COD Correction of the VSX Light Source

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Abstract

The closed orbit distortion (COD) correction of the VSX light source and the effects of residual COD, dispersion function distortion (DFD) and tune shift (TS) on the dynamic aperture are surveyed.

1 Introduction

A sophisticated COD correction is very important for the synchrotron light source. Especially for recent very low emittance rings, it is crucial for the stable operation. Unless COD is well corrected, the dynamic aperture should be shrunk away. We present here that the COD of the VSX light source [1] can be well corrected, so that the dynamic aperture would suffer nearly no loss.

It is well known that the alignment error of magnets is the most dominant error to produce COD for the third generation light source. Thus, as shown in Table 1, we have calculated four cases (a), (b), (c), and (d) each with one kind of alignment error. Also we have calculated an additional case (e) with all these errors and other errors such as field and rotation error.

A correction code [2], [3], [4] is used for the COD correction, but no constraint condition is imposed in this paper.

Case	element	error	σ	Max
(a)	Q	horizontal alignment error	50μm	100μm
(b)	Q	vertical alignment error	50μm	100μm
(c)	S	horizontal alignment error	50μm	100μm
(d)	S	vertical alignment error	50μm	100μm
(e)	Q,S,B	horizontal alignment error	50μm	100μm
	Q	vertical alignment error	50μm	100μm
	S	vertical alignment error	50μm	50μm
	Q,S,B	strength error	0.05%	0.1%
	Q,S,B	rotation error	200μrad	400μrad

Table 1 The contents of errors. Q is an abbreviation for quadrupole magnets, S for sextupole magnets, and B for bending magnets. The σ is the rms value of gaussian error distribution. If the absolute value of generated random number exceeds the Max value, the random number is re-generated.

2 Results of COD Correction

Figure 1 shows an example of the CODs and corrector angles for the low emittance mode (1GeV, 0.78 nmrad). The oscillation numbers of uncorrected CODs are almost equal to the betatron tunes that are 19.4 in the horizontal direction and 9.71 in the vertical direction. On the other hand, the oscillation numbers of residual CODs are much higher than betatron tunes. The corrector angles are all within 1 mrad, the maximum allowable angle of correctors.

2-(i)

mode	Case	direction	EV	before correction COD (mm)	before correction $\delta\eta$ (mm)	before correction $\delta\nu$	after correction COD (mm)	after correction $\delta\eta$ (mm)	after correction $\delta\nu$
low	(a)	horizontal	26	0.85	9.12	6.0E-03	7.4E-02	1.14	1.1E-03
		vertical	0	0	0	8.7E-03	0	0	3.8E-03
	(b)	horizontal	0	6.8E-04	9.6E-02	4.8E-04	9.9E-05	1.2E-02	2.4E-04
		vertical	40	1.96	238.06	1.4E-03	2.8E-02	2.30	3.6E-05
	(c)	horizontal		1.1E-02	1.80	3.0E-03			
		vertical		0	0	1.4E-02			
	(d)	horizontal		1.6E-04	7.6E-02	1.3E-04			
		vertical		3.1E-03	5.57	8.7E-05			
	(e)	horizontal	24	0.85	59.89	1.8E-03	7.7E-02	2.43	1.5E-03
		vertical	48	2.10	250.49	3.8E-03	1.9E-02	5.88	9.7E-03

2-(ii)

mode	Case	direction	EV	before correction COD (mm)	before correction $\delta\eta$ (mm)	before correction $\delta\nu$	after correction COD (mm)	after correction $\delta\eta$ (mm)	after correction $\delta\nu$
high	(a)	horizontal	40	1.17	5.01	4.3E-03	2.4E-02	0.46	2.0E-04
		vertical	0	0	0	2.4E-03	0	0	1.4E-04
	(b)	horizontal	0	1.2E-02	3.8E-01	6.7E-05	2.0E-04	1.8E-02	0.0E+00
		vertical	28	0.94	7.88	9.1E-04	5.1E-02	1.52	8.0E-05
	(c)	horizontal		1.9E-04	4.71	3.6E-03			
		vertical		0	0	6.1E-04			
	(d)	horizontal		2.1E-04	4.0E-02	7.8E-06			
		vertical		2.2E-03	2.39	5.2E-05			
	(e)	horizontal	40	1.18	9.01	7.2E-03	1.9E-02	7.51	5.0E-03
		vertical	40	1.19	9.71	2.1E-03	3.2E-02	3.96	1.2E-03

Table 2 The rms of COD, DFD and the average of the absolute value of tune shift. For each case, five machine samples were calculated. Table 2-(i) is for the low emittance mode and Table 2-(ii) for the high emittance mode (1.6GeV, 5.2 nmrad). In Case (c) and (d) for both modes, generated COD is negligibly small. EV is the number of eigenvalues/vectors used.

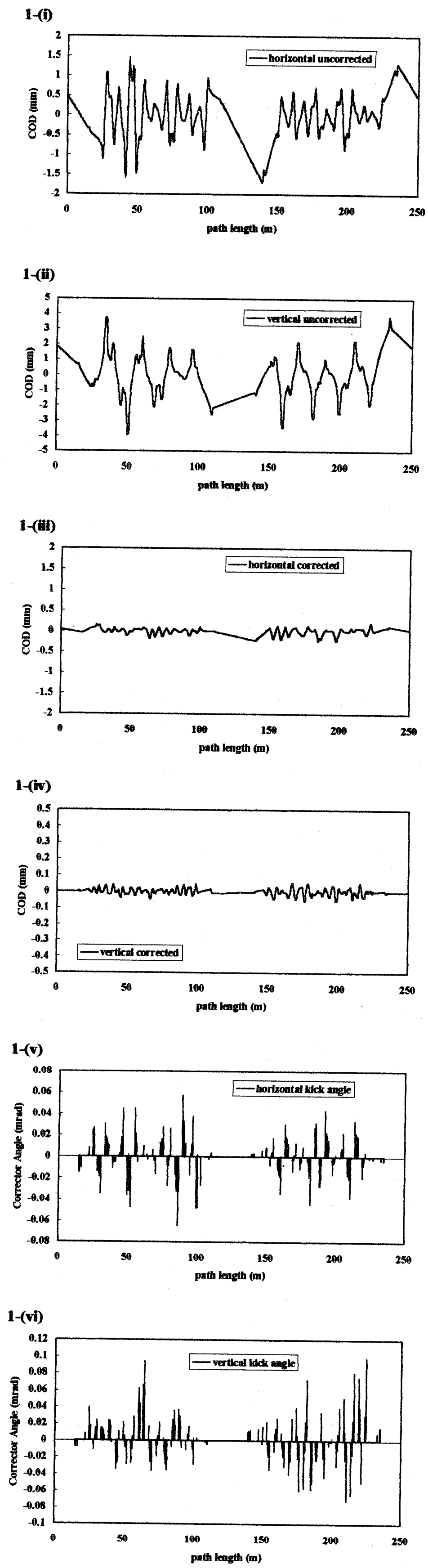

Fig. 1 Typical example of COD and corrector angles along the ring in Case (e) for low emittance mode. Figures 1-(i) and (ii) are the horizontal and vertical CODs before correction. Figures 1-(iii) and (iv) show those after correction. Figures 1-(v) and (vi) show the kick angles of horizontal and vertical correctors. The numbers of BPMs are 128 and those of correctors are 140. For the full details of the ring configuration, see the reference [5].

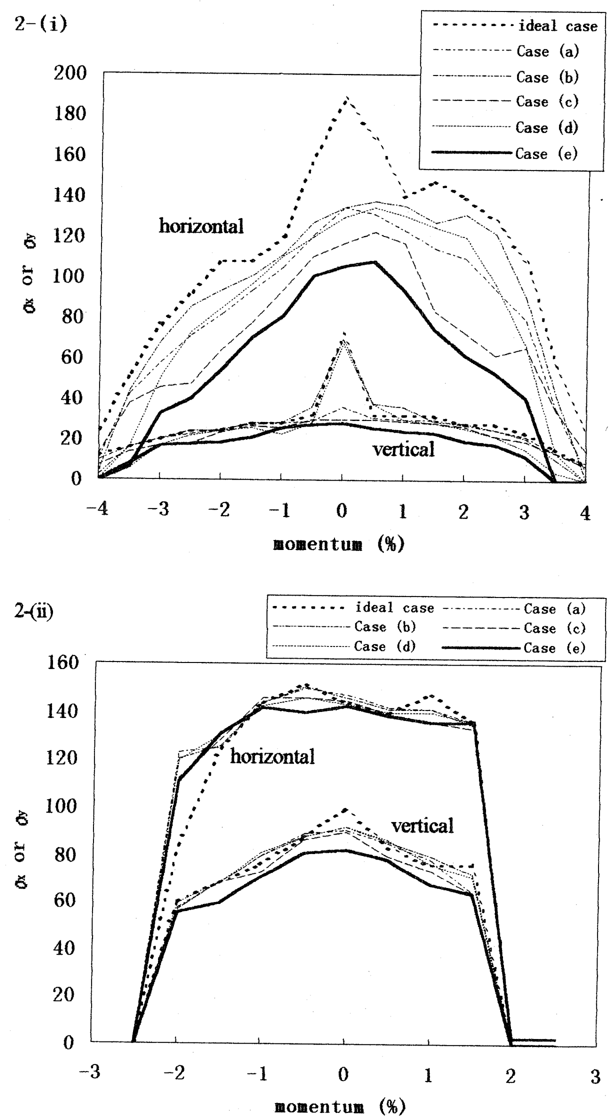

Fig. 2 Dynamic apertures after correction in various cases. Figure 2-(i) is for low emittance mode, and Figure 2-(ii) for high emittance mode. The σ_x and σ_y are defined as,

$$\sigma_x = \sqrt{\frac{2J_x}{\varepsilon_x + \varepsilon_y}}, \quad \sigma_y = \sqrt{\frac{2J_y}{\varepsilon_x + \varepsilon_y}}.$$

Here, J_x, J_y are the action variables of betatron oscillation, ε_x, ε_y the natural emittances.

The numerical values of the distortions of various orbit parameters are given in Table 2.

The CODs generated by the alignment error of quadrupole magnets (Cases (a) and (b)) are well corrected for both low and high emittance modes. In these cases, the DFD (dispersion function distortion) and TS (tune shift) are also simultaneously well corrected as seen in Table 2.

For low emittance mode, the distortions of orbit parameters of Cases (a), (b) and (e) before correction are calculated with sextupoles turned off, otherwise the calculation do not converge for almost all cases. After first correction, sextupoles are switched on and then full correction is made. Thus, some parameters before correction in Table 2 are smaller for low emittance mode than for high emittance mode.

Very small CODs are generated by the alignment error of sextupoles (Cases (c) and (d)). Therefore, the COD correction is not needed in these cases. DFD and TS generated are not so small, but in this paper these distortions have not been corrected yet.

When all kinds of errors are included (Case (e)), some amount of DFD and TS remains after correction as in Case (c) and (d).

3 Effect on the Dynamic Aperture

The dynamic apertures are shown in Fig. 2.

For low emittance mode, the horizontal dynamic apertures with errors decrease from that of an ideal case, i.e., the case without errors. However, the decreases of dynamic apertures in Cases (a) and (b) are smaller than those in Case (c), (d) and (e).

There are many other examples of calculation (not presented here) which have almost the same dynamic apertures as the ideal case. All these examples have nearly the same or more amounts of residual CODs, but less residual DFD and TS.

On the other hand, there are almost no decreases in dynamic aperture for the high emittance mode

4 Discussions

Section 2 shows that the COD correction works very well in all cases. However, small DFD and TS remain in Cases (c), (d), and (e). These residues of orbit parameter distortions are considered to cause the loss of dynamic aperture for low emittance mode.

The reason why DFD and TS remain after the COD correction is that the alignment error of sextupoles. If the beam do not pass the centre of sextupoles, the beam feels the quadrupole components, which in turn generate the DFD and TS. In Cases (c), (d) and (e), the beam cannot pass the centre of sextupoles even after correction, while in Cases (a) and (b) the beam can pass nearly the centre of sextupoles.

In summary the results in this paper show that the alignment error of quadruples is the most dominant error to produce COD, and that the lower the emittance, the severer the effect of the alignment error of sextupoles on dynamic apertures.

5 Conclusion

The COD correction and the effect on the dynamic aperture of VSX light source are investigated. For both low and high emittance modes, the COD corrections are shown to be successfully done. For high emittance mode, there are almost no losses in dynamic aperture. Meanwhile, for the low emittance mode, the residual DFD and TS give rise to the decrease in the dynamic aperture. On the other hand, there are many examples that have small residual DFD and TS, and have almost the same dynamic apertures as the ideal case. It implies that there would be no loss in dynamic aperture if we correct DFD and TS. In near future we will simultaneously correct them as well as the COD.

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