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Effect of the Geometrical Shape of the Magnetic Poles and the Distance between Them on the Focal Properties of the Condenser Magnetic Lens in the Scanning Electron Microscope (SEM)

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Abstract The research aims to study the effect of changing the geometric shape of the poles and the distance between them on the focal properties in the condenser magnetic lens and thus the efficiency of the scanning electron microscope through its impact on the amount of miniaturization in the electronic beam passers-through optical column system lenses as well as the amount of aberrations that contribute to reducing the clarity and precision in the resulting image for the sample to be tested. We used six condenser lenses equal in the internal and external geometry and the length of the lens as well as for the coil area and vary the poles and the distance between them to get out the best model.

Keywords: *condenser lens, scanning electron microscope, thermionic emission scanning electron microscope, ray tracing*

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1. Introduction

The scanning electron microscope is one of the most common instruments for measurement and analysis of micro structures with a high degree of accuracy through the use source of electron beam with short wavelength less than 1nm [1].

Classifies scanning electron microscope depending on the type electron gun into two types, namely scanning electron microscope with a thermal emission and scanning electron microscope with field emission, high analysis capability prefers to use a electron microscope field emission, but because of the high cost and the fact that requires a high degree of vacuum up to Torr10 -10 [2,3]. As well as high precision in the alignment so it preferred to use a thermal emission, which is still Aoudad high share in the markets because of the relatively few cost as well as being does not require a high degree of vacuum up to 10-7 Torr.

Currently, it has a scanning electron microscope with a thermal emission actually analyzed 50 times larger than the boundary theory as a result of irregularities in the electron source size, aberrations and energy dispersive through the optical column and the adoption of precision in magnetic lenses and other defects manufacturing and engineering industry, so manufacturers have focused electron microscopes modern development source the electron beam for the degree of high brightness, system lenses low aberration and scattering a few energy.

Using scanning electron microscope, accelerated electron beam with a very short wavelength less than 0.01nm, so to enhance resolving power compared with optical microscope, which depends on the visible light source wavelength extent with range between 300-700nm.

To facilitate the design of the electron lens system and reduce the time and the loss resulting from the manufacture of these lenses and thus proving its failure has applied numerical simulation software widely as suggested Munro [3] finite element method from first order to analysis of the electron lenses. while developed Renou et, al. [4] analysis programs for electron gun based on the boundary element method. from another side applied [5] Zhu and Munro finite element method of the second order for the analysis of different kinds of electron guns. As display Grella et, al. [6] method of Monte Carlo to calculate the scattered electrons. use each Khursheed and Osterberg [7] finite element method in the design spectroscopy scanning electron microscope.

2. The Theoretical Side

Magnetic lens consists generally of a circular coil is made of copper wire insulated electrically, coil contains (N) of turns When passes a continuous electrical current amount (I) in the coil, it generates a magnetic field symmetry axially(Bz) along an axis (Z) acts on deviation electrons passers through it towards the coil center according to ampers law. [8].

$$\int_{z_o}^{z_i} B_z dz = \mu_o NI$$

$$\mu_0 = 4\pi * 10^{-7} H.m^{-1}.$$

Vacuum permeability
Bz Axial magnetic flux density.

To study the effect of the shape of the poles and the distance between them in the condenser magnetic lens on the optical performance have to create a small image of the first real image composed within the thermal gun, which ranges in diameter dG of (20-100) μm were six models of condenser magnetic lenses equal in geometrical dimensions, internal and external diameter and area of the coil but different in shape of the poles and the distance between them (Figure 1) shows the illustrate of the six designs of the condenser magnetic lens.

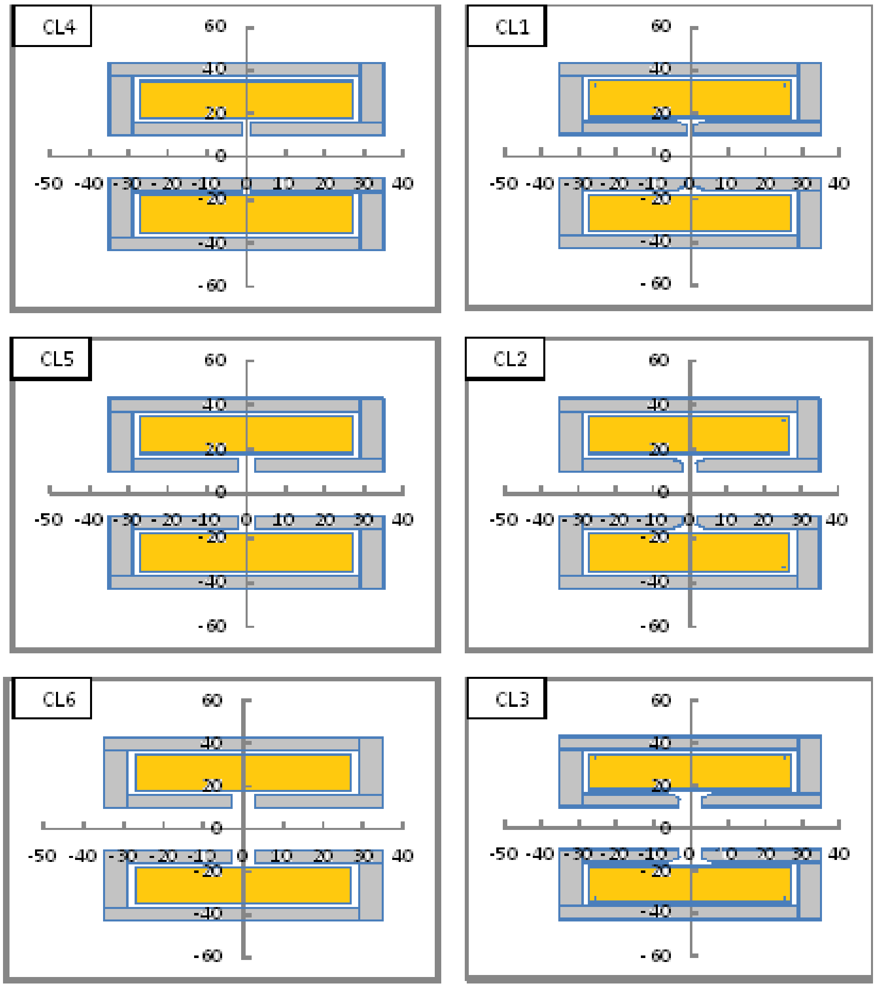

Figure 1. shows the condenser magnetic lenses CL1, CL2, CL3, CL4, CL5, CL6

It is also necessary to study the distribution of the trajectory of magnetic flux lines inside the lens to see the flux leakage in its structure (Figure 2) shows the trajectory of magnetic flux lines within six magnetic lenses, which are parallel and regular on the optical axis.

As has been the distribution of the density of magnetic flux axial Bz for condenser magnetic lenses described in figure (1) When excitation NI = 1000A.t using a program [9] AMAG which is based on the finite element method to know the properties of the focus of (focal length f, and image position Zi, and the number of times demagnification dM ... etc). Figure 3 shows the distribution of magnetic flux density Bz along the Z axis.

Table 1. Bmax values and positions, values of the refraction of the beam Zp, location of the intersection of the beam with the optical axis or the focus positions Zf, and the focal length f

Sample	Location Bmax(mm)	Maximum value of magnetic flux density B_{max} (T)	location of refraction beam Zp (mm)	Location of focus Zf (mm)	Focal length f(mm)
CL1	0	.08677712	-1.72	8.5	8.19
CL2	0	.08444092	-1.84	8.617	8.34
CL3	0	.08181226	-1.97	8.88	8.60
CL4	0	.08619454	-1.71	8.614	8.26
CL5	0	.08424169	-1.83	8.671	8.37
CL6	0	.08193578	-1.96	8.905	8.61

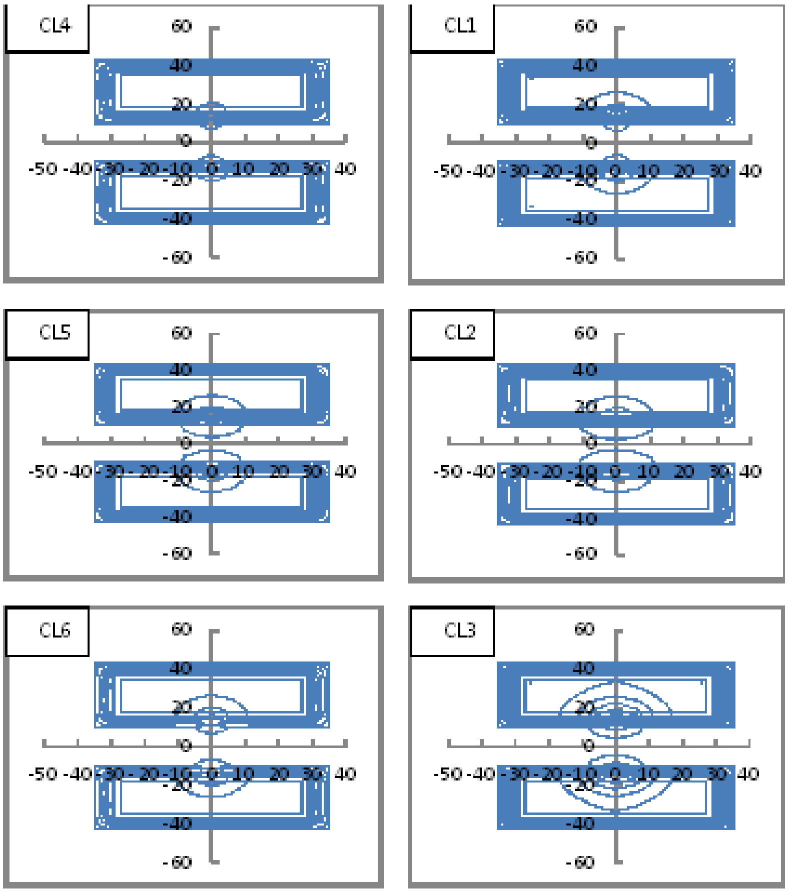

Figure 2. trajectory of magnetic flux lines within the magnetic lenses CL1, CL2, CL3, CL4, CL5, CL6

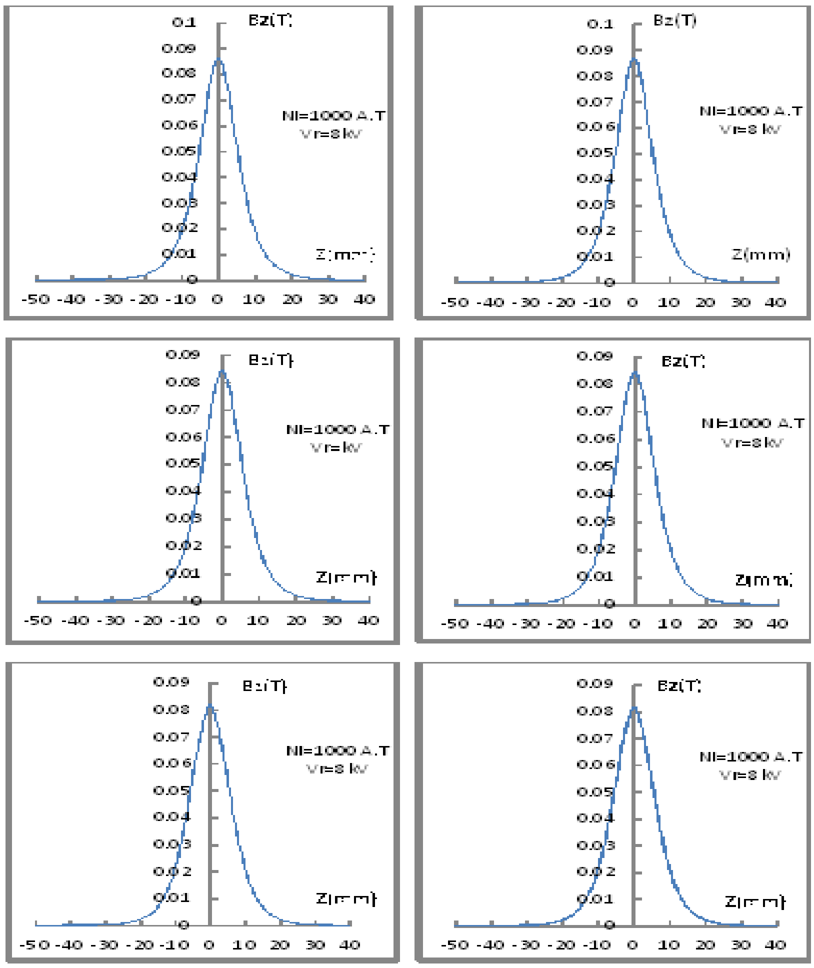

Figure 3. shows the distribution of magnetic flux density Bz along the axis Z

The electron beam trajectory is calculated by solving the axial Ray equation numerically using the method of (Rang-Kutta) from fourth order Figure 4 shows trajectory of the accelerated electron beam by voltage Vr = 8kV when excitation NI = 1000A.t starting from the point of intersection of the electron gun at (Zo = -40) to the position of the image plan formed by the condenser lens Table 1 shows the values and positions Bmax and values of refraction of the electron beam position Zp and the location of the intersection of the electron beam with the optical axis or focus position Zf and focal length of the condenser magnetic lens six.

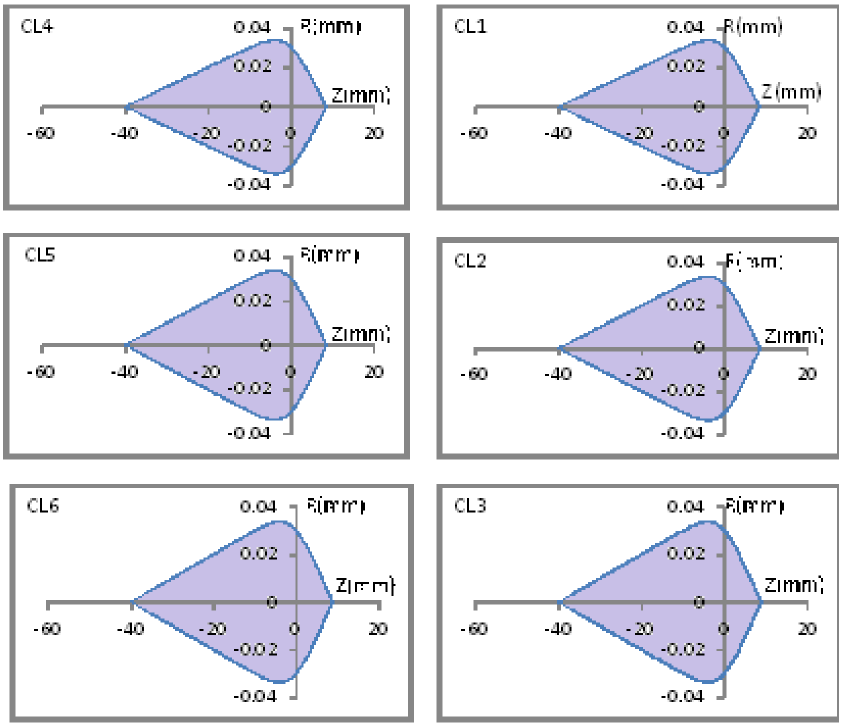

Figure 4. Ray tracing of electron beam accelerated by voltage Vr = 8kV when excitation, NI = 1000A.t

It was awarded a number of times demagnification and beam diameter emerging from condenser magnetic lenses d1 on the assumption that dG = 50µm [10] as well as the calculate of Spherical aberration coefficient, chromatic aberration coefficient and the focal length Table 2 shows the demagnification, beam diameter, Spherical aberration and chromatic aberration.

Table 2. demagnification values, electron beam diameter, spherical and chromatic aberration

Sample	Value of demagnification dM	Beam diameter d1(nm)	Spherical aberration Cs(mm)	Chromatic aberration Cc(mm)
CL1	4.05	12345	7.46	6.32
CL2	3.96	12626	7.43	6.42
CL3	3.83	13054	7.48	6.60
CL4	4	12500	7.60	6.38
CL5	3.95	12658	7.49	6.45
CL6	3.81	13123	7.50	6.61

3. Conclusion

Showing from changes that made on the geometrical shape of the magnetic poles and the distance between them, its affecting on the focus properties of the condenser magnetic lens and electron beam diameter required downed on the objective lens that acts in its role on increasing demagnification in electron beam diameter and bring it down to the desired sample surface study of the surface to get a clear image and free of defects and deformities.

Explained the results that we have obtained from the study of the six models of magnetic lenses that CL1 model has the best focal properties of spherical Cs and chromatic Cc aberrations, the magnetic flux intensity Bz, the focal length f, as well as the smaller electron beam diameter d1, therefore be adopted as the best condenser magnetic lens from the six models.

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