IEEE Transactions on Nuclear Science, Vol.NS-22, No.3, June 1975

STORAGE ACCELERATOR BENDING MAGNET WITHOUT MEDIAN PLANE SYMMETRY*

G. Parzen and K. Jellett
Brookhaven National Laboratory
Upton, New York 11973

Summary

An H-magnet with no median plane symmetry, in which all the current carrying coils lie below the median plane, has been studied using the GRACY magnet program. This magnet was suggested by A. vanSteenbergen and has several possible advantages for use in a superconducting storage accelerator. The field multipoles violating median plane symmetry were found to be small, and correctable with small correction coils. In addition, it was found possible to reduce these undesired multipoles considerably by shaping the iron pole face.

I. Introduction

Figure 1 shows a possible bending magnet suggested by A. vanSteenbergen for an AGS stretcher ring. The magnet is a modified H-magnet with only one coil below the median plane. This magnet does not have median plane symmetry. A computer study, using the GRACY magnet program, indicates that the median plane field is, nevertheless, quite good, and requires very small correction coils to be made acceptable for use in a storage ring. The field can also be improved considerably by shaping the upper pole.

II. Magnet Field Results

The magnet considered here is shown in Fig. 1. It has a pole width of 20 cm, and magnet gap of 6 cm. The desired good field region is about ± 2.5 cm. The magnet is to be used at fields no larger than about 10 kG, so that there are no appreciable iron saturation effects.

Table I shows the multipoles present in the vertical and radian fields in the median plane, which are defined by

$$B_z = B_o(b_o + b_1x + b_2x^2 + b_3x^3 + \dots) \quad ,$$

$$B_r = B_o(a_o + a_1x + a_2x^2 + a_3x^3 + \dots) \quad ,$$

where B_o is the vertical field at the magnet center. Units for b_n and a_n are cm^{-n}. One sees that the vertical field is good, while the radial field B_r has appreciable a_1 and a_3 which would require correction. We find $a_1 = -1.28 \times 10^{-3}$/cm and $a_3 = -0.058 \times 10^{-3}/cm^3$ which correspond to pole tip fields of 0.0038 and 0.0016 relative to B_o at the pole face which is 3 cm from the median plane. These undesired multipoles a_1 and a_3 could then be corrected out with small correction coils surrounding the desired aperture of ± 2.5 cm.

The forces on the coils are of interest. One finds at B_o = 10 kG, a downward force F_y = - 933 kG/m, and an outward force F_x = 326 kG/m.

III. Effect of Errors in the Coil Positions

For this magnet, one would like the field to be relatively insensitive to rather large displacements of the current blocks. Table I lists the rms value of the error multipoles introduced into the median plane magnetic field by a random displacement of the two current blocks by 0.5 cm. The only error multipoles that are appreciable are Δa_o and Δb_1, and these are still within the usual tolerances for an accelerator. We find that $\Delta a_o = 0.12 \times 10^{-3}$ and $\Delta b_1 = 0.11 \times 10^{-3}$ cm^{-1}.

IV. Pole Shaping to Eliminate the Radial Field

Because of the lack of median plane symmetry, the median plane magnetic field has appreciable a_1 and a_3. It is possible to eliminate the a_n by shaping the pole. One approach is shown in Fig. 1 where the upper pole is made narrower by 2.4 cm at each edge. Suprisingly, it is possible to essentially eliminate both a_1 and a_3 using the one parameter, the width of the upper pole. Narrowing the upper pole, while reducing the a_n multipoles in the radial field, increases the b_n multipoles. However, the b_n so introduced are small, although they may still require correction. The multipoles b_n and a_n found by narrowing the pole by 2.4 cm at each edge are given in Table I. The iron removed from the upper pole is 2.4 cm by 1 cm at both sides of the pole.

TABLE I

The column headed Rectangular Poles gives multipoles present in a magnet with rectangular poles, and the coils are only below the median plane. The column headed Narrowed Upper Pole shows the reduction in the multipoles obtained by narrowing the upper pole by 2.4 cm on each side. The columns headed Coil Errors show the rms values of the error multipoles introduced by an rm error in the coil position of 0.5 cm.

	Rectangular Poles		Narrowed Upper Pole		Coil Errors	
	b_n	a_n	b_n	a_n	Δb_n rms	Δa_n rms
n	10^{-3} cm^{-n}	10^{-3} cm^{-n}	10^{-3} cm^{-n}	10^{-3} cm^{-n}	10^{-3} cm^{-n}	10^{-3} cm^{-n}
0	1000	0	1000	0	---	0.12
1	0	-1.28	0	0.000	0.11	0.01
2	-0.008	0	-0.0417	0	0.002	0.001
3	0	-0.058	0	0.001	0.000	0.000
4	-0.002	0	-0.0051	0	0.000	0.000
5	0	-0.001	0	0.000	0.000	0.000
6	0.000	0	0.000	0	0.000	0.000

*Work performed under the auspices of the U.S. Energy Research & Development Administration.

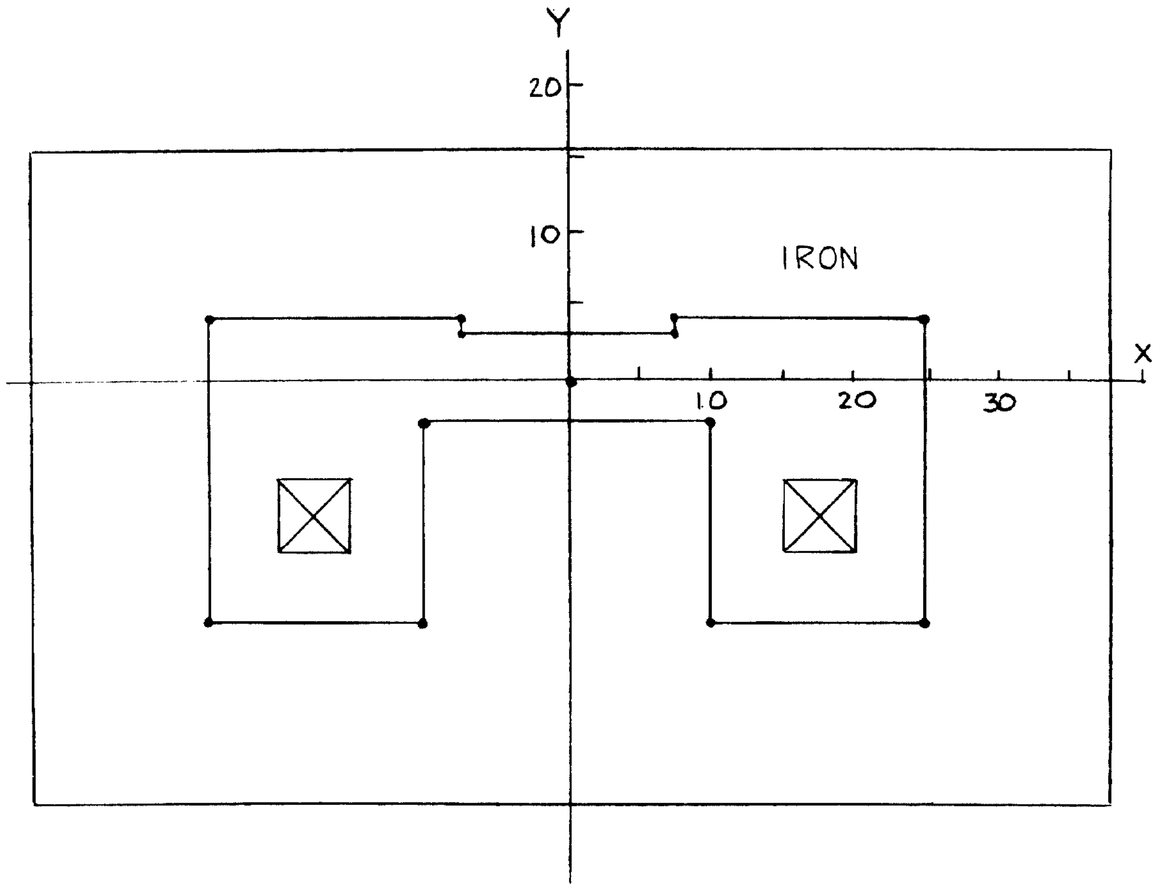

Fig. 1. A magnet without median plane symmetry.