DEVELOPMENT AND INSTALLATION OF SKEW QUADRUPOLE MAGNETS FOR SPRING-8 STORAGE RING

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Abstract

The SPring-8 storage ring, an 8 GeV electron storage ring for synchrotron radiation source, consists of Chasman-Green type lattice. We installed twenty-four skew quadrupole magnets to decrease the vertical dispersion of the ring. This paper describes their design, fabrication and results of the vertical dispersion correction.

1 INTRODUCTION

User operation of the SPring-8 started in 1997 and 30 beamlines have been supplied for user experiments presently. Beam energy of the storage ring is 8 GeV, and the beam is operated on the tune of 43.16 for horizontal (ν_x) and 21.36 for vertical (ν_y). The beam emittance is estimated to be about 6 nmrad and the x-y coupling is estimated to be smaller than 0.1% while all insertion devices open their gaps [1,2]. The vertical beam size is estimated from these parameters to be about 5 μm at the straight sections where the insertion devices are placed. On the other hand, the vertical dispersion of the ring was measured as 10 mm in maximum (4.5 mm in RMS) and the momentum spread of the beam $\delta p/p$ is 0.11%. Since the vertical beam size caused by momentum spread and by radiation excitation is equivalent to the beam size due to the betatron coupling, reduction of the vertical dispersion is important to reduce the total beam size. To reduce the vertical dispersion we had planed to install twenty-four skew quadrupole magnets into dispersive sections. We started design and fabrication in the spring 1999 and these magnets were installed to the storage ring in the summer maintenance period of 1999.

2 MANUFACTURE AND PERFORMANCE

2.1 Design of the Skew Quadrupole Magnets

The skew quadrupole magnets were planned to install at the arc section where the horizontal dispersion η_x is 0.4 m. Since the strength of residual vertical dispersion to be corrected was about 10 mm, the field strength 0.0012 [1/m] was required to the skew quadrupole magnet. Each pole of the magnet was divided into two in order to avoid the antechamber as shown in Fig. 1 and the magnet was held as a cantilever. The dimensions of the magnets are 250 mm wide, 220 mm high and 140 mm long. Bore diameter is ϕ 95 mm.

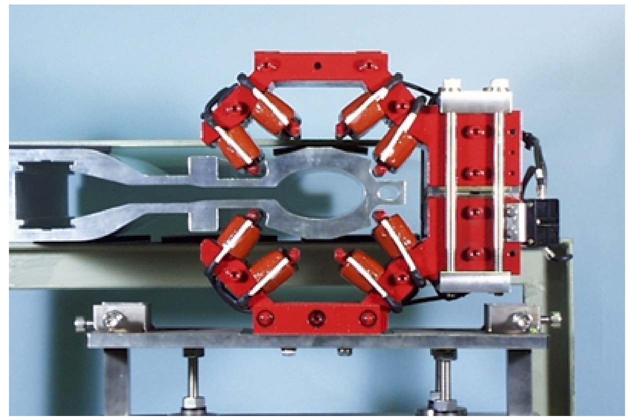

Figure 1: Side view of the skew quadruple magnet and the vacuum chamber

2.2 Magnetic Field Calculation

Magnetic fields were calculated with the 2-dimensional code POISSON. Figure 2 and Fig. 3 show the flux lines and the field distribution on the median plane, respectively. The strength of the field gradient is 0.262 [T/m] at 240 [A turns/pole] in magnetomotive force. The position of the field center shifts 0.11 mm horizontally from the geometric center of the magnet toward yoke side because of the magnet asymmetry.

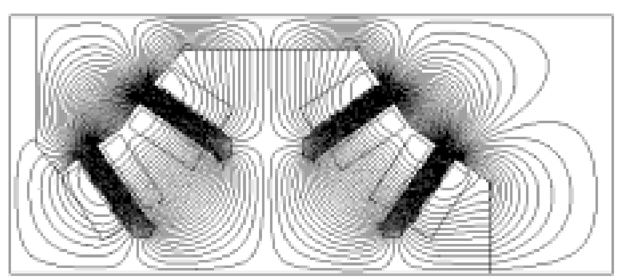

Figure 2: Flux lines of the skew quadrupole magnet calculated with POISSON

2.3 Structure

The magnet is made of stack of stamped silicon steel plates that have a small coercive force (Hc < 20 A/m) with thickness of 0.5 mm. The stacked core was not welded but bolted with end plates. Dimensional accuracy in bore radius was 0.1 mm after assembling. Coils are wound by 48 turns with enamel wire (2 mm x 1.2 mm) and are air-cooled. Rated current is 5 A.

2.4 Field Measurement

All the skew quadrupole magnets were measured with a long rotating coil. A typical field distribution is shown in Fig.3. Magnetic field lengths of all the magnets were distributed within 1.2 x 10^{-3} and the average length was 0.129 m. The magnetic field center has a horizontal shift of 0.42 mm in average from the geometric center of the magnet. The shift of the field center measured by short rotating coil was about 0.1 mm which agrees with the calculation result as described in section 2.2. This difference will be due to fringe effect of the magnet.

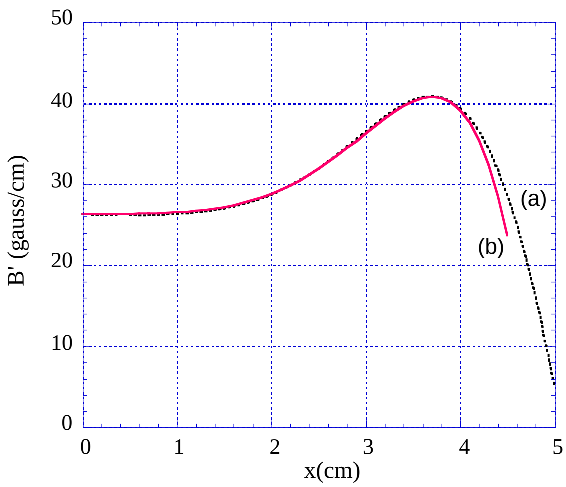

Figure 3: Magnetic field distribution on a median plane. (a) Two-dimensional calculation. (b) Long coil measurement.

2.5 Alignment

The skew quadrupole magnets were installed in dispersive sections at every even cell in the storage ring. The magnets were aligned along the adjacent quadrupole and the sextupole by a laser tracker system SMART (Leica KK.). The magnets were aligned by using field measurement data. So that the magnetic field center coincides with the center of adjacent magnet. Alignment accuracy was about 0.1 mm for both horizontal and vertical directions.

2.6 Influence upon magnetic fields of the adjacent quadrupole

The space between the skew quadrupole magnet core and the adjacent quadrupole core is 122 mm. The reduction of the integrated field strength of the quadrupole due to existence of the skew quadrupole was measured with the rotating coil, and that was about 0.18 % independent of the excitation current of the quadrupole. Since it was found by simulation that systematic reduction of the quadrupole strength deteriorates lattice parameters considerably, the current of twenty-four adjacent quadrupoles was increased to compensate the reduction.

3 RESULTS

3.1 Displacement of the field center of the magnet from the beam orbit

To measure the displacement of the field center of each skew quadrupole magnet from the beam orbit, we generated horizontal (vertical) COD at the position of each magnet and measured the amplitude of the vertical (horizontal) COD due to the off-center kick. Figure 4 shows the reading of the beam position monitors (BPMs) when the beam goes through the field center of each magnet and the estimated BPM "offsets" by another method [3]. Reading of neighbor BPMs situated on both sides of a skew quadrupole is shown. We see a good agreement between the two data and this indicates that the skew quadrupole magnets are aligned well as designed. The difference at some points is, however, larger than the tolerance of the alignment (0.1 mm). This will be due to the ambiguity of the BPM "offsets", since they were estimated from high harmonic components of COD and low harmonic contributions were neglected [3]. It was also found in the figure that the center of the BPMs shift to negative x direction in average compared with center of the magnets. However, this reason is not clear.

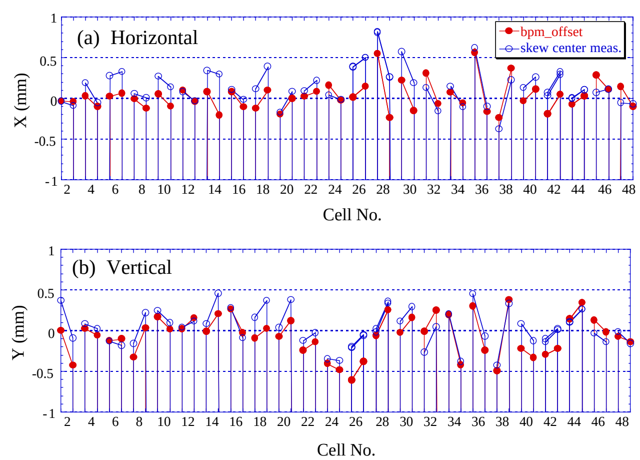

Figure 4: Reading of the beam position monitors (BPMs). (a) Horizontal direction. (b) Vertical direction. Open circle: In case that the beam goes through the field center of skew quadrupole magnet. Solid circle: BPM "offsets" estimated by high harmonic components of the COD.

3.2 Correction of the vertical dispersion

Figure 5 shows the measured horizontal and vertical dispersion with and without correction using the skew quadrupole magnets. While the vertical dispersion was 10 mm in maximum at position of BPMs without correction, it was found that the vertical dispersion decreased to one fifth by the correction. As the result, the beam size at the straight section for insertion devices is expected to be 60 % of that before correction.

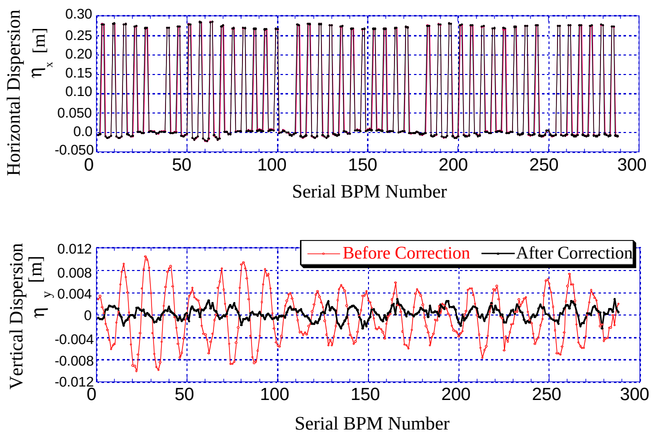

Figure 5: Measured horizontal and vertical dispersion before and after correction by 24 skew quadrupole magnets

4 CONCLUSIONS

Twenty-four skew quadrupole magnets are installed in dispersive sections in the SPring-8 storage ring. The vertical dispersion decreased to 1.1 mm in RMS after the correction. The beam size at the straight section for the insertion devices is expected to reduce to 60 % of that before correction. Presently, the vertical dispersion is corrected with skew quadrupoles in the usual operation for synchrotron radiation users. Further these skew quadrupole magnets are being used in machine study to control the vertical dispersion to investigate the beam characteristics [4].

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