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RESIDUAL ORBITS ESTIMATION OF THE INJECTION PAINTING BUMPS FOR CSNS*

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Abstract

There are three bumps (one chicane bump and two painting bumps) in the injection system of the China Spallation Neutron Source (CSNS). They are the core parts of the injection system and the important guarantee that the Linac beam injecting into the rapid cycling synchrotron (RCS). During the beam commissioning, to check the effect of the residual orbits of the three bumps in the injection region was an important problem. In this paper, the residual orbits of BH and BV painting bumps were studied and estimated in the beam commissioning. The data analysis results showed that the residual orbits of BH and BV painting bumps were very small and they didn't need to be corrected.

INTRODUCTION

The accelerator of the China Spallation Neutron Source (CSNS) consists of an 80 MeV H^- Linac which is upgradable to 300 MeV and a 1.6 GeV rapid cycling synchrotron (RCS) with a repetition rate of 25 Hz which accumulates an 80 MeV injection beam, accelerates the beam to the designed energy of 1.6 GeV and extracts the high energy beam to the target [1][2]. The design goal of beam power is 100 kW and capable of upgrading to 500 kW [3].

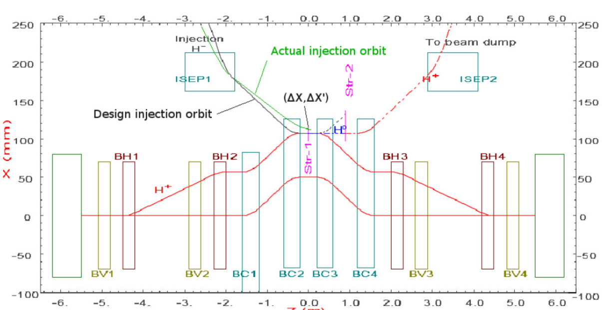

Figure 1: Layout of CSNS injection system.

In order to reduce the beam loss caused by the space charge effects, the phase space painting in the position was used in both horizontal and vertical planes for CSNS [4][5]. Figure 1 shows the layout of CSNS injection system. It can be found that there are three kinds of orbit bumps: a horizontal chicane bump (four dipole magnets, BC1-BC4) in the middle for an additional closed-orbit shift of 60 mm; a horizontal bump (four dipole magnets, BH1-BH4) used for painting in the horizontal plane; a vertical bump (four dipole magnets, BV1-BV4) used for painting in the vertical plane.

In the beam commissioning of CSNS [6], to check the effect of the residual orbits of the three bumps in the injection region was an important problem and should be studied in detail. In our previous work [6], the residual orbit of BC bump had been studied in detail. The methods to measure and correct the residual orbit of BC bump had been given and confirmed. In this paper, the residual orbits of BH and BV painting bumps would be studied and estimated. The estimating methods of the residual orbits of BH and BV painting bumps would be applied to the beam commissioning.

RESIDUAL ORBIT ESTIMATION OF BH PAINTING BUMP

In order to reduce the beam loss caused by the space charge effects, there are a horizontal bump and a vertical bump used for transverse painting. According to the physics design, the BH painting bump doesn't divulge in theory. However, if there is residual orbit of BH painting bump in the actual operation, the horizontal orbit of the RCS circular beam will be affected during the injection process and the injection result of phase space painting will be less effective. The residual orbit of BH painting bump needs to be further studied and corrected.

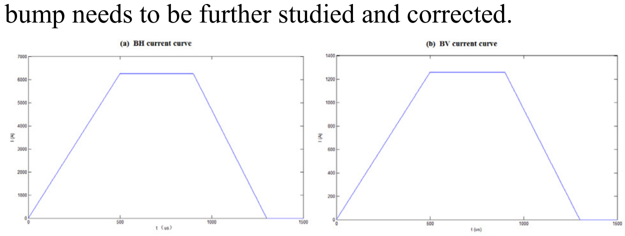

Figure 2: Special current curves of BH and BV pulse powers that are used for estimating the residual orbits of BH and BV painting bumps. BH current curve is shown in sub-figure (a) and BV current curve is shown in sub-figure (b).

In actual measurement of the residual orbit of BH painting bump, in order to reduce the orbit error due to the beam loss, the BH and BV pulse powers should be on. By comparing the horizontal positions of the circular beam outside the injection region while the current value of BH pulse power is zero and which is nonzero, the information about the residual orbit of BH painting bump can be obtained. In the experiment, special current curves

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of BH and BV pulse powers should be selected, as shown in Fig. 2. It can be found that, compared to the normal current curves of BH and BV pulse powers, the special current curves given in Fig. 2 are very simple which are linear over time in their descending parts.

During the measurement of the residual orbit of BH painting bump, the turn-by-turn data of different BPMs inside and outside the injection region need to be measured and analyzed. Figure 3 shows the turn-by-turn data of the first 1000 turns of different BPMs inside and outside the injection region (R1BPM01 is inside the BH bump of the injection region, R1BPM02, R2BPM01 and R3BPM02 are outside the injection region). It can be found from sub-figure (a) that: while the turn number is smaller than 400, the current value of BH pulse power is nonzero; while the turn number is larger than 400, the current value of BH pulse power is zero. From sub-figure (b-d), it can be found that the horizontal positions of the circular beam at different BPMs outside the injection region are almost unchanged no matter that the current value of BH pulse power is zero or nonzero. Therefore, the BH pulse power has no effect on the circular beam positions at different BPMs outside the injection region. The residual orbit of BH painting bump is very small and it doesn't need to be corrected.

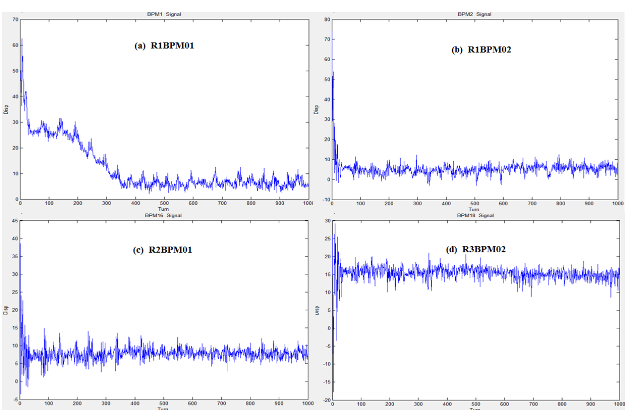

Figure 3: Turn-by-turn data of different BPMs inside and outside the injection region. R1BPM01 is inside the BH bump of the injection region (sub-figure (a)); R1BPM02, R2BPM01, and R3BPM02 are outside the injection region (sub-figures (b-d)).

RESIDUAL ORBIT ESTIMATION OF BV PAINTING BUMP

Similar to the BH painting bump, according to the physics design, the BV painting bump doesn't divulge in theory. However, if there is residual orbit of BV painting bump in the actual operation, the vertical orbit of the RCS circular beam will be affected during the injection process and the injection result of phase space painting will be less effective. The residual orbit of BV painting bump needs to be further studied and corrected.

In actual measurement of the residual orbit of BV painting bump, the current curves of BH and BV pulse powers are also selected that are given in Figure 2. By comparing the vertical positions of the circular beam outside the injection region while the current value of BV pulse power is zero and which is nonzero, the information about the residual orbit of BV painting bump can be obtained. During the measurement of the residual orbit, the turn-by-turn data of different BPMs inside and outside the injection region also need to be measured and analyzed. Figure 4 shows the turn-by-turn data of the first 1000 turns of different BPMs inside and outside the injection region (R1BPM01 is inside the BV bump of the injection region, R1BPM04, R4BPM11 and R4BPM02 are outside the injection region). It can be found from sub-figure (a) that: while the turn number is smaller than 400, the current value of BV pulse power is nonzero; while the turn number is larger than 400, the current value of BV pulse power is zero. From sub-figure (b-d), it can be found that the vertical positions of the circular beam at different BPMs outside the injection region are almost unchanged no matter that the current value of BH pulse power is zero or nonzero. Therefore, the BV pulse power has no effect on the circular beam positions at different BPMs outside the injection region. The residual orbit of BV painting bump is very small and it doesn't need to be corrected.

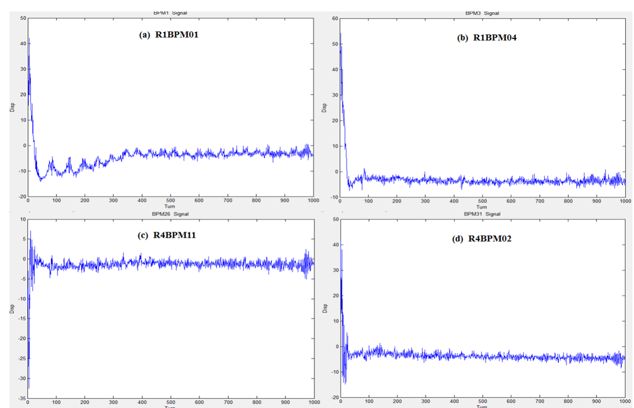

Figure 4: Turn-by-turn data of different BPMs inside and outside the injection region. R1BPM01 is inside the BV bump of the injection region (sub-figure (a)); R1BPM04, R4BPM11, and R4BPM02 are outside the injection region (sub-figures (b-d)).

CONCLUSIONS

During the beam commissioning of CSNS, to check the effect of the residual orbits of BH and BV painting bumps in the injection region was an important problem and need to be studied in detail. In this paper, a method to estimate the residual orbits of BH and BV painting bumps was given and applied to the beam commissioning. After the machine study and data analysis, it can be found that the residual orbits of BH and BV painting bumps were very small and they didn't need to be corrected.

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