Alignment of Magnets for the SPring-8 Synchrotron

Kenji FUKAMI[1)], Shigeki OHZUCHI[1)], Hiroto YONEHARA[1)], Hiromitsu SUZUKI[1)], Tsuyoshi AOKI[1)], Soichiro HAYASHI[1)], Yutaka HIRATA[2)], Teruyasu NAGAFUCHI[2)], Norio SUETAKE[2)], Yukio YOSHIWARA[2)] and Hiromasa ITOH[2)]

1) SPring-8, Kamigori, Hyogo, 678-12, JAPAN
2) TOSHIBA co., 2-4 Suehiro-cyo, Tsurumi-ku, Yokohama, 230, JAPAN

Abstract

The SPring-8 synchrotron is composed of 64 bending magnets, 80 quadrupoles and 60 sextupoles. The 80 quadrupoles and the 60 sextupoles are supported on girders. The circumference is about 400 m. Since the tunnel of the synchrotron is narrow, SMART310, laser tracker for 3D measurements of moving targets, is used for the alignment. Here the alignment method, results and present status are reported.

1. Introduction

The SPring-8 synchrotron is under construction now. In June 1995, we began with the first survey of reference points for prealignment. The alignment is based on reference points inside the shielding tunnel since there is no reference points outside it. This alignment consist of two steps. The first step is the network which survey and set the reference points of the prealignment for installing the magnets. The second step is the network for the precise alignment of the magnets. For bending magnets, the precise alignment was finished on December 1995. For other magnets, it is carrying out now.

2. Tolerances

The tolerances of the alignment error are relative precision of ±0.2 mm in radial, vertical and beam direction and of ±0.2 mrad in tilt of the magnets. Table 1 shows the deviation of the relative error of the alignment.

Table 1 Deviation of the relative error

Magnet	Vertical (mm)	Radial (mm)	Beam (mm)	Tilt (mrad)
Bending	±0.2	±0.2	±0.2	±0.2
Quadrupole	±0.2	±0.2	±0.2	±0.2
Sextupole	±0.2	±0.2	±0.2	±0.2
Correction	±1.0	±1.0	±1.0	±1.0

3. Alignment Method

3-1 Reference Points Setting and Prealignment

The first step of the alignment is setting the reference points for the magnets installation. We survey the reference points and set them for the proper location. The reference points of the synchrotron are shown in Fig.1. Two points L1 and L2 which are on the injection line from the SPring-8 linac ensure the correct location and orientation of the synchrotron to the linac. Based upon them, The reference points S1 to S12 were set. These reference points were imbedded in the floor and were able to be adjusted in X-Y directions. Monuments are set up on the points. Using L1, L2 and other supplementary points, reference points on the straight line are set.

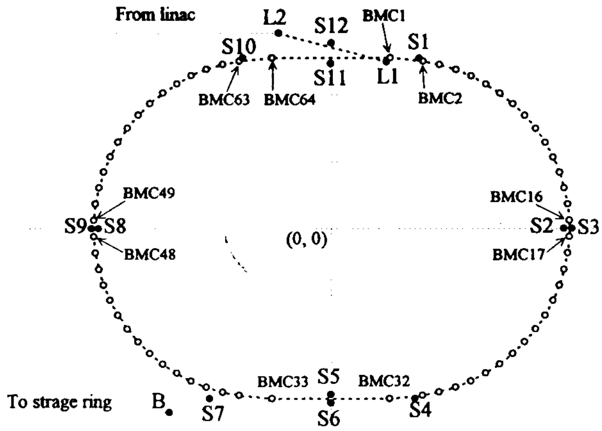

Fig.1 Reference points of the SPring-8 synchrotron

Since the tunnel is narrow and reference points are limited in number, it is remarkable difficult to realize highly accurate positioning of the reference points by triangle network calculation. For this reason, we use the center point of the 64 dipole magnets as supplementary points. Survey network comprises nearly 80 points. The objective of the first step alignment is that the deviation of the network points is less than ±1 mm.

3-2 Precise Alignment

Monuments are set on the reference points. SMART310, theodolite and N3 level were used as survey equipment. Number of the bending magnets are defined as follows. First magnet from injection point along the beam direction is called BM1. Then, magnets were named as BM2 ~ BM64 in order of the beam direction. Fiducials on the 64 dipole magnets are used as supplementary points in order to obtain the accuracy of the network calculation. There are three fiducials on a dipole magnet. "BMU" means upstream, "BMC" means center and "BMD" means downstream. The BMC of *n* th magnet is called BMC*n*.

3-2-1 Precise Alignment of Vertical Direction

Height of the magnets were measured by N3. Sphere mounted target for N3 is positioned on the BMCs. The target has a pattern of concentric circles and diameter of the center circle is 0.2 mm. The height reference is taken from the linac. BMC1 was adjusted to the height reference. Dial gages were put on the girder to check the shift of the magnet. Similarly, the BMC64 was adjusted.

From BM2 to BM32, the height of downstream-side magnet was adjusted to upstream-side magnet clockwise. N3 was installed in the middle of above two magnets every adjustment. After every adjustment, the difference between these two magnets was measured by means of N3. Similarly, the height of upstream-side magnet was adjusted to downstream-side magnet counter-clockwise from BM33 to BM64 starting from BM64.

3-2-2 Precise Alignment in Radial and Beam Direction

Alignment in radial and beam direction was performed using SMART310 and theodolite. Sphere mounted retroreflector of SMART310 is positioned on the three fiducials. BM1 and BM64 were adjusted to S1 and S10, respectively. Dial gages were put on the girder to check the shift of the magnet. From now on, BM1 and BM64 were fixed.

SMART310 was installed in the middle of above two magnets. The BMC1 and BMC64 were measured and the straight line BMC1-BMC64 was stored as a coordinate axis. Then, the coordinates of fiducial of BM2 was measured. According to the measurement, magnets were adjusted to the design values. The BMCs were observed by N3 taking care not to change the height of magnets before and after the shift. To confirm the adjustment, angles made by neighboring three BMCs were measured by means of theodolite.

For the far away from BM3, SMART310 was moved every adjustment of four magnets. After the movement, upstream-side two magnets which have been adjusted were measured and a straight line connecting the BMCs of both magnets was stored as a coordinate axis freshly. The adjustment were performed clockwise from BM2 to BM32 according to the above mentioned method. Similarly, the adjustment were carried out counter-clockwise from BM33 to BM64 starting from BM64.

After the alignment, in order to obtain the position of magnets in sub-millimeter, triangle network calculation of BMCs were carried out. First, the side length of the triangles were measured. Distances from BMC*n* to BMC*n-4* ~ BMC*n-1* were measured using SMART310. Secondary, the inside angle of them were measured. Theodolite was installed on BMC*n*. The azimuth angle of BMC*n-4* direction was defined to be 0 deg and then the angles of BMC*n-3* ~ BMC*n+4* were measured. The position of BMC2 ~ BMC63 were calculated using these measured values with the fixed points of BMC1 and BMC64. Based on the difference between designed positions and calculated ones, necessary shifts of the magnets were decided and then above mentioned adjustment was performed over again. These processes were repeated three times.

4. Results

Relative deviation from neighboring magnet is shown in Fig.2(a). Error in the height-measurement was evaluated to be 0.054 mm which comes from the resolving power and systematic error of N3 and manufacture-precision of target. Relative deviation in vertical direction was within the specification value of ±0.2 mm. Root mean square (r.m.s.) value was 0.051 mm.

Difference between designed and measured circumference of the synchrotron was obtained to be 0.2±1.1 mm based on the coordinate-measurement. The relative deviation of magnets in radial and beam directions are shown in Fig.2(b) and (c), respectively. Error in the coordinate-measurement in the radial and beam directions were evaluated to be 0.044 mm and 0.034 mm, respectively considering the resolving power of SMAT310 and theodolite, reading-error of target and installing-error of theodolite. Both the relative deviations in radial direction and one of beam direction were within the specification of ±0.2 mm for all magnets. The r.m.s. deviations of the former and the latter were 0.087 mm and 0.059 mm, respectively.

Tilts of the magnets were also adjusted by means of digital level gauge which was put on BMCs. It was confirmed that the tilts of magnets were also within the specification of ±0.2 mrad.

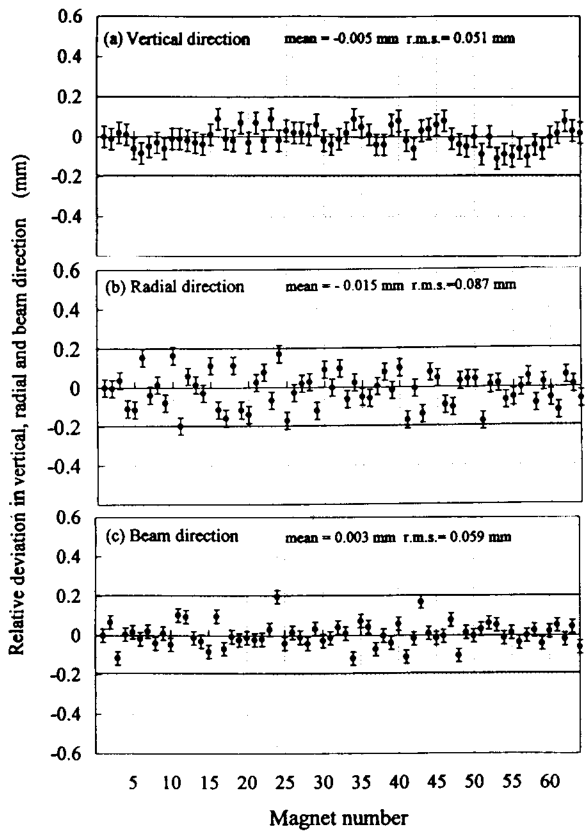

Fig.2 Relative deviation of bending magnets in vertical, radial and beam directions. Straight line indicate the specification of relative precision.

5. Conclusion

The precise alignment of bending magnets of the synchrotron was finished. The specification of relative precision of vertical, radial and beam direction and tilt were satisfied completely. The precise alignment of other magnets is in progress now.