THE SIMULATION STUDY OF BEAM DYNAMICS FOR CSNS LINAC DURING BEAM COMMISSIONING

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Abstract

China Spallation Neutron Source (CSNS) is a high intensity accelerator based facility. Its accelerator consists of an H- injector and a proton Rapid Cycling Synchrotron. The injector includes the front end and linac. The RFQ accelerates the beam to 3MeV, and then the Drift Tube Linac (DTL) accelerates it to 80MeV[1]. An Medium Energy Beam Transport (MEBT) matches RFQ and DTL, and the DTL consists of four tanks. Commissioning of the MEBT and the first DTL tank (DTL1) have been accomplished in the last run. Due to the difference of actual effective length and theoretical effective length of magnets in MEBT and DTL1, in order to compare its impact of beam transport, this paper takes a beam dynamics simulation on beam transport in MEBT and DTL1 with IMPACT-Z code[2]. Meanwhile, the transport of beam with different emittance in MEBT and DTL1 is studied because of the large emittance at RFQ exit. All the simulation includes magnet error and RF error.

INTRODUCTION

Before the magnet measurement , the magnet effective length of lattice is theoretical value, so the commissioning software and the beam dynamics simulation both take this value. After the magnet measurement, the magnet effective length closer to the actual situation is given. In order to compare its effects on beam transport in MEBT and DTL1, under circumstance of match, the three-dimensional code IMPACT-Z is taken to study. Due to the large emittance at the exit of RFQ in the beginning, some steps had been taken to decrease emittance in order to avoid more beam loss. Before these steps, the transport of beam with different emittance at the exit of RFQ needs to be considered. All the simulation includes magnet error and RF error.

SIMULATION STUDY OF BEAM DYNAMICS ON MEBT AND DTL1

CSNS/DTL consists of four accelerating cavities, the length among the cavities is designed to maintain longitudinal continuity. Figure 1 shows the layout of the front end and linac, inside the red box is MEBT and DTL. The last beam commissioning includes MEBT and DTL1. Correspondingly, in this paper, the simulation study have been taken on MEBT and DTL1. Beam is matched from RFQ exit to DTL1 entry by MEBT. Corresponding to the theoretical effective length and actual effective length of magnets, there are two lattices for MEBT and DTL1 which are both matched. Through comparing beam emittance growth of two lattices, the difference between them can be gotten.

Through giving different beam emittance from small to large at RFQ exit, the simulation can get the influence of initial emittance on the beam transportation in DTL1, and get the results how much emittance does RFQ exit achieved when beam loss occurs.

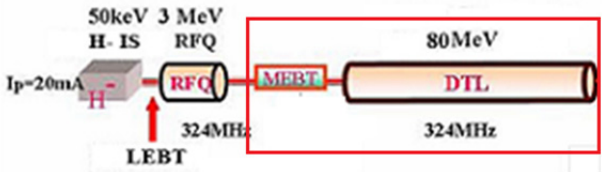

Figure 1: Layout of the front end and linac.

Emittance Growth with Different Magnet Effective Length

In the simulation, the initial distribution of particles is 6D water bag, the number of macro particles is 100,000, the currents of beams is 15mA, the normalized RMS emittance of beam at RFQ exit is 0.2 π mm.mrad. Table 1 shows all the theoretical statics errors about magnet and RF. In this simulation, assumed errors just include quadruple magnet alignment error and RF amplitude error. Figure 2 is a comparison of the horizontal emittance evolution of beam along linac. Figure 3 is a comparison of the vertical emittance evolution of beam along linac.

Table 1: Theoretical Static Errors

Errors	Range
Quad alignment error (transverse displacement)	±0.1mm
Quad alignment error (roll error)	±3mrad
Quad gradient error	±1%
RF amplitude error	±1%
RF phase error	±1degree

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ISBN 978-3-95450-178-6

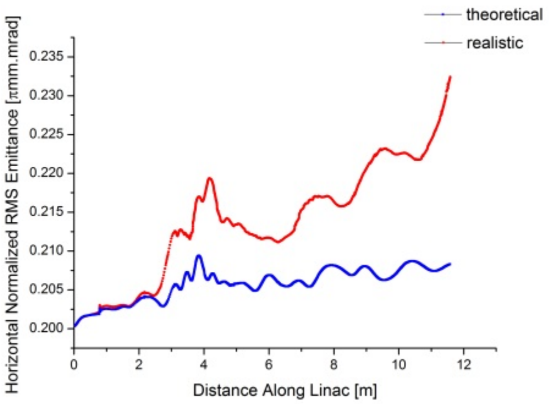

Figure 2: Beam horizontal RMS emittance growth along linac.

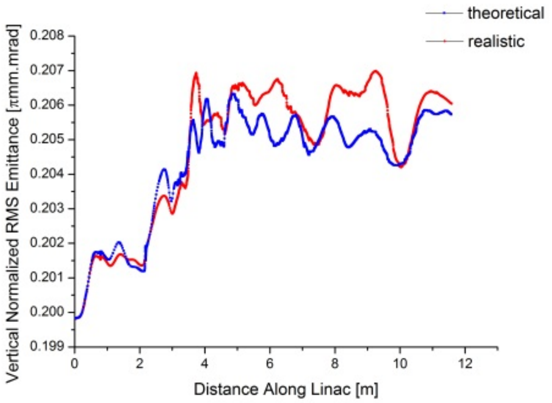

Figure 3: Beam vertical RMS emittance growth along linac.

As can be seen from the Figure 2, beam's horizontal RMS emittance growth is very small with theoretical effective length of magnets , but the emittance growth with actual effective length is significantly enlarge. However, Figure 3 shows that the difference of beam's vertical emittance is quite small. It seems beam's horizontal emittance is more sensitive to mismatch than vertical. Through comparing Figure 2 to Figure 3, a conclusion can be gotten that differences between two lattices is quite large, and the later simulation study must take the lattice with actual effective length of magnets in order to close with the actual situation.

Simulation Study of Different Emittance at RFQ Exit

In the simulation, the initial distribution of particles is also 6D water bag, the number of macro particles is still 100,000, the currents of beams is 15mA, the normalized RMS emittance of beam at RFQ exit is from 0.2 π mm.mrad to 0.32 π mm.mrad which are respectively 0.2, 0.22, 0.24, 0.26, 0.28, 0.30, 0.32. In this simulation, assumed errors include quadruple magnet alignment error, gradient error and RF amplitude error. Table 2 is the beam loss number of beam with different initial emittance. Figure 4 is a comparison of the horizontal emittance evolution of beam along linac. Figure 5 is a comparison of the vertical emittance evolution of beam along linac.

Table 2: Beam Loss Number

Emittance	0.20~0.28	0.30	0.32
Beam loss	*0*	*1*	*8*

As can be seen from the Table 2, it starts to appear beam loss when the initial emittance of beam at RFQ exit increases to 0.3. Also with the increase of initial emittance, beam loss corresponding enlarge. However, during the actual commissioning, beam loss may be more than this. Figure 4 shows that the horizontal emittance growth enlarge with the initial emittance increasing. However, Figure 5 shows that the vertical emittance growth is not obvious. It also seems beam's horizontal emittance is more sensitive to mismatch than vertical. As a result, the normalized RMS emittance of beam at RFQ exit is better limited to below 0.3.

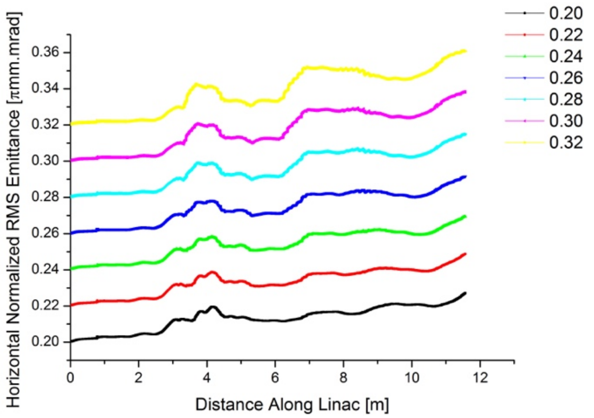

Figure 4: Beam horizontal RMS emittance growth along linac.

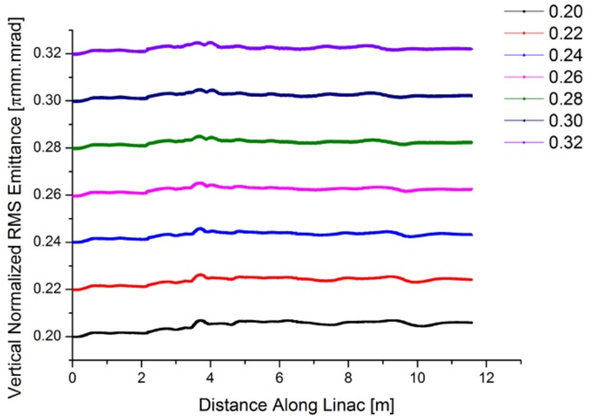

Figure 5: Beam vertical RMS emittance growth along linac.

CONCLUSION

In this paper, three-dimensional space-charge code IMPACT-Z is taken to study the impact of beam transport with theoretical magnet effective length and actual

ISBN 978-3-95450-178-6

effective length in MEBT and DTL1 during beam commissioning, a conclusion can be gotten that the later simulation study must take the lattice with actual effective length of magnets in order to close with the actual situation. Beam transport in MEBT and DTL1 is also studied under circumstance of different initial emittance at RFQ exit, it turns out the normalized RMS emittance of beam at RFQ exit is better limited to below 0.3πmm.mrad.

ACKNOWLEDGEMENTS

The author would like to thank colleagues in AP group at CSNS for some meaningful discussing.

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