OPTICS CORRECTION AT BEPCII STORAGE RING *

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Abstract

Optics correction is an important work at BEPCII. Due to the errors in all kinds of components of a storage ring, the real optics is different from the design one. This paper introduces some developments of optics calibration at the BEPCII storage ring. We use the method what fits the measured response matrix to the model response matrix to get the fudge factor of the quadrupole field and the sextupole field. On the other hand, in considering fringing fields of quadrupole magnet, and the interaction between iron cores of quadrupole and sextupole, the model is well calibrated.

INTRODUCTION

BEPCII is the upgrading project of the Beijing Electron Positron Collider (BEPC). For the colliding beams the design luminosity is $1\times10^{33}\text{cm}^{-2}\text{s}^{-1}$, optimized at the beam energy 1.89 GeV, which is about two orders higher than that of BEPC. To achieve a high luminosity, beam dynamics is needed to be studied. The beam-beam simulations show that 0.51/0.58 is the best working point region for BEPCII to reach the design luminosity. However, the working point is so much close to the half integer resonance that the nonlinearities could be large and the consequent optimization becomes rather difficult. One of the challenges for the BEPCII beam dynamics is optics calibration which plays the part of the foundation of many methods.

Table 1: Main Parameters of BEPCII Colliding Mode.

Energy	(GeV)	1.89
Circuference	(m)	237.53
RF voltage	(MV)	1.5
Beam current	(A)	0.91
Bunch length	(cm)	1.5
Momentum compaction		0.0235
Beta-function at IP(x/y)	(m)	1/0.015
Luminosity	($\text{cm}^{-2}\text{s}^{-1}$)	1×10^{33}

To understand the dynamics in an accelerator, it is essential to have a good model representing its realistic lattice. The application of optics calibration based on response matrix contributes a lot to BEPCII. But the model of BEPCII using now isn't precise enough for the research on higher-order effects. For example, the model of magnet ignores the fringe field effect, which makes coupling parameters, chromaticity calculation and some other parameters difficult to adjust. To avoid useful message being covered by model error, it's necessary to fix the model of BEPCII optics.

The regular means of magnet model calibration include magnet measurement and calculation. Calculation gives a ideal model. However, there are differences all the time. So magnet measurement could give more accurate distribution of real magnet strength. For practical calibration, we also use optics measurement data as foundation of model.

This paper describes some work of the magnet model calibration on BEPCII. It includes the fringe fields of quadrupole and dipole magnet and quadrupole field affected by sextupole magnet iron core. Some computation results of calibration are shown at last.

MODEL

The main foundation of magnet model calibration we used comes from the magnetic field measurement. And the comparison between calculation and measurement of actual optics parameters is used to assist to determine the effect of calibration. We focus on a sort of quadrupole magnet named "105Q", which are the main quadrupole magnets at BEPCII. The other quadrupole magnets are dealt with the similar method. The fringe field of dipole magnet is taken into account too.

Fringe Field of Dipole Magnet

In the case of BEPCII, the dipole magnet is a kind of rectangular bend. So the fringe field of dipole magnet produces vertical focusing. LOCO program provides a suitable model for this case and we use this model directly. We just need to provide parameters like HGAP and FINT to change the dipole with hard edge model to soft edge. HGAP indicate the aperture of dipole magnet. FINT is dipole fringe field integral, and it can be expressed as

$$\mathtt{FINT} = \int_{-\infty}^{\infty} \frac{B_y(s)(B_0 - B_y(s))}{g \cdot B_0^2} ds, \qquad (1)$$

here g=2*HGAP, which is same as MAD's definition[1].

The parameters are determined by the design value. There are two kinds of dipole magnet at BEPC, which is named "67B" and "70B". Here "67" and "70" indicate aperture. FINT factors are 0.448 and 0.495, respectively.

Fringe Field of Quadrupole Magnet

In our model calibration, we set the fringe field by analyzing the magnetic field measurement data by different methods. The magnetic field measurement data is made up of position data and magnetic field strength data, K1. At first, we find the maximum K1 of the magnetic field measurement data, then normalize the

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other measurement data and find the flat top area length. We drop the field data with too little value to avoid two long tails.

For the curve of fringe field we choose 6 order polynomial fitting and linear fitting as approximation. For 6th-order polynomial fitting, we choose 95% of the maximum K1 of the magnet field measurement data as the starting point of the fringe field. For linear fitting, we choose three points, 90%, 95% and 98% of the maximum K1 as the starting point of the fringe field. Ending point depends on keeping magnet field of integration constant, As shown in Figure 1.

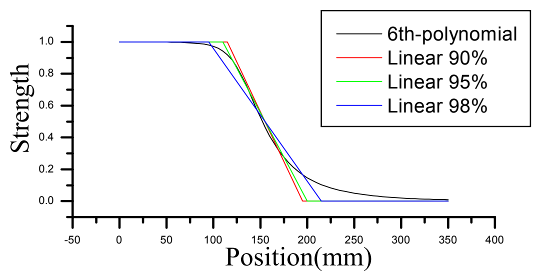

Figure 1: Different model of fringe field of quadrupole magnet.

To simplify the calculation, we slice the fringe field into several segments. When the number of the segments of the fringe fields is more than 10, the results become constant. So we slice the fringe field into 10 segments as approximation.[2]

Influence of Sextupole Core over Quadrupole

If the distance between two magnets is comparable with the summation of the bore diameter of these two magnets, the magnetic field between two magnets will be affected by the core of the magnets. The arrangement of BEPCII is so crowded that quadrupole magnet is so close to sextupole magnet (17.3cm). In the arcs , the fringe field of 105Q is affected by 130S(sextupole) magnet. Calculation demonstrates that the fringe field of quadrupole magnet decreases obviously, because of the cost of intensity of magnetic flux by sextupole magnet core.

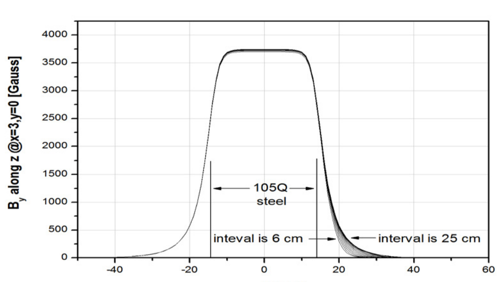

Figure 2: Influence of 130S magnet core over the fringe fields of 105Q magnet

So the strength of quadrupole magnet needs to be fixed. We fix the field of integration by a factor, which is equal to 99.4% by measurement of quadrupole field with sextupole iron.

CALCULATION

The following results are from the BEPCII BPR ring lattice. The 105Q quadrupole strength of different models is set with same value without fudge factors.

We use the code LOCO to calculate optics parameters, which are used to compare with that measured values in real machine. The difference and calculated results of each model are shown in Table 2.

Table 2: Model difference and calculated result.

Model	**Quadrupole magnet fringe field**	**Dipole magnet fringe field**	**Influence of sextupole core over quadrupole**
Original model	hard edge	NO	NO
Model A	hard edge	YES	NO
Model B	hard edge	NO	YES
Model C	6th-polynomial	NO	NO
Model D	Linear 90%	NO	NO
Model E	Linear 95%	NO	NO
Model F	Linear 98%	NO	NO
Model G	Linear 95%	YES	YES

Model	ν_x/ν_y	$\Delta\nu_x/\Delta\nu_y$ **from original model ***	$\Delta\nu_x/\Delta\nu_y$ **from measure****
Measure	6.5370/5.5733	−0.1185/−0.08	0/0
Original model	6.6555/5.6533	0/0	0.1185/0.08
Model A	6.6555/5.6403	0/−0.013	0.1185/0.067
Model B	6.5395/5.6175	−0.116/−0.0358	0.0025/0.0442
Model C	6.5429/5.6384	−0.1126/−0.0149	0.0059/0.0651
Model D	6.5515/5.6485	−0.104/−0.0048	0.0145/0.0752
Model E	6.5498/5.6465	−0.1057/−0.0068	0.0128/0.0732
Model F	6.5455/5.6414	−0.11/−0.0119	0.0085/0.0681
Model G	6.5325/5.5973	−0.123/−0.056	−0.0045/0.024

* $\Delta\nu=\nu_{model}-\nu_{original\ model}$

** $\Delta\nu=\nu_{model}-\nu_{measure}$

As Table 2 shows, Model B represents the influence of sextupole core over quadrupole. Model C-F represent fringe field of Quadrupole. Model G represent that fringe field of dipole and quadrupole magnets, and influence of sextupole core over quadrupole are all taken in. the results of Model B and Model C-F show that the effect of the fringe field of quadrupole and influence of sextupole iron core are comparable. Although disparity between Model A-G, the results of calculation show that each tunes of these models are closer to measurement than original hard edge model. Model G is much better to stand for real machine than original model. Calculation of BETA function shows similar appearance in Fig. 3. Figure 3 shows the BETA difference between calculation and

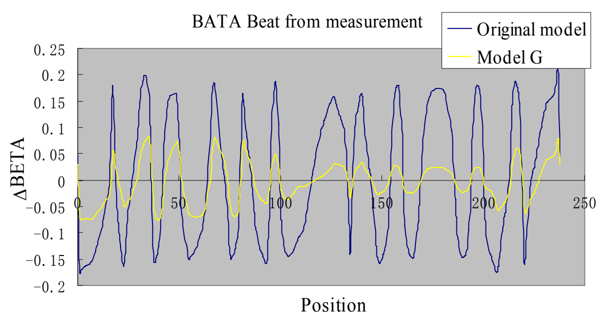

Figure 3: Beta function of hard edge model and liner model compared with measured BETA.

measurement. New model's BETA function is closer to real BETA too.

Fudge factors shown in Fig.4 demonstrate that almost all fudge factors of 105Q are reduced. Moreover, some information used to be covered by background is more obvious as small picture of the Fig.4. The fudge factors in small picture appear as a bulge among several magnets. It may be mainly due to the effect of orbit in sextupole magnets in arc.

The above discussions focus on the linear effect of fringe field. In the design of BEPCII, the effects of higher order harmonics of each magnet have been considered. For quadrupole magnet, major higher order harmonics are required to be $<10^{-4}$. So higher order effect could be ignored compared with linear effect, this is proved by simulation. So result of slice segment is similar from 3D simulate calculation.

Additionally, we use SAD/FFS code to repeat the calculation for verification. In SAD, fringe field is calculated by higher order simulate. The result is similar to LOCO.

CONCLUSION

We choose different models for quadrupole magnet. Then we use the new model's optics to compare with measurement.

The analysis of different models of 105Q magnet indicates that the new model is more approximate to real magnet. This is helpful for adjusting some parameters like chromaticity, coupling, etc. These are important methods to promote the luminosity of BEPCII in the near future. Although more studies are required to fully understand and make use of such models.

ACKNOWLEDGEMENTS

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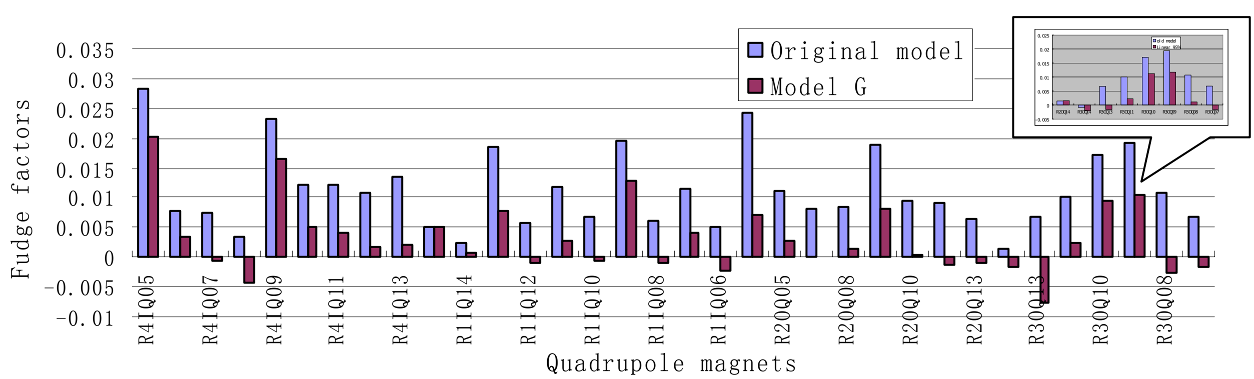

Figure 4: Fudge factors of 105Q magnets obvious reduce.