MOPAB089

EFFECT OF DIFFERENT MODELS OF COMBINED-FUNCTION DIPOLES ON THE HEPS PARAMETERS*

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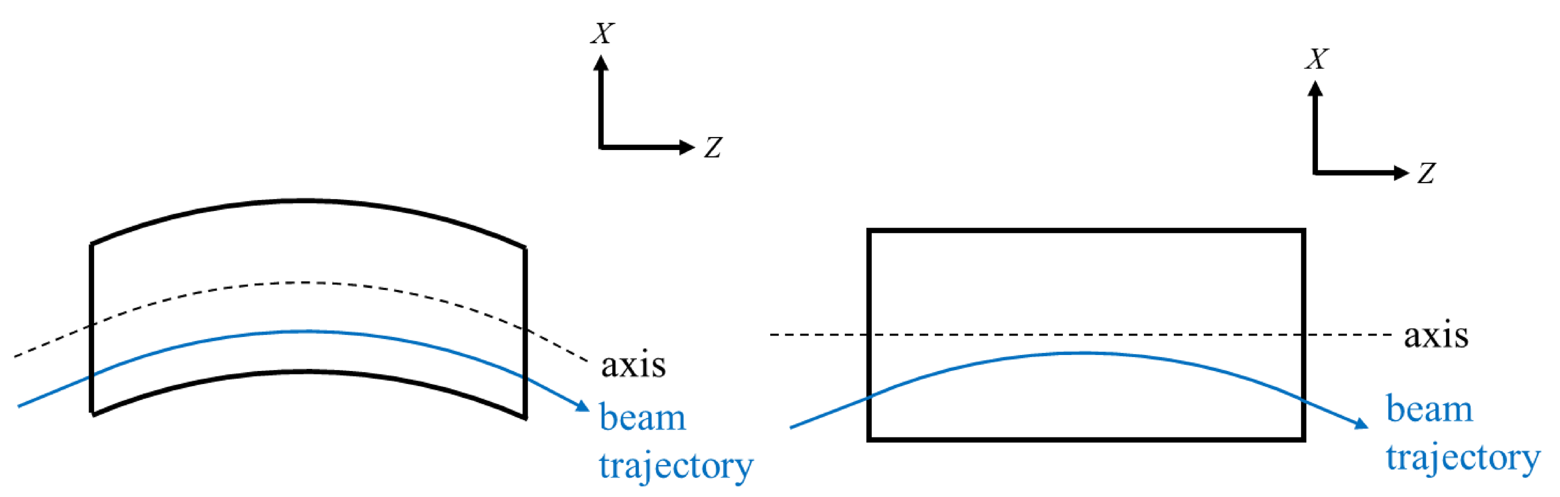
Abstract:
The high energy photon source (HEPS) is a 6 GeV, kilometer-scale storage ring light source being built in Beijing, China. In the current ring lattice, the combined-function dipoles are used and assumed to have constant dipole field. However, in the actual magnet design, an eccentrically placed quadrupole is adopted, in which the bending field along the trajectory is not constant. In this paper, we will present the effect of the two models of combined-function dipoles on the parameters of the storage ring.

INTRODUCTION



Curvilinear (left) and straight (right) model of combined-function dipoles. In the evolution process of the storage ring lattice, the model of curvilinear combined-function dipole with constant dipole field is used. However, in the actual magnet design it is considered to be a quadrupole with a transverse offset.

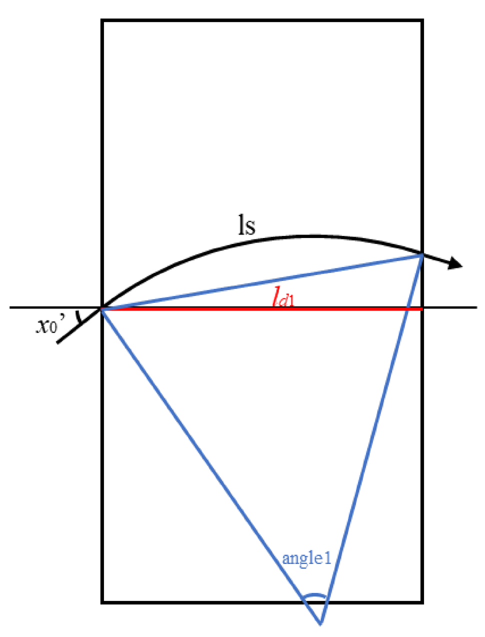
PARAMETERS OF STRAIGHT LINE COMBINED-FUNCTION DIPOLE

Method 1: Geometric method

- $\mathrm{Cor}_1 = [z_1 = 0, x_1 = x_{off}]$ as the starting point
- $B = G^* x_1 \rightarrow \delta\theta \rightarrow \mathrm{Cor}_2 = [z_2, x_2] \rightarrow B = G^* x_2$
- By minimizing $[L_{curve}, q_{total}]$-$[L_B, q_B]$, the optimal x_{off} and L_Q can be obtained.

Method 2: Transfer matrix method

- $x_0 = x_{off}$, $x_0' = \theta_B/2$,
- $n^* l_s = L_B$, $angle_1 = \frac{l_s * B_1}{B\rho} = \frac{l_s * G * x_0}{B\rho}$
- $l_{d1} = 2 * \frac{ls}{angle_1} * \sin\left(\frac{angle_1}{2}\right) * \cos\left(x_0' - \frac{angle_1}{2}\right)$
- Transfer matrix of Q $\rightarrow (x_1, x_1')$



$\rightarrow angle_2 \ldots$

- Scan x_{off} to get the optimal value

Method 3: Differential equation method

- $x''[t] = K * x[t] * c^2 * (1 - (x'[t])^2/c^2)^{0.5}$
- $z''[t] = K * x[t] * c^2 * x'[t]/c$
- $t=0$, $x'[0]=0$, $z'[0]=c$, $x[0]=dx$, $z[0]=0$
- $x_{off} = x[L_B/2/c]$, $L_Q = 2 * z[L_B/2/c]$

parameter	Method1	Method2	Method 3
x_{off}	−14.713 mm	-14.714mm	−14.714mm
L_Q	1.0972m−22μm	1.0972m−24μm	1.0972m−24μm

Note： 1.0972m is the nominal arc length of the combined-function dipole

EFFECTS ON THE PARAMETERS OF STORAGE RING

Model 1 from method 1

Dividing the magnet into 116 slices, The transfer matrixes of straight line and curvilinear combined-function dipole are close. Then the slice model is substituted into the lattice and some main parameters are calculated.

Model 2 from method 2

The straight line combined-function dipole is replaced by 100 dipoles. Each dipole has the same length $l_s = L_B/100$ and a little different bending angle.

Model 3 base on ELEGANT

In the ELEGANT lattice file, we replace the combined-function dipole with 'CCBEND' and calculate the parameters of the lattice.

parameters	curvilinear model (AT)	straight line model(model 1)	straight line model(model 2)	straight line model(model 3)
Circumference (m)	1360.4	1360.4013	1360.4	1360.4
Net bending angle (deg.)	360	360-0.0071	360+1.3E-5	360 [c]
Horizontal natural emittance (pm·rad)	34.8271	35.8311	35.8312	36.0510
Working point (x/y)	115.1521/ 104.2905	115.1521/ 104.2908	115.1520/ 104.2903	115.1618/ 104.2169
Beta functions at the center of high-beta sections (x/y) (m)	8.1757/ 4.9976	8.1754/ 4.9978	8.1756/ 4.9970	8.2038/ 4.9540
Momentum compaction (10^{-5})	1.8311	1.8621	1.8621	1.8476
Energy loss per turn, U_0 (MeV)	2.6412	2.6461	2.6473	2.5888
Energy spread (10^{-3})	1.0031	1.0095	1.025	1.0280

Summary

As described above, we studied the difference of straight line and curvilinear combined-function dipole. The differences come from that the dipole field along the beam trajectory in the straight line combined-function dipole is not constant while that in the curvilinear combined-function dipole is constant. This leads to the differences of bending radius which result in the differences of the parameters related to the bending radius. Among them, the most concerned is the horizontal natural emittance, which increases by about 1 pm·rad.

* Work supported by High Energy Photon Source (HEPS), a major national science and technology infrastructure and NSFC (11922512)
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