BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York

ACCELERATOR DEPARTMENT
Informal Report

A SEVEN BLOCK COIL CONFIGURATION FOR A
COSINE BENDING MAGNET

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 ISABELLE PROJECT

INTERSECTING STORAGE ACCELERATOR NOTES

A SEVEN BLOCK COIL CONFIGURATION FOR A COSINE BENDING MAGNET

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This note presents a particular coil configuration for a cosine bending magnet wound out of a ribbon type conductor. The geometry is shown in Fig. 1. There are seven blocks in a quadrant which are arranged essentially as suggested by R. Beth.¹ A good field region of 76% of the apertures within the coils, or ± 1.14 in., for a 3 in. inner diameter coil is achieved. This is accomplished by the choice of the ribbon distribution and by introducing small azimuthal displacements, $\Delta\theta_n$, of each of the seven blocks which cancel out the harmful lower harmonics in the current distribution. No radial displacements of the blocks are used.

It was shown by G. Morgan that one can eliminate roughly $2N$ lower multipoles by using both radial and azimuthal displacements of the $2N$ blocks in a quadrant and thus get an adequate good field region. This note shows that one can get an adequate good field region using only azimuthal displacement of the blocks, by using a proper choice of ribbon distribution and the number of blocks.

Choice of the Number of Blocks

The choice of 7 blocks is partly suggested by the fact that there are ribbon distributions which make b_2 , b_4 , and b_8 vanish, where the b_n are defined by the median phase field being written as

$$B = B_0 (1 + b_2 X^2 + b_4 X^4 + b_6 X^6 + \dots) \quad (1)$$

The multipoles b_2 , b_4 , and b_8 will vanish for certain ribbon distributions, if each block has a uniform current density proportional to the ribbon distribution. This seems desirable for then the corrections required to cancel out the

lower multipoles are small, and there is less chance that the corrections will excite the higher multipoles strongly.

If one has 7 blocks and if one wants to restrict one's self to correcting the field by using only azimuthal displacements $\Delta\theta_n$ of the blocks and not using any radial displacements, than one can hope to use the $\Delta\theta_n$ to correct for the 7 lowest multipoles $b_2, b_4, b_6, b_8, b_{10}, b_{12}$, and b_{14} . If the $\Delta\theta_n$ required to correct the b_2 to b_{14} are large, then these $\Delta\theta_n$ may excite a large b_{16} or higher multipole.

Another reason for choosing 7 blocks is that 7 blocks in the Beth arrangement has a theoretical maximum good field aperture² of about 73%. One desires a good field aperture of 68% in ISABELLE. One would expect to do somewhat worse than the theoretical maximum good field, if one corrects using only $\Delta\theta_n$ displacements of the blocks and no Δr_n . Thus, the choice of 7 blocks seems about the lowest number of blocks that will do. The case of 6 blocks in the Beth arrangement has a theoretical maximum good field of about 68% and appears to be slightly too low in number of blocks to expect to get the desired 68% good field aperture using $\Delta\theta_n$ corrections only.

The Ribbon Stacking

The ribbon distribution for the 7 block case considered here is 15, 14, 13, 11, 9, 6, 3 or a total of 71 turns of ribbon. This ribbon distribution has the property that a uniform current density in each block proportional to the above ribbon distribution would make b_2, b_4 and b_8 vanish.

The procedure used to space the ribbons within each block was to simply place the ribbons in the center of each block with no separators between them. Thus, there is a fair amount of space between the blocks which have much less than 15 ribbons between them, and thus room for the azimuthal displacements, $\Delta\theta_n$, required to correct the field.

This procedure is not critical. A more uniform spacing of the ribbon in each block would reduce the $\Delta\theta_n$ required to correct the field, and would be acceptable provided there is enough space between the blocks for the $\Delta\theta_n$ displacements.

The ribbons are stacked parallel to the radial line at the center of the block and each ribbon is moved in radially until it touches the circle of radius $R_c = 1.5$ in. The ribbon thickness used was 0.0209 in.

Table I shows the corrected field and the corrections $\Delta\theta_n$ required for the case of 7 blocks with 71 ribbon turns.

A 7 Block 56 Ribbon Arrangement

Other ribbon arrangements are possible that have fewer total ribbons and thus a larger ribbon thickness and which still make b_2 , b_4 , and b_8 vanish for the ideal uniform current density in each block case. One such arrangement has 56 ribbons, 7 blocks, and a ribbon distribution of 12, 11, 10, 8, 6, 4, 2. The ribbon thickness here is 26.1 mils. When corrected, using $\Delta\theta_n$ displacements of the current blocks, one obtains a good field aperture of 71.5%. The results for this case are shown in Table II.

References

1. R.A.Beth, Brookhaven National Laboratory Accelerator Department Report AADD-135 (1967).
2. G. Parzen and K. Jellett, Brookhaven National Laboratory Accelerator Department Report, AADD-188 (1972).

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x (in.)	$\frac{B'}{B}/10^{-3}$ (in. ⁻¹)	$\frac{B''}{B}/10^{-3}$ (in. ⁻²)	m	$b_m/10^{-3}$ (in. ^{-m})
0	0		2	0.008
0.125	0	0	4	0.009
		0	6	0.001
0.25	0.001		8	-0.001
0.375	0.002	0.01	10	0.001
		0.02	12	0.000
0.5	0.005		14	0.000
0.625	0.010	0.04	16	-0.001
		0.06	18	-0.001
0.75	0.017			
0.875	0.024	0.06		
1.0	0.014	-0.08	Block	θ_n
				$\Delta\theta_n$
1.125	-0.074	-0.70		$\Delta\theta_n/10^{-3}$
				(deg.) (deg.) (rad.)
1.250	-0.218	-1.15	1	6
			2	18
			3	30
			4	42
			5	54
			6	66
			7	78
				0.057
				-0.027
				-0.053
				-0.125
				0.045
				0.270
				0.355
				0.99
				-0.46
				-0.92
				-2.18
				0.78
				4.72
				6.20

TABLE I

Results for a dipole having 7 blocks in a quadrant, a total of 71 ribbon turns, and a ribbon distribution of 15, 14, 13, 11, 9, 6, 3. The $\Delta\theta_n$ are the azimuthal displacements needed to cancel the undesired lower multipoles, b_2 to b_{14} , and with these $\Delta\theta_n$, a good field aperture of 76.4% or ± 1.146 in. is achieved. B'/B and B''/B are the corrected first and second derivatives of the field. The inner radius of the current distribution is $R_c = 1.5$ in. The ribbon is 5/8 in. wide and 0.0209 in. thick.

x (in.)	$\frac{B'}{B}/10^{-3}$ (in. ⁻¹)	$\frac{B''}{B}/10^{-3}$ (in. ⁻²)	m	$b_m/10^{-3}$ (in. ^{-m})
0	0		2	-0.006
0.125	0	0	4	0.006
0.25	0	0	6	0.001
0.375	0.001	0.01	8	-0.002
0.500	0.003	0.02	10	0.002
0.625	0.006	0.02	12	-0.001
0.75	0.011	0.04	14	0.000
0.875	0.022	0.09	16	0.004
1.0	0.052	0.24	18	-0.002
1.125	0.122	0.56		
1.250	0.755	5.06		

Block	θ_n (deg.)	$\Delta\theta_n$ (deg.)	$\Delta\theta_n/10^{-3}$ (rad.)
1	6	0.130	2.277
2	18	0.211	3.684
3	30	-0.039	-0.677
4	42	0.051	0.890
5	54	0.428	7.462
6	66	1.114	19.447
7	78	2.231	38.945

TABLE II

Results for a dipole having 7 blocks in a quadrant, a total of 56 ribbon turns, and a ribbon distribution of 12, 11, 10, 9, 7, 5, 2. The $\Delta\theta_n$ are the azimuthal displacements needed to cancel the undesired lower multipoles, b_2 to b_{14} , and with these $\Delta\theta_n$, a good field aperture of 71.5% or ± 1.07 in. is achieved. B'/B and B''/B are the corrected first and second derivatives of the field. The inner radius of the current distribution is $R_c = 1.5$ in. The ribbon is 5/8 in. wide and 0.0261 in. thick.

Current Block Arrangement

7 Blocks