

Design Study of Combined-function Magnets for HiSOR-II Storage Ring

Takaya Narai^a, Christian John^a,
Miho Shimada^{b,a}, Hiroshi Miyauchi^{b,a}, Masahiro Katoh^a

^a*Hiroshima University*

2-313 Kagamiyama, Higashi-Hiroshima, Hiroshima 739-0046, Japan

^b*High Energy Accelerator Research Organization (KEK)*

1-1 Oho, Tsukuba, Ibaraki 305-0801, Japan

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At Research Institute of Synchrotron Radiation Science, Hiroshima University, we are planning to build an electron storage ring, HiSOR-II, as a successor to the present light source accelerator HiSOR, which is losing reliability and competitiveness due to aging. To achieve high performance while remaining appropriate in size as a university facility, the new storage ring should be as compact as possible. To realize this, we are considering introducing a combined-function magnet that generates multiple magnetic field components with a single magnet. In this article, we report on some results from the preliminary design study of a quadrupole/sextupole combined-function magnet.

There are two schemes to realize a combined-function magnet of this kind. One is to optimize the shape of the magnetic poles. Generally, poles of a single-function magnet is shaped so as to be the equipotential surface of a required magnetic field component. In case of combined-function magnet, it would be a sum of equipotential surfaces of several field components [1]. In this method, a magnetomotive force produce several field components all at once. Therefore, it is advantageous for energy saving. On the other hand, the ratio of the field strengths of those components are fixed and cannot be changed independently. This would give some limitations on the accelerator operation.

Another is to put additional coils on the magnetic poles of a normal quadrupole magnet [2]. In this case, one pair of coils is put on each magnetic pole. One coil is put on the pole face and another near the base of the pole. These two coils produce magnetic fields which consists of dipole field and sextupole field with different ratio in strengths. By adjusting the excitation currents of the coils, the dipole field can be cancelled and consequently only the sextupole field remains. In this scheme, the sextupole field strength can be changed independently from the quadrupole field strength. On the other hand, additional electromotive forces are necessary which is a disadvantage for energy saving. In addition, the coils on the pole face should be water cooled because which have relatively large electric current density because the coils on the pole shape cannot have so large diameter because of the limited space between the pole and the beam pipe. This may increase the construction cost and also would cause water leakage troubles in future.

We are going to merge these two schemes described above to eliminate the disadvantages. The magnet will produce two field components mainly by the pole shape scheme, but it also has additional coils to realize the independent change of the strengths of the two components for certain extent. The details of the magnet design and of the magnetic field simulation are described elsewhere [3]. Here, we just describe their outlines. The target magnetic field is 15 T/m for quadrupole and 100 T/m² for sextupole. The bore radius of the magnet was determined so as to fit a beam pipe of an elliptical cross section with the inner diameters of 60 mm in horizontal and 30 mm in vertical and with a 3mm wall thickness. The pole shape was determined to fit to the equipotential surface of the required magnetic field which consists of two components. In this study, the shape of the return yoke and the width of the pole were not well optimized, which were not significant on the field strength. A pair of additional coils are put on each pole as described above.

The magnetic field was calculated by POISSON [4], which is a 2-D simulation code based on the finite element method. First, the simulation was carried out for without the additional coils. The result is shown in

Figure 1 (left). The field lines mostly seem like those of quadrupole field but small asymmetry can be seen, which corresponds to the sextupole components. Then, the simulation was carried out for producing sextupole field only by using additional coils. The current of the coils were determined so that the dipole field at the magnet center was cancelled. The result is shown in Figure.1 (right). It can be seen that, at around the center, pure sextupole field was produced. Finally, the simulation was carried out for exciting both main coil and additional coils. As fixing the current of the main coil and changing those of additional coils, it was confirmed that the field strength of quadrupole is kept constant against the change of the current of the additional coils. The strength of the sextupole field varied by about 3% for the current of the additional coils on the pole face of 20 AT. If the additional coil has 4 turns and 20 A, the adjustability of the sextupole field larger than 10% would be realized.

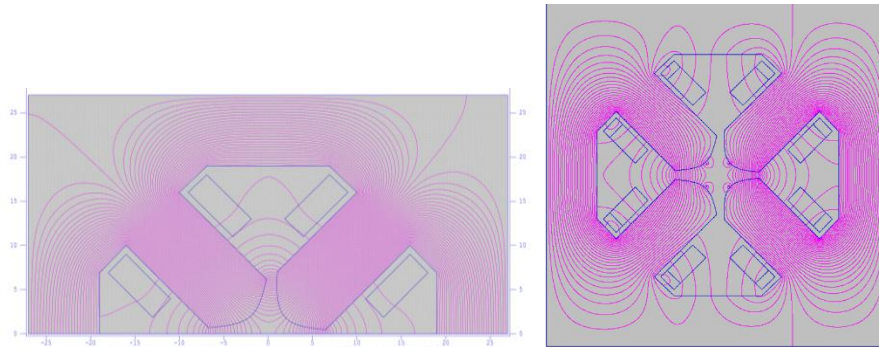


FIGURE 1. Field lines of combined-function magnet. Left; Quadrupole/sextupole combined field produced by pole shaping. Only the upper half of the cross section is shown. Right; Sextupole field produced by additional coils on the pole. The size of the magnet is same as the left figure but full cross section is shown. [3]

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