MAGNET ALIGNMENT AND CLOSED ORBIT DISTORTION OF THE SPring-8 STORAGE RING

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Abstract

Third generation synchrotron radiation sources have high sensitivity against errors and generate large closed orbit distortion(COD). We found the alignment method to reduce the effective sensitivity[1] and applied it to the SPring-8 storage ring. We succeeded to reduce the effective sensitivity substantially. Observed CODs without correction were 1.4 mm for horizontal and 2.4 mm for vertical direction. We accomplished a first turn and storage of the beam without any orbit correction.

1 INTRODUCTION

The SPring-8 storage ring is the third generation synchrotron radiation source of 7 nm emittance and a 1436 m circumference with 48 cell double bend achromat lattice(DBA). The electron beam of the third generation source is focused in bending magnets by the strong quadrupoles to reduce the beam emittance. As a results, the large chromaticities are generated and strong sextupole magnets are needed for the chromaticitiy correction. These strong magnets make the sensitivity against errors high, which means that small misalignments generate a large COD. Betatron oscillations are also coupled by the strong sextupoles.

This high sensitivity makes it difficult to commission a ring and supply a stable beam. Therefore small effective sensitivity with small emittance are required as the characteristics of the third generation synchrotron radiation source.

For this requirement, we found the effective sensitivity reduction method : The effective sensitivity can be reduced substantially if the quadrupoles and sextupoles between the bending magnets are aligned on a straight line precisely[1][2]. According to this alignment method, small COD and small coupling resulting from sextupoles are expected.

In this paper we described the principle of alignment method, actual alignmment, alignment results and calculated and observed COD.

2 ALIGNMENT METHOD

2.1 *Principle*[1]

The magnet lattice of the SPring-8 is a DBA type, which has two bending magnets and three short straight sections in a cell. The opposite polarity of quadrupoles and sextupoles are placed closely in a short straight section. In the SPring-8 storage ring, one focusing (QF) and two defocusing quadrupoles (QD) are placed in the first and third straight sections. A focusing (SF) and defocusing sextupoles (SD) for harmonic correction are also placed in the same straight sections. In the second straight section there are two QF, QD and a pair of SF and SD. Integrated strength of these magnets on a girder is very small. This means that if the betatron phase advance between the magnets within a girder is small and the magnetic center is aligned on a straight line, kick forces which generate COD or betatron oscillation coupling cancel within a girder even if the girder is misaligned from the design orbit. Contrary to this, if magnets are aligned randomly as an usual alignment, COD is simply a sum of randomly generated CODs and no cancellation works.

Phase advance of horizontal and vertical oscillations of the SPring-8 storage ring is 0.1π between the quadrupoles on both ends of a girder. Therefore we can reduce the effective sensitivity if we can align the magnets precisely in a short straight sections. Fortunately the distance between the both ends of the girder is 4 to 5 m and short enough to align the magnetic center precisely on a straight line.

We aligned the magnets according to the above described principle. First we align the girders with the usual alignment accuracy and next we align the magnets on a girder with high accuracy.

Table 1 Torelances for magnet misalignment.

Magnet	Δx(mm)	Δy(mm)	Δz(mm)
Quadrupole and Sextupole	0.05	0.05	0.25
Girder	0.2	0.2	0.25
Dipole	0.5	0.5	0.5

2.2 *Girder Alignment*[3]

For horizontal alignment we made the survey network using the fiducial points on the magnets of both ends of girder, two fiducial points on a wall per cell and the laser tracker SMART 310. The distance between these points were measured by the SMART 310. The position of the magnets of the both ends of the girder were determined and the girder was moved to the correct position. The survey and the positioning was done three times.

Levels of the fiducial points on a wall were measured and adjusted using the Precision Level N3. Levels of the magnets on the both ends of the girder were adjusted to this level.

2.3 Quadrupole and Sextupole Alignment[4]

Actual alignment method of the quadrupoles and sextupoles on a girder are shown in Fig. 1. As shown in Figure, magnetic center is measured by the rotating coil and the coordinate of the fiducial point is measured by the laser and CCD camera. The coordinate of the magnetic center transferred to the fiducial point is aligned on a straight line using the fiducial point of the quadrupoles of the both ends of a girder as reference points. Tilt of the magnets were measured by a tilt meter (Tayler Hobson Talybel 4).

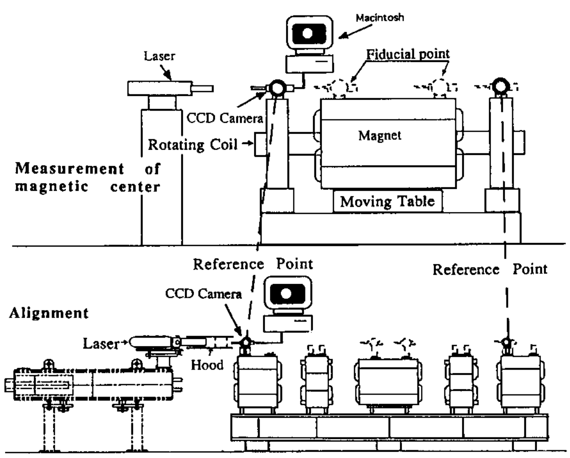

Fig. 1 Measurement of magnetic center and alignment of quadrupole and sextupole magnets on a girder.

2.4 Bending Magnet Alignment

Position of bending magnets were measured by the laser tracker SMART 310 using quadrupoles as references and positioning was done until the correct position was obtained.

3 ALIGNMENT RESULTS

3.1 Girder

We aligned the girder with the relative accuracy of 0.04 mm. After ten months later it was changed to 0.06 mm. This was considered to be due to the temperature change in the tunnel because the temperature in the tunnel at girder positioning period was not well controlled. We corrected 29 girders out of 144 girders. As the final accuracy before commissioning we obtained 0.05 mm accuracy. Results are shown in Fig. 2. Vertical accuracy was also deteriorated. We corrected 21 girders and obtained 0.04 mm accuracy as shown in Fig. 3.

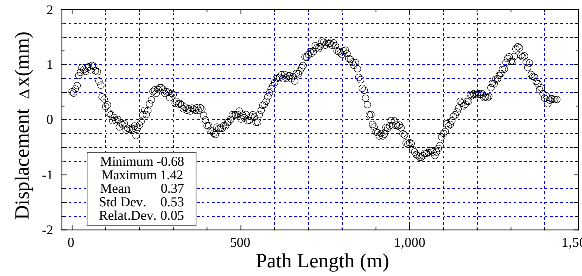

Fig. 2 Alignment results for horizontal direction.

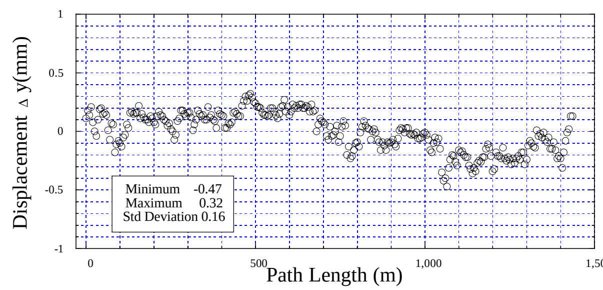

Fig. 3 Alignment results for vertical direction.

3.2 Quadrupole and Sextupole Magnet

Alignment accuracy was about 6 μm just after the adjustment. However it was made worse due to magnet division and recovery for chamber installation and baking. Final accuracies were 17 μm for horizontal direction and 16 μm for vertical one. Standard deviation of the magnet tilt was 31 μrad.

3.3 Bending Magnet

Bendings were positioned with accuracy of 0.13mm and 0.11mm for horizontal and vertical direction, respectively. After evacuating chamber, bending magnets were moved to downstream by 0.26mm in average.

4 CLOSED ORBIT DISTORTION

COD was generated by misalignment of quadrupoles from the straight line on a girder and girder alignment error. For horizontal direction, field strength error of bending magnets and systematic movement to the downstream due to the atmospheric pressure were added. CODs were calculated based on the measurement results of alignment. Calculated results are shown in Figs. 4 to 9, and are summarized in Table 2. Random errors of quadrupole most contributes to the CODs. Its sensitivity is $\sigma_{CODx}/\sigma_{\Delta x}$=117, $\sigma_{CODy}/\sigma_{\Delta y}$=54. Though the misalignments between the girders are larger than the random quadrupole misalignment, contribution to the COD is smaller than that. Their sensitivities are $\sigma_{CODx}/\sigma_{\Delta x}$=2.4, $\sigma_{CODy}/\sigma_{\Delta y}$=6.2 for absolute error and $\sigma_{CODx}/\sigma_{\Delta x}$=25, $\sigma_{CODy}/\sigma_{\Delta y}$=25 for relative error.

First measurement COD without correction by steerings are shown in Fig. 10. Observed standard deviations of COD are 1.4 mm and 2.4

mm for horizontal and vertical direction, respectively. These values are smaller than the calculated ones but the tendencies agreed with them.

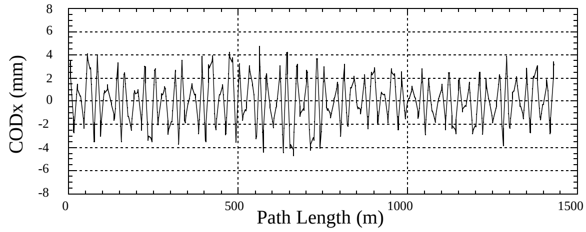

Fig. 4 Horizontal closed orbit distortion resulting from random quadrupole magnet misalignment on a girder.

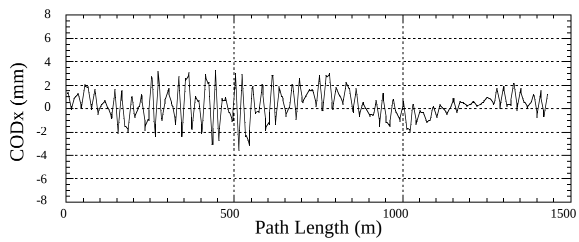

Fig. 5 Horizontal closed orbit distortion resulting from girder misalignment.

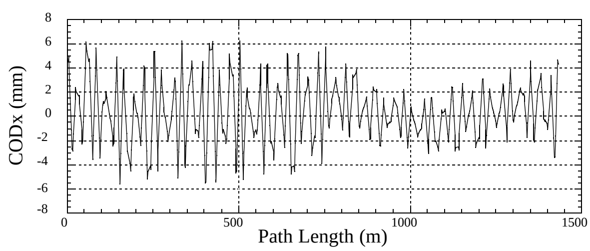

Fig. 6 Horizontal closed orbit distortion resulting from random quadrupole and girder misalignment.

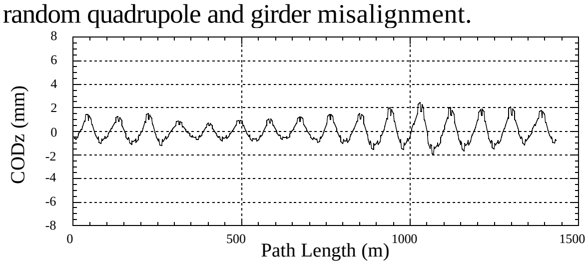

Fig. 7 Vertical closed orbit distortion resulting from random quadrupole magnet misalignment on a gider.

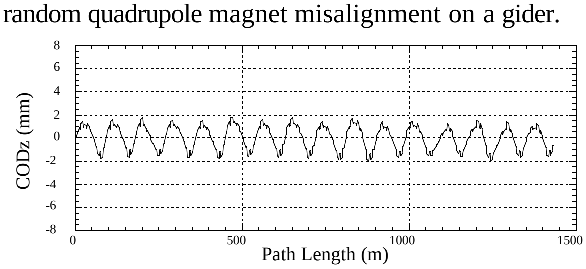

Fig. 8 Vertical closed orbit distortion resulting from girder misalignment.

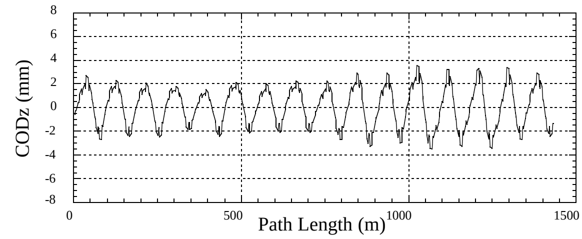

Fig. 9 Vertical closed orbit distortion resulting from random quadrupole and girder misalignment.

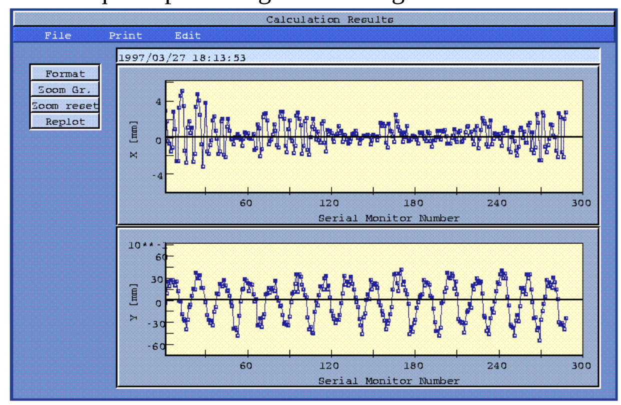

Fig. 10 Obseved closed orbit distortion.

Table 2 Calculated and obseved closed orbit distortion.

	σ_{codx}	σ_{cody}
Quadrupole	2.0 mm	0.9 mm
Girder	1.3 mm	1.0 mm
ΔB, $B_{\Delta S}$	0.3mm,0.4mm	------------
Total	2.7 mm	1.6 mm
Obseved	1.4 mm	2.4 mm

5 CONCLUSION

We have adopted a new alignment method to the SPing-8 storage ring, which can reduce effective sensitivity against errors substantially. Closed orbit was calculated based on the alignment data and small orbit distortion was foreseen. Electron beam was stored without COD correction as expected. Observed CODs were 1.4 mm for horizontal and 2.4 mm for vertical direction, tendency of which agreed to the calculated results.

We confirm the effectiveness of our alignment method from these results.

REFERENCES

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[4] S. Matsui et al., ibid, p174(1995).