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STUDY ON THE FIXED POINT INJECTION DURING THE BEAM COMMISSIONING FOR CSNS*

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Abstract

In order to inject the H$^-$ beam into the Rapid Cycling Synchrotron (RCS) of China Spallation Neutron Source (CSNS) accurately, different injection methods were used in different periods of beam commissioning for CSNS. In the early stage of beam commissioning, since the precise relative position of the injection beam and circular beam was unknown and the injection beam power was relatively small, the fixed point injection method was used. In this paper, the fixed point injection method is studied in detail and the beam commissioning results are given and discussed. In addition, a method to adjust the timing of the injection pulse power is presented and confirmed by the beam commissioning.

INTRODUCTION

China Spallation Neutron Source (CSNS) is a high power proton accelerator-based device [1]. Its accelerator consists of an 80 MeV H$^-$ linac which can be upgradable to 250 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. The design beam power is 100 kW and capable of upgrading to 500 kW [2].

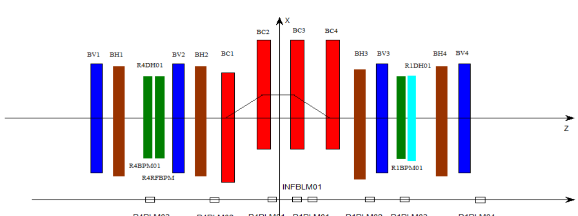

Figure 1: Layout of CSNS injection system.

For the high intensity proton accelerator, such as CSNS, in order to reduce the beam loss caused by the space charge effects, the phase space painting method is used for injecting the beam of small emittance from the linac into the large ring acceptance [3]. For CSNS, the position painting is used in both horizontal and vertical planes. Figure 1 shows the layout of CSNS injection system. It can be seen that there are four dipole magnets (BH1-BH4) used for painting in the horizontal plane and four other dipole magnets (BV1-BV4) used for painting in the vertical plane [4][5]. However, in order to reduce the difficulty of the beam commissioning, different injection methods were used in different periods of beam commissioning for CSNS. In the early stage, since the precise relative position of the injection beam and circular beam was unknown and the injection beam power was relatively small, in order to inject the beam into the RCS as soon as possible, the fixed point injection method was used. In the following process, in order to increase the beam power and reduce the beam loss, the phase space painting in the horizontal plane was used. Finally, the phase space painting in both horizontal and vertical planes was used, and the painting ranges and painting curves were optimized.

In this paper, the fixed point injection method is studied and adjusted in detail during the beam commissioning. In addition, the method to adjust the timing of the horizontal and vertical pulse power was studied and presented which is confirmed by the beam commissioning.

FIXED POINT INJECTION

The fixed point injection method means the beam from the linac injected into the ring at a fixed point. Figure 2 shows the positions of the ring acceptance ellipse during the fixed point injection process. It can be seen that the relative position of the injection beam and circular beam is unchanged during the injection process. In the early stage of beam commissioning for CSNS, since the precise relative position of the injection beam and circular beam was unknown and the injection beam power was very small, in order to inject the beam into RCS as soon as possible, the fixed point injection method was selected.

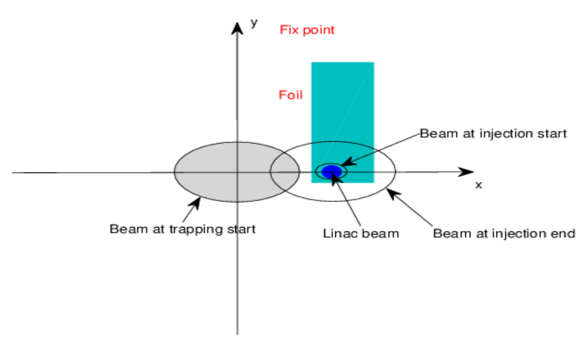

Figure 2: Positions of the ring acceptance ellipse during the fixed point injection process.

During the injection beam commissioning, there is large beam loss due to the mismatching injection beam

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position. In order to search the suitable relative position of the injection beam and circular beam, different painting bump sizes of the fixed point injection were studied. Considering that the proton beam is injected into the centre of circular beam in the vertical plane in theory, the injection processes with different horizontal eccentric position of the injection beam and circular beam were studied. Figure 3 shows the curve that the beam passing rate of RCS changing with the BH bump size during the fixed point injection. It can be known that while the BH bump size is near 60 mm, the relative position of the injection beam and circular beam is suitable.

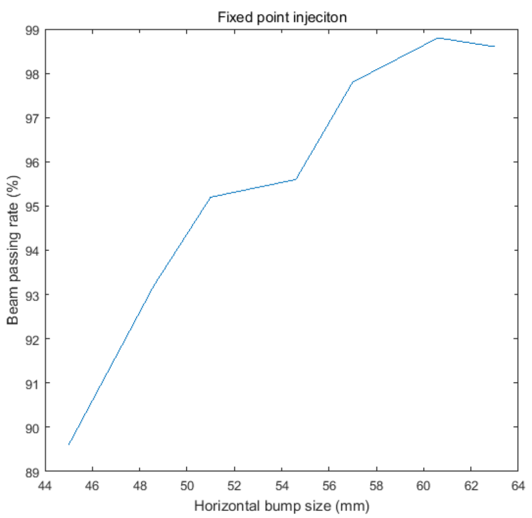

Figure 3: The curve that the beam passing rate of RCS changing with the BH bump size during the fixed point injection process.

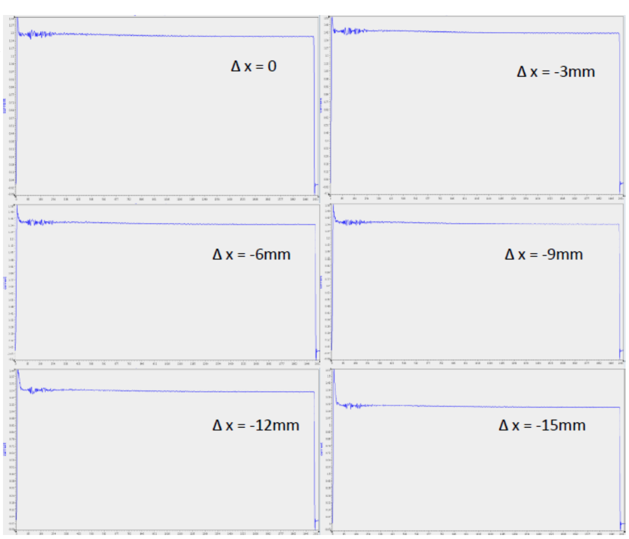

Figure 4: RCS DCCT display while the fixed point injection is used. △x is the eccentric position between the circular beam and injection beam.

While the fixed point injection method is used, there is some beam loss which cannot be removed during the injection process. Figure 4 shows the RCS DCCT display while the fixed point injection is used. It can be found that there is suddenly beam loss during the injection process no matter the matching of the injection beam and circular beam. In addition, the commissioning results shows that the suddenly beam loss increases with the eccentric position between the circular beam and injection beam.

A METHOD TO ADJUST THE TIMING OF THE INJECTION PULSE POWER

In the early stage of injection beam commissioning, the timing of the injection pulse power need to be adjusted and corrected. In the following sections, a method to adjust the timing of the injection pulse power is presented and applied to the beam commissioning.

While the fixed point injection process is completed, the pulse power current need to be reduced to zero and there will be a falling process for the circular beam position which measured within the BH bump and BV bump. By analyzing the turn-by-turn numbers measured by the R1BPM01, Fig. 5 shows the horizontal position of the circular beam during the injection process and it confirms that there is a falling process for the horizontal position of the circular beam.

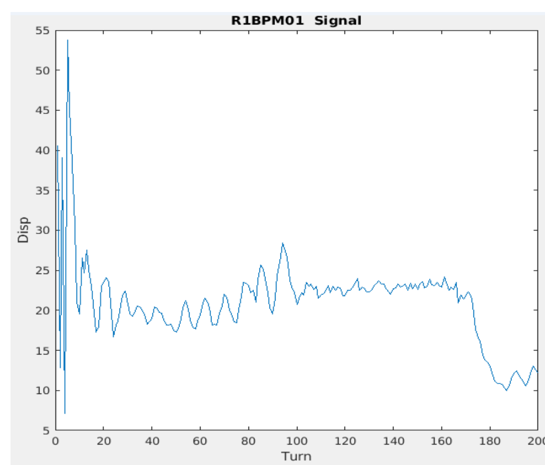

Figure 5: The horizontal position of the circular beam measured by the R1BPM01during the injection process.

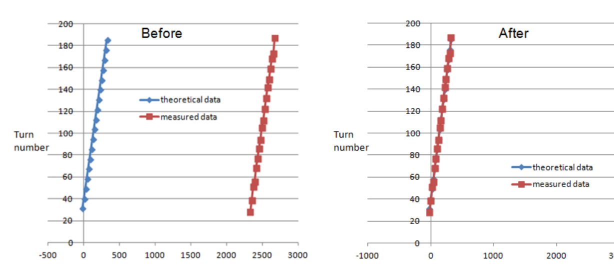

Figure 6: Turn number from the beginning of the injection to the ending of the beam position falling changing with the timing of the horizontal pulse power.

By adjusting the timing of the injection pulse power, the turn number from the beginning of the injection to the ending of the beam position falling will be changed. To compare the variation of the turn number calculated in

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theory with that measured in experiment, the suitable timing of the injection pulse power can be obtained. Figure 6 shows the turn number from the beginning of the injection to the ending of the beam position falling changing with the timing of the horizontal pulse power. It can be found that, in order for the variation of the turn number calculated in theory and that measured in experiment to be consistent, the suitable timing of the horizontal pulse power can be found which is 2346 us. In the same way, the timing of the vertical pulse power can be measured which is 2348 us. After the adjustment of the timing of the injection pulse power, the injection beam state was satisfied the requirement of the beam commissioning.

CONCLUSIONS

In the early stage of beam commissioning, in order to inject the beam into the RCS as soon as possible, the fixed point injection method was used and studied. The suitable BH bump size was obtained to match the injection beam and circular beam. During the beam commissioning, there is suddenly beam loss during the injection process no matter the matching of the injection beam and circular beam. In addition, the suddenly beam loss increases with the eccentric position between the circular beam and injection beam.

A method to adjust the timing of the injection pulse power was presented and the suitable timing of the horizontal and vertical pulse powers was obtained. The beam commissioning results confirmed that the method works well.

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