BNL-105197-2014-TECH

Booster Technical Note No. 153;BNL-105197-2014-IR

THE EDDY CURRENT MULTIPOLES OF THE BOOSTER VACUUM CHAMBER

S. Y. Lee

November 1989

Collider Accelerator Department

Brookhaven National Laboratory

U.S. Department of Energy

USDOE Office of Science (SC)

DISCLAIMER

THE EDDY CURRENT MULTIPOLES OF THE BOOSTER VACUUM CHAMBER

AD
BOOSTER TECHNICAL NOTE
NO. 153

S. Y. LEE and S. KAHN

NOVEMBER 16, 1989

ACCELERATOR DEVELOPMENT DEPARTMENT
BROOKHAVEN NATIONAL LABORATORY
UPTON, NEW YORK 11973

Booster Project
Alternating Gradient Synchrotron Department
BROOKHAVEN NATIONAL LABORATORY
Associated Universities, Inc.
Upton, New York 11973

Booster Project
Technical Note

No. 153

THE EDDY CURRENT MULTIPOLES OF THE BOOSTER VACUUM CHAMBER

S. Y. Lee and S. Kahn

Abstract

The multipole coefficient of the Booster vacuum chamber is calculated based on the Booster conceptual design configuration. We found that the multipole coefficient are not negligible for large $\dot{B}$ operation.

1. Introduction

The eddy current multipole coefficients of the Booster vacuum chamber has been calculated with PE2D program earlier by Morgan and Kahn[1]. Since the proposed vacuum chamber geometry in AGS Booster is different from that of Morgan and Kahn's calculation, it is worthwhile to recalculate these multipole coefficients.

Recently, an analytic method for calculating the multipole coefficient has been developed[2], we can calculate the higher multipole reliably. However, we shall also compare the analytic calculation with that of numerical result of PE2D.

2. Multipoles and the Radius of Convergence

The proposed Booster vacuum chamber geometry is shown in Fig. 1. The operational parameter is as follows:

$$\dot{B}/B = 25/\text{sec}$$
$$\sigma^{-1} = 1.28\ \mu\Omega\,\text{m}$$
$$h = 0.002\ \text{m}$$

where h and σ are thickness of vacuum wall and conductivity of Inconel respectively.

The multipole coefficient can be calculated analytically by integrating the multipole coefficient of reference 2 along the vacuum chamber wall. At the same time, we also calculate these multipole coefficients by using the numerical integrator of PE2D. Table 1 lists the multipole coefficients.

Table 1 <u>**Eddy Current Multipole Coefficients**</u>

n	$b_n[m^{-n}]$	
	Analytic	PE2D
0	-6.025×10^{-3}	-6.22×10^{-3}
2	0.5038	0.5175
4	4.8133	7.542
6	-5.9830×10^{3}	-6.00×10^{3}
8	2.1705×10^{6}	3.20×10^{5} *
10	-1.2692×10^{9}	
12	3.6064×10^{11}	
14	-2.1826×10^{14}	
16	1.3680×10^{17}	
18	-8.8354×10^{19}	

* To obtain reliable b_8 in the numerical calculation, the mesh size should be decreased.

The multipole coefficients in Table 1 is much larger than that obtained in Reference 1 mainly due to the different vacuum chamber geometry.

Figure 2 shows the exact $\Delta B(x)/B_o$ vs $\Delta B_N(x)/B_o$, obtain from the multipole expansion, i.e.,

$$\frac{\Delta B_N(x)}{B_o} \equiv \sum_{n=0}^{N} b_n x^n$$

The multipole expansion is thus valid only up to x = 45 mm. However, off x axis, in the x, y, plane, the field must be rich in harmonics. We expect, therefore, the dynamical aperture would be about 45 mm.

3. Shape Dependence of Multipole Coefficients

The multipole coefficients is a delicate contribution of various part of the currents. In Table 2, we compare the multipole coefficients of the shapes of the Booster polygon, ellipse and rectangle with width ± 3.25" and height ± 1.375". We found that the multipole for the ellipse and rectangle have substantially smaller multipole.

Figure 3 compares the exact field shapes with $\Delta B_{N=10}(x)/B_o$. We note that the smaller multipole content of the elliptical and rectangular geometry is reflected to have larger radius of convergence.

Table 2 Multipole Coefficients of Different Shape Vacuum Chamber

n	$b_n[m^{-n}]$*		
	Booster Polygon	Ellipse	Rectangle
0	-6.025×10^{-3}	-4.884×10^{-3}	-7.170×10^{-3}
2	0.5038	0.4849	0.5738
4	4.8133	-16.056	-9.937
6	-5.9830×10^{3}	2.487×10^{2}	-1.836×10^{3}
8	2.171×10^{6}	7.412×10^{4}	-1.563×10^{5}
10	-1.269×10^{9}	2.341×10^{6}	-1.708×10^{6}
12	3.606×10^{11}	8.324×10^{7}	6.323×10^{8}

* All vacuum chamber have the same height and width.

4. Conclusion

The Booster vacuum chamber geometry may create nonlinear field which limits the dynamical aperture in the large $\dot{B}$ operation mode. The elliptical vacuum chamber seems to be the best choice for fast cycling synchrotrons.

References:

1. G. Morgan and S. Kahn, Booster Tech. Note #4, January 28, 1986.

2. S. Y. Lee, "Multipole Expansion", Acc. Phys. Tech. Note #12, AD/AP/TN-12.

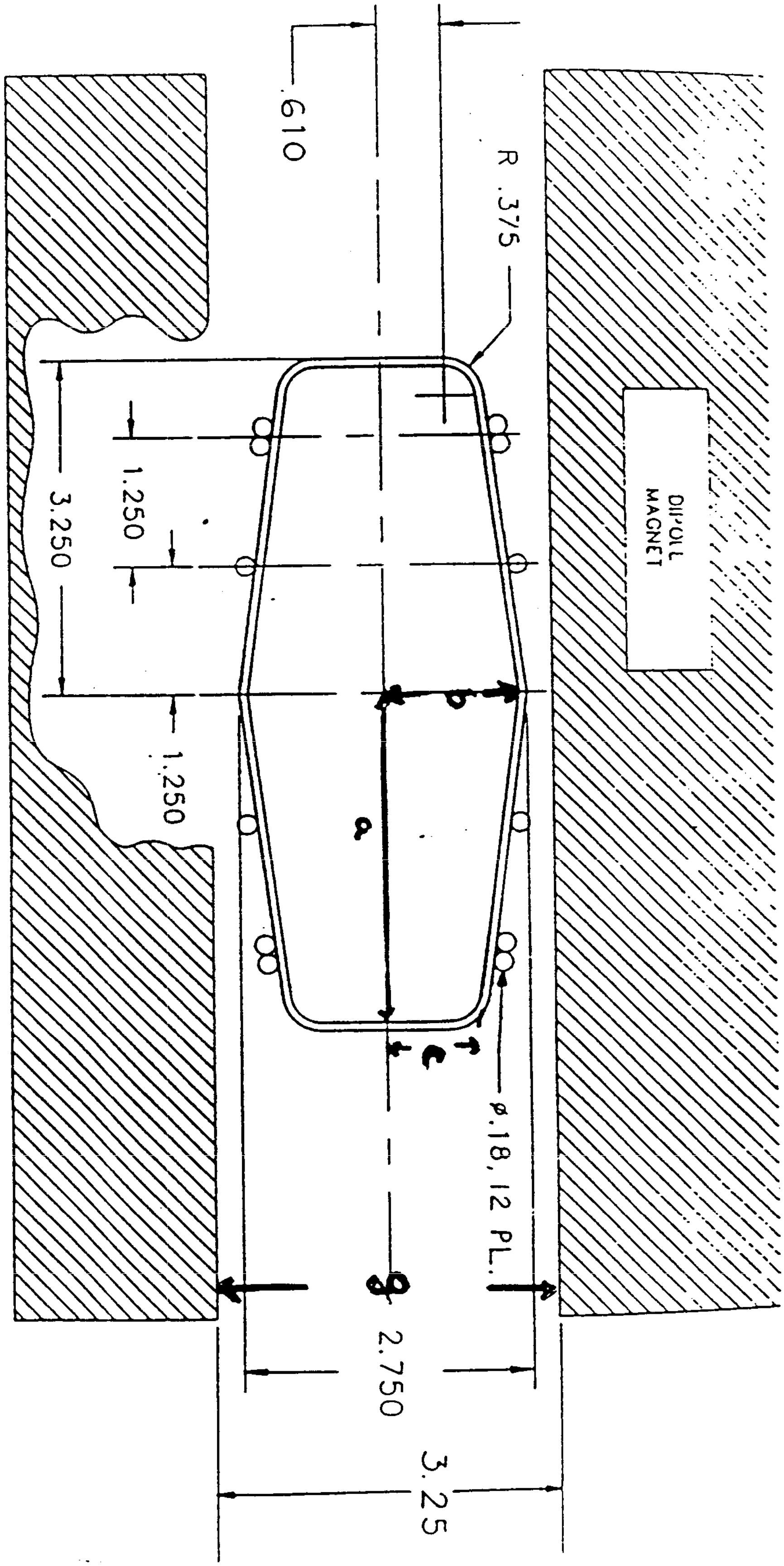
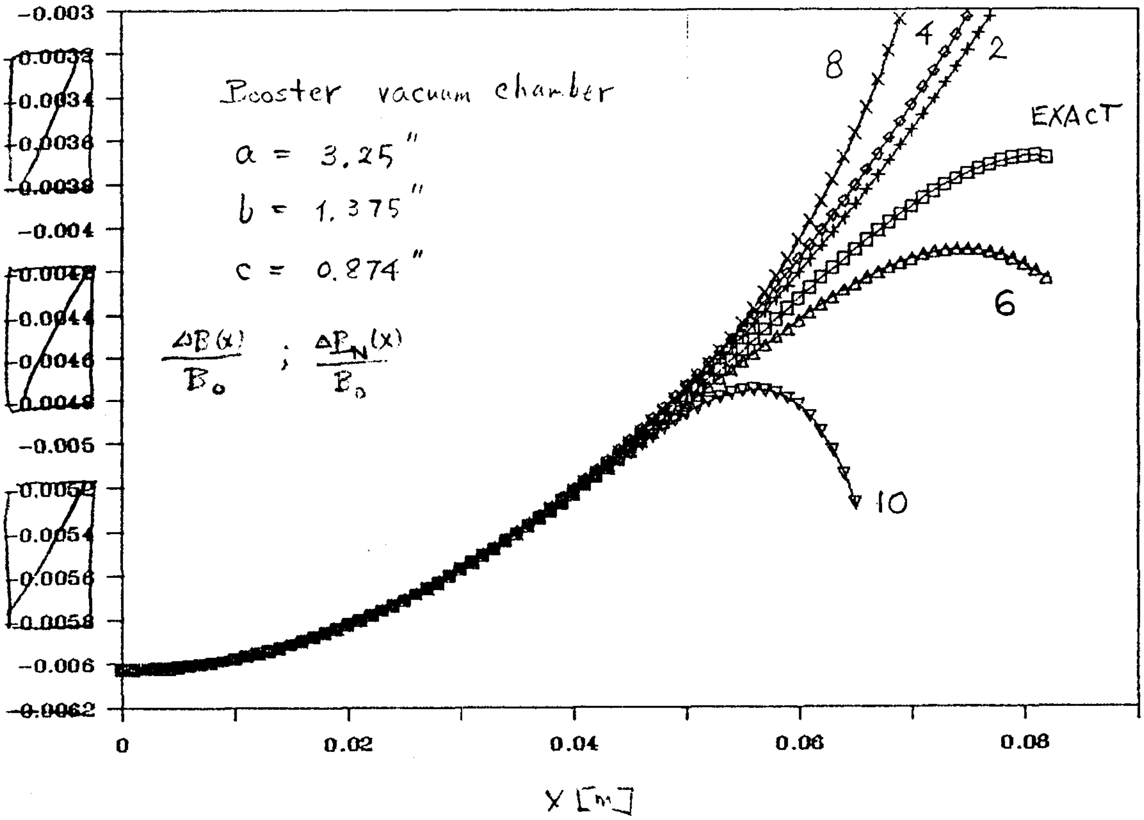


Fig. 1


Booster vacuum chamber
a = 3.25"
b = 1.375"
c = 0.874"
ΔB(x)/B0 ; ΔBN(x)/B0
8
4
2
EXACT
6
10
-0.003
-0.004
-0.005
-0.006
-0.0062
0
0.02
0.04
0.06
0.08
X [m]

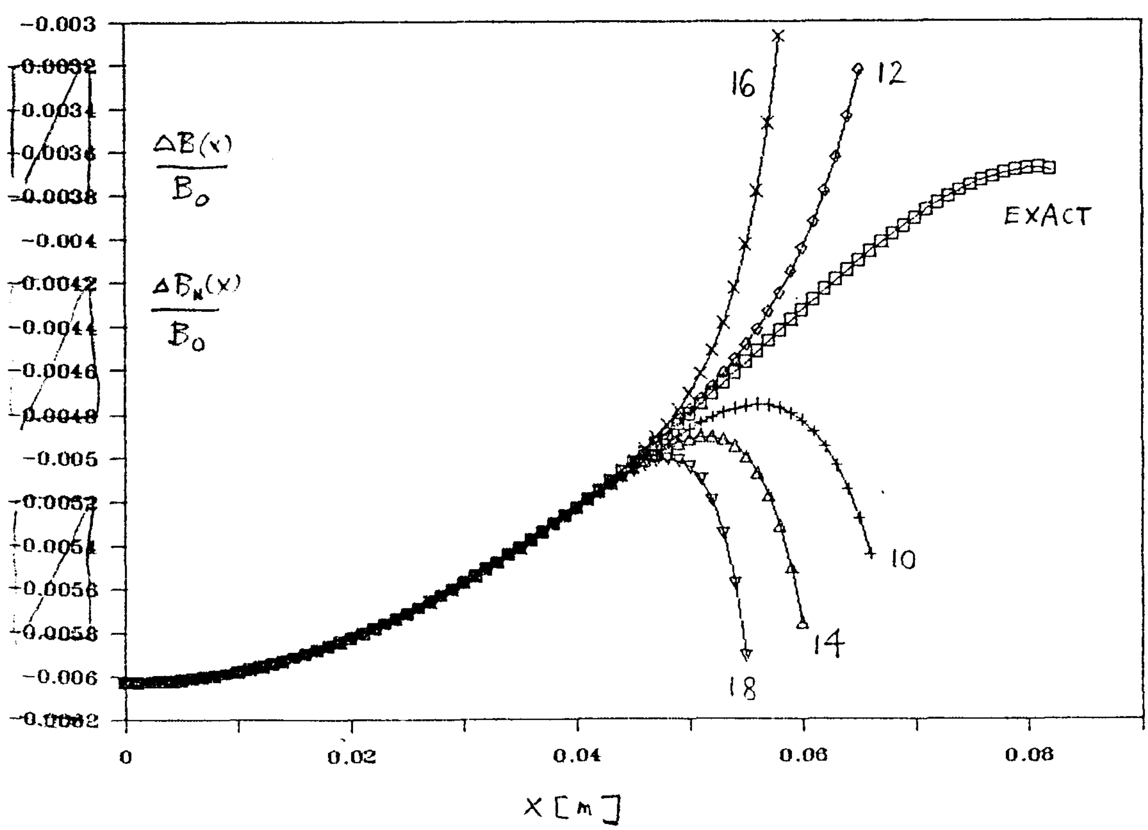
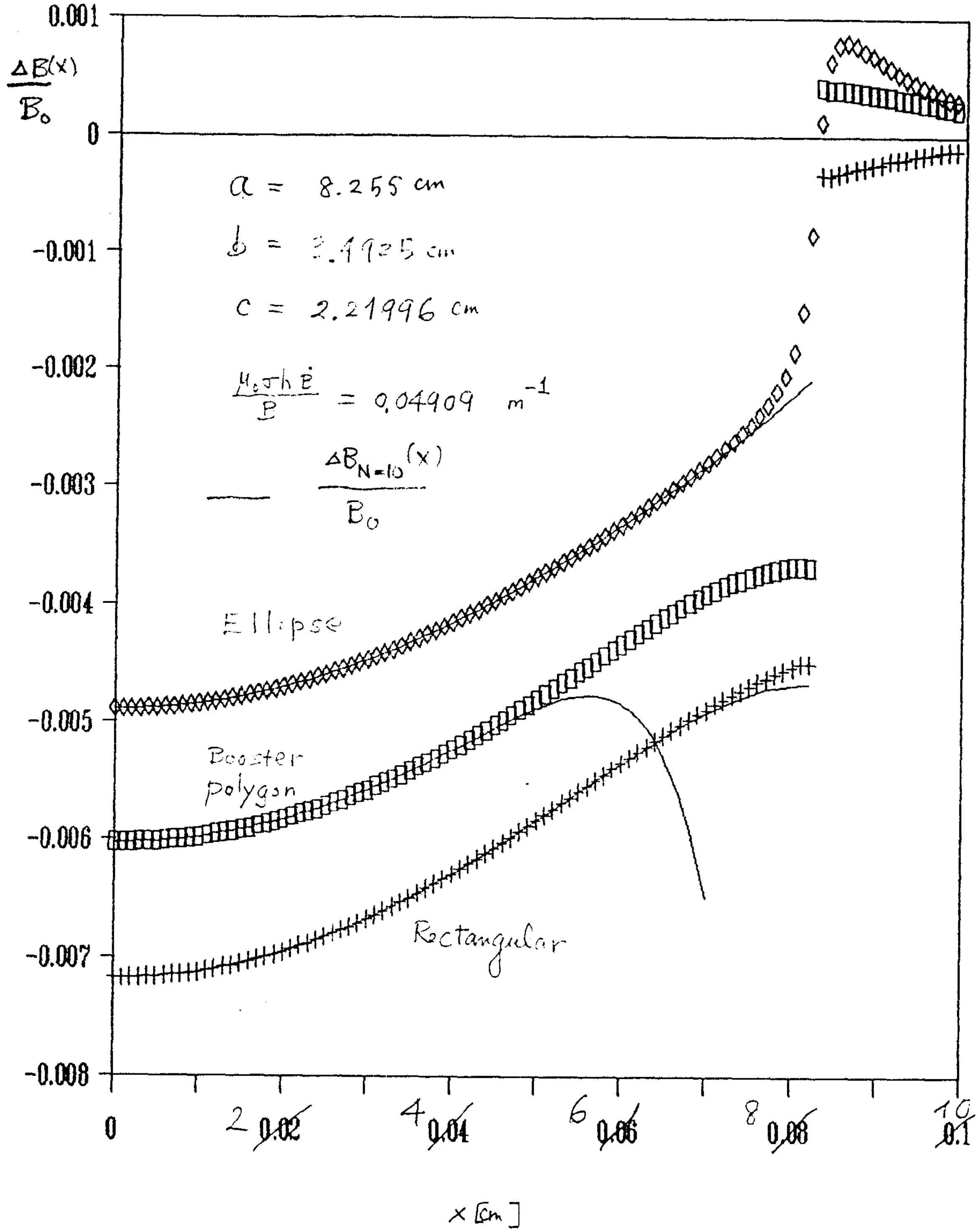

ΔB(x)/B0
ΔBN(x)/B0
16
12
EXACT
10
14
18
-0.003
-0.004
-0.005
-0.006
-0.0062
0
0.02
0.04
0.06
0.08
X [m]

fig. 2



0.001
$\frac{\Delta B(x)}{B_0}$
0
-0.001
-0.002
-0.003
-0.004
-0.005
-0.006
-0.007
-0.008
a = 8.255 cm
b = 3.4925 cm
c = 2.21996 cm
$\frac{\mu_0 J h \dot{B}}{B} = 0.04909 \ m^{-1}$
$\frac{\Delta B_{N=10}(x)}{B_0}$
Ellipse
Booster polygon
Rectangular
0
2 ~~0.02~~
4 ~~0.04~~
6 ~~0.06~~
8 ~~0.08~~
10 ~~0.1~~
x [cm]

Fig 3