Modelling Modulation and Dynamic Tuning of Insertion Devices at SRRC

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Abstract

Insertion device's modelling modulation of SRRC's Accelerator Physics Application Program (APAP) has been done to provide accurate physical parameters for insertion device commissioning, machine operation and machine study. To insure the orbit change while pole gap is varied within 10 μm, dynamic tuning of undulator, part of the dynamic orbit correction, with the built-in corrector table has been studied.

1 INTRODUCTION

Two insertion devices (IDs), namely W20 wiggler and U10P undulator prototype, had been installed in the storage ring TLS at SRRC. The perturbation on the linear and non-linear beam dynamics due to these IDs in the ring were studied. Those included the tune shift and beta beating induced from vertical focusing of the fields, the reduction of dynamic aperture, and the decrease of beam lifetime with pole gap closed [1, 2]. The measured linear effects were in good agreement with the model calculations. Tune shift and beta beating could be compensated or reduced by tuning local quadrupoles beside the IDs. Fig. 1 shows the vertical beta beating of SRRC's W20 and U10P. The horizontal beta beating is very small since both the two IDs of SRRC are B_y periodic pole field structure.

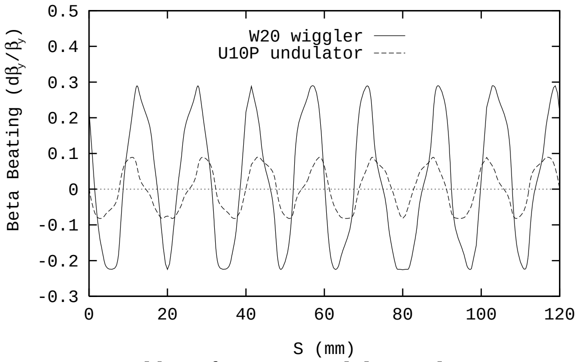

Figure 1: Vertical beta function modulation due to SRRC's W20 and U10P.

Small difference of tune shift of W20 between measurement and modelling was corrected by modelling modulation. Dynamic orbit distortions due to ID's field errors and the change of lattice functions are concerned when pole gap of undulator is varied. To insure the dynamic orbit change within 10 μm, a feed forward system with a built-in corrector table as a function of gap is studied. Digital global (or local) orbit feedback system is also developed [3, 4, 5]. Here we will focuse our attention on the work of modelling modulation and dynamic tuning of IDs.

2 MODELLING MODULATION OF INSERSION DEVICES

SRRC's IDs, W20 and U10P, are designed with symmetric pole arrangement. The sequences of pole strengths of W20 and U10P at 22 mm gap are shown in Fig. 2 and Fig. 3.

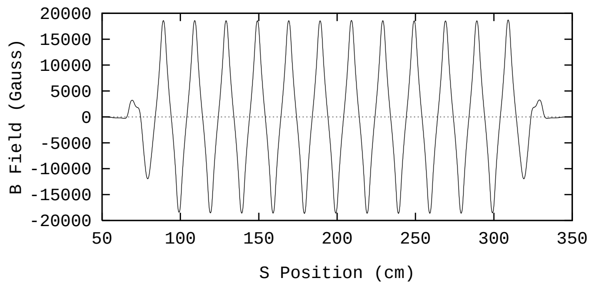

Figure 2: B field of SRRC's W20 wiggler at 22mm gap.

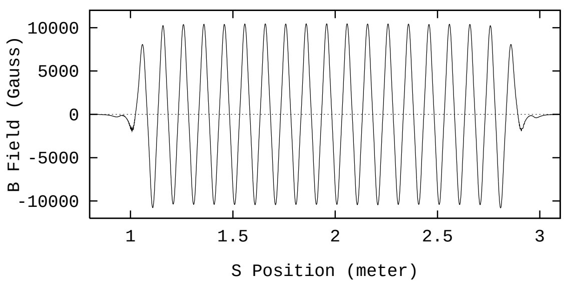

Figure 3: B field of SRRC's U10P undulator at 22mm gap.

Piecewise hard-edge model of ID was added in SRRC's APAP in order to provide physical parameters for ID commissioning. In modelling of IDs, the pole field is described by a sinusoidal distribution $B_y(x=0) = B_n \cos(2\pi s/\lambda)$, where B_n is the n-th pole's strength and λ is the period length. Each pole is cut into six parts with the ratio of length as $2:2:1:1:2:2$. When we look through the measured pole field distributions at different gaps of IDs, we find both pole strengthes and shapes are changed. The unmatched error of field shape causes tune shift difference between measurement and modelling.

$$\delta(\Delta\nu_y) = (\Delta\nu_y)_{\mathrm{modelling}} - (\Delta\nu_y)_{\mathrm{measurement}}$$

The maximum pole strength at 22 mm gap of W20 is 1.85 Tesla and the shape distortion caused by high order expansion component is more severe than U10P with maximum pole strength 1.04 Tesla at 22 mm gap.

To compensate the field shape error in modelling, modulation of the effective field strength of each piece of hard-edge dipole segments was done for W20. In other words, it was done to compensate the high order terms of pole field expanded in sinusoidal functions. Fig. 4 and Fig. 5 show the W20's and U10P's differences of measured pole field and the sinusoidal distribution pole field used in modelling. W20 has more evident pole field difference than U10P. The tune shift of W20 is $\Delta\nu_y = 0.036$ caused

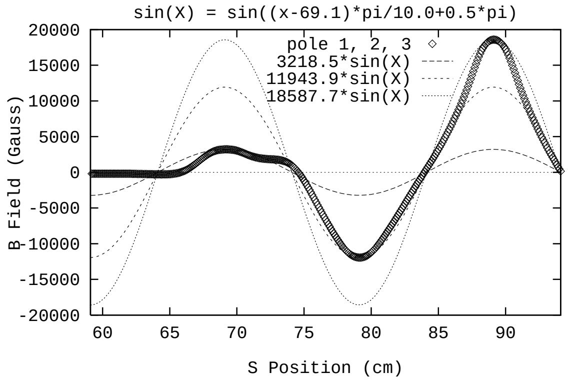

Figure 4: W20's field difference of measured pole field and sinusoidal distribution pole field used in modelling.

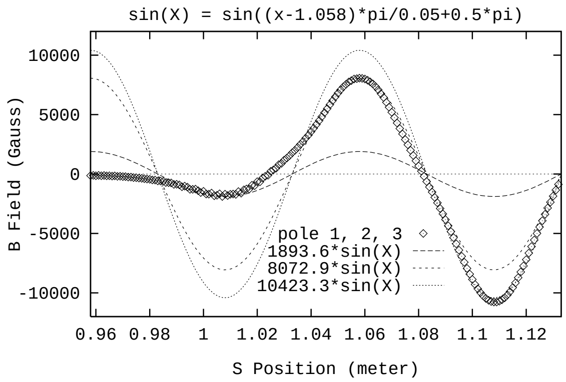

Figure 5: U10P's field difference between measured pole field and sinusoidal distribution pole field used in modelling.

by closing gap. Fig. 6 shows the measured tune shift and modelling tune shift before and after modelling moulation. Fig. 7 shows the measured tune shift and modelling tune shift of U10P with W20 gap closed and open. Measured tune shifts of U10P is 0.00987/0.00755 with W20's gap $230/22.5$ mm and modelling tune shifts of U10P is 0.00993/0.00777 without strength moulation. There is a little difference between them without beta beating correction of W20.

3 DYNAMIC TUNNING OF U10P UNDULATOR

Gap-dependent residual errors of the net change in angle I_1 and position I_2 introduced by IDs may give rise to a

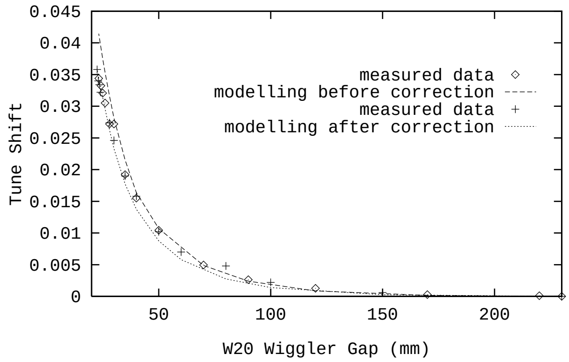

Figure 6: Measured and modelling tune shift of SRRC's W20.

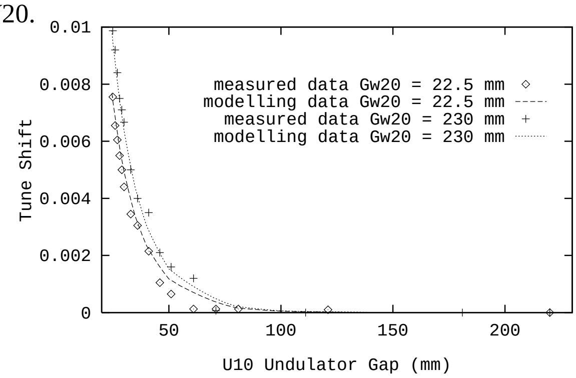

Figure 7: Measured and modelling tune shift of SRRC's U10P.

distortion of the closed orbit [6]. The two quantities I_1 and I_2 at the centre of IDs, those usually are required to be zero designedly and may not vanish with residual errors, can be expressed as:

$$I_1 = \frac{e}{\gamma m_0 c}\int_{-\infty}^{+\infty} B_y ds \neq 0$$

and

$$I_2 = \frac{e}{\gamma m_0 c}\int_{-\infty}^{+\infty} sB_y ds \neq 0.$$

Such dipole steering errors have to be minimized to avoid any interference in users' experiments while dynamic tuning of undulator gap with stored beam is required for normal operation of users' beam time. To satisfy the users' need, four electron beam position monitors (BPMs) with root mean square (rms) 4 μm of reading fluctuation and one pair of correctors for each transverse plane, all are locally closed to both ends of U10P, are adopted to detect and correct orbit distortion. With series of fixed undulator gaps, orbit distortions detected by BPMs can be compensated by calculation of the needed strengthes of correctors. The correction table can be established under such a static condition. Performance or feasibility of the fine tune with correction table should be examined by recording the residual orbit distortion during dynamic tuning of U10P.

To obtain the strengthes of the two end-correctors of U10P in each plane, the algorithm being used can be either MICADO with simple boundary constrains or a simple optimization method as follows:

$$\text{Minimize the Objective Function } : \mathcal{F}(\vec{x})$$

$$\mathcal{F}(\vec{x}) = \sum_i \left[\frac{m_i + \sum_j A_{ij} x_j}{\sigma_i} \right]^2 ,$$

i.e.,

$$\frac{\partial \mathcal{F}(\vec{x})}{\partial x_j} = 0, \quad \text{for } j = 0,\ 1.$$

Here $\vec{x} = (x_0, x_1)$ is the setting of these two end-correctors in each plane, m_i the orbit distortion detected by the i-th selected electron BPM, A_{ij} the measured response factor of the i-th BPM vs. the j-th end-corrector, and σ_i the standard deviation (S.D.) of the i-th BPM's fluctuation.

With the above algorithm, the rms of orbit distortion referred to the target orbit can be controlled within 15 μm for both transverse planes under static condition, as shown in Fig. 8 and Fig. 9 with log-log scale. During dynamic tuning of the U10P gap, the dynamic orbit distortion was found to be within 20 μm, which is slightly larger than that observed under static condition.

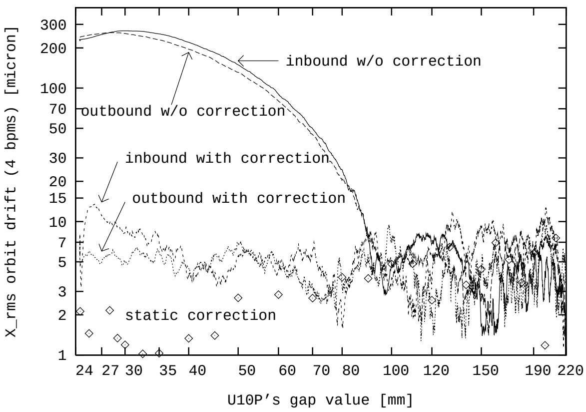

Figure 8: The rms of horizontal orbit drift detected from four BPMs beside U10P.

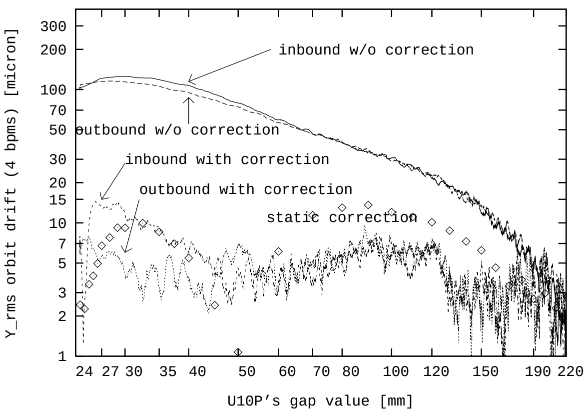

Figure 9: The rms of vertical orbit drift detected from four BPMs beside U10P.

Some problems emerged during our dynamic testing: There is a tolerence among the four half-gap readings of linear encoders, one pair on each upper- and down-stream of U10P, which is identifed that the closed-loop feedback mechanism has malfunction during gap movement but only work when the set position of gap is reached. U10P's mechanical backlash was measured to be 120 micron which perturbed the orbit at turn points of gap. The resultant different behavior during gap movement in outbound and inbound sequence may be the main error source of the discrepancy between static and dynamic orbit distortion. Which may be due to the different mechanical characteristic of the upper- and lower magnetic arrays including compensation springs, or come from the distinction of the four motors' individual drive.

Signiticant, time delay between the reading and real gap value had also been observed. It made the dynamic correction effect not as good as what was done under static condition. With update-rate improvement of the gap reading, the build-in table correction of U10P had also been modified by shifting gap value with $-0.5/+0.5$ mm for closing/opening sequency to correct the possible time delay from control system.

Power supplies used for orbit correction of U10P's dynamic tuning have improper current ranges. The measured setting values of horizontal correctors sometimes exceed their maximun current range (± 2 Amp). On the other hand, the maximun current range of vertical correctors is ± 20 Amp. And their resolution is poor that the measured S.D. of current fluctruation is 30 mA. Those are unsuitable for the practical need with current range $\sim \pm 5$ Amp and resolution ≤ 2 mA.

Conclusively, to fulfill the users' strict requirement on the dynamic tuning of undulator, the tolerance limits and resolution of power supplies should be improved, and the discrepance between static and dynamic mechanical behavior should be minimized. That is either the feedback loop should be always on or off but with two different correction tables. A further study on dynamic tuning for undulator U10P is in progress.

4 REFERENCES

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