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MAGNETS FOR THE HIGH BRILLIANT CONFIGURATION AT THE PHOTON FACTORY STORAGE RING

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Abstract

The quadrupole and sextupole magnets have been fabricated for the high brilliant configuration at the Photon Factory Storage Ring. The field measurement of these magnets is now in progress. The shape and thickness of the end-shims in both of the quadrupole and sextupole magnets were determined to correct the higher multipole fields, whose effects were less than $\pm 1\times10^{-4}$ for the quadrupoles and $\pm 2\times10^{-4}$ for the sextupoles at a position of 36 mm from the magnetic center.

1. Introduction

The emittance upgrade for the high brilliant configuration is made by doubling the quadrupole and sextupole magnets in the normal cell section [1]. Severe conditions are however required to these magnets. The space to place the double magnets is limited and they are interfered with the photon beam lines because the bending magnets are fixed. Moreover, they are rather strongly excited than the existing ones; twice for the quadrupoles and ten times for the sextupoles at maximum. Under such conditions the magnets have been designed and fabricated, and the field measurement is now going.

2. Design and Fabrication

2-1. Quadrupoles

Two types of the quadrupoles for QF and QD in the normal cells were designed. Their principal parameters are summarized in Table 1. The schematic drawing is shown in Figure 1. They have same cross-sectional view and are different in core length. The cores are made of soft iron. The coils are water-cooled. Because of the space limitation, not only the core lengths but also the mechanical lengths including coils were made as short as possible. The bore radius (40 mm) is smaller than that of the present quadrupoles (55 mm) to produce field gradient strong enough to realize a 3 GeV operation with the smallest emittance optics. Not to disturb the SR extraction to the existing beam lines, the cores are Collins types. The cores are supported by SUS blocks to keep the field symmetry. The outer SUS supports have several types of shape to fit several types of the SR extraction ports.

2-2. Sextupoles

The core of all the sextupoles are same. Their principal parameters are summarized in Table 1. The schematic drawing is shown in Figure 2. The cores are made of soft iron and are C-shaped for the SR extraction. The coils are water-cooled. The lengths and the bore radius are small because of the same reason on the quadrupoles. The cores are supported by SUS blocks to prevent mechanical deformations, which have several types of shapes as in the case of quadrupoles. The sextupoles have auxiliary windings for vertical steering to save the spaces for correcting magnets. They also have auxiliary windings to correct the field asymmetry which arises from the core shape.

Table 1 Specifications of the magnets

Type	QF	QD	SX
Core Length	0.40 m	0.25 m	0.20 m
Bore Radius	40 mm	40 mm	45 mm
Max Field Gradient	24 T/m	24 T/m	600T/m^2
Max. Current	900 A	900 A	450 A
Turns/Coil	19 turns	19 turns	17 turns
Power Dissipation	17 kW	13 kW	6 kW
Water Flow	9.4 l/min	7.2 l/min	4.0 l/min

3. Field Measurement

The field measurements of these magnets are now in progress using a harmonic coil method [2], which is a standard technique to obtain the main field and the higher multipole components precisely. In this method, the induced voltage is represented as a function of an angular position since a coil is rotated in a magnet. Then the harmonic content of the magnet is directly given as the Fourier components of the induced voltage.

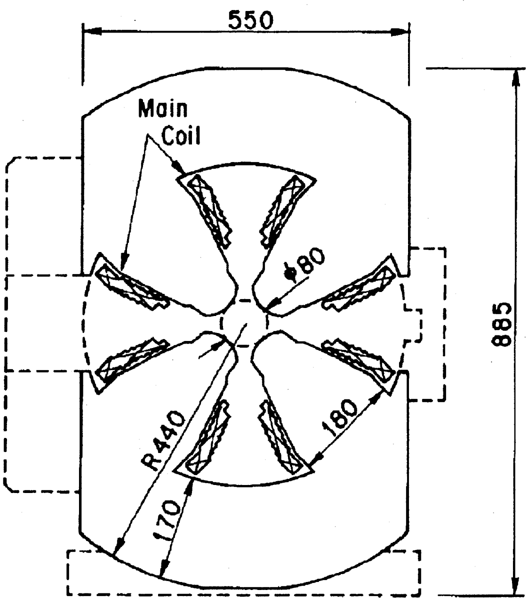

Fig.1 Schematic drawing of the quadrupole magnet

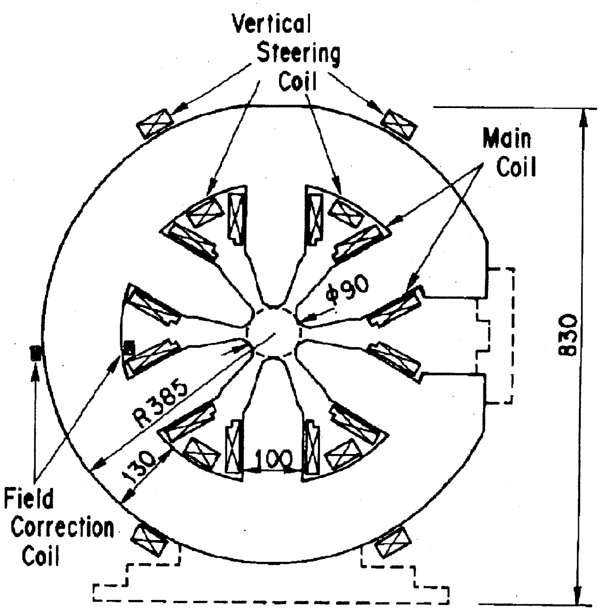

Fig.2 Schematic drawing of the sextupole magnets

3.1 Measurement System

Figure 3 shows the schematic view of our measurement system. The system is designed so that we can measure two magnets simultaneously; for example, a pair of quadrupole and sextupole magnets. The length of the coil is within 1 m in consideration of a distortion of the bobbin made of glass-epoxy resin, in which the coil is winded. The bobbin is packed in the rotating cylinder which is fixed by two chacking collet. The reproducibility of the cylinder position is less than ± 50 μm. The cylinder is rotated by a DC motor whose speed is available to change from 10 to 100 rpm. During rotation an angular encoder mounted in one side of the cylinder outputs an angular position signal, which is used as a trigger of the integration of the induced voltage. The alignment between the geometric center of the magnet and the coil axis is made using a level scope and targets whose center position is marked. Two digital integrators employing a voltage-to-frequency converter (VFC) and a precise amplifier are used in data acquisition. They are controlled by on-line computer through GP-IB interface. The specification of the system are listed in Table 2.

Table 2 Specifications of the harmonic coil measurement system

Guarder		
	material	iron
Coil Support		
	method	chacking collet
	signal output	4 pin rotary connector
DC Motor		
	rotating speed	10 ~ 100 rpm
Angular Encoder		
	resolution	6000 pulse/turn

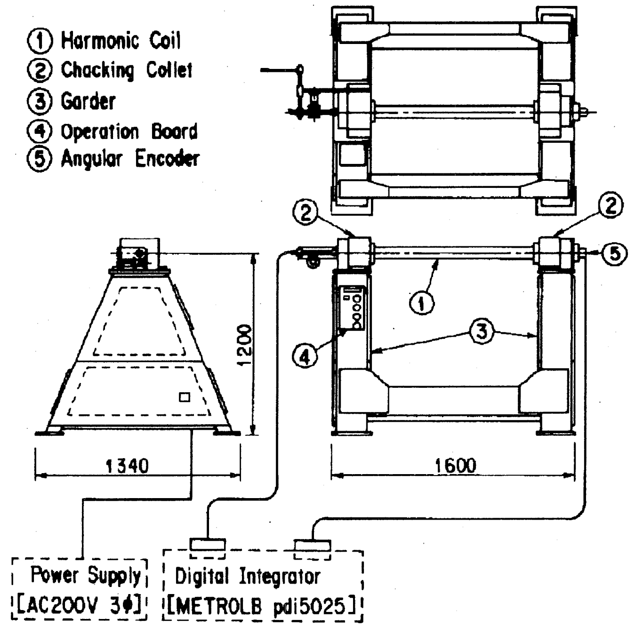

Fig. 3 Schematic view of the harmonic coil measurement system

3.2 Rotating Coil Probe

Two different set of the rotating coil probe are used in the measurement; one is a radial coil set, and the other is a tangential. The radial coil set is located in the plane of one axis, while the tangential is installed on the cylinder surface.

The radial coil set consists of two separate coils; one is a long coil for measuring the integrated field gradient and the other is a short for the point field gradient, whose parameters are listed in Table 3. The purpose of the radial coil is to measure a precise main field gradient and a deviation of the magnetic center from the geometric center.

Table 3 Parameters of the radial coil set

Coil	Long	Short
Length (mm)	1000	20
Radius (mm)	29.9	29.5
Turn Number	10	50

On the other hand, the tangential coil set is composed of six different coils; ϕ4, π4, π/2, and 3/2π coils for the quadrupole magnets and ϕ6, π6, π/2, and 3/2π for the sextupole magnets are connected. The cross section view of coil geometry is shown in Fig. 4. All are long coils to measure the integrated field. Since the main field components reduce with proper angles and turn numbers of the coils listed in Table 4, the higher multipole components should relatively enlarge. For example, the measured data are shown in Figs. 5 for QD and SX types. While the main field components reduced in both magnets, the higher multipole ones are clearly observed; the dodecapole component (n=6) is dominant for QD and the 18 poles (n=9) for SX without a end-shim correction.

Table 4 Parameters of the tangential coil set

Coil	$\phi4$	$\phi6$	$\pi4$	$\pi6$	$\pi/2$	$3/2\pi$
Length (mm)	925	925	925	925	925	925
Radius (mm)	36.0	36.0	36.0	36.0	36.0	36.0
Angle (rad)	0.206	0.148	π	π	0.5π	1.5π
Turn Number	10	14	2	6	2	2

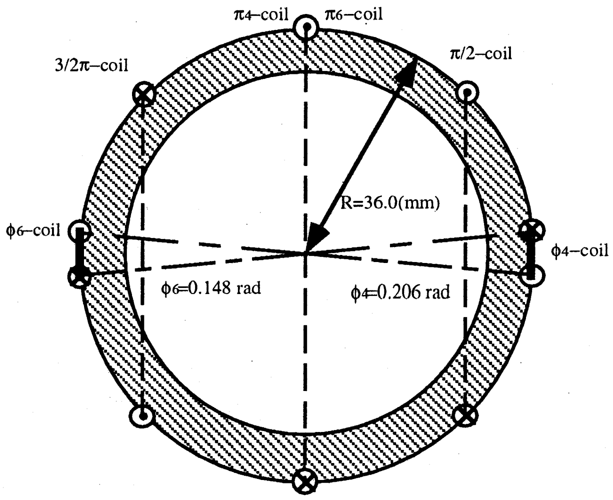

Fig.4 Cross section view of the tangential coil geometry

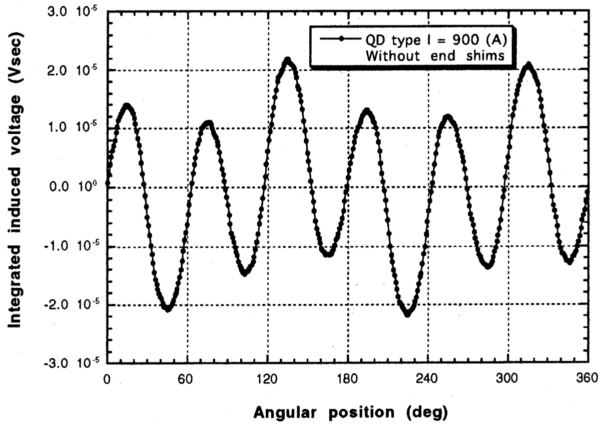

Fig.5-a The integrated induced voltage as a function of an angular position at an excitation current of 900 A on QD

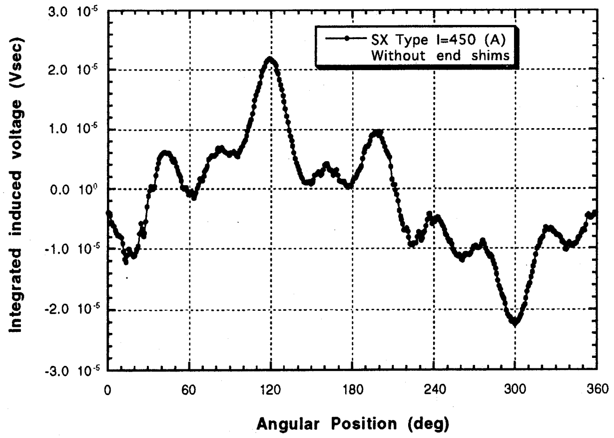

Fig.5-b The integrated induced voltage as a function of an angular position at an excitation current of 450 A on SX

3.3 End-Shim Correction

Since large higher multipole fields are undesirable in real operation, it is hopeful to reduce them as possible. In general it is available using a proper end-shim implemented on the magnetic poles. So one of the important purpose in the field measurement is to search parameters of the end-shim. Figures 6 show a field gradient ratio of the dominant higher multipole field component to the main field one. Data were measured by 100 A step of an excitation current and 2 mm step of a thickness using a tangential coil. Since the higher multipole effect depends on the thickness of the end-shim we could easily determine the best thickness to reduce them; 4 mm for QD and QF, and 3 mm for SX. As a result the higher multipole effects were reduced less than $\pm1\times10^{-4}$ for QD and QF and $\pm2\times10^{-4}$ for SX at a position of 36 mm from the magnetic center.

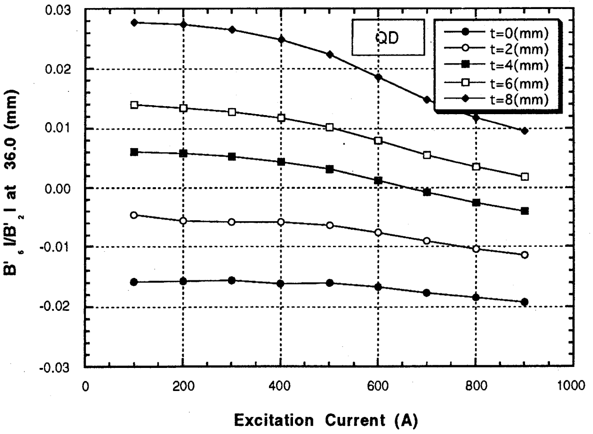

Fig.6-a The field gradient ratio of the dodecapole field to the quadrupole field on QD

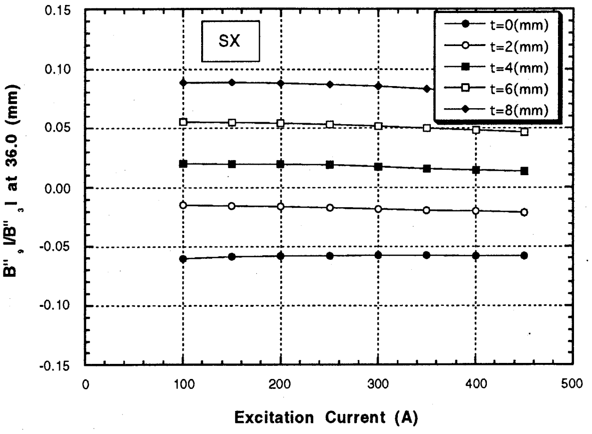

Fig.6-b The field gradient ratio of the 18 pole field to the sextupole field on SX

References

[1] M. Katoh and Y. Hori, " Status of the Emittance Upgrade Program at the Photon Factory storage Ring", in this proceedings.

[2] L. Walckiers, "The Harmonic-Coil Method", CERN 92-05, p.138