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Fringe field interference of neighbor magnets in China spallation neutron source

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ABSTRACT

In CSNS accelerator construction, the field measurement of all RCS magnets have been finished and the magnets have been installed in the tunnel before the end of 2015. The electromagnetic quadrupoles have a large aperture and the core-to-core distance between magnets is rather short in some places. The corrector magnet or the sextupole magnet is closer to one of the quadrupole magnets which caused certain interference. The interference caused by magnetic fringe field has been appeared and it becomes a significant issue in beam dynamics for beam loss control in this high-intensity proton accelerator. We have performed 3D computing simulations to study integral field distributions between the quadrupole and the corrector magnets, and the sextupole and the other quadrupole magnets. The effect of the magnetic fringe field and the interference has been investigated with different distances of the neighbor magnets. The simulation and the field measurement results will be introduced in this paper.

1. Introduction

China Spallation Neutron Source (CSNS) is under construction at Dongguan, Guangdong. Its accelerator consists of an H^- linac and a Rapid Cycling Synchrotron (RCS) with output beam energy of 1.6 GeV at 25 Hz repetition rate [1]. The RCS lattice is preferred with four-fold symmetry structure to assign separated function to each long straight section. The RCS consists of 24 dipole magnets, 48 quadrupole magnets, 16 sextupole magnets and some other corrector magnets. The main dipole and the main quadrupole magnets are excited at a 25 Hz repetition rate. Fig. 1 shows the main magnet layout in one of the four-fold periods. Each period consists of six 160B dipole magnets, four 206QA quadrupole magnets, four 272QB quadrupole magnets, two 222QC quadrupole magnets, two 253QD quadrupole magnets, four 230S sextupole magnets and four 300CH/300CV corrector magnets. Their major parameters are listed in Table 1.

In the lattice design, magnets are arranged closely in some location, for example, the core distance between a quadrupole and a corrector is only 22.2 cm. The short distance between magnets will obviously cause the fringe field interference, and thus the fringe field effects must be studied very carefully [2,3]. As it is well known the fringe field interference mainly affects the integral field strength (BL), the effect of the fringe field interference should be analyzed and measured systemically, such as, between the quadrupole and corrector magnets, and between the sextupole, quadrupole and sextupole magnets.

2. Fringe field interference in quadrupole and corrector magnets

2.1. Simulation models

OPERA 3D/TOSCA [4] code is used to simulate models with different distance between quadrupole (RCS-272QB) and horizontal/vertical corrector (RCS-300CH/300CV) magnets. Fig. 2 shows simulation models of the RCS-272QB and RCS-300CH magnets. In the cases that the core-to-core distances between the two magnets are 22.2 cm, 28.2 cm and 34.5 cm, the field distribution is obtained with the code and the magnetic field interference is expressed in terms of the changes in the integrated field between the case with only one magnet and the case with two magnets together.

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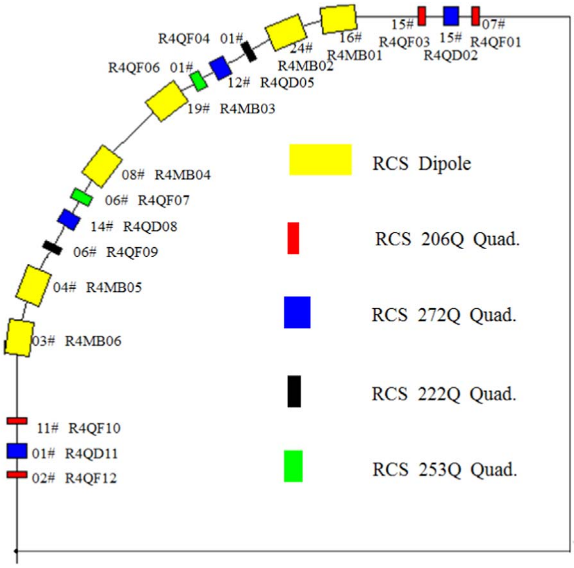

Fig. 1. Schematic layout of magnets in one of the four periods of the RCS.

Table 1
Main parameters for the magnets.

Magnet	Aperture/Gap (mm)	Core length (mm)	Effective length (mm)	Integral gradient (T/m, T, T/ m^2)
206QA	206	360	410	6.6
272QB	272	810	900	5
222QC	222	410	450	6
300CH	300	132	200	0.04
230S	230	170	200	40

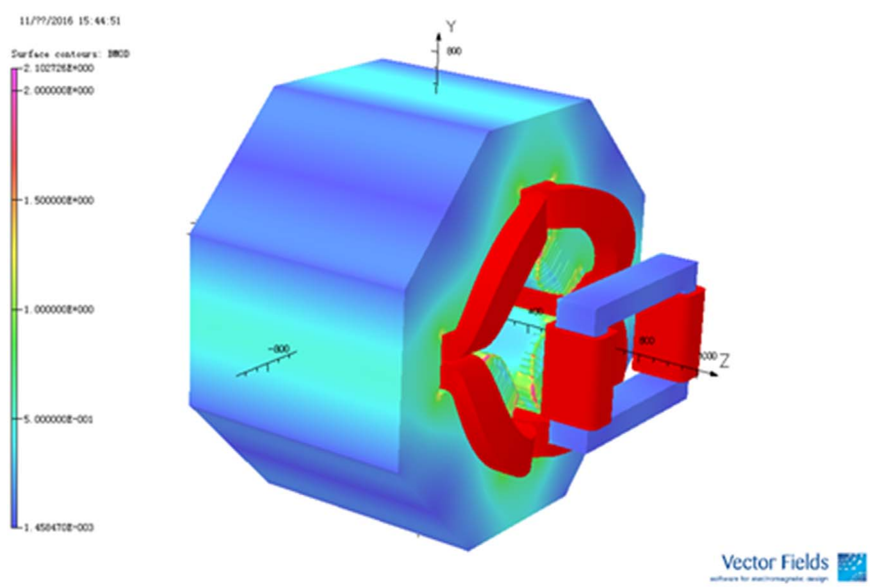

Fig. 2. 3D simulation model of RCS-272QB and RCS-300CH magnets.

For each case of the core-to-core distances, the 3D simulations include two aspects [5]: (1) the quadrupole magnet core affects the integrated field of the corrector magnet; (2) the corrector magnet core affects the integrated field of the quadrupole magnet. In the first step, the horizontal corrector magnet is driven by 33 A current, while the quadrupole magnet is not powered. 3D simulation results show that the integrated field of the corrector are 7.41 T mm, 7.67 T mm and 7.83 T mm respectively for the core-to-core distances of 22.2 cm,

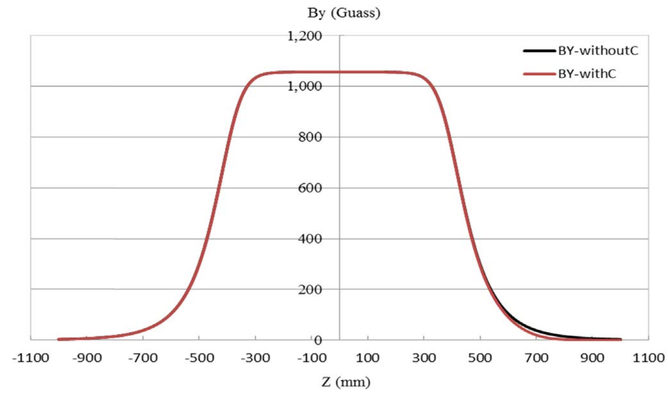

Fig. 3. Field distribution of the RCS-272QB magnet with and without RCS-300CH magnet.

28.2 cm and 34.5 cm. The horizontal corrector magnet is simulated individually with the same current and the integrated field is 8.68 T mm. The results indicate that the integrated field of the horizontal corrector magnet are reduced by14.6%, 11.6% and 9.8% due to the neighbor quadrupole magnet core. In the second step, the quadrupole magnet is energized at 650 A, but the exciting current of the horizontal corrector magnet is 0 A. The 3D simulation results show that the integrated field alone the longitudinal direction at x=50 mm, y=0 mm are 97.28 T mm, 97.51 T mm and 97.66 T mm. An individual quadrupole magnet is simulated and the integrated field is 97.9 T mm. Therefore, the integrated field of the quadrupole magnet is reduced by 0.63%, 0.41% and 0.25% due to the horizontal corrector magnet for the three cases. Fig. 3 shows the field distribution along the longitudinal direction at x=50 mm, y=0 mm of the RCS-272QB magnet with and without the RCS-300CH magnet in the case of 22.2 cm core-to-core distance, whereas Fig. 4 shows the field distribution along the central line of the RCS-300CH corrector magnet with and without the RCS-272QB magnet.

The harmonic errors of quadrupole magnet are also calculated by the code for the case of minimum core-to-core distance, and the simulation results show that only b4 is obviously changed from −0.05 units to 4.5 units while the changes of other harmonic errors are rather small. Since the variation of b4 is still within the margin value of 5 units, the influence on harmonic errors of the quadrupole magnet due