Positioning the Storage Ring Dipole Magnets

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1. Introduction[1]

The SPring-8 storage ring adopts a Chasman-Green (CG) magnetic lattice, which is composed of 48 cells, that is, 44 normal CG cells and 4 straight cells. Normal CG cell has 10 quadrupoles and 7 sextupoles positioned on three girders, and two dipoles as shown in Fig. 1. The storage ring with a 1436m-circumference has 88 dipoles.

Dipoles are C-shaped silicon steel laminated magnets. The basic design parameters are shown in Table 1. This paper describes the dipoles alignment principal and achieved results.

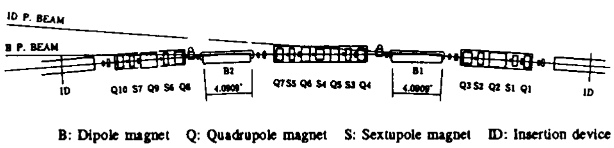

Fig. 1. Magnet arrangement of one cell

Table 1. Storage ring dipole parameters

Maximum field strength	0.679	T
Gap distance or bore diameter	64.04	mm
Effective field length	2.804	m
Bending radius	39.2718	m
Magnet length	3.09	m
Magnet weight	4950	kg

2. Magnet Alignment Procedure of the Storage Ring

The procedure of the storage ring survey and alignment are divided simply into several steps as follows: The first step is setting up the magnets and girders according to the monuments on the floor surveyed beforehand. [2] The second step is survey and adjustment of the girder position. The network consists of quadrupole fiducial points, monuments and auxiliary brackets on inner wall. The survey of the network is performed by using a SMART 310 laser tracker system from Leica. [3] The level is surveyed with Wild N3. After this, dipoles are aligned by using the adjacent quadrupoles as fiducial points since they are positioned with the local accuracy of better than ±0.05 mm. Finally, the quadrupoles and sextupoles on each common girder are aligned on a straight line using a high accuracy laser system. [4]

3. Dipole Alignment

The alignment tolerances for the dipoles are listed in Table 2. Each dipole is mounted on two girders, via a four-point support system, and has two fiducials on the top of yoke at upstream and downstream, which are made of machined planes with a hole of 20 mm in diameter. Figure 2 shows a sketch of dipole alignment. A dipole is aligned by monitoring the position and tilt of its fiducial points using SMART 310 and NIVEL respectively.

The SMART 310 is a mobile 3D coordinate measuring system which is capable of following a moving target, meanwhile determining its position with accuracy of 0.05 mm. The NIVEL is a tilt meter with a resolution of 1 μrad.

Actually, at first, the coordinate system is made by measuring positions of the two quadrupoles adjacent to dipole and a level reference point on the wall with the SMART 310. For example, for B1, we used Q3, Q4 and a level stage on the wall. At the

Table 2. Tolerances for dipole misalignment

rms. displacement error			rms. rotation error		
Δx	Δy	$\Delta z^{1)}$	θx	θy	$\theta z^{2)}$
(mm)			(mrad)		
0.5	0.5	0.5	1.0	1.0	0.1

1)* Δx, Δy, and Δz denote the horizontal, vertical, and longitudinal displacement errors, respectively

2)* θx, θy, and θz denote the rotation errors around the horizontal, vertical, and longitudinal axes, respectively

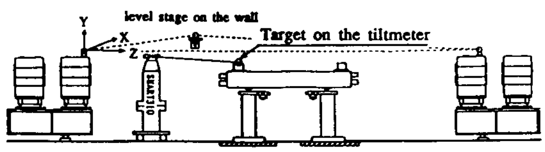

Fig. 2. Sketch of dipole alignment

same time, we measured other quadrupoles (Q1, Q7) in order to confirm that the setting of coordinate system is correct.

Next, a retroreflector for the SMART 310 and the tilt meter were set up on the fiducial point of the dipole. Furthermore, while the SMART 310 and the tilt meter were kept operating in continuous mode, we adjusted the dipole to its ideal position in the coordinate system made from the adjacent quadrupoles.

Table 3. Result of positioning dipoles

	Average			RMS		
	Δx	Δy (mm)	Δz	Δx	Δy (mm)	Δz 1)
B1	0.03	0.03	0.02	0.12	0.09	0.08
Q1	-0.01	-0.07	0.07	0.09	0.16	0.24
Q7	-0.05	-0.22	0.16	0.12	0.25	0.26
B2	-0.01	0.05	-0.00	0.13	0.13	0.07
Q4	0.02	-0.04	0.02	0.12	0.23	0.29
Q10	-0.03	-0.18	0.19	0.10	0.20	0.25

1)* Δx, Δy and Δz denote the horizontal, vertical, and longitudinal displacement errors, respectively

Table 3 shows the positioning results for 59 of total 88 dipoles. The positions of the quadrupoles were measured to check the coordinate system. As shown in this table, displacement errors of the quadrupoles both in X (horizontal) and Z (longitudinal) directions meet the tolerance of the girder alignment (RMS: Δx=0.2mm, Δz=0.5mm, Δy=0.2mm). However, in Y (vertical) direction, error is larger than the tolerance, because the SMART has less accuracy in vertical direction.

The adjustment errors for dipoles include the deviations of fiducial points on two adjacent quadrupoles which are composed of our ideal coordinate system. According to table 3, even with the consideration of measurement error, the alignment errors of dipoles are smaller than the required tolerances.

Table 4 shows the tilt error of dipoles around beam direction after positioning. Since the dipole tilt was adjusted by monitoring the tilt meters on the fiducial planes, the obtained tilt errors are very small as listed in left side of the Table 4. On the other hand, the right column shows the tilt of the pole face, which was measured after positioning of the dipoles in order to confirm the fabrication accuracy of the fiducial planes. The results are comparable to the tolerance although the systematic error is a little large.

Table 4. Tilt error around beam direction

fiducial planes		polefaces	
Average (mrad)	RMS	Average (mrad)	RMS
0.00	0.02	-0.09	0.11

4. Beam Line Fiducial Points

In addition, two basic points on each beam line from dipole or insertion device were set up on the ground by the same method. After positioning the dipole, we operated SMART in continuous mode to find the position of the point on the ground. First, we stuck a seal on the ground with a accuracy of ±1 mm, then used the puncher to find the exact position with the help of the SMART. Finally we made a punch on the seal. Table 5 shows the displacement of the fiducial points. The obtained positioning errors are small enough for the requirement of about 0.5 mm. Comparing table 5 with table 4, we can find the measurement error of the SMART is larger than the errors for dipoles, the reason is that in our measurement, the beam line fiducial points are far from the fiducial points of the quadrupoles.

Table 5. Fiducial points for beam lines

Average		RMS	
Δx (mm)	Δz	Δx (mm)	Δz
0.00	-0.04	0.18	0.10

5. Conclusion

The alignment of dipole magnets and making points for beam lines are performed by using the SMART 310 system. The final position errors are caused mainly by measurement error, position error of fiducial points on adjacent quadrupoles, fabrication error of fiducial points on magnets and calibration error of the SMART. However, in consideration of all errors, final position accuracy are smaller than tolerances.

References

[1] SPring-8 project team, "SPring-8 Project Part 1, Facility Design 1991 [Revised]", August 1991.

[2] S. Matsui et al., Proc. 4th Int. workshop on Accelerator Alignment, Tsukuba, Japan, November 14-17, 1995,pII/174.

[3] C. Zhang et al., ibid., pII/185.

[4] Y. Chida et al., ibid., pII/194.