First Alignment Results of the Storage Ring Magnet Units

Chao ZHANG and Sakuo MATSUI

SPring-8, Kamigori, Ako-gun, Hyogo 678-12, Japan

1. Introduction

The SPring-8 storage ring has a circumference of 1436 m with a Chasman-Green lattice of 48 cells. Each cell consists of two bending magnets, and seventeen multipoles which are set on three girders. There are total of 144 magnet units in the storage ring. A two-stage alignment method is adopted for the magnets to reduce the amplitudes of orbit distortions induced by the quadrupole misalignment. By using the two fiducial points of the end quadrupoles in each unit as references, the magnet units are aligned in advance with a tolerance of ±0.2 mm RMS error in the tunnel. Then, within the unit the magnets are aligned to the two end quadrupoles with an accuracy of ±50 μm.

The magnet installation for the storage ring is divided into five phases: in the first phase four cell magnets are installed, from cell number c40 to c43; second phase eight cells, from c44 to c03; then from c04 to c11, c12 to c23, and c24 to c39. All the units are recommended to be put to the positions as precisely as possible before executing the final survey for the whole ring.

Magnet alignment aims to put the magnetic centers to a designed beam orbit. The errors of magnet absolute positions are the sum of many random and systematic errors such as that of networks, instruments, magnet fiducialization, atmospheric condition etc. These errors cause magnet positions can not be obtained more precisely than an error envelope of cigar-shaped[1]. Figure 1 shows sketchily the actual reference curve of magnet alignment within the error envelope between two monuments. It is no meaning to compare the absolute positions of magnets within the envelope among independent surveys. In the magnet alignment of the SPring-8, effort is made to reduce the error width by optimize the networks, calibrating the laser tracker, using the monuments as the guideposts etc.

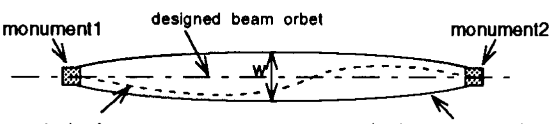

Fig. 1 Absolute error envelope of magnet alignment.

2. Alignment of magnet units

2.1. Monument survey

Alignment of magnet units for the storage ring consists of monument survey, and magnet survey and alignment. 10 monuments are buried outside the ring building, and 88 monuments are set under the bending magnets in the tunnel. Among these monuments 21 are made of isolated concrete blocks of 1 m high from rock before building construction and are buried to their surfaces with concrete around them when tunnel construction, most of which are surveyed two times before building construction. From December 1994 through April 1995, all monuments in the tunnel are surveyed with the SMART 310, a three-dimension dynamic measurement system. Survey network includes 192 points and 480 distances with two fixed points. Angle measurements for every two cells with the theodolite T3000 were added after, to reduce systematic biases caused by the change of air refraction and the errors of laser tracker calibration and reference datum etc. Simulation is done for monument survey which has a RMS error of ±0.5 mm, peak to peak error of ±1.3 mm (w in Fig.1) in radial direction. Figure 2 shows the deviations of the third time survey from the first and the second times in horizontal plane. Difference between them is small,

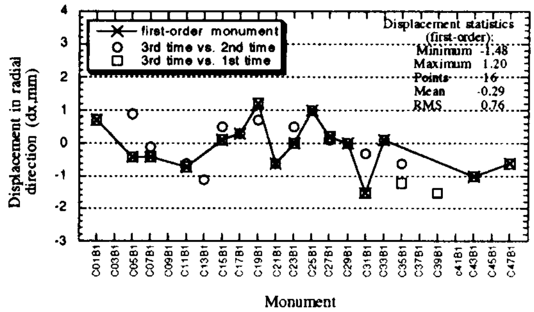

Fig. 2 Deviations of the three time surveys.

and most monuments have little movement even after the tunnel construction. From these monuments 16 reference points are selected (first- order references). These monuments are convinced to have small displacements from designed positions both in radial (statistics in Fig. 2) and beam direction, when comparing three times of surveys. It can be seen that both the survey in the tunnel and the surveys before the tunnel construction did not cause large deviation for these reference points. The final coordinates of the 88 monuments are obtained by best-fitting to the first-order monuments to reduce datum definition bias.

The survey results are compared with the angle measurements of the theodolite T3000, difference between them is small. It is believed that the monument survey error is within 0.7-0.8 mm for peak to peak value.

2.2. Magnet survey

Magnet survey for the storage ring is executed with a network which is composed of the two end quadrupoles in each magnet unit, auxiliary brackets on the wall, and the monuments for every two cells as well. Total measuring points is 480, and total distance measurements is around 1440. Distances are measured with the SMART 310. This survey network is optimized in several aspects [2]. It is particular in its measuring configuration. Within each cell the SMART 310 has only four measuring stations. Over 50 percent distances are measured directly by the laser tracker's interferometer, these distances are much more precise than that of when the angle encoders of the tracker are involved in measurements. Error ellipse analysis shows this network has a sufficient precision to control magnet displacements: Maximum displacement is ±0.9 mm RMS in radial direction and the relative displacement is ±0.04 mm between adjacent units.

2.3. Adjustment for the magnet units

Magnet survey and alignment is carried out two rounds. A third round of survey is also necessary to check the magnet final positions. Survey error for the magnets is about ±0.9 mm RMS at the worst place of the ring, that means the absolute positions of magnets may displace by 2σ of 2 mm. Considering that the summed error from the two independent measurements of monument survey and magnet survey may cause a maximum displacement of 2.5 mm to the magnets, in the first round of adjustment we use monuments as the guideposts to reduce the absolute error envelope. Magnets are adjusted to a smooth curve of polynomial that less than 6th order which best-fits to the monuments. In the second round, magnets are adjusted to a weighted smooth curve which fits to magnets only.

3. Results

Figure 3 shows the magnet displacements after the section by section surveys are completed and enclosed in the ring. Maximum displacement is 1.4 mm for the magnets.

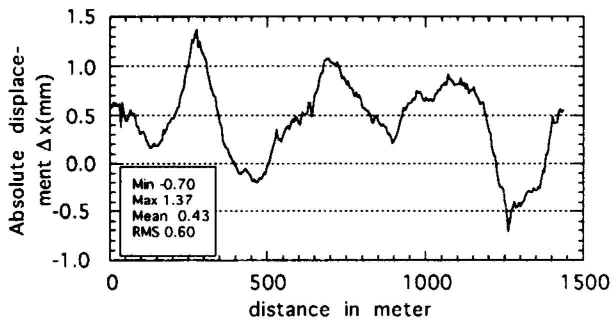

Fig. 3 Magnet displacements in radial direction.

After two round of adjustments, the relative precision between units is ±0.04 mm RMS in radial direction. In beam direction the deviation is ±0.3 mm (Fig.4). Both are well within the tolerance of ±0.2 mm and ±0.5 mm respectively.

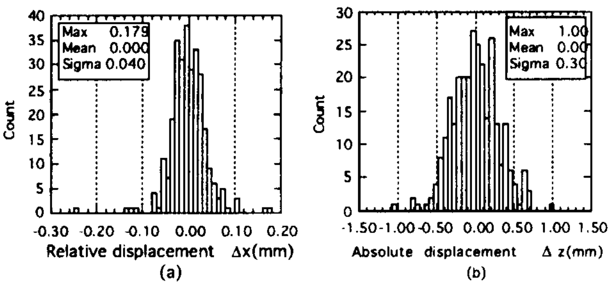

Fig. 4 (a) Magnet relative displacement in radial direction, (b) Magnet absolute displacement in beam direction.

Reference

[1] R. E. Ruland, SLAC-PUB-5672, October (1991).

[2] C.Zhang and S.Matsui, annual report 1994, SPring-8, 141-142.