The Influence of Narrowing Grivet-Lenz Model on the Projector Properties of Magnetic Lenses

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Abstract:

Present work consist of a computational investigation aims at reveal the influence of narrowing or extending Grivet-Lenz model on its own projector properties. For this reason the well known formula of Grivet-Lenz model is raised to a power named in this work by “shape factor”. Projector properties and their related variables were determined for several values of the shape factor. Results have shown that as the shape factor value increases the magnetic field become more narrowing and its projector properties efficiency get worse. Accordingly to enhance the projector properties of Grivet model it should be extended over a wide axial interval.

الخلاصة:

يتألف البحث الحالي من بح حاسوبي يهدف لدراسة تأثير تضييق او توسيع نموذج كرفت–لنز على الصفات المسقطية الخاصة به. لهذا السبب فقد تم رفع صيغة نموذج كرفت–لنز الى القوة التـــي سميت في هذا البحث بـــ"عامل الشكل". ان الخصائص المسقطية والمتغيرات المتعلقة بها حسبت لعدة قيم من عامل الشكل. اظهرت النتائج بأنه كلما زادت قيمة عامل الشكل زاد ضـــيق عـــرض المجـــال المغناطيسي وان كفائة الخصائص المسقطية اصبحت اسوء. في ضوء ذلك ولغرض تحسين الصـــفات المسقطية لنموذج كرفت فأنها يجب ان تمتد لمراحل محورية واسعة.

1. Introduction

Conventionally to get rapid approximation for the properties of imaging magnetic field, one has to use analytical function to represent the axial magnetic field. One of the most useful functions is the Grivet-Lenz model. This model had been extensively studied for both objective and projector properties by several author, see for example [Szilagyi, 1988; Al-Batat, 1996; Warid, 2004]. It can be say that up to now Grivet-Lenz model can be investigated through three optimization variables namely the half width, magnetic peak value and the lens length.

However present work propose a new optimization parameter for this model named ‘shape factor’. Where the conventional mathematical form of Grivet-Lenz is raised to a variable power and called shape factor. This new variable is capable for extending or localizing the magnetic field distribution corresponds to Grivet-Lenz model along the optical axis. Precisely, this work aims at investigating the influence of varying the value of the shape factor on the projector properties of the modified Grivet-Lenz model and their related parameters.

1. Theory

The conventional form of Grivet-Lenz model usually given by the following expression [Hawkes, 1982]:

$$B_z(z)=B_m \mathrm{Sech}\,(2.27z/W) \qquad (1)$$

Where B_z is the axial magnetic flux density distribution along the optical axis z which in practice start at $z=z_1$ and extend to $z=z_2$. B_m and W are the peak value and the half width of the distribution respectively.

Equation (1) is modified in this work to be as shown in the following expression:

$B_z(z)=B_m\text{Sech}^n\,(2.27z/W)$ (2)

The exponent n is the shape factor. It is added to the Secant function in equation (1) in order to controlling the B_z distribution extension along the optical axis-z. In fact this will increase the degree of freedom for assigning B_z distribution. Now by a suitable choice for B_z, W and n the magnetic field along the required interval $z_1 \le z \le z_2$ can be determined.

In order to examine the projector properties of the distribution computed according to equation (2) by means of the following two equations that describe respectively the radial and spiral distortion coefficients [Hawkes, 1972]:

$$D_r=\left(\frac{\eta}{128V_r}\right)\int_{z_1}^{z_2}\left[\left(\frac{3\eta}{V_r}B_z^2+8B_z'^2\right)r_\alpha r_\gamma^3-4B_z^2\left(r_\gamma'^2 r_\alpha r_\gamma+r_\gamma' r_\alpha^2 r_\alpha'\right)\right]dz \qquad (3)$$

$$D_s=\int_{z_1}^{z_2}\left[\frac{3}{128}\left(\frac{\eta}{V_r}\right)^{3/2} r_\alpha^2 B_z^3+\frac{1}{16}\left(\frac{\eta}{V_r}\right)^{1/2} r_\alpha'^2 B_z\right]dz \qquad (4)$$

The paraxial ray equation [Szilagyi, 1988]:

$$r''+\frac{\eta}{8V_r}B_z^2 r=0 \qquad (5)$$

have to be solved initially to determine the charge particle trajectory $3r(z)$, of a charge to mass along the interval $z_1 \le z \le z_2$ for a certain accelerating potential V_r . In this work equation (5) was solved for the case of zero magnification condition.

2. Results and Discussions

Present work is mainly concern with investigating the influence of varying the shape factor (n) on the projector properties of the distributions obtained from equation (2). Thus the remaining parameters B_m and W are maintained constant at the following values respectively B_m=1T and W=1mm. It is important to mention thha the parameter W does not necessarily means the half width B_z .

Figure (1) shows the B_z distributions corresponds different values of n. It can be seen that the increasing of n leads the magnetic field to be more localized along the optical axis. Consequently the refractive power of B_z will decreases.

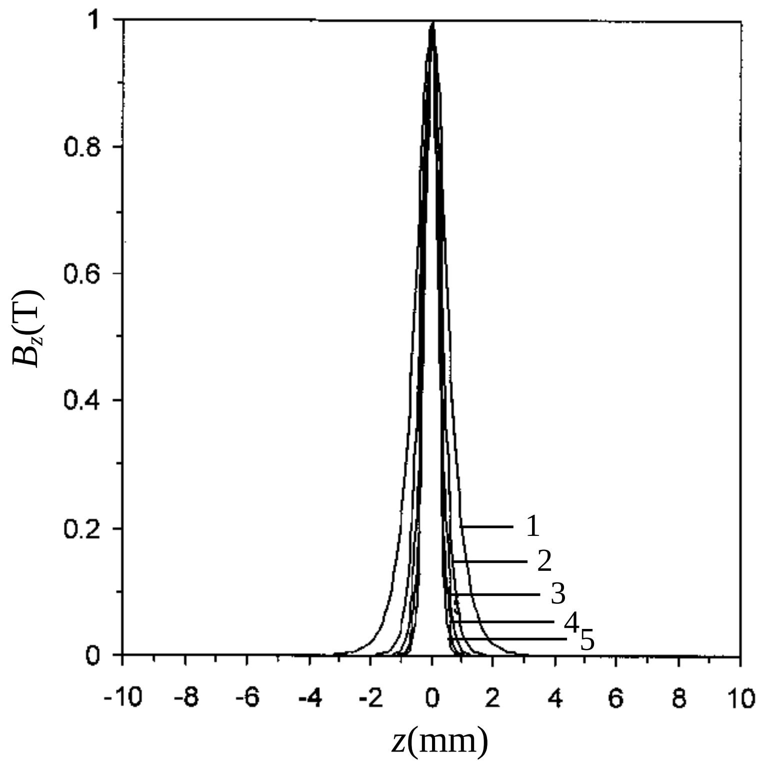

Figure (1): The axial magnetic field distribution for different n value.

Figure (2) shows variation of D_r and D_s as a function of n at the excitation parameter ($NI/V_r^{1/2}$) that gives minimum value of the projector focal length $(F_p)_{\min}$. It is clear that D_r and D_s getting further worse as n increase i.e. the image become more distorted as long as n takes higher values. In other word, in order to enhancing image quality n should be taken to be small as possible as can. Further more this figure shows that the magnification decrease as n increases due to the behavior of $(F_p)_{\min}$.

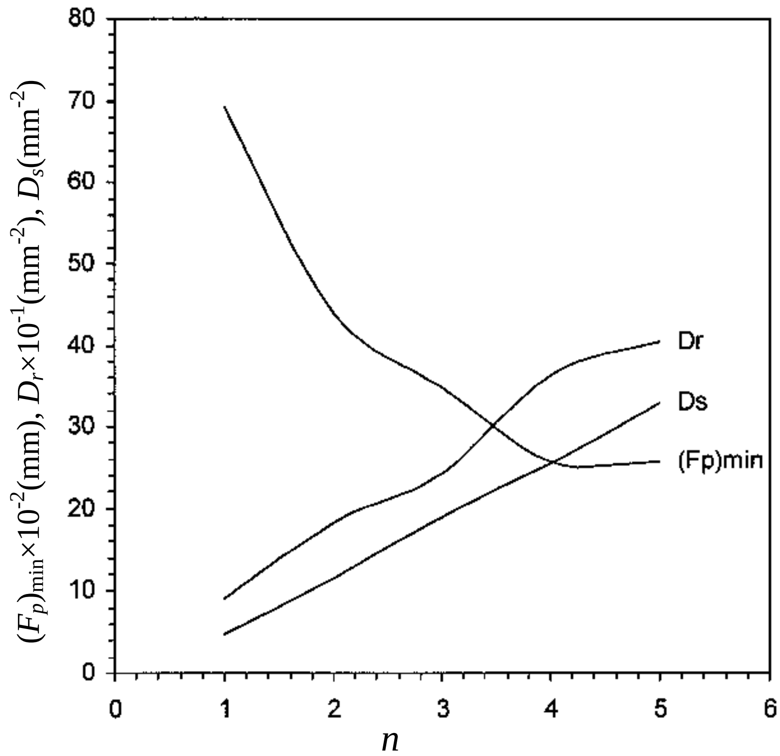

Figure (2): The projector properties D_r, D_s and $(F_p)_{min}$ at the first magnification point.

It is of more interest to visualize D_s behavior at $(NI/V_r^{1/2})$ value when D_r vanishes. Figure (3) proof that although the image is free from radial distortion its spiral distortion increases as *n* increases. Hence in order to obtain a highly magnified small distortion the *n* value have to be as small as could.

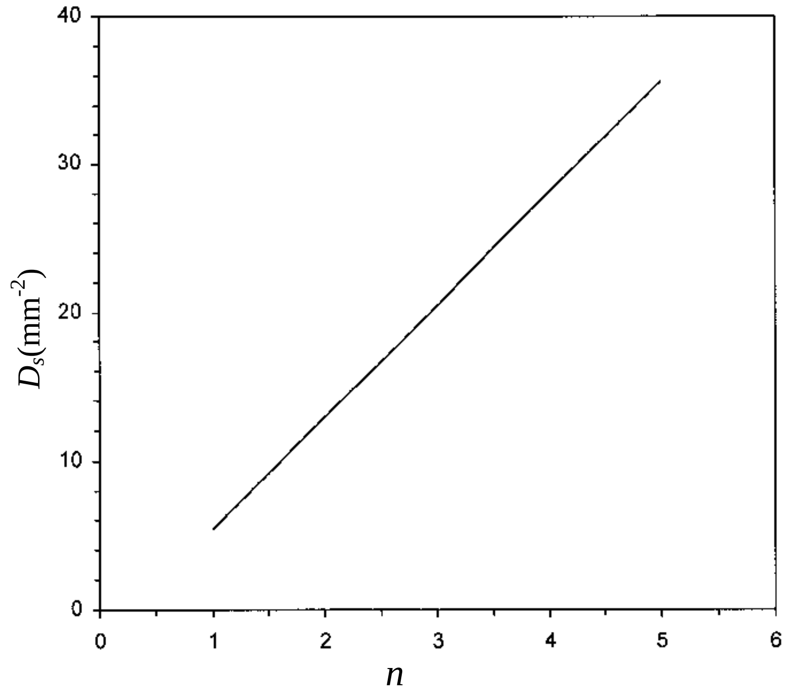

Figure (3): The spiral distortion D_s for various values of n at D_r=0.

3. Conclusions

According to the above results one may say that the extending of the magnetic field over a wide interval along the optical axis will enhance the projector properties. Thus the long lenses is better than the short one to use as a projector lens.

4. References

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