Design of the magnet for the SPring-8 Storage Ring

N. Kumagai, J. Ohnishi, H. Takebe, K. Kumagai and S. Motonaga
RIKEN-JAERI SPring-8 Project team
Hirosawa 2-1, Wako-shi, Saitama, 351-01, Japan

Abstract

Final design of the lattice main magnets for the SPring-8 Storage ring is described. The purpose of the final design is in reducing the production and the operation cost. Main items of alteration for designed parameters are reduction of pole width for dipole magnets, reduction of magnet length and bore radius for quadrupole and sextupole magnets, and simplification of the configuration of sextupole magnets. Reduction of weight is estimated to be nearly 30, 35 and 40 percents for dipole, quadrupole, and sextupole magnets respectively. Total electric power is reduced about 30 percents. Power supplies and their control system are also presented.

1. INTRODUCTION

The storage ring of SPring-8 (8-GeV Super Photon ring) is being constructed at RIKEN to be a high brilliant synchrotron radiation source [1]. General description of the design of the lattice main magnets and their arrangement in the ring were reported previously [2]. The ring has 44 normal cells, and 4 straight cells to make a long straight section as shown in Fig.1. In unit cell, 2 dipole, 10 quadrupole, and 7 sextupole magnets will be installed in usable space of 21.06 m in length together with other elements. Then total numbers of dipole, quadrupole, and sextupole magnets are 88, 480, and 336 respectively. For the COD correction, 432 steering magnets will be installed in the ring.

The purpose of the final design is in avoiding complicated structure such as previous design of the sextupole magnet, reducing magnet lengths to make space between magnets, and avoiding the interference of photon beam lines and magnet yokes.

Negotiation with manufacturer for the magnet fabrication is now in progress. The fabrication will be started in the middle of 1991.

Table 1.
Required specifications of the dipole, quadrupole, and sextupole magnets

Magnet	Dipole	Quadrupole	Sextupole
Maximum field strength	0.679 T	18 T/m	420 T/m^2
Gap distance or bore diameter	64 mm	85 mm	92 mm
Effective field length	2.804 m	0.35, 0.41, 0.51, 0.97 m	0.30, 0.53 m
Field uniformity	ΔBl/Bl	ΔGl/Gl	ΔGl/Gl
	<5 x 10^{-4}	<5 x 10^{-4}	<3 x 10^{-3}
Region size	H:±30 mm V:±15 mm	H:±35 mm V:±15 mm	H:±35 mm V:±15 mm

ΔBl/Bl, ΔGl/Gl indicate transversal variations in integrated field strength and integrated field gradient, respectively.

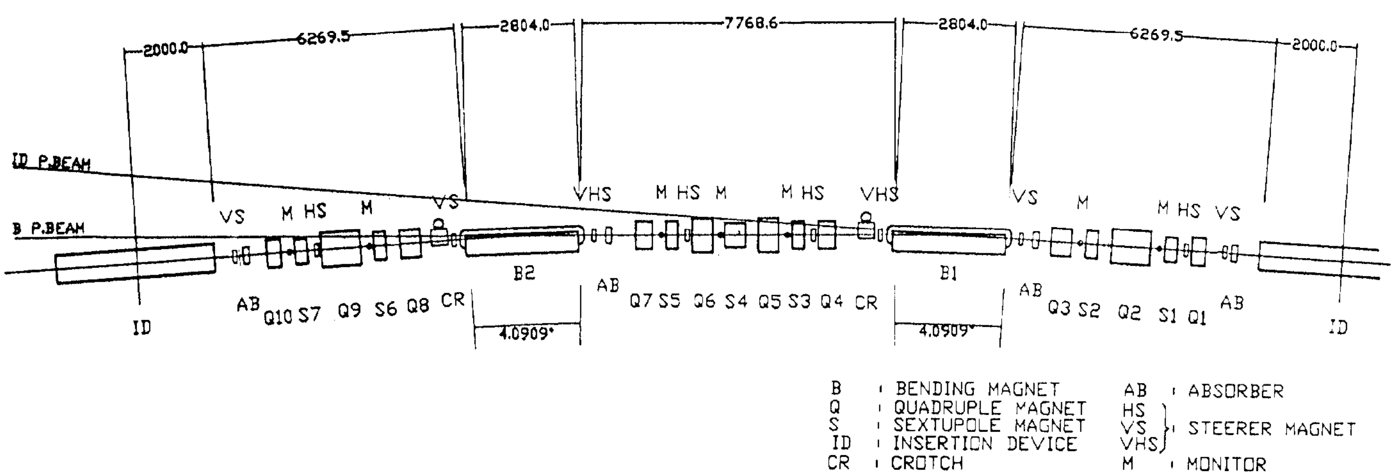

Fig. 1. An arrangement of lattice main magnets and other elements on unit normal cell.

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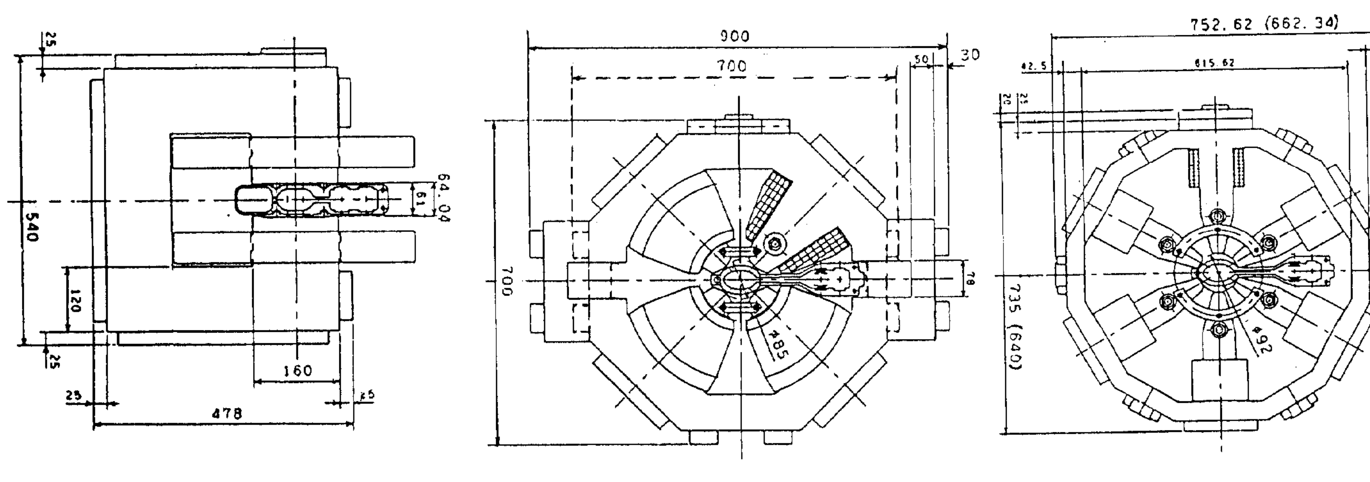
2. LATTICE MAIN MAGNET

The field quality required for the dipole, quadrupole, and sextupole magnets given in Table 1 was changed from initial one. Field strengths of all quadrupoles, and sextupoles have been determined to be satisfied with all operation conditions of the ring. The maximum field strengths for a quadrupole and sextupole are 18 T/m and 420 T/m^2, respectively. Final design of these magnets have been made optimizing calculation by taking account of results on the field measurement of prototypes. Designed parameters of the lattice main magnets are listed in Table 2.

All magnets are made by laminating 0.5 mm thick silicon steel plates in order to make the field distributions of all magnets as identical as possible. The stamped silicon steel. plates are stacked and welded exterior surface extending between SUS-304 end plates under compression. Tight tolerance limits are imposed on both core material and fabrication.

Table 2.
Design parameters of lattice magnets

Family		dipole	quadrupole Q1,Q10	Q4,Q7	Q3,Q6 Q8	Q2	Q5	Q9	sextupole S1,S7	S2,S3 S5,S6	S4
Number of magnets		88	96	96	144	48	48	48	96	192	48
Bore diameter	(mm)	64.04	85	85	85	85	85	85	92	92	92
Effective field length	(m)	2.804	0.35	0.41	0.51	0.97	0.51	0.97	0.30	0.30	0.50
Magnet length	(m)	3.09	0.48	0.54	0.64	1.10	0.64	1.10	0.41	0.37	0.61
Magnet weight	(Kg)	4950	870	1000	1220	2240	1370	2510	500	580	740
Field strength, max	(T, T/m, T/m^2)	0.679	17	16.2	17.4	17.6	17.1	17.6	420	420	420
Magnetomotive force	(x10^4 AT)	3.5	1.27	1.22	1.31	1.33	1.29	1.33	0.57	0.57	0.57
Turn numbers per pole		14	24	24	24	24	24	24	20	20	20
Conductor size	(mm)	26 x 18.5	10 x 16	10x 16	10 x 16	10 x 16	10 x 16	10 x 16	9.5 x 8	9.5 x 8	9.5 x 8
Hollow size	(mm)	ø10.5	ø5	ø5	ø5	5 x 9	ø5	5 x 9	ø5	ø5	ø3.5
Current, max	(A)	1090	536	504	544	552	533	552	285	285	285
Current density	(A/mm^2)	3.23	3.81	3.59	3.88	4.80	3.80	4.80	4.29	4.29	4.29
Conductor resistance	(mW/MAG)	9.10	17.2	18.9	21.7	37.8	21.7	37.8	37.4	37.4	47.6
Voltage drop, max	(V)	11.6	9.22	9.53	11.8	20.9	11.6	20.9	10.7	10.7	13.6
Power dissipation	(KW)	14.7	4.94	4.80	6.42	11.5	6.18	11.5	3.03	3.03	3.87
Cooling circut		2	4	4	4	4	4	4	2	2	6
Water flow	(l/min)	22.1	11.0	10.4	9.63	15.8	9.6	15.8	4.00	4.00	6.77
Pressure drop	(Kg/cm^2)	5	5	5	5	5	5	5	5	5	5
Temperature rise	(°C)	9.5	6.4	6.6	9.5	10.4	9.2	10.4	10.9	10.9	8.2



Dipole (D) magnet

Quadrupole (Q) magnet

Sextupole (S) magnet.

Fig. 2. Cross sectional views of dipole, quadrupole, and sextupole magnets. Figures of Q and S magnets show two types of them. Solid (dashed) lines of Q-magnet indicate larger one. Dimensions of larger S-magnet are given in the figure. Those of smaller one are in parentheses.

A. Dipole magnet

The dipole magnet has a C-shaped rectangular configuration as shown in Fig. 2 and its designed parameters are listed in Table 2. The C-shaped design is essential to allow good access to the inserting of vacuum chambers, and the field measurement. The pole is flat over a horizontal range of 120 mm and has radial shims of 1.5 mm in thickness at both radial ends. The distance of the gap between the shims is sufficient to allow the vacuum chamber to be installed from the open side. The transverse variation of field integration along beam direction will be corrected with end shims.

B. Quadrupole magnet

A cross sectional view of the quadrupole magnet is shown in Fig. 2. Two types of magnets having different yoke structure have been designed to avoid interference between vacuum chambers or photon beam lines and the magnet yokes. All magnets have the same pole contour. Bore diameter is 85 mm, and four different magnet lengths are designed. Configuration of magnet yokes is not four-hold symmetry because the yokes are interferenced with the vacuum chamber and the photon beam line on the median plane. Yoke width is 50 mm at the median plane. The designed value of the maximum field gradient is 18 T/m. Ampere factor is calculated to be 1.04 and field strengths inside the pole and yoke are 1.7 T and 1.4 T at the quadrupole field strength of 18 T/m. In order to enlarge a uniform field gradient region, field correction will be carried out with end shims.

C. Sextupole magnet

Major points for the design alteration for the sextupole magnet are in reducing bore diameter to 92 mm, and separating steering function which was incorporated to a sextupole magnet. Beam steering for the COD correction is done with some steering magnets located individually in the cell. Magnet length is reduced to make space for the steering magnets, therefore the field strength is increased to 420 T/m2 in maximum as seen in Table 2. A cross sectional view of the sextupole magnet is shown in Fig. 2. Yoke structure is completely symmetric, and two different size of the exterior (663 mm, 763 mm) are designed for installation of the vacuum chambers and photon beam lines. Pole contour and width of the yokes are the same for all magnets. Ampere factor at the maximum field strength is calculated to be less than 1.05 for both types of magnets.

3. COD CORRECTION SYSTEM

7 beam position monitors and 10 steering magnets are installed in the unit cell for the COD correction as shown in Fig.1. Total 480 steering magnets are placed over the ring. The field strengths required for vertical and horizontal steering is 0.0135, and 0.027 Tm respectively. The parameters for those magnets are given in Table 3. Three types are designed as shown in Table 3. Detailed design of these magnets are now under way.

Table 3.
Parameters of steering dipole magnets

Types		horiz.	vert.		horiz./vert.	
Numbers		192	144	48	96	96
Max. Bo	(T)	0.14	0.067	0.067	0.086	0.043
Effective L	(m)	0.19	0.20	0.20	0.31	0.31
Gap height	(mm)	68	90	88	100	100
Turns/pole		765	2400	5070	690	1086
Max. current	(A)	5	5	5	5	5
Voltage	(V)	27	22	33	33	128
Cooling		air	air	air	air	water

4. POWER SUPPLY SYSTEM

Total electric power supplied for all magnet power supplies is estimated to be 7.2 MVA. The all dipole magnets are electrically connected in series and powered with a single power supply. The same assigned quadrupole and sextupole magnets in each cell are connected in series between 48 cells. The field adjustment of each magnet is controlled by individual small power supplies. Current stability is required 1×10^{-4} for dipole and quadrupole magnets and 1×10^{-3} for sextupole magnets. Four buildings for power supplies are distributed along the inside of the ring.

4. CONCLUSION

The final design of the main magnets for the SPring-8 storage ring have been completed and their fabrication will be started in the middle of this year. Detailed design for the structure is undergoing by discussion with manufacturer. First magnets for dipole, quadrupole and sextupole will be completed in the beginning of 1992.

5. REFERENCES

[1] M.Hara, and et.al., "Status of the SPring-8 project (storage ring)" in this conference.

[2] S. Motonaga, J. Ohnishi, and H. Takebe: Proc. 2nd European Particle Accelerator Conference, 1125 (1990)