QUADRUPOLE AND SEXTUPOLE MAGNETS FOR THE SUPER SOR STORAGE RING

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Abstract

Quadrupole and sextupole magnets of the Super SOR storage ring are presented. For the quadrupole magnet, Collins type profile is adopted to accommodate synchrotron radiation beamline. The magnet core consists of symmetrical upper and lower parts. They are joined each other by stainless spacers. The spacers have a large hole for a vacuum pumping port. A prototype model has been fabricated and the field measurement has been carried out using harmonic coil method. In this paper, we describe the results of prototype measurement. For sextupole magnet, design study has been made to obtain a good field quality. All of the sextupole have auxiliary coils to provide both horizontal and vertical dipole fields for the COD correction. The design of the sextupole and calculated results of main sextupole and correcting fields are presented.

1 INTRODUCTION

The Super SOR light source is a candidate of future Japanese facility for synchrotron radiation (SR) science in VUV and soft X-ray regions. The storage ring has a racetrack shape with circumference of 250m and can be operated at beam energies between 1.0 and 1.6 GeV. The lattice configuration of normal cells is Theoretical Minimum Emittance type. The ring is able to achieve extremely small emittance of 0.75 nm·rad in 1.0 GeV operation [1].

The lattice of Super SOR requires 35 dipoles (28 for arc sections and seven for saw-tooth configuration in one long straight section), 148 quadrupoles, 72 sextupoles and more than 100 steerings for fast orbit feedback system. Design and R&D's of the magnet system have been proceeding at ISSP by collaboration with RIKEN and KEK.

2 QUADRUPOLE

All of the quadrupole magnets have identical cross section of C-type profile but there are four different core lengths, 0.2, 0.3, 0.35 and 0.4 m. The magnet core consists of symmetrical upper and lower parts, which are joined by stainless spacers.

Parameters of the quadrupole prototype are listed in Table 1. The prototype is made of 0.5 mm-thick laminated silicon steel and assembled by gluing without any supporting plates on each end. The stainless spacer has a hole of 190 mmϕ, to which a pumping port of beam duct can be attached [2]. Figure 1 shows a photograph of the prototype.

Table 1: Parameters of the quadrupole prototype.

Bore radius [mm]	70
Core length [m]	0.37
Maximum field gradient [T/m]	21
Turns / pole	25
Maximum current [A]	500

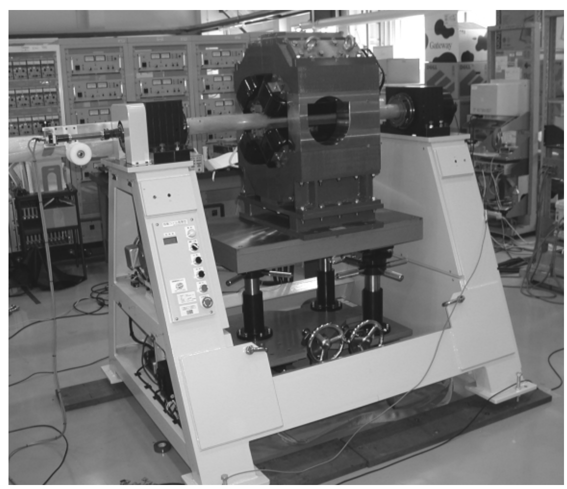

Figure 1: The prototype model of quadrupole

The field measurement has been carried out using a newly fabricated harmonic coil system. Design of the system is based on a measurement bench developed at KEK [3] and modified for the Super SOR magnets.

We prepared two radial coil probes; one is a long coil (length: 1000 mm, radius: 24.85 mm and turn number: 10) for measuring the integrated field gradient and other is a short coil (length: 20 mm, radius: 24.25 mm and turn number: 50 turns) for measuring the central field gradient. They are mounted in a GFRP cylinder, which is rotated in the aperture of the magnet by an inverter-controlled DC motor. Induced signals from the coils are integrated over equally spaced angular intervals by a two-channel digital integrator (PDI5052, METROLAB). The integrator is triggered by a cylinder position signal from angular encoder. Multipole components of magnetic field are obtained by the Fourier analysis of the digitized signals.

Excitation curve measured by the short coil is shown in Fig. 2. This measurement was performed without end correction. The maximum field gradient of 21 T/m is achieved with a current of 450 A. Figure 3 shows effective length calculated from the measured ratio of the integrated and central field gradients.

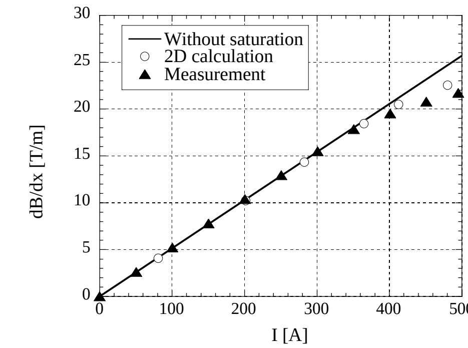

Figure 2: Excitation curve of the quadrupole prototype.

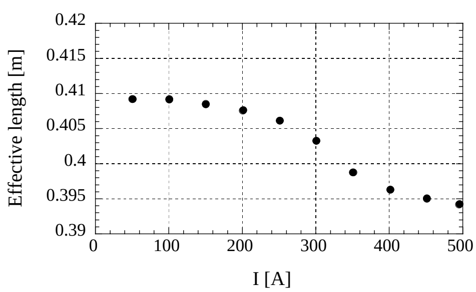

Figure 3: Current dependence of the effective length.

End correction was performed by shimming to the end of magnet core. Silicon-steel plates with various thickness were attached to both edges of the magnet pole to reduce dodecapole field, the dominant higher component of the quadrupole. Figure 4 shows the ratio of normal field components of dodecapole and quadrupole with different thickness of the shimming. The dodecapole component decreases gradually with the thickness and changes sign at 6 mm. Figure 5 shows amplitudes of multipole components for the shimming of 6 mm. These values are normalized by the quadrupole component. All of the higher components are below a required level of 5×10^{-4}.

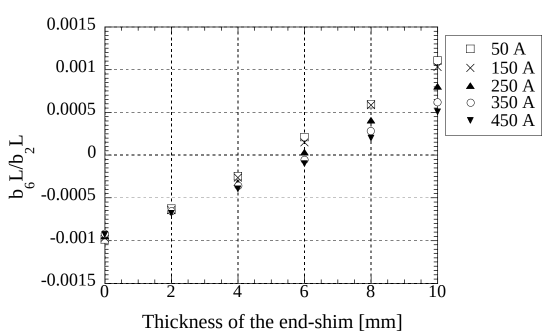

Figure 4: Dependence of the dodecapole to quadrupole ratio on thickness of the end-shimming.

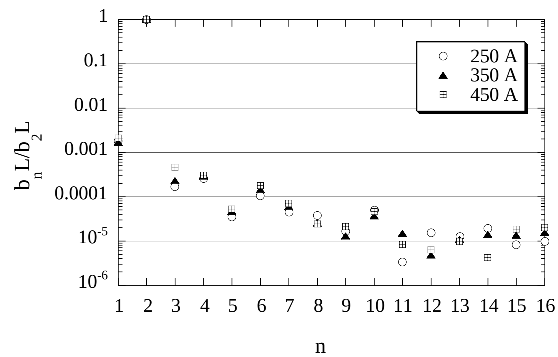

Figure 5: Multipole field amplitudes normalized by the quadrpole component.

3 SEXTUPOLE

The sextupole magnets are divided into two families. The main parameters of the sextupoles are given in Table 2.

Table 2: Parameters of the sextupoles

	SF	SD
Number	48	24
Bore diameter	80 mm	80 mm
Effective length	0.2 m	0.4 m
Field strength		
Nominal	209.8 T/m^2	108.7 T/m^2
Maximum	500 T/m^2	500 T/m^2

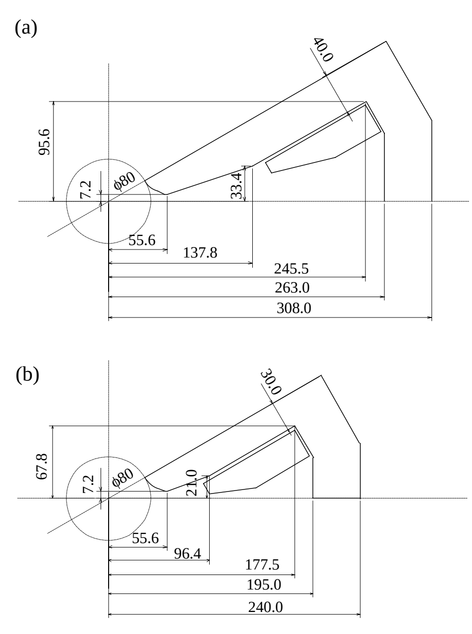

Figure 6: Geometry of the sextupoles (a) SF and (b) SD.

Geometry of the sextupoles SF and SD is shown in Fig. 6. Half number of the SF's are positioned just downstream of dipole magnet and as such, SF has a relatively large yoke. An SR beamline from the dipole passes through the inner space of the yoke. On the other hand, SD has a compact yoke size. The SR beamline passes outside of the yoke. The shape of SF and SD has been determined by 2D calculations using POISSON. The pole profile was optimized to obtain a field gradient uniformity better than 5×10^{-4} within a horizontal region of ±30 mm. Excitation curves of SF and SD are shown in Figure 7.

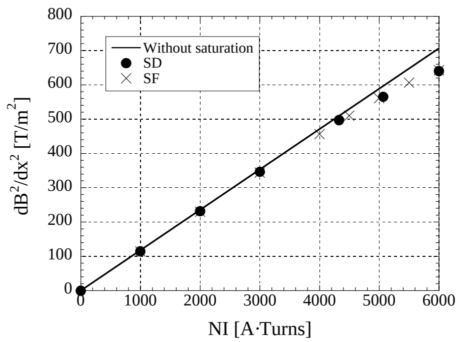

Figure 7: Excitation curves of the sextupoles.

All of the sextupoles have auxiliary coils to excite horizontal and vertical steering fields for COD correction. For the sextupole SF, the required steering field strength is 0.017 T in maximum. It corresponds to kick angle of 1 mrad at 1.0-GeV operation. These steering fields should be adjusted independently and not affect the main sextupole component.

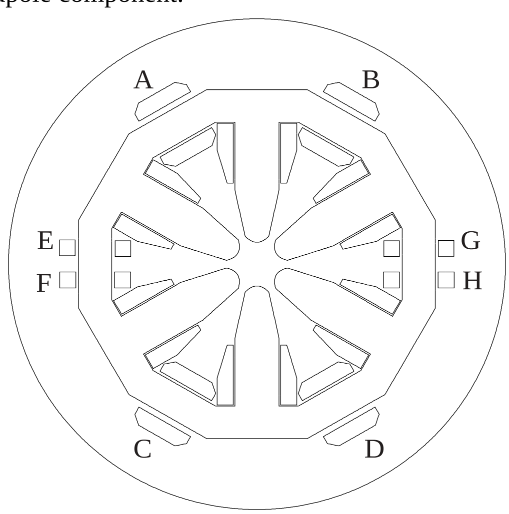

Figure 8: Configuration of the auxiliary coils on SF.

The auxiliary coil configuration on SF is shown in Fig. 8. The coils A - D (steering coils) are used for steering field excitation and E - H (correction coils) are used for correction of vertical sextupole component which is produced by the steering coils.

We have evaluated the quality of steering field using POISSON. The dipole and sextupole components excited by the auxiliary coils are listed in Table 3. For the vertical field, sextupole component without the correction coils is 36 T/m^2, it is a significant level comparing with the main sextupole field. The effect of the additional component on stored beam can not be disregarded. On the other hand, the sextupole component reduced satisfactory by an appropriate excitation of the correction coils as shown in the third row of this table. Figure 9 shows the vertical (horizontal) steering field distribution as a function of horizontal (vertical) position on x=0 (y=0) axis. Homogeneity of the vertical field is largely improved using the correction coils.

Table 3: The dipole and sextupole components excited by the auxiliary coils at a reference radius of 30 mm.

	Vertical field		Horizontal field
	A-D: 950 AT E-H: 0 AT	A-D: 320 AT E-H: 315 AT	A-D: 550 AT E-H: 0 AT
Dipole	0.017 T	0.017 T	0.017 T
Sextupole	36 T/m^2	0.15 T/m^2	0.011 T/m^2

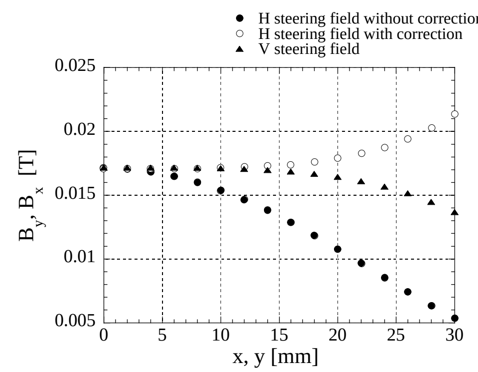

Figure 9: The steering field distribution.

We also investigated the case when both main sextupole and steering fields are excited. At maximum field strengths (500 T/m^2 for sextupole, 0.017 T for horizontal and vertical steerings), the highest flux density in the iron yoke is calculated to be 1.5 T. It implies the effect of magnetic saturation is not significant at the maximum excitation. In fact, field distribution can be explained by simple superposition of the main sextupole and steering fields in this maximum excitation case.

4 REFERENCES

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[3] Y. Kobayashi *et al.*, "Magnets for the High Brilliant Configuration at the Photon Factory Storage Ring", Proc. 10th Symposium on Accelerator Science and Technology, Japan, October 1995.