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The pre-designed recipes of asymmetric magnetic lens

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ABSTRACT

Theoretical study was conducted using a software package coded by Visual Basic language called (CATDEL) on a single magnetic lens with a conical pole shape which is investigated its objective properties previously using Fortran programming language. To verify the accuracy of current work and compared with literature survey, the same specifications of pre-designed lens should be adopted completely. Present investigation proof that there is a great affinity between extracted and previous results in literature survey.

Keywords: Electron optics, Magnetic Lenses, Objective Properties

1. INTRODUCTION

The origins of charged particle optics can be traced back to the mid-1800s [1], when some of the first studies examined the effects of electric currents in gases, and later when cathode ray tubes were studied. A formal theory of charged particle optics (namely, using electric and magnetic fields to accelerate and guide electrons for imaging applications) was developed in the 1920, providing the theoretical foundation for the first electron microscope in 1930 [2]. The main basic concept of the electron optics had been built on two fundamentals. First of them is De Broglie hypothesis (1925) which states that any movement of an elementary particle must be associated with a wave that its length depend on the particle momentum. The second one, however, is optical definition of electron lenses that proved by Hans Busch (1927). Busch in that time discovered that the time–independent magneto-static fields of a solenoid (axially symmetric coil) acts on charged particles in the same way of glass lens in sense of geometrical optics, at least in a first-order approximation [3]. These two important discoveries lead Ernst Ruska to build the first electron microscope in which the electrons used instead of photons. i.e., visible light in optical microscope is replaced by charged electron beams of varying wavelength depending on the accelerated voltage in the column of the electron microscope. It is well known that, external electromagnetic fields play an important rule for controlling beams of charged particles concerning the acceleration, focusing and deflecting. So, electron and ion optics arise as the theory and practice of production, control and utilization of the charged particle beams [4].

2. MAGNETIC LENS DESIGN

The single pole-piece lens and its geometrical parameters of proposed lens was constructed, which consists of cast shield made of mild steel, it has simple geometrical shape of truncated cone pole-piece of taper angle equals 53^o [5].
The analysis is based on dividing the upper half of the cross-section for the lens into quadrilateral areas so as to make the lens geometry correctly specified. This coarse mesh is sub-divided into small quadrilateral areas to the fine meshes automatically by the same program [6].

3. THE POLE-PIECE PROFILE

By using CADTEL software, the user easily can obtained auto computations and its representations as plots. One of this plots, the geometrical shape of asymmetric proposed lens shown in figure 1. Actually the precise match proofs the full identical between this figure and the correspondence original ones. Figures 2 show the meshes projection for this lens. However, the produced mesh grid or the finite elements for this lens plotted in figures 3. It is important to mention that as long as an accurate result would be obtained a higher mesh line density should be used especially in and around the lens action region. Furthermore, radial meshes should never be intersected with each other along the region to be analyzed. Consequently the same thing is hold for the axial meshes [7].

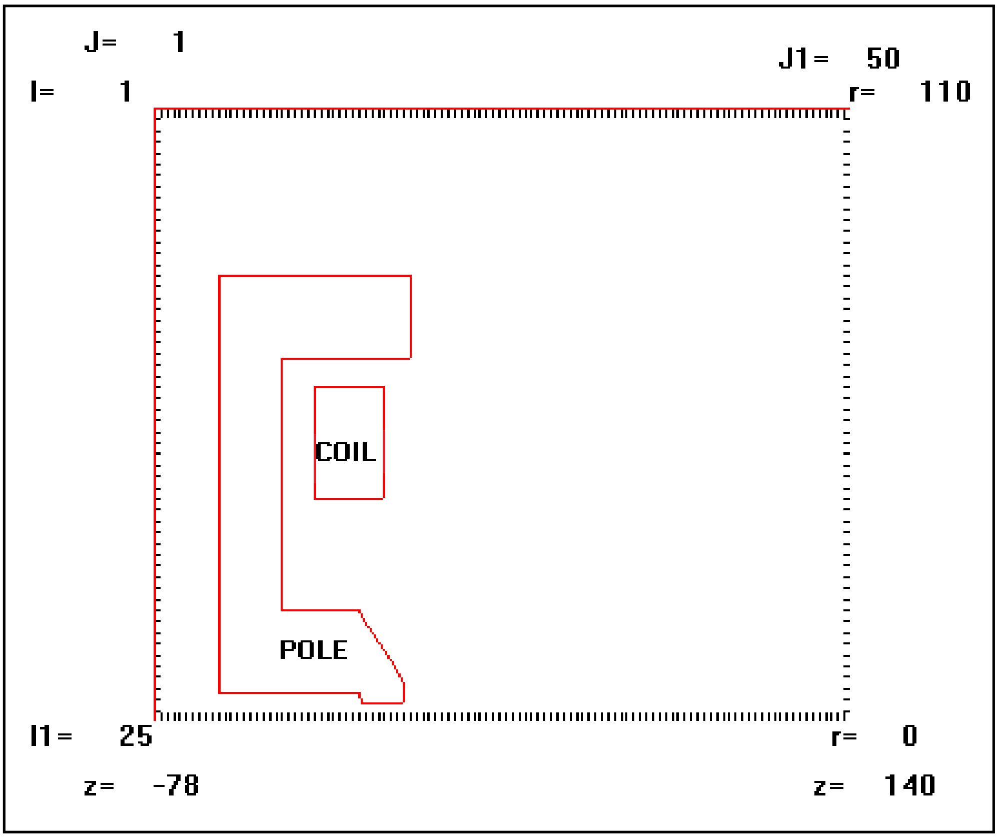


Figure 1 The geometrical shape of proposed asymmetric lens

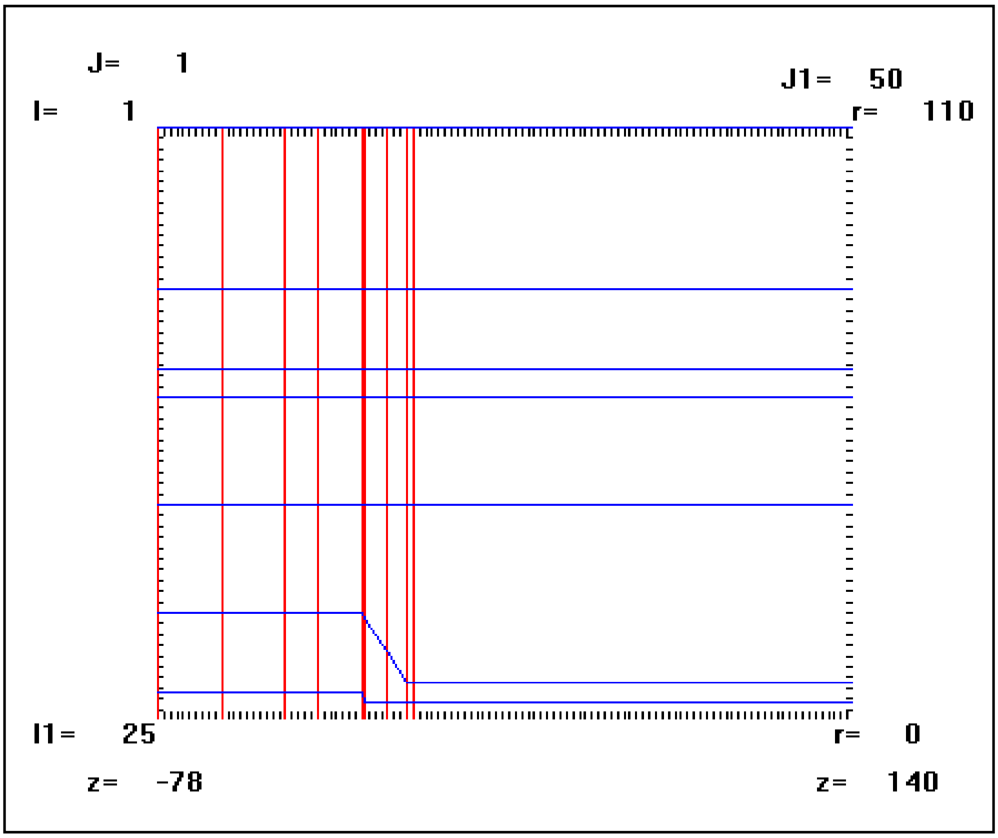


Figure 2 The mesh projection of proposed asymmetric lens

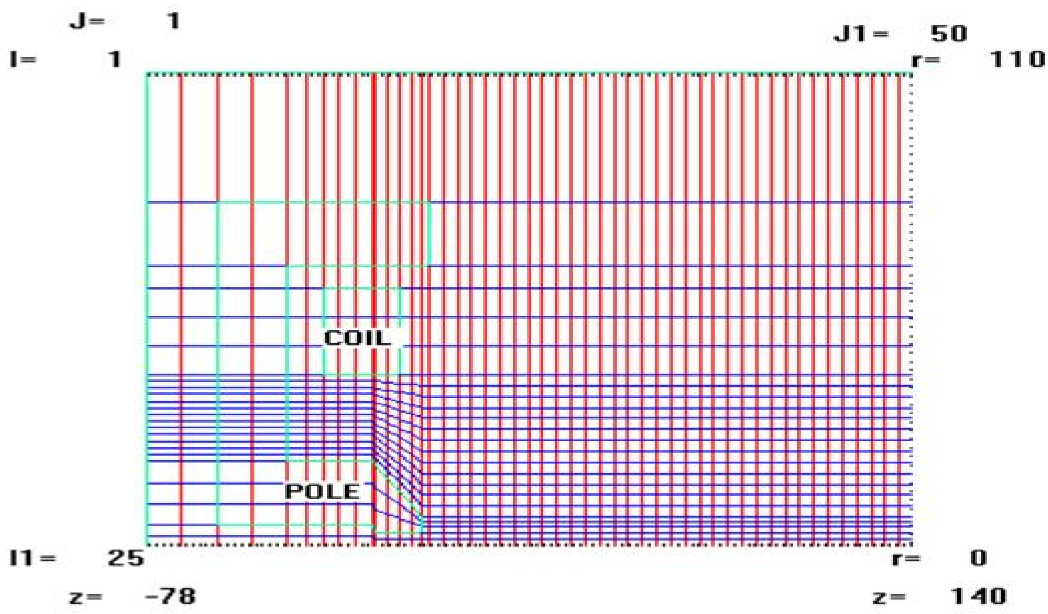
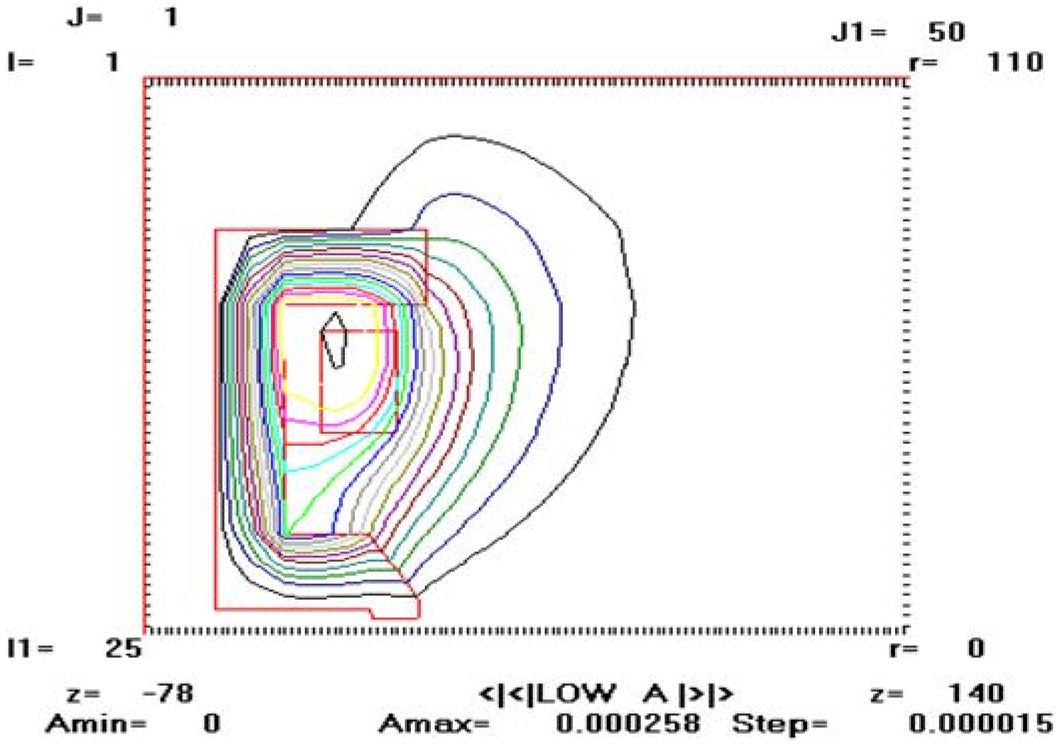


Figure 3 The produced mesh grid of proposed asymmetric lens

4. THE MAGNETIC FLUX LINES

Figures 4a and b shows the magnetic flux lines of proposed asymmetric lens for two values of excitations (NI). The start, end and step values of magnetic vector potential **A** (also named magnetic flux lines) are chosen to be 0 Wb/m , 0.000258 Wb/m, and 0.00001 Wb/m at NI=1k(ampere-turn) and 0 Wb/m, 0.000516 Wb/m, and 0.000035 Wb/m at NI=2k(ampere-turn) respectively [7]. It should be mentioned that, from the figures, the one can see the decreasing in magnetic vector potential values as away from out of loops.



(a) NI=1k(ampere-turn)

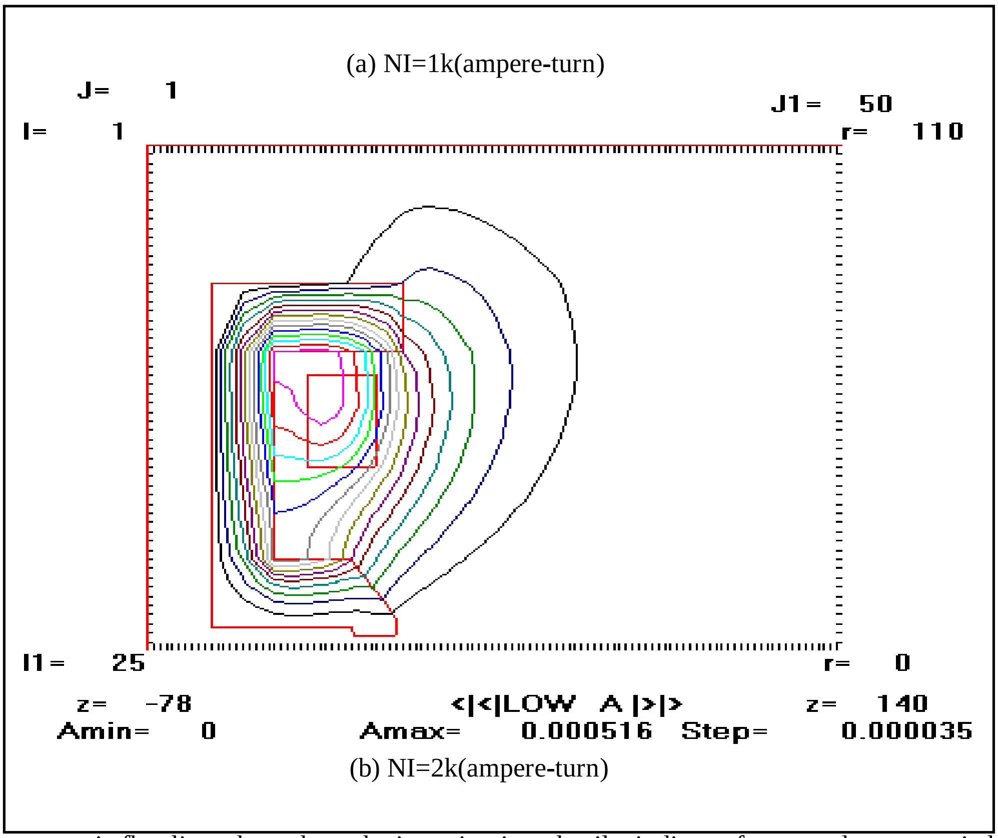


Figure 4 The magnetic flux lines throughout the iron circuit and coil windings of proposed asymmetric lenses at excitations (a) 1k(ampere-turn), and (b) 2k(ampere-turn)

5. THE AXIAL MAGNETIC FLUX DENSITY

The axial magnetic flux density distribution $B_z(z)$ along the lens axis could be determined with aid of CADTEL software. Where the cubic spline differentiation technique is used to produce $B_z(z)$. The plot results of B_z distributions according to CADTEL software are shown in figure 5 of asymmetric lens at NI=1 k(ampere-turn) , and 2 k(ampere-turn) [7].

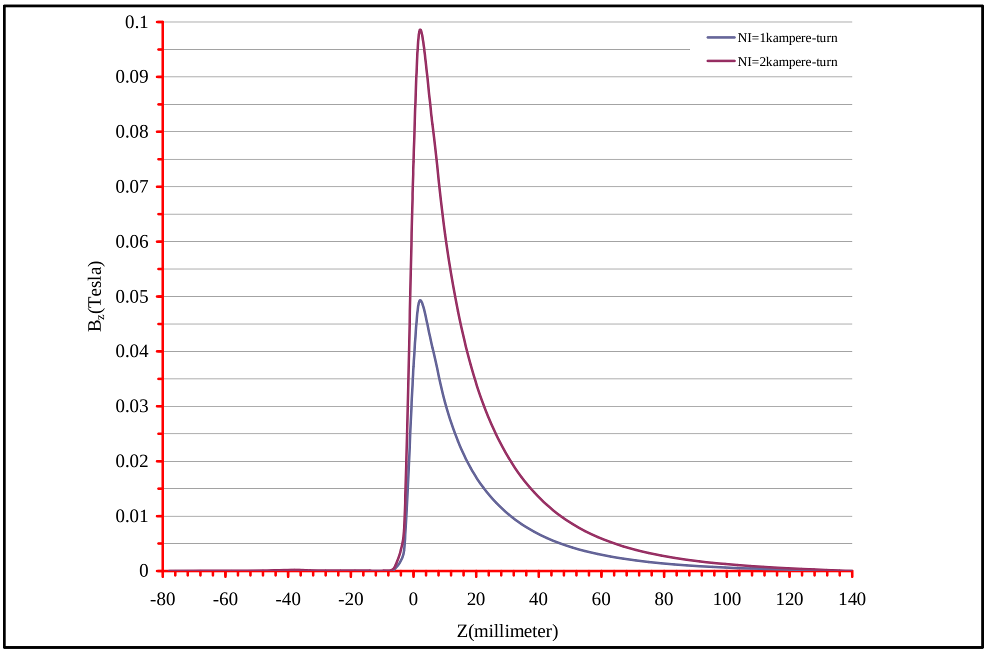
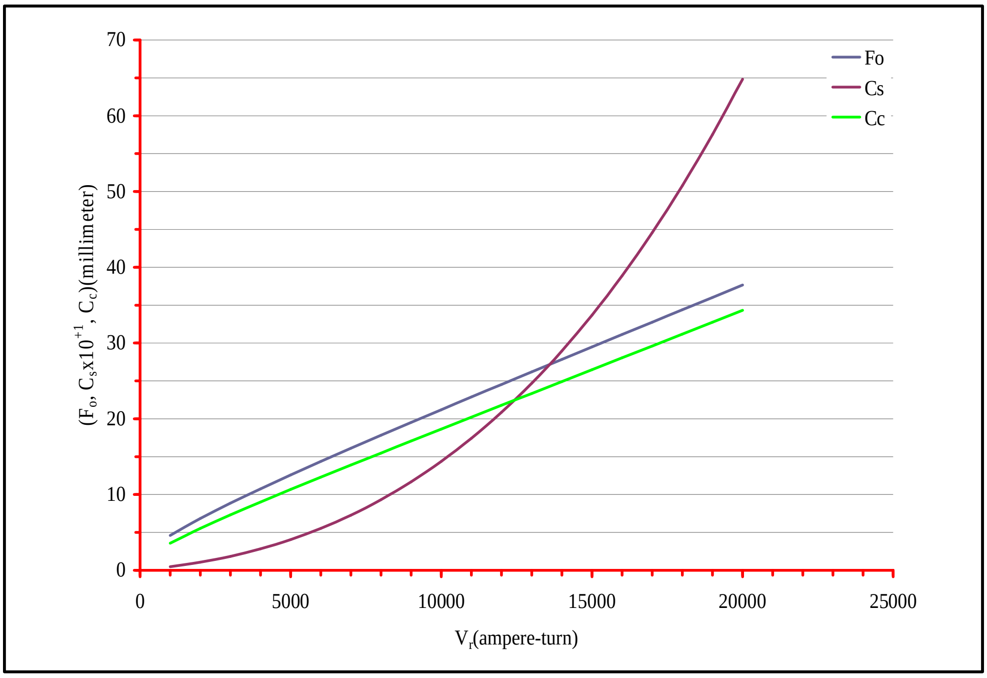


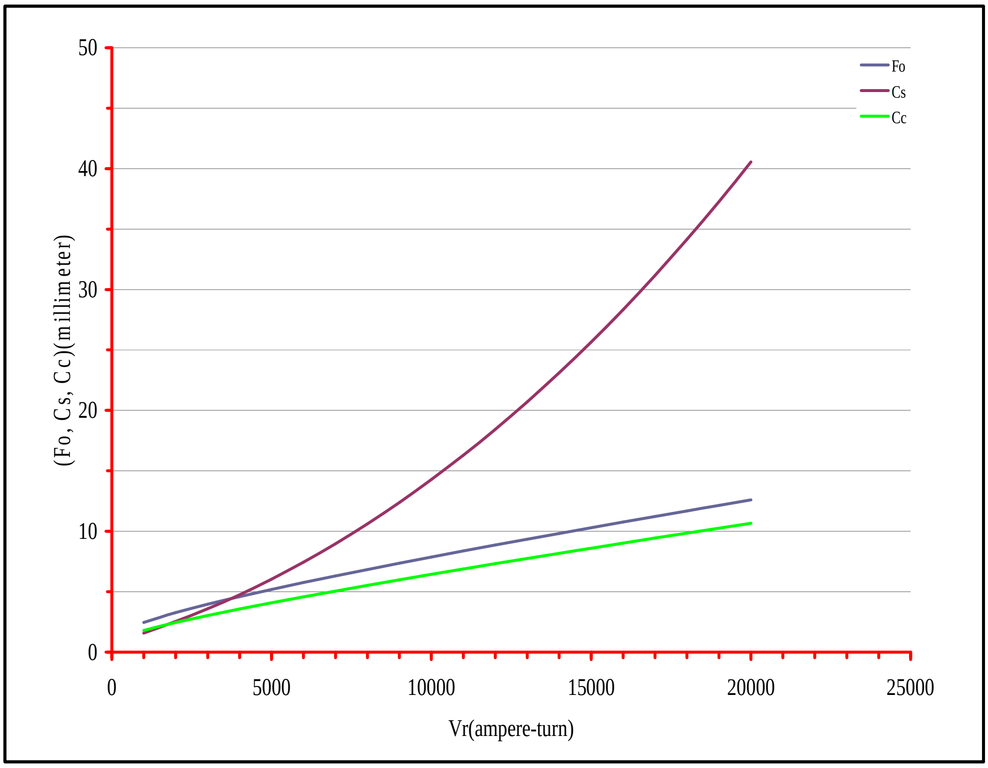
Figure 5 The axial flux density distribution as a function of axial distance Z of proposed asymmetric lens at NI 1k(ampere-turn) , and 2k(ampere-turn)

6. THE OBJECTIVE PROPERTIES

The computations of objective focal parameters; objective focal length (F_o), spherical aberration coefficient (C_s), and chromatic aberration coefficient (C_c) by CADTEL software for any round magnetic lens. Furthermore, these parameters have been determined under zero magnification condition. Figure 6a and b shows the relationship between the objective properties as a function of the relativistically-corrected accelerating voltage for proposed asymmetric lens at NI=1 k(ampere-turn) , and 2 k(ampere-turn) respectively. It should be mentioned that in figure 6a there is a big approach between the values of parameters (F_o) and (C_c) and slow increases with increase V_r , while the parameter C_s increased rapidly with increase V_r. Also, figure 6b shows there is a little different between the values of (F_o) and (C_c) , and increased with increase V_r , but, the value of C_s increases rapidly with increase V_r.



(a) NI=1k(ampere-turn)



(b) NI=2k(ampere-turn)

Figure 6 The objective focal properties (F_o, C_s, C_c) as a function of accelerating voltage V_r of proposed asymmetric lens at (a) NI=1k(ampere-turn), and (b) NI=2k(ampere-turn)

7. CONCLUSIONS

The results which obtained from CADTEL software proved excellent identical with others obtained from Al-Khashab lens which is computed by using the Fortran programs of the same proposed lens. It should be mentioned that a good properties obtained at excitation 2k ampere-turn than 1k ampere-turn. And at the same time, there is a low aberration obtained in low accelerating voltage with the case of 2k ampere-turn.

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