ISBN: 978-3-95450-184-7 doi:10.18429/JACoW-IPAC2018-TUPAL002

NUMERICAL CALIBRATION OF THE INJECTION BUMP SIZES DURING THE BEAM COMMISSIONING FOR CSNS*

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Abstract

In order to control the strong space charge effects, which cause large beam loss during the injection and acceleration processes, phase space painting method was used for injecting a small emittance beam from the linac into the large acceptance of the Rapid Cycling Synchrotron (RCS). During the beam commissioning, in order to control and optimize the painting results, the positions and ranges of the horizontal and vertical painting should be adjusted accurately. Therefore, the numerical calibration of the injection bump sizes was very important and need to be done as soon as possible. In this paper, a method to calibrate the horizontal and vertical bump sizes was presented and applied to China Spallation Neutron Source (CSNS). The numerical calibration results would be given and discussed.

INTRODUCTION

China Spallation Neutron Source (CSNS), which is a high power proton accelerator-based facility [1], began to build in 2011 and finally completed in 2018. Its accelerator consists of an 80 MeV H^- linac and a 1.6 GeV Rapid Cycling Synchrotron (RCS) with a repetition rate of 25 Hz. The RCS accumulates the 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 goal of beam power for CSNS is 100 kW and capable of upgrading to 500 kW [2].

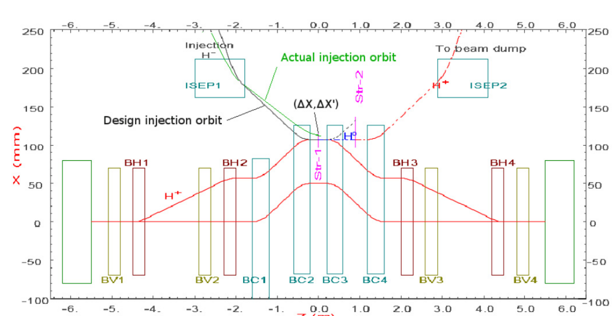

Figure 1: Layout of the CSNS injection system.

For the high intensity proton accelerators, the phase space painting method is used to reduce the beam loss which caused by the space charge effects [3]. For CSNS, the painting in the position was used in both horizontal and vertical planes. Figure 1 shows the layout of the CSNS injection system. It can be found that there is a horizontal bump (BH1-BH4) which can be used for painting in the horizontal plane and a vertical bump (BV1-BV4) which can be used for painting in the vertical plane [4].

During the beam commissioning, in order to control and optimize the phase space painting results, the positions and ranges of the horizontal and vertical painting need to be adjusted accurately. Therefore, in the early stage, the numerical calibration of the horizontal and vertical bump sizes was very important and need to be done as soon as possible. In the following sections, a method to calibrate the horizontal and vertical bump sizes was studied and applied to CSNS.

NUMERICAL CALIBRATION OF THE BH BUMP

By studying the structure of the injection system, it can be found that there are two BPMs (R1BPM01 and R4BPM01) within the BH bump and BV bump. Therefore, the numerical calibration of the injection bump size may be done by measuring the turn-by-turn numbers of these two BPMs. In order to measure the injection bump size accurately, it is better to inject the proton beam on the flat-top of the injection bump. Then, the fixed point injection method should be selected in the experiment of numerical calibration. Figure 2 shows the current curve of the BH pulse power during the fixed injection process.

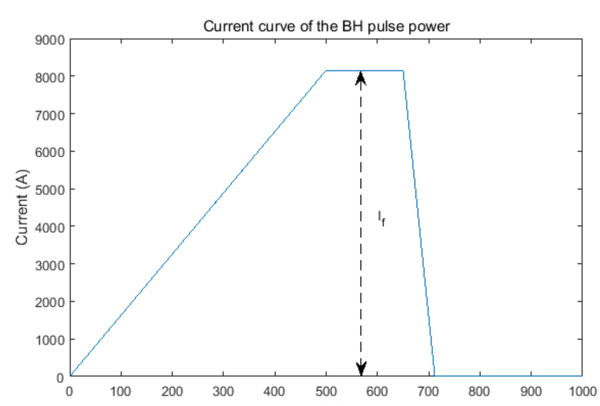

Figure 2: The current curve of the BH pulse power during the fixed injection process.

By using the magnetizing relationship of the BH magnet which was obtained in the magnetic test [5], the

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BH bump size in theory while the flat-top current is I_f can be calculated. In the beam commissioning, the turn-by-turn numbers of R1BPM01 and R4BPM01 can be measured while the current curve was used for the BH pulse power. Figure 3 shows the turn-by-turn numbers measured by R1BPM01 and R4BPM01 in the experiment of BH bump calibration. It can be found that there is a flat-top position which corresponding to the flat-top of the BH bump current curve. In order to obtain a better numerical result, the flat-top position can be averaged in several turns. In addition, the background and errors of the orbit should be removed, i.e. the average orbit after the injection process should be removed. Therefore, the BH bump size measured in the beam commissioning can be obtained. By changing the flap-top current I_f, different BH bump sizes in theory and measured can be given.

Figure 4 shows the comparison of the BH bump size measured in the beam commissioning and that calculated in theory. It can be seen that the calibration error of the BH bump size is smaller than 4 mm which is caused by the system errors and measurement errors of the two BPMs.

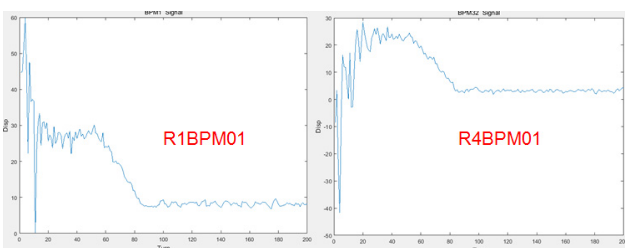

Figure 3: The turn by turn numbers measured by R1BPM01and R4BPM01 in the experiment of BH bump calibration.

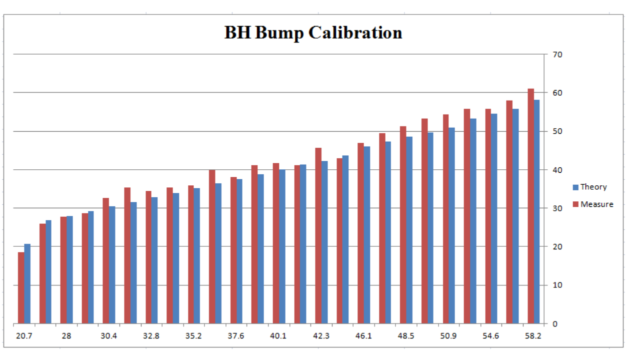

Figure 4: Comparison of the BH bump size measured in the beam commissioning and that calculated in theory.

NUMERICAL CALIBRATION OF THE BV BUMP

After the numerical calibration of the BH bump size, the BV bump size also needs to be calibrated. The fixed point injection method was also selected in the experiment of numerical calibration. Figure 5 shows the current curve of the BV pulse power during the fixed injection process.

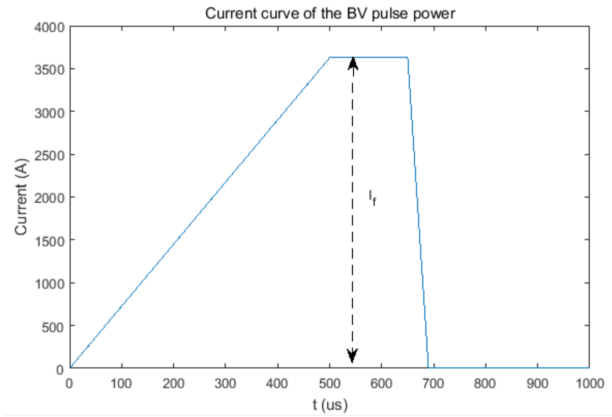

Figure 5: The current curve of the BV pulse power during the fixed injection process.

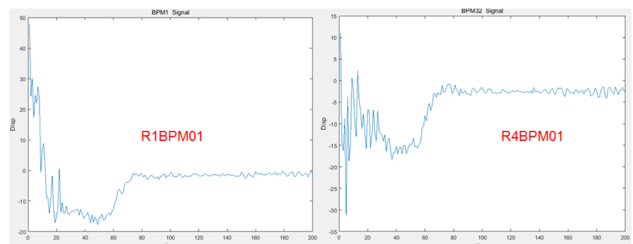

Figure 6: The turn by turn numbers measured by R1BPM01and R4BPM01 in the experiment of BV bump calibration.

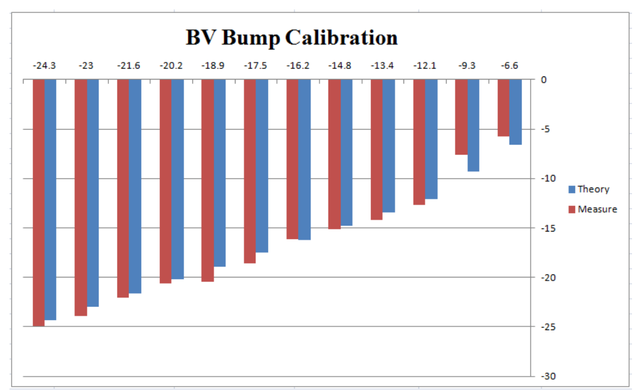

Figure 7: Comparison of the BV bump size measured in the beam commissioning and that calculated in theory.

Similar to the BH bump, by using the magnetizing relationship of the BV magnet which was obtained in the magnetic test [5], the BV bump size in theory while the flat-top current is I_f can be calculated. In the beam commissioning, the turn-by-turn numbers of R1BPM01 and R4BPM01 can be measured while the current curve was used for the BV pulse power. Figure 6 shows the turn-by-turn numbers measured by R1BPM01 and R4BPM01 in the experiment of BV bump calibration. It can be found that there is a flat-top position which corresponding to the flat-top of the BV bump current curve. In order to obtain a better numerical result, the flat-top position can be averaged in several turns. In addition, the background and errors of the orbit need to be removed, i.e. the average orbit after the injection process should be

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removed. Therefore, the BV bump size measured in the beam commissioning can be obtained. By changing the flap-top current I_f, different BV bump sizes in theory and measured can be given. Figure 7 shows the comparison of the BV bump size measured in the beam commissioning and that calculated in theory. It can be seen that the calibration error of the BV bump size is smaller than 2 mm which is caused by the system errors and measurement errors of the two BPMs.

CONCLUSIONS

In this paper, in order to control and adjust the positions and ranges of the horizontal and vertical painting accurately, in the early stage of CSNS beam commissioning, the numerical calibration of the injection bump sizes was done. After careful study, a method to calibrate the horizontal and vertical bump sizes was presented and applied to CSNS.

The numerical calibration results shows that the calibration error of the BH bump size is smaller than 4 mm and that of the BV bump size is smaller than 2 mm. These errors are caused by the system errors and measurement errors of the two BPMs.

ACKNOWLENDGMENTS

The authors would like to thank other CSNS colleagues for the discussions and consultations.

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