THE ERRORS STUDY ON A RECENT HEPS LOW-BETA DESIGN *

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Abstract

The next synchrotron light source High Energy Photon Source was currently studied at Beijing. A recent design for the HEPS, in a hybrid 7BA lattice and with an emittance of 60 pm·rad in a circumference of 1.3 kilometres, was completed for further study. In this paper, we present some work on error effect based on a recent lattice design. Topics covered include dynamic aperture and beam parameters affected by magnetic field error, systematic and random multipole errors and misalignment effect.

INTRODUCTION

High Energy Photon Source (HEPS), which proposed to be built in Beijing early in 2008, was a storage ring light source with beam energy of 5 to 6 GeV. Related study have been made on the lattice design for these years.

A hybrid 7BA design for the HEPS, has been made [1]. This design with a 59.4 pm·rad natural emittance, ~3% MA and dynamic aperture (DA) ~2.5 mm in x and 3.5 mm in y plane, provide a basic for the further studies to be based on. The main parameters were listed in Table 1. More details of this design and related studies are shown in Ref. [2].

Table 1: HEPS Recent Lattice Design Parameters

Parameters	Values
Energy E_0	6 GeV
Beam current I_0	200 mA
Circumference	1295.6 m
Natural emittance ε_{x0}	59.4 pm.rad
Working point υ_x/υ_y	116.16/41.12
Natural chromaticities (H/V)	-214/-133
No. of superperiods	48
ID section length L_{ID}	6 m
Beta functions at ID sect. (H/V)	9/3.2 m
Energy loss per turn	1.995 MeV
Rms energy spread	7.97×10^{-4}
Momentum compaction	3.74×10^{-5}

Therefore it is essential to evaluate the ring performance in presence of various errors to check the robustness of the latest design. Also, the simulation of error effect can provide the guideline to restrict the manufacture redundancy of the hardware. In this paper, we present the results of our first attempt to take error into lattice and the simulation result of beam performance with error and correction. Accelerator Toolbox (AT) was used for beam tracking and calculation.

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ERROR SETTING

At present, the HEPS error study covered some common errors in practical accelerator as below:

Alignment and Rotation Angle Error

The alignment technique of HEPS would occupies a significant place. The elements on one girder would have the capability of micro-motion adjustment. Even so, the alignment error would make beam injection difficultly and had the biggest influence on beam performance.

In this study, we assumed 30~50μm displacement and 100 μrad rotation r.m.s error for each magnet element.

Field Error of Magnet

For each magnet, a random relative error was added to the original field. Considering that the magnet field would have been corrected in future, the scale for different type magnets list as blow:

- Quadrupole magnets: 0.02%;
- Sextupole magnets: 0.1%;
- Bending magnets: 0.1%;

Multipole Field Error of Magnet

As a first step discussion, random systematic multipole errors of 1e-4 were added to magnet by same type no matter with the bending, quadrupole or sextupole magnets.

ORBIT AND OPTICS CORRECTION

Because of the strong quadrupoles and sextupoles in a DLSR design, the residual orbit and optics deviation will cause considerable effect on beam performance, which make the lattice calibration to be an important and essential issue.

The lattice arrangement was shown in Figure 1. In recent design, each sextupole magnet was used as H/V corrector at same time. One piece of bending magnets in BS is used as H trim coils corrector. And closed to Q1 there is one additional H/V corrector. Moreover, among the middle section of two cells is one H/V corrector set. So 11 horizontal correctors and 9 vertical correctors per cell were used for orbit correction.

There were 12.5 BPMs in a cell for the recent design. One of two long straight sections had a BPM. 6 BPMs, each was closed to a sextupole magnet, was supposed to control the orbit in sextupole magnet. 2 BPMs near the Q1, provided the beam position at the straight section ends. And 4 BPMs was in the middle section to restrain the orbit among five bending magnets and four quadrupole magnets. The resolution of BPM was set as 0.5μm for now.

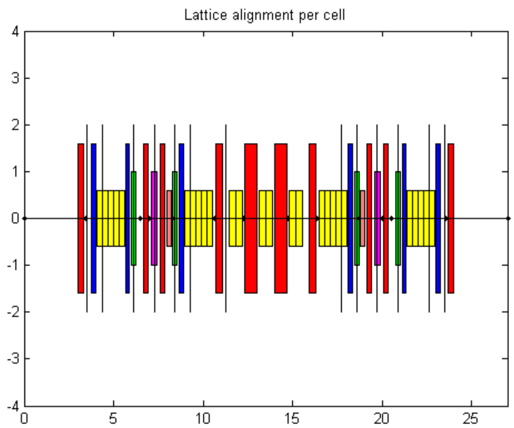

Figure 1: Lattice cell arrangement in recent design. Black dot was BPM, and long black line was corrector.

The Orbit Response Matrix method (ORM) was used for orbit correction. Because the amount of BPMs was more than the correctors' in this lattice, the ORM was not full rank. SVD method was used to avoid the orbit be out of control, in which the singular value shown as Figure 2 was chosen automatically.

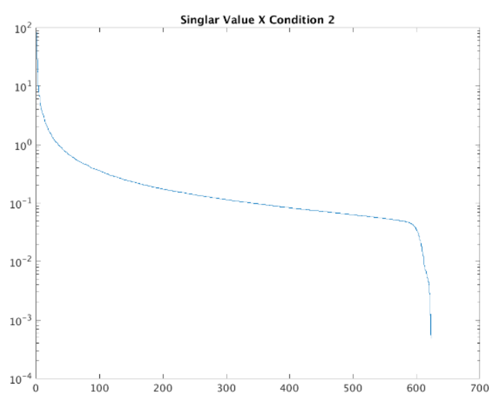

Figure 2: Singular value of horizontal orbit correction.

When the shift errors were much more than BPM resolution ($5 \times 10^{-7} m$), especially for the quadrupole magnets, the residual orbit after correction would be decided by the element shift errors (Figure 3). Therefor the beam performance include linear optics and non-linear effects worsen with the shift error by residual orbit effect, which make the shift error requests significant improvement and well study.

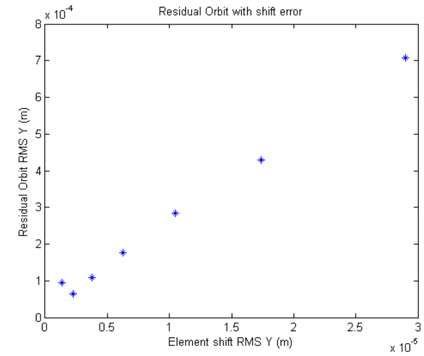

Figure 3: The residual orbit increases with element shift error.

The residual orbit in sextupole magnet, the field errors of quadrupole magnet and other errors made the linear optics was deviated from design lattice. So after orbit correction, linear optics also needed to be corrected in simulation. A simulated response matrix made by lattice with error was fitted by the Linear Optics from Closed Orbits (LOCO) code based on AT. All the quadrupole magnets were fitted to correct the linear optics closed to the original optics. Figure 4 showed the betabeat before and after optics correction.

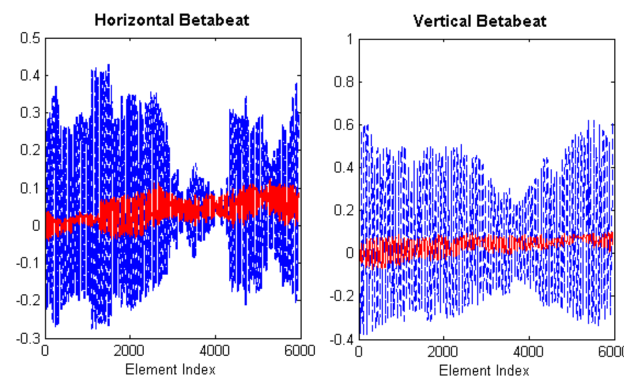

Figure 4: The betabeat of one simulation result. (blue):before optics correction. (red): after optics correction.

BEAM PERFORMANCE

Through the procedure described above, we was able to track beam performance with a new lattice with errors and correction. To get a statistic analysis of error effects, as a preliminary attempt, a few different seeds could be used to generate several cases for simulation. Eight DA tracking results were shown in Figure 5. Compared with original lattice, the DA decreased obviously with error effect, and with optics correction, the DA would increase than without correction.

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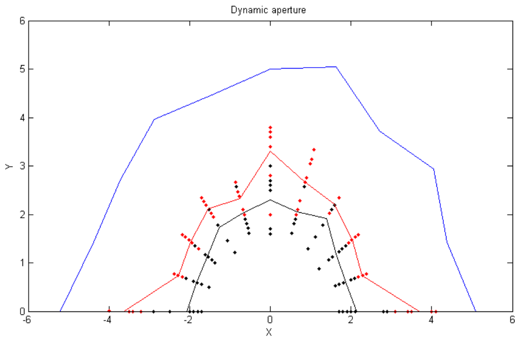

Figure 5: DA tracking result. (Blue line): original lattice DA; (black dot): 8 cases tracking result with errors after orbit correction; (black line): average DA with errors after orbit correction; (red dot): 8 cases tracking result with errors after orbit and optics correction; (black line): average DA with errors after orbit and optics correction.

Figure 6 shows the emittance with error and correction of 8 cases. The x axis represent the different case. With the errors and correction, the horizontal emittance increase about 10%~20%. And the vertical emittance reach to 30 pm·rad. The correction of optics didn't bring obvious improvement, which might be because the dispersion and coupling were not been corrected. Especially, the vertical emittance increase mainly because of the vertical dispersion. It indicates that more study on the correction of simulation and application in future real machine is necessary.

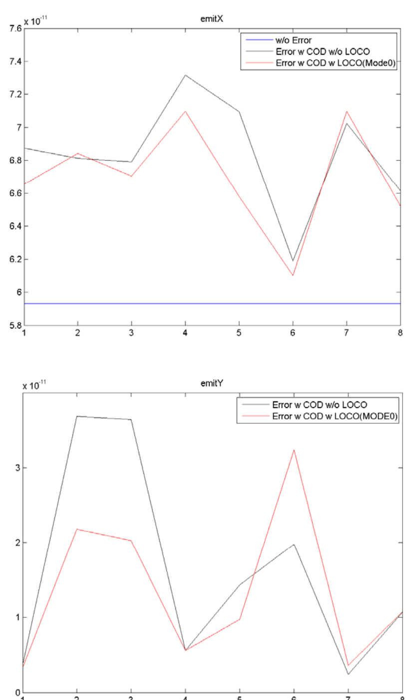

Figure 6: The emittance result with errors and correction. (Above): horizontal emittance. (Below): vertical emittance.

CONCLUSION

As described above, we provide a procedure to study the error effect on an existed lattice, include dynamic aperture and beam parameters affected by magnetic field error, systematic and random multipole errors and misalignment effect. As an example, some basic evaluation of DA and emittance with errors and correction based on recent lattice was given. However the emittance result after correction showed that the correction wasn't effective enough for the present. More study, such as on simulating the effects of all possible errors combination on machine performance, and simulated a systematic correction process assuming at initial commissioning stage, needed more study.

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