Estimation of Alignment Accuracy of the SPring-8 Synchrotron

Kenji FUKAMI[1], Shigeki OHZUCHI[1], Mitsugu TANIMOTO[1], Hiromitsu SUZUKI[1], Tsuyoshi AOKI[1], Norio TANI[1], Naoyasu HOSODA[1], Soichiro HAYASHI[1], Teruyasu NAGAFUCHI[2], Hiromasa ITOH[2] and Hiroto YONEHARA[1]
1) SPring-8, Kamigori, Ako-gun, Hyogo, 678-12, Japan
2) TOSHIBA Co., 2-4 Suehiro-cho, Tsurumi-ku, Yokohama, 230, Japan

1. Introduction

The SPring-8 Synchrotron accepts an electron beam of 1GeV from the SPring-8 Linac, accelerates the beam up to 8GeV, and ejects the beam to stack into the SPring- 8 Storage Ring with a repetition period of one second.
The Synchrotron is composed of a FODO lattice of 40 cells and its circumference is 396.124m [1]. There are 64 dipole, 80 quadrupole and 60 sextupole magnets. Horizontal and vertical closed orbit distortions (CODs) are induced mainly by relative displacements of the quadrupole magnets. These CODs were measured at a beam energy of 1GeV and 8GeV. After the first COD measurements, we confirmed that the alignment of the magnets was achieved within the expected accuracy.

2. Tolerances and alignment method

The tolerances of the relative displacements of the dipole, quadrupole and sextupole magnets in the horizontal, vertical and longitudinal directions were designed to be ±0.2mm. The tolerances of the pitch and roll of the magnets were designed to be ±0.2mrad. These values were determined to be realistic alignment errors.

The horizontal and vertical CODs, which are induced by the displacements of the quadrupole magnets, were estimated by the simulation code of “RACETRACK”.
The distribution of the displacement was assumed to be gaussian and the root mean square (rms) of a displacement is equal to standard deviation σ of the gaussian distribution. The tolerance was assumed to be 2σ displacement which was larger than 2σ, was not inputted in the simulation.

Since the CODs also depend on the arrangement of the displacements in the Synchrotron, the simulation was carried out fifty times under various arrangements selected at random, with the same rms displacement. The maximum orbit distortions were picked up from the fifty samples. The maximum orbit distortion with the rms displacement of the quadrupole magnets is shown in Fig. 1. The standard deviations of the distortions are also shown in Fig. 1 as error bars.

A SMART310 system, a theodolite and level gauges of Wild N3 were used for the alignment [2]. The SMART310 has a laser tracker system to measure a position in three dimensions. To obtain the position of the magnets, triangulation was carried out. The heights of the magnets were adjusted by the N3.

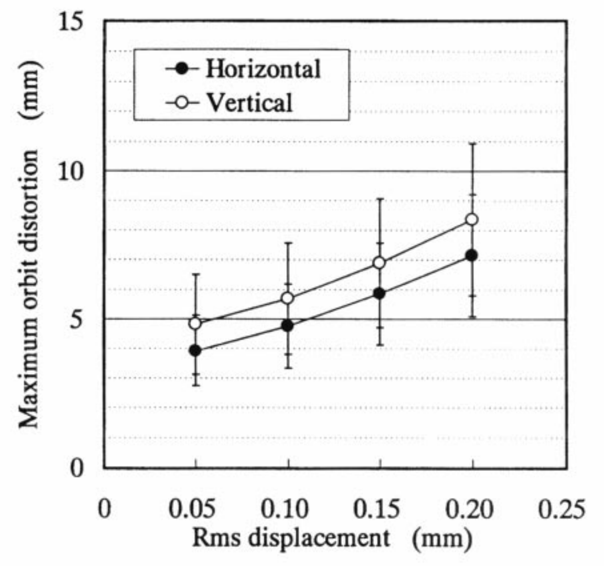

Fig. 1 Maximum orbit distortions with the rms displacement of the quadrupole magnet.

3. Results of the alignment

The relative displacements of the quadrupole magnets in the horizontal and vertical directions are shown in Fig.2. The maximum displacement values in the horizontal and vertical directions were 0.15mm and 0.11mm, respectively, and they were less than the specifications of ±0.2mm. The rms displacements in the vertical and horizontal directions were 0.048mm and 0.050mm, respectively.

The displacements of the dipole, quadrupole and sextupole magnets are shown in Table 1. The rotation errors of the magnets are also shown in Table 1.

Table 1 Summary of the rms alignment errors.

Magnet	Relative displacements (mm)			Rotation errors (mrad)	
	V	H	L	pitch	roll
DM	0.051	0.087	0.059	0.032	0.054
QM	0.048	0.050	0.037	0.039	0.035
SM	0.043	0.036	0.042	0.047	0.039

Symbols DM, QM and SM indicate the dipole, qudrupole and sextupole magnets, respectively. Symbols V, H and L indicate the vertical, horizontal and longitudinal directions.

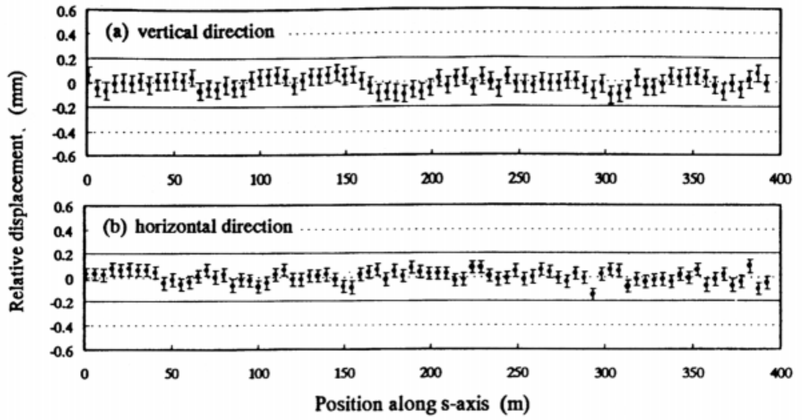

Fig. 2 Relative displacements of quadrupole magnets. The upper and lower figures indicate the errors in the vertical and horizontal directions, respectively.

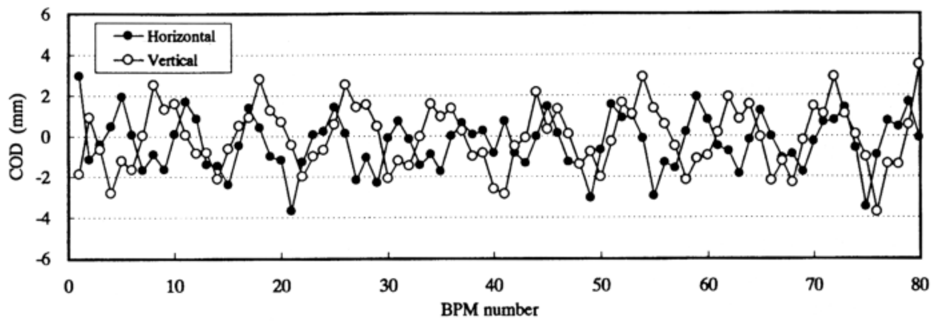

Fig. 3 Horizontal and vertical CODs without orbit correction.

4. Estimation of the alignment accuracy

We measured the horizontal and vertical CODs by 80 BPMs [3] at a beam energy of 1GeV and 8GeV. The COD at 1GeV is shown in Fig. 3. The maximum distortions in the horizontal and vertical directions were 3.69mm and 3.74mm, respectively. The rms CODs were 1.31mm and 1.55mm, respectively. If the CODs were generated only by the displacements of the quadrupole magnets, the maximum orbit distortions and the rms CODs corresponded to the case of the rms displacement of 0.05mm in Fig. 1. This evaluated value is equivalent to the measured displacement in Table 1.

The average of CODs should be equal to zero if the electron beam oscillates around the designed orbit. In the vertical direction, the average COD was measured to be 0.01mm. It was negligibly small compared with the position-determination error of the BPM (0.06mm).

The average COD in the horizontal direction, however, was 0.47mm. It was not negligible. This was caused by the difference of the circumference from the designed value. To estimate the deviation, the horizontal COD with the radio frequencies was measured (Fig. 4).
The average COD with radio frequencies is shown in Fig.5. The beam orbit was not changed in the straight cell (BPM1, 35~41 and 75~80) due to the dispersion-free region. In the other region, the beam passed through more toward the outside as the radio frequency was lower because the total length of the orbit was longer. When the radio frequency was 4kHz lower than the designed value of 508.58MHz, the average COD was almost zero. This indicated that the circumference was 3.1mm longer than the designed value.

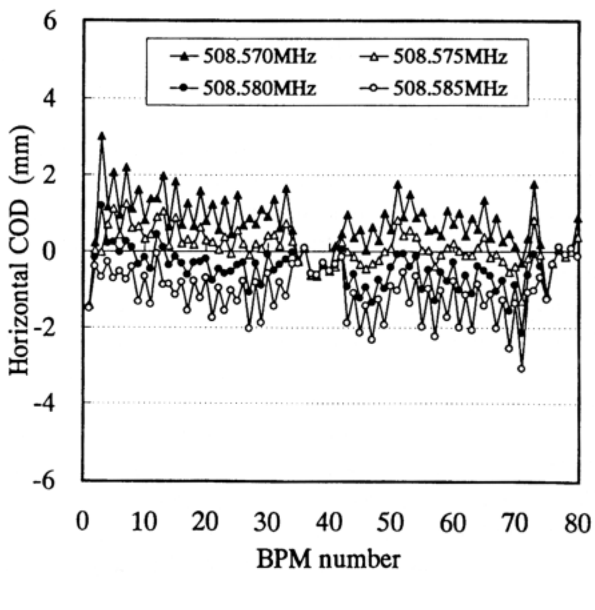

Fig. 4 Horizontal COD with radio frequencies.

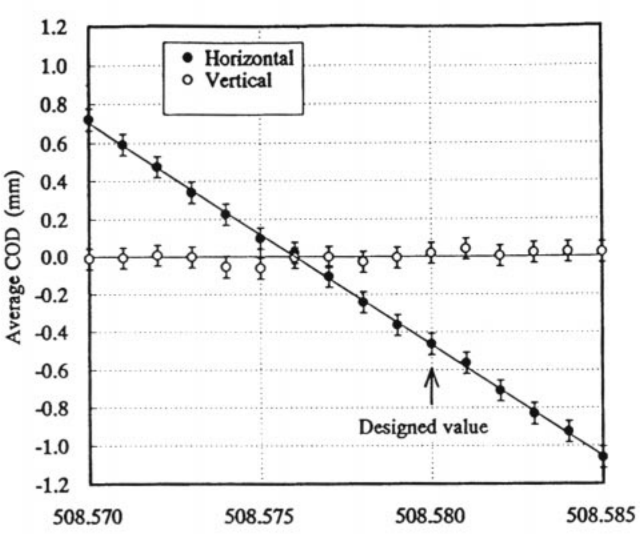

Fig. 5 Average CODs with radio frequencies.

5. Summary

The alignment of the lattice magnets was completed successfully. It was confirmed that the alignment of all of the magnets satisfied the specifications. The measured displacements of the quadrupole magnets were compatible with the evaluated displacements based on measurements of the CODs.

References

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[3] T. Aoki et al., Proceedings of SRI'95, Review of Scientific Instruments, Vol. 67, No. 9, 1996, Page 3367.