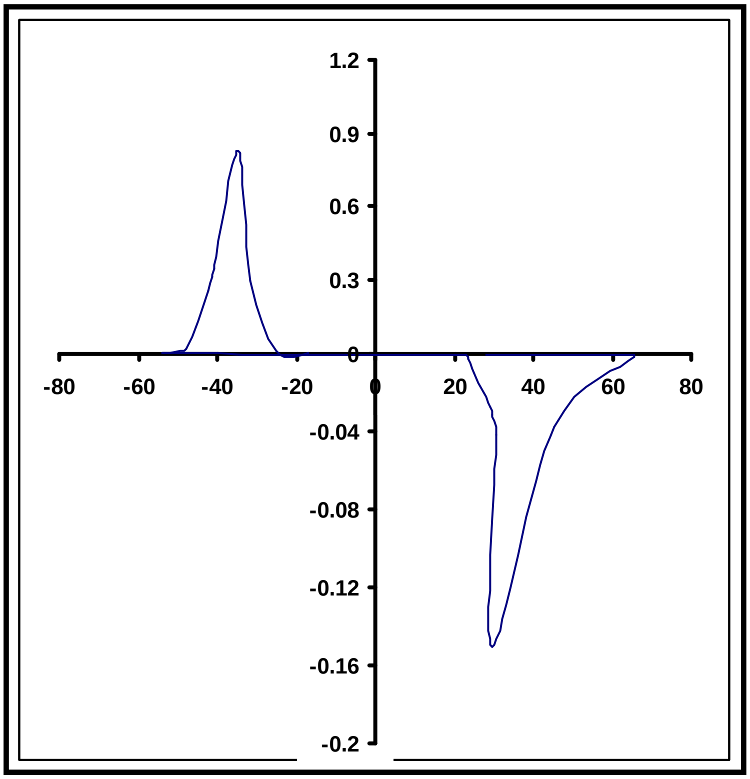

Figure (4) distribution of axial magnetic field in the second maximum magnification region

Figure (5) shows relationship projector Focal length Fp, radial distortion coefficient Dr and coefficient of spiral distortion Ds with the excitation parameter NI / SQRTVr in the second maximum magnification region. It is noted that the minimum value of projector Focal length (Fp) min is equal to 1.12 mm and located at NI/SQR(Vr) =12.75.

It also is the minimum value of redial and spiral distortion coefficient, when the excitation parameter one NI / SQRTVr =14 This means having access to image of free from distortion but a good magnification.

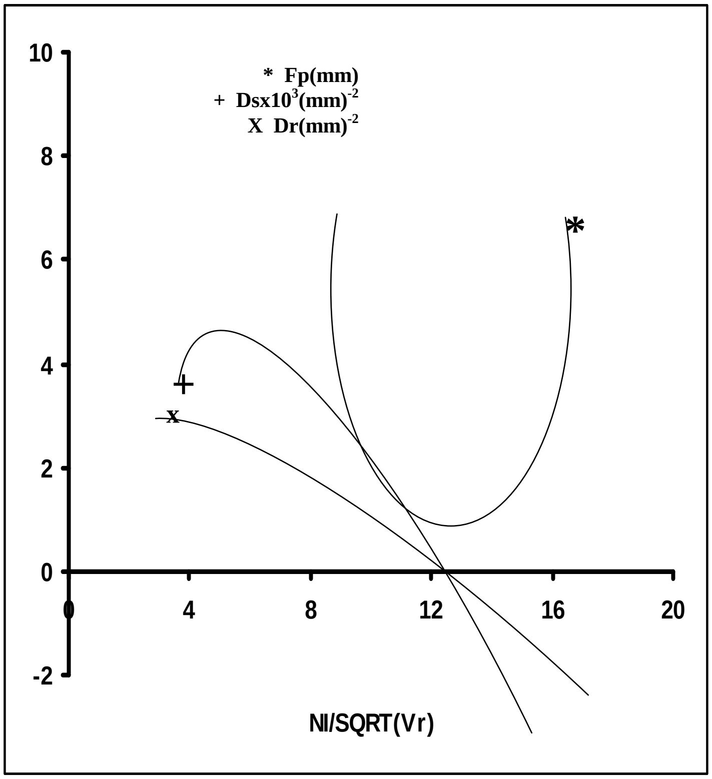

Figure (5) relationship of Fp, Dr and Ds with (NI / SQRT(Vr)

in the second maximum magnification region.

Conclusions:

In this work, the triplet project magnetic lens with different pole pieces has been designed to get on image of free from redial and spiral distortion in the first and second maximum magnification region in that one. It was found that to get on image of free from redial and spiral distortion in the first maximum magnification region must reduce the density of axial magnetic flux in the first projector lens for equivalent of the displacement from the optical axis in the second projector lens The results showed that can be corrected of distortion in the first maximum magnification region, but an increase of axial Magnetic Flux density in the second .projector lens equivalent large displacement for the optical axis in the third projector lens The results showed that obtained the image of free from distortion in the maximum magnification region when excitation parameter, which is located the minimum value of projector Focal length. while get the image of free from distortion in the second maximum magnification region, but when excitation parameter approach to those obtained then the

greatest magnification in terms of loss of a large magnification and their importance can not be as important as get rid of redial and spiral distortion at the same time.

References:

[1] Wischnitzer S., "Introduction to Electron Microscopy ", 3rd ed . Pergamon press, 1981.

[2] Al-Nakeshli, I. S., Al-Obaidi, H. N. and A1-Naimi, I. M., "Iron . Magnetization of the Doublet Projector Electron Lens"., J. Col. of Edu., Al-Mustansiriyah University, 4,101 -111, 1994.

[3] Hawkes P.W. , Electron optics and electron microscopy (London: Taylor and Francis), 1972.

[4] Chalab M .R., "Investigation for the Projective Properties of the Symmetric the Tapered Cylindrical Double Pole Piece Magnetic Lens" J. University of Thi-Qar .4.5.1-11, 2010.

[5]Juma, S. M. , "Rotation Free Magnetic Electron Lenses"., Ph.D. Thesis, University of Aston, Birmingham, England, UK,1975.

[6] Al-Saady A.K. , "Computation on the Properties of Magnetic Boublet Lenses for the Transmission Electron Microscope" Ph.D. Thesis, University of Al-Mustansiriyah, 1995.

[7]Zain alabdeen , F. Sh., " Distortion and Rotation Free triplet projector Lens with spherical Pole Piece " M.Sc. Thesis University Al-Mustansiriyah, Baghdad, Iraq, 1997.

[8] Al-Saady A.K. , Al-Shummary B.A.N. , and Al- Shfii T.M.A., "Magnification of a Double Projector Lens for the Transmission Electron Microscope" Journal of the University of Karbala , 3 , 12 , 30-35, 2005.

[9] Al- Shfii T.M.A., "Computational Investigation for Desgin Lenses of Transmission Electron Microscope" Ph.D. Thesis, University of Al-Mustansiriyah, 2007.

[10] Lencova, "Program AMAG for the Computation of Vector Potential Distribution in Rotationally Symmetric Magnetic Lenses by Finite Elements Method", Czechosl. Acad. Sci .Brno. Kralovopolska, 147, 612-664, 1988.

[11]Munro, E. "Computer Aided-Design Method in Electron Optics". Ph.D. Thesis., University of Cambridge, U. K. 1971.

electron lenses" , Ph.D. [12] Marai F.Z., "Electron optical properties of single- pole magnet

Birmingham , UK , 1977. Thesis , University of Aston

[13] Liebmann, G. and Grad, E. M. (1952)., " Image Properties of a . Series of Magnetic Electron Lenses ". Proc. Phys. Soc.

London, B1,1951-1956 .