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Optimization of Rotation Angle of the Helical Dipole Magnets

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Spin Note

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Abstract

To minimize the deflection of a beam orbit in Siberian Snake magnets, the rotation angle of helical dipole magnets should be optimized. Thus the three dimensional magnetic field was calculated using TOSCA, and the rotation angle was adjusted to cancel out integral of transverse magnetic field along the beam axis.

1. Introduction

According to the basic idea, by applying helical dipole magnets for the Siberian Snake, deflections of beam orbits will be canceled due to 360 degree rotation of magnetic field. However, in actual magnets, there are fringing fields and 360 degree rotation does not always cancel the deflection of orbits. Then in order to optimize the rotation angle of the helical dipole, the magnetic fields along the beam axis have been integrated by using TOSCA.

2. Definition of the rotation angle

2. 1 Mechanical definition of the rotation angle

Mechanical definition of the rotation angle is indicated in Fig. 1. There is a reference point at the center of curvature of winding conductors in each end, and the difference between dipole directions at these two reference points is defined as the mechanical rotation angle. In this note, let us take this angle to identify a model in various types. Original design of the Slotted type model takes 340 degree in this definition. A helical pitch of this design corresponds to 360 degree rotation within 2400 mm of effective length.

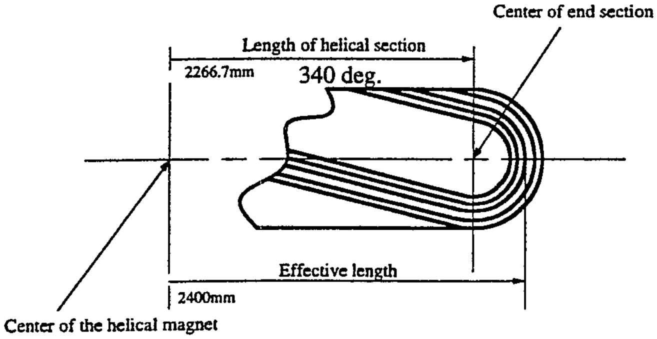

Fig. 1 Mechanical definition of the magnet end

2. 2 Rotation angle of dipole field[1]

Figure 2 describes the relationship between field strength and phase angle of the dipole component in a typical helical dipole magnet. Dots simply indicate the strength and phase angle at every 30 mm on the beam axis. In an end region, the field strength decreases and this makes the rotation angle shorten from 360 degree. However the density of the dots in the end region, around 0 degree, is rather high and change of phase angle is gradual. This means the integral of the magnetic fields within the end region is effectively large. A solid line in Fig 2. takes this effect into account. The field strength is multiplied by a ratio which is the average change of phase angle in the body region divided by each change of the phase angle. Viewed in this light, it seems difficult to define the rotation angle of the dipole component direction in the actual snake magnets.

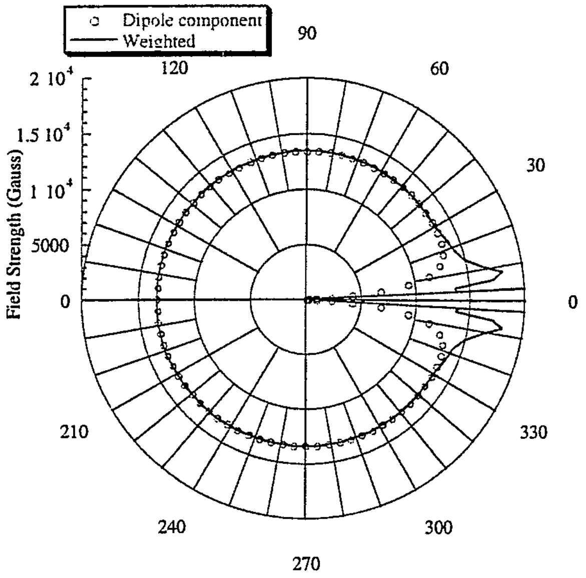

Fig. 2 Field strength and phase angle in a helical dipole

2. 3 Integral of the transverse magnetic fields

In Fig. 3, a typical magnetic field is shown by vertical, By, and horizontal, Bx, components. Applying the coordinates which are used by this figure, a symmetry condition makes an integral of Bx component along the beam axis automatically zero. Therefore we have to pay attention only to the By component, and have to optimize the integral of this component to zero in designing helical magnets. When this condition is achieved, we may say this magnet has effectively 360 degree of rotation angle.

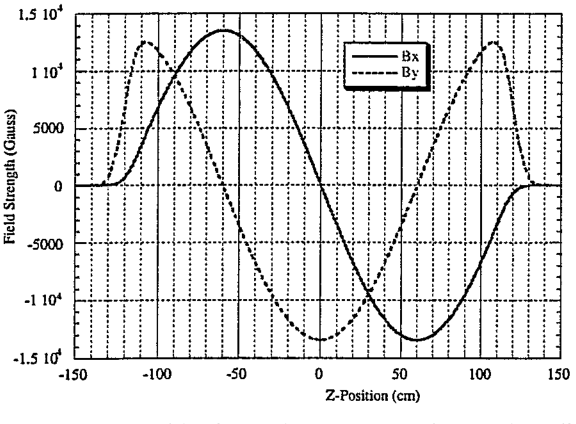

Fig. 3 Vertical and horizontal components in a helical dipole

3. Magnetic calculations

By using TOSCA, integration of the By component for several magnets which have different rotation angle were computed. These calculation models use a periodicity condition and have about 190000 nodes. It took about 4 days to complete one of these models. Current was assumed as 100 A/cable, and amplitude of magnetic field was predicted as 1.384 T at the center of magnet.

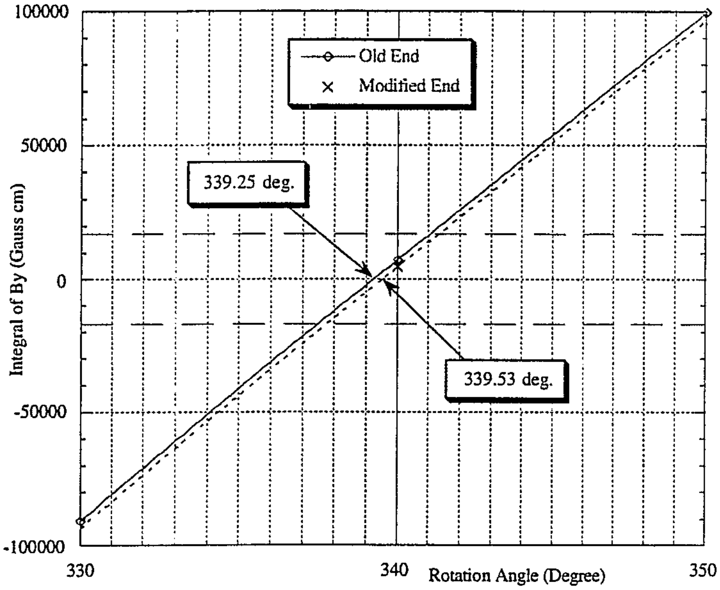

Fig.4 Integral of the vertical component

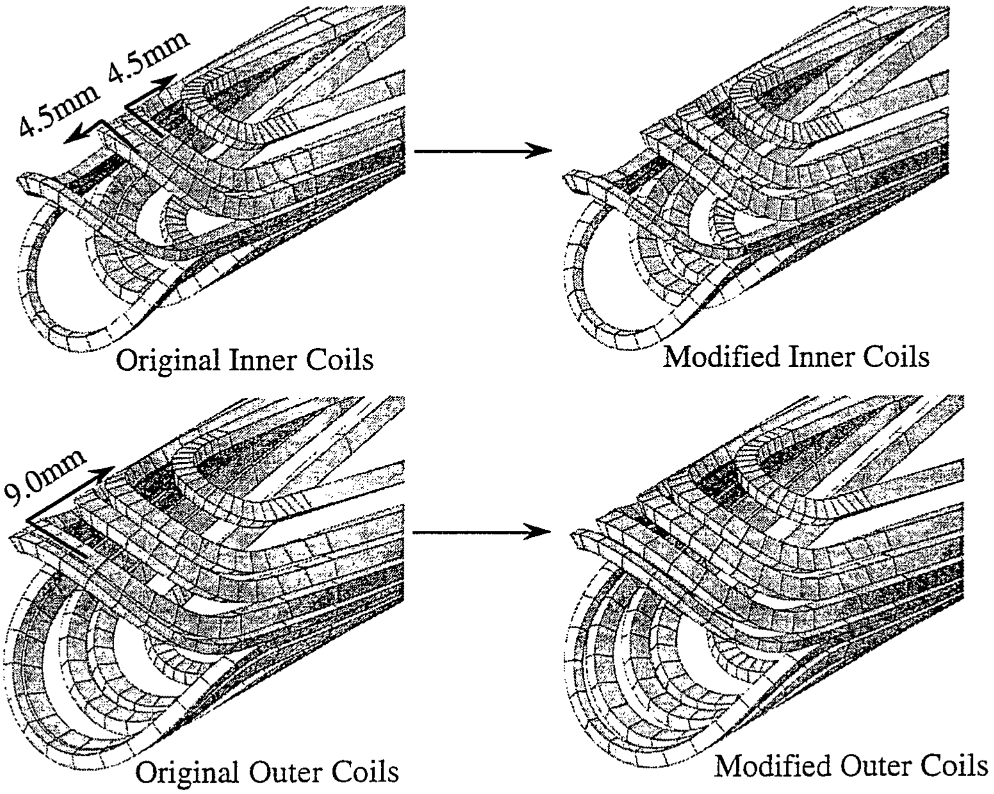

Fig. 5 Modification in the end section

About cross sectional magnet design, number of layers at most inside slots, closest to each poles, of both inner and outer coils was reduced from 9 to 8 layers in latest version which was proposed by E. Willen and R. Gupta. Of course these models use the latest cross sectional design. The results are shown as diamonds in Fig. 4. The solid fit line crosses By=0 at 339.25 degree. About end design of the magnets, due to a request from automatic coil winding methods, arrangement of a few slots will be changed also. Exact numerical data for this modification is not available yet. This modification was assumed as in Fig.5, and only one modified model was calculated. In Fig. 4, the result of this modified model is indicated as a cross and dotted line was drawn using same coefficient of the solid fit line. According to this line, the zero integrated field for this modified model requires 339.53 degree of mechanical rotation angle. So we only need to change this angle very slightly from the original design. Broken horizontal lines indicated in Fig. 4 express tolerances for the snake magnets[2] as proposed by M. Syphers.

4. Conclusion

For previous end design, not modified, the mechanical rotation angle should be 339.25 degree. For modified end design, correct angle is predicted to be 339.53 degree.

5 Acknowledgment

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References

[1] T. Tominaka Private communications
[2] M. J. Syphers Spin Note AGS/RHIC/SN No. 58