Design of Distortion and Rotation Free Double gaps Electromagnetic Lenses

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***Abstract*— In this research, a theoretical computational investigation for studying the analysis method for possibility to produce magnetic lens of free from a rotation and distortion. The doublet projector magnetic lens with cylindrical pole pieces has been designed. The radial and spiral distortions have been corrected by using this lens , after the magnetic field has been computed, by the use of computer programs based on the finite element method (FEM),this magnetic field has been used for calculation the projector focal properties for this lens. Where, a rotation and distortion free images have been obtain by suitable choice of the ratios values of gaps and bores of first lens and second lens.**

***Index Terms*— Electron Optics, Electromagnetic Lenses, Distortion and Rotation free**

I. Introduction

In the field of charged particle, The projector magnetic lens in the transmission electron microscope (TEM) is considered an important lens in the imaging system. This lens magnifies the image formed by the objective lens, and projects it on the screen, but it suffers from fundamental defects, the most significant of which are the radial and spiral distortions. Spiral distortion changes in the images formed by magnetic projector electron lenses only and radial distortions changes in the images formed and area by magnetic projector electron lenses **[1].**

In the present work a computational method has been developed to correct the two distortions of the doublet projector magnetic lenses **[2]**. In magnetic lens the important feature it is the rotation of image about the optical axis as the imaging electron beam passes through the lens magnetic field **[3].**

The rotation angle is given by the following equation **[4]**.

$$\theta = 0.1863 \left(NI / V_r^{1/2} \right) \ldots\ldots\ldots\ldots\ldots\ldots\ldots (1)$$

where V_r is the relativistically corrected acceleration voltage and NI is the number of ampere- turns. Equation (1) shows that the direction of rotation depends on the direction of the current in the coil .

The first theoretical and practical study about projector lenses with rotation free image has been investigated by **[5-8].** The simplest formula of the projector magnetic lens of rotation free is the double gaps lens which consists of identical two lenses in design and are working under the condition $(NI)_1 = -(NI)_2$ so that the net rotation of the image zero. Tsuno and Harada **[9]** designed the double gaps projector electromagnetic lens. In the first rotation they obtained an image with spiral distortion rate of 0.07% at excitation parameter $(NI/SQRT(V_r))$ where the radial distortion equal to zero. Al- Obaidi, **[10]** designed a doublet magnetic lens consists of two lenses, fist air gap width S_1 of the first lens is different forms of second air gap width S_2 for second lens, which earned image of rotation and distortion free in the great magnification. While Al-Saady **[11]** obtained an images of rotation and distortion free in the low and high maximum magnification region using doublet gaps projector magnetic lenses with the cylindrical pole pieces

.Al-Saady **[12]** get an image of free of rotation and distortion in on points of bones first and second magnetic lenses using double projector magnetic lenses but with conical pole.

II. Lens design

In the present work , in an attempt to obtain free of rotation and distortion in first great magnification region for transmission electron microscopes , an double gaps projector magnetic lens with cylindrical pole pieces has been designed , it is consist of two lenses , both of them has double - cylindrical pole piece **[13]**, the air gap of each lens is equal to (5mm),as shown in Figure (1). The coil is located within each lens and the installation of steel about (5 mm) from the face of the pole **[14].** The section area of each coil is ($A = 1200\ mm^2$).

In order to get an images with a free of rotation in this lens, the excitation in the first lens must be equal and opposite to the excitation of the second lens 1000A.t., this means that the number of coil laps the first lens N_1 equals the number of coil laps of second lens N_2, and the current I_1 in a pass-through is equal to the first lens and goes against the current I_2 lens coil in a second. Several computer programs have been used in this study such as program (AMAG) **[15]** to calculate the magnetic flux density distribution and program (Pro1) **[16]** to calculate the projector focal properties of the double gaps lens.

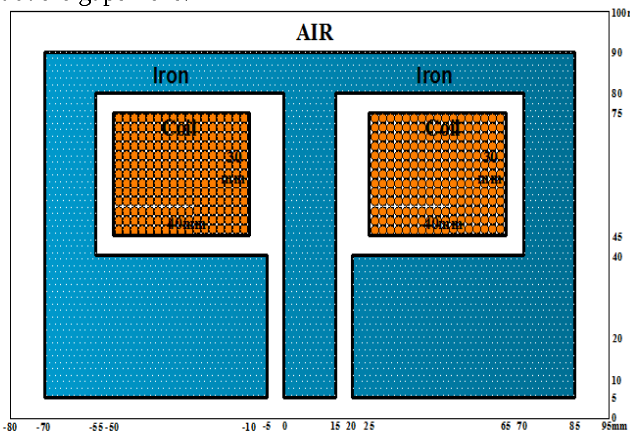
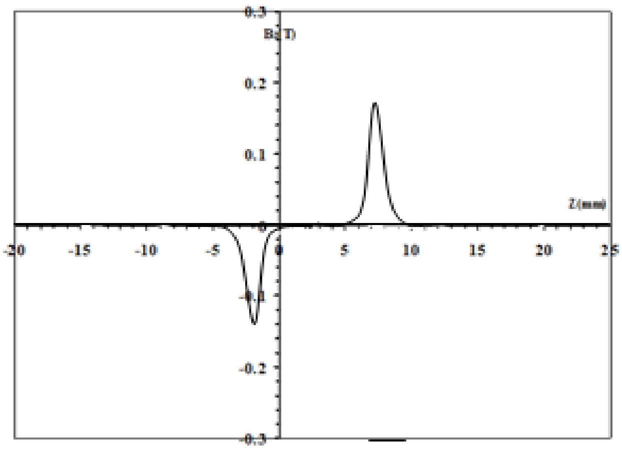


Figure (1):Cross section of the upper half of doublet projector magnetic lens.

III. RESULTS AN DISCUSSION

Figure (2) show as The axial magnetic flux density distribution B_z of the double gaps projector lens for bore ratio D_1: D_2: D_3 =14:10:10 and the air gap width of each lens equal $S_1 = S_2$ = 5mm, in the first great magnification region. As noted in Figure that the magnetic field distribution of the first lens is opposite in direction to that of the second lens so as to obtain rotation-free image, the maximum magnetic flux density B_{m1} of the first double- cylindrical lens is equal to 0.140 Tesla and located in the middle of air gap due to a symmetrical of magnetic field, while the maximum magnetic flux density B_{m2} of the second double -cylindrical lens is equal to 0.165Tesla and located in the middle of air gap due to a symmetrical of magnetic field too.

By using the distribution of the axial magnetic flux density shown in figure (2) to calculate of the focal properties of the double gaps projector lens. Where the figure (3) shows change the projector focal length (F_p), radial distortion coefficient (D_r) and the spiral distortion coefficient (D_s) as a function of excitation parameter ($NI/V_r^{1/2}$). Noting that the minimum value of the projector focal length (F_p) is equal to 18.530 mm and located at the excitation parameter $NI/V_r^{1/2}$ = 8, the radial distortion coefficient (D_r) and the spiral distortion coefficient (D_s) vanishes at the same excitation parameter of about $NI/V_r^{1/2}$ = 8, a distortion – free at high magnification region is obtained.



Figure(2):Axial magnetic field distribution B_z for the bores ratio D_1:D_2:D_3= 14:10:10 at a constant excitation of 2000 A.t.

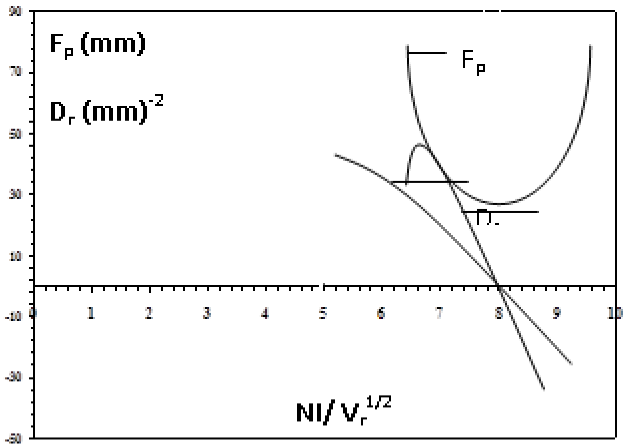


figure (3): Variation of the projector focal length F_p redial distortion coefficient D_r and Spiral distortion coefficient D_s with the excitation parameter $NI/V_r^{1/2}$ at the first magnification region.

IV. CONCLUSION

It appears that the correction of distortion depends on the magnetic geometry. In order to cancel the distortion at first magnification region, the axial magnetic flux density of the first lens must be lower than that of the second, to be equivalent to a small displacement from the optical axis in the second lens.

The results show the possibility of designing rotation-free and distortion-free double gaps projector magnetic lenses at high magnification in the transmission electron microscope (TEM) and scanning transmission electron microscope (SEM) over a wide range of accelerating voltages.

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