BEAM TRAJECTORY CORRECTION FOR SNS*

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Abstract

Automated beam trajectory correction with dipole correctors is developed and tested during the Spallation Neutron Source (SNS) warm linac commissioning periods. The application is based on the XAL Java framework with newly developed optimization tools. Also, dipole trajectory corrector polarities and strengths, and beam position monitor (BPM) polarities were checked by an orbit difference program. The online model is used in both the orbit difference and the trajectory correction applications. Experimental data for both applications will be presented.

INTRODUCTION

The SNS is an accelerator for pulsed, high-intensity neutron production. Because of high beam intensity, beam loss due to transverse motion has to be minimized by correcting unwanted large beam excursions. There are more than 170 dipole correctors in the SNS linac, accumulator ring and beam dump lines for this purpose. To manually correct the beam trajectory is impractical and time consuming. Therefore, an automated trajectory correction program is prepared for the SNS commissioning and operation. The beam trajectory is measured by BPMs and corrected by dipole correctors accordingly. It is necessary to calibrate the BPMs and dipole correctors with an orbit difference program before an automated trajectory correction program can perform. Both the orbit difference and trajectory correction programs are written with the XAL framework [1, 2]. The entire process for trajectory correction is shown in Fig. 1.

ORBIT DIFFERENCE

The idea of orbit difference is to take two BPM trajectory measurements and then subtract the former from the latter one, and the same subtraction between the two corresponding model predicted trajectories; then plot the measured curve on top of the model prediction. If there is any obvious discrepancy between these two curves, the following possible problems might exist: incorrect BPM polarity or calibration or incorrect dipole corrector polarity or current to field conversion.

In order to ensure that the online model calculation is correct, we had previously benchmarked it with Trace-3D for the SNS MEBT. We also carefully checked the agreement between the online model and the SNS convention for the coordinate system and magnet polarity definition.

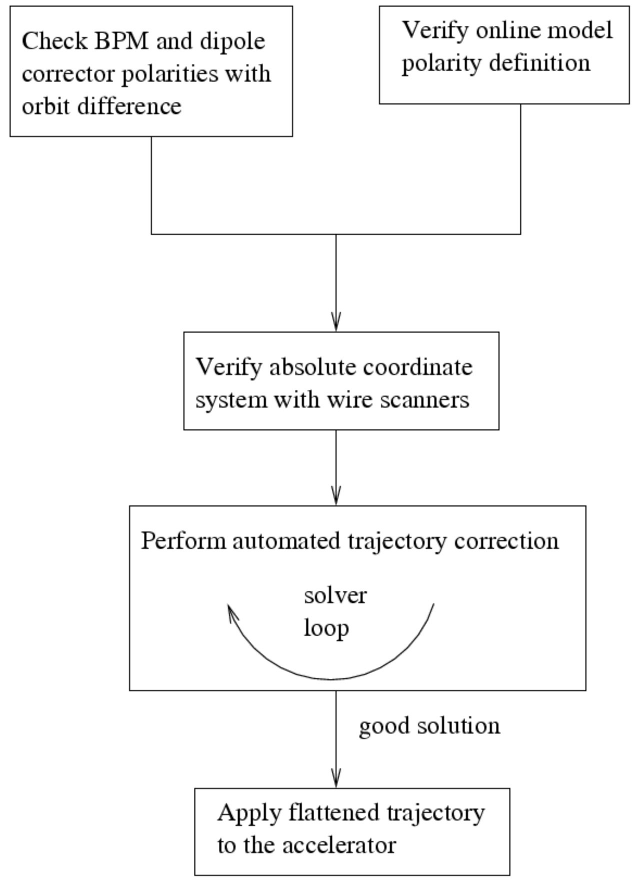

Figure 1: Schematic chart for trajectory correction procedures.

Orbit Difference Measurement

An application originally written for displaying XAL online model calculations was modified to perform as an orbit difference tool. The orbit difference measurements for SNS DTL6 through CCL3 are shown as examples in Figs. 2 and 3. The first measurement showed a large discrepancy between the model and the measured data. We then found that the dipole corrector field conversion had mistakenly used integrated field instead of field. After we corrected this error, the resulting measurement showed very good agreement between the model and the measurement. Both figures are screen snapshots of the online model application.

Wire Scanner Measurement

If the polarities for both dipole correctors and BPMs are reversed, the orbit difference will not be able to detect the errors. Therefore, we chose some nearby wire scanners for absolute BPM polarity measurement. The wire scanner movement is well known. Note that there should

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not be any quadrupoles in between the upstream dipole corrector and the downstream BPM.

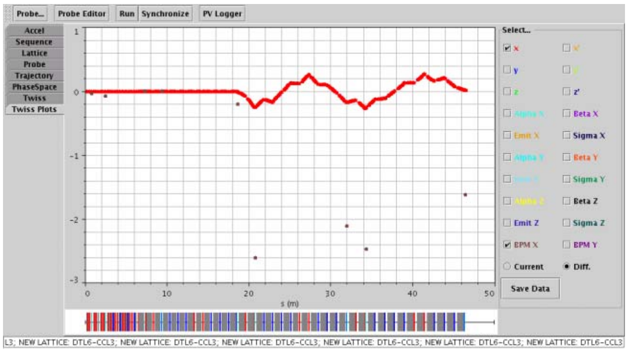

Figure 2: First orbit (trajectory) difference measurement for SNS DTL6 through CCL3. The solid line is online model calculation based on measured lattice and the dot points are BPM measurement.

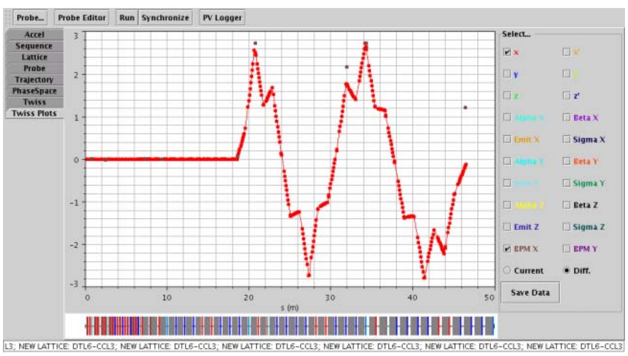

Figure 3: Orbit difference measurement after the dipole corrector magnetic field strength corrected.

TRAJECTORY CORRECTION

An orbit correction application was developed and tested to correct transverse orbit errors with dipole correctors in the linac. Among the features of this application are the ability to load a logged orbit snapshot from the database, correct orbit errors to zero and correct the orbit to a reference orbit. This application uses a newly developed optimization engine to both minimize orbit errors and keep the orbit distortions smooth while keeping the correctors within their control limits. The objectives are specified in terms of nonlinear satisfaction curves to generate a realistic and intuitive representation of the correction goals. The use of satisfaction curves eliminates the need to introduce artificial weights, as is often the case with many optimization approaches. Instead we intend to represent the problem directly in terms of user satisfaction in its fully nonlinear form. This means that we can no longer rely on the commonly used linear optimization techniques to solve this problem reliably.

Within XAL we have developed a framework for solving a wide class of general, multi-variable, nonlinear optimization problems. An undergraduate summer student, Adrian Kennedy, implemented [3] the initial version of this framework in Java and incorporated it into the XAL project. To use the optimizer, the developer simply reveals their problem to the solver by scoring trial solutions generated by the framework. The solver adapts its algorithms as solutions are scored. Additionally, the developer may provide hints to the solver to improve performance. This optimizer has proven useful in the orbit correction application.

When correcting an orbit, the user can choose whether to correct the orbit based on the online model or through empirical measurement. The empirical approach has the advantage that it works well independent of magnet or BPM polarity errors and calibration. At the time of our machine study such issues were still being addressed and only the empirical method provided consistent orbit correction. We intend to further study the online model method in future machine studies. Also, since the time of the machine studies, the performance of the optimizer has been significantly improved.

During a machine study on January 10, 2005, we intentionally introduced an orbit distortion using several correctors and then attempted to correct the orbit using the application. The results are shown in Fig. 4. Typically, for the beam line from MEBT to CCL1 the optimizer can find the best solution for both horizontal and vertical planes within a few seconds. This section of the beam line contains about 19 BPMs and 22 dipole correctors for each plane.

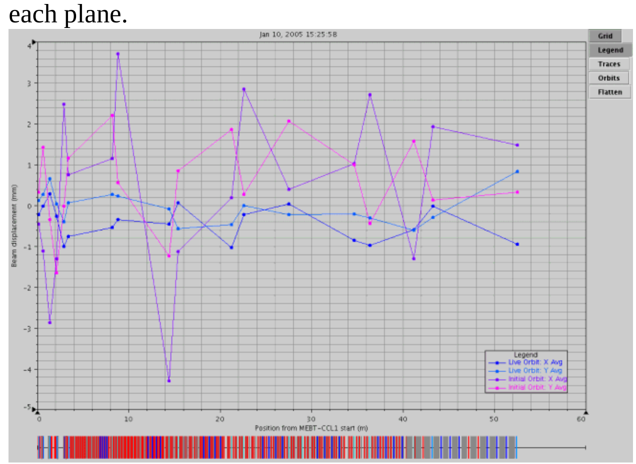

Figure 4: Orbit correction from the MEBT through CCL1. The four trajectories shown here are initial horizontal and vertical trajectories (purple and pink, respectively), and horizontal and vertical trajectories after correction (blue and light blue, respectively). The initial trajectory excursion is about 4 mm horizontally and 2 mm vertically. After correction, trajectory oscillation in both planes is within 1 mm.

The machine study demonstrated that the automated orbit correction is effective in removing large orbit distortions. Since then, offline studies with more current versions of this application and optimizer indicate that we can achieve much better orbit correction in less time. Additionally, we have recently extended this application to provide orbit correction in the ring as well as the linac. This application can also serve as a live orbit display.

CONCLUSION

- We have developed a procedure using orbit difference method to check the polarities and rough calibration for dipole correctors and BPMs.
- We have demonstrated automated trajectory correction using either online model or empirical method. In particular, the empirical method works well even if there is BPM or corrector polarity error.

ACKNOWLEDGMENTS

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