TUNE MEASUREMENT OF SRRC BOOSTER DURING RAMPING

K.T. Hsu, J. Chen, T.S. Ueng, K.K. Lin, SRRC, Hsinchu, Taiwan

Abstract

The setup for tune measurement of Synchrotron Radiation Research Center (SRRC) booster and its performance are described in this report. Tune drift during ramping was observed in routine operation. The fractional tune drift can be as large as 0.2. In some of the cases, beam capture at injection and its acceleration was severely degraded. In order to improve this situation, a measurement system was set up to monitor tune shift during ramping. Tune information was obtained by using FFT conversion of turn by turn beam position signals. Besides, tracking errors among focusing/defocusing quadrupoles and dipole were monitored with precision magnetic current meters. Their ratio varied during ramping was correlated to the tune shift mentioned above. With the help of these two monitoring tools, the working tunes were optimized to get more efficient operation.

1 INTRODUCTION

In order to provide 1.5 GeV electron beam for the SRRC storage ring, electrons have to be generated and accelerated. The electron is first emitted by an electron gun and accelerated up to 50 MeV through an rf linac. This 50 MeV electron beams is then injected into a booster synchrotron in which the electron beam energy is raised up to 1.5 GeV. Finally, the electron beam is extracted from the booster and fed into the storage ring. It happened that the electron beams were lost during injection and energy ramping after some major failure of the power supplies systems and their components. Usually, maneuvering the booster lattice to appropriate working points can solve the problem. Recently, a tune monitoring system was installed into the booster control system. It provides the capability of monitoring the booster tunes, ν_x and ν_y , during ramping. By comparing the measured tune drift during ramping with the observed tracking errors among magnet families, correlation between these two features can be concluded. The experimental setup and preliminary test result of this tune monitoring system is described in this report.

2 EXPERIMENTAL SETUP

2.1 The Tune Monitor

The functional block diagram of this tune monitor system is shown in Fig. 1. It is a modified version of a previous design[1]. The stored electron beam in the booster was excited with a magnetic pulse from the kicker. While the electron beam executed betatron oscillation along the booster ring, the transverse motion of the beam signal was picked up by the stripline through a log ratio amplifier. The associated turn by turn information was recorded with a transient digitizer where the length of the recording data was defined. The raw data was then saved to the control console where the FFT analysis and peak identification were performed.

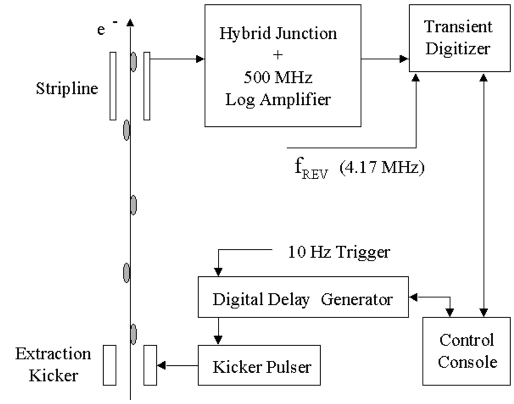

Figure 1: Functional block diagram of the tune monitor.

2.2 Horizontal Excitation Kicker

The electron beam excitation was achieved by firing the booster extraction kicker at different time along ramping cycle. This pulsed kicker is a window framed, two-turn, ferrite magnet capable of providing 1.4 mrad horizontal kick to the 1.5 GeV electron beam[2]. Since the accelerating electron beam covers a wide range of energy change, from 50 MeV to 1.5 GeV, The kicker strength has to be finely tuned so as not to over-kick and loss the electron beam. A sinusoidal-like excitation function of kicker strength, matched with the ramping cycle, was implemented for this purpose. Amplitude of the kicker strength was tunable for different needs. An offset strength tuning knob was also included for adjusting the strength needed especially in probing the low energy region (< 300 MeV).

2.3 Enhance the Vertical Tune Signals

Since the excitation kicker produces only horizontal deflection to the electron beam, it is difficult to identify the vertical component signals in many studied cases if one uses this kicker. For the purpose of solving present situation, a small DC dipole magnet was assembled and installed in the booster ring at 45 degree off the vertical axis. It was hope that this arrangement could transfer part of the horizontal motion of the electron beam to the vertical component and would enhance the vertical tune signal readings. The estimated deflection strength of this small dipole is about 0.2 mrad for 50 MeV electron. Although the strength is small, it can kick of the electron beam in some different injection conditions. Tuning of this small dipole strength is needed for this experiment and the vertical tune signals can be identified successfully.

2.4 Magnets Current Monitors

Magnet currents of dipole, focusing and defocusing quadrupoles (FQ and DQ) families were monitored for complete ramping cycles during the experiment. The magnet current ratio of the FQ to dipole and DQ to dipole were calculated instantly and then displayed together with these three magnet driving currents. At different tuning strength of FQ and DQ, the said ratio changes correspondingly. When this happen, the associated betatron tunes drift accordingly. With this magnets current monitoring tool, it was possible to correlate the tune drift during ramping to the magnet current ratio changes.

3 TEST RESULTS

3.1 Magnets Current Tracking

Typical examples of the relative magnet current variation of FQ and DQ to the dipole are shown in Fig. 2. The total ramping duration is 0 ~ 50 ms.

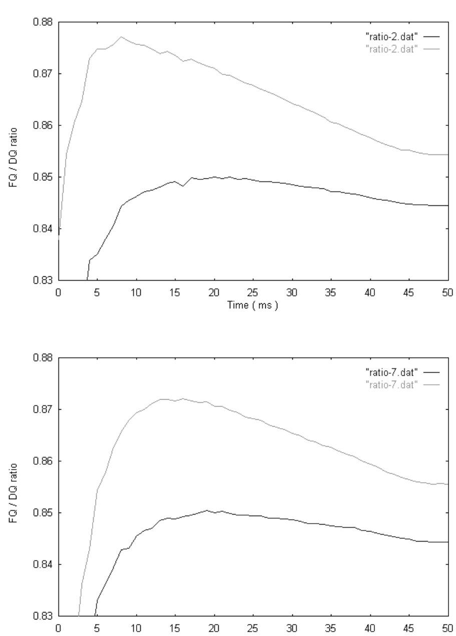

Figure 2: Typical examples of relative current amplitude of FQ and DQ to the dipole magnet.

During this period, the electron beam is ramped up from 50 MeV to 1.5 GeV and is extracted from the booster. The magnets are ramped down in the following 50 ~ 100 ms and the booster is ready for next injection. In the upper half figure, the DQ shows a rapid increase of its ratio amplitude at the beginning of the ramping cycle and decrease gradually after 10 ms. On the other hand, the FQ ratio change is relatively slow. For the lower half figure, the FQ ratio change stays the same as in the upper half case. However, the DQ ratio change becomes slower than that of the upper half case. This implies that the betatron tune ν_y would be different in these two cases due to the different setting of DQ especially at the early injection stage.

3.2 The Tune Measurement

The measured results of ν_x and ν_y during ramping for the above two cases are shown in Fig. 3.

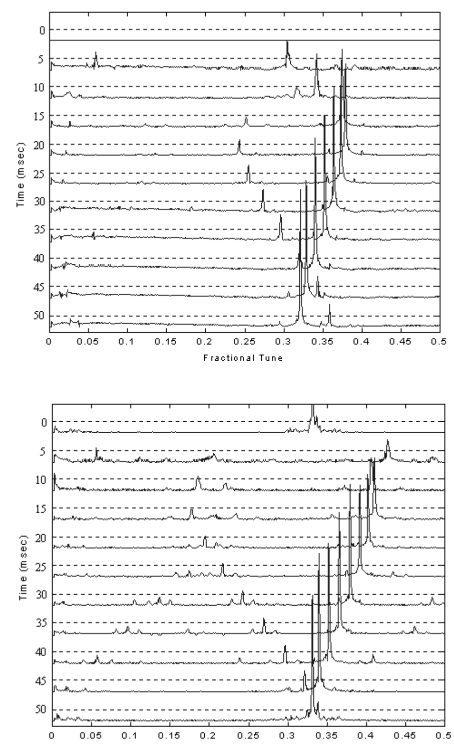

Figure 3: The measured ν_x and ν_y for the cases given in Fig. 2

Since the extraction kicker is deflecting the electron beam in the horizontal plane, the ν_x signal is more significant than that of the ν_y signal. Notice that the ν_x signal remains similar trend in both cases while ν_y appears differently. In the upper half of the figure, the ν_y value is higher than that of the lower half case especially for the beginning 10 ms of the ramping cycle. This feature is qualitatively consistent with what was expected in examining the observed data shown in Fig. 2. Note that in some of the measurement, the data were lost. It happened more frequently in the low-energy region than that of the high-energy region. It was mainly caused by the disturbance to the low energy electron beam. Also, the ν_y signal is not significant enough to provide complete information such as the case shown in Fig. 3.

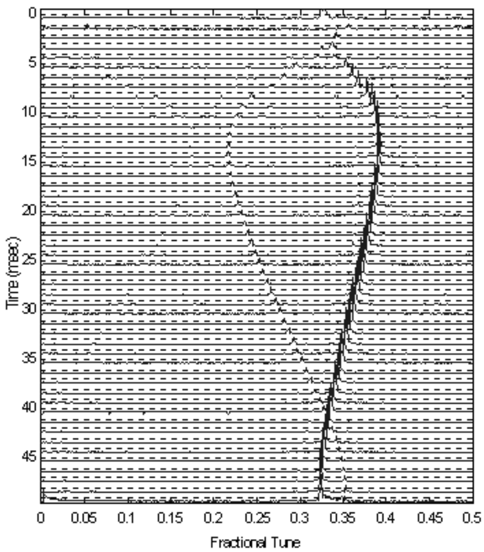

Figure 4: A detailed observation of the booster tune drift during ramping.

After fine-tuning of the experimental setup, a more detailed observation of the booster tune drift during ramping has been carried out and the result is shown in Fig. 4. In this figure, it shows that both ν_x and ν_y drifted during ramping in this particular case and the ν_x and ν_y crossing resonant lines can be clearly examined.

4 SUMMARY

The tune measurement system has been installed and tested for the SRRC booster. Owing to the fast data acquisition and calculation capability, the tune drift during ramping can be observed in cycle to cycle basis. In cooperating with the monitoring system of FQ and DQ to dipole magnet strength, optimization of the booster working point can be efficiently achievable in tuning the accelerator. The result shown in this report indicates that this tune measurement system is a very useful tool in understanding the ramping behavior of the booster.

REFERENCES

[1] J.Chen, K.T. Hsu, C.H. Kuo, K.K. Lin, “Design and Implementation of a Digital Receiver Based Tune Monitor”, EPAC’98, Stockholm, June 1998.

[2] J.P. Chiou, J.S. Chen, C.S. Fann, C.H. Ho, K.T. Jsu, S.Y. Hsu, C.S. Hwang, K.K. Lin, J.T. Sheu, T.S. Ueng, “The Upgrade of SRRC Booster Extraction System”, PAC’99, New York, March 1999.