ANALYSIS OF THE CLOSED ORBIT DISTORTIONS IN THE MMF STORAGE RING

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Abstract

The determination of the closed orbit distortions due to the magnet misalignments and field errors is one of important problem in the storage ring. The simulation of the closed orbit distortions of the Moscow Meson Factory Storage Ring [1] has been carried out. The probability and spectra of closed orbit distortions are presented. The tune shifts caused magnetic lattice imperfection have been calculated. Both main operation modes of the Storage Ring have been considered.

Introduction

The linearized transverse particle motion can be expressed as a transformation [2]:

$$\begin{bmatrix} y(s) \\ y'(s) \\ 1 \end{bmatrix} = \begin{bmatrix} C(s) & S(s) & U(s) \\ C'(s) & S'(s) & U'(s) \\ 0 & 0 & 1 \end{bmatrix} \cdot \begin{bmatrix} y(s_o) \\ y'(s_o) \\ 1 \end{bmatrix}$$

where y is a particle coordinate relatively reference orbit, s is a longitudinal coordinate, C(s), S(s) are known as cosinelike and sinelike trajectories [2] and U(s) is a special solution of the motion equation with nonzero righthand side F(s). U(s) can be written as [2]:

$$U(s) = S(s)\cdot\int_{s_o}^{s} F(t)\cdot C(t)\cdot dt - C(s)\cdot\int_{s_o}^{s} F(t)\cdot S(t)\cdot dt.$$

The function S,C and U are easy received for magnetic lattice elements such as dipole, quadrupole and drift spaces with various imperfections. A ring transfer matrix M(s) is obtained by matrix multiplication and equation for the closed orbit determination is

$$\begin{bmatrix} y_{co}(s) \\ y'_{co}(s) \\ 1 \end{bmatrix} = M(s)\cdot \begin{bmatrix} y_{co}(s) \\ y'_{co}(s) \\ 1 \end{bmatrix}. \qquad (1)$$

The tune shifts can be evaluated from a change of the diagonal matrix elements.

Simulation method and perturbations

The simulation of the closed orbit distortion has been carried out by solving equation (1) and matrix tracing with a random distribution of imperfections. All results have been obtained by Monte-Carlo method for number of realization up to 10^5.

Storage ring magnetic lattice consist of 8 dipole magnets, 4 bump dipole magnets and 15 quadrupole lenses. Circumference of the ring is 106.7 m. Such imperfections as dipole field errors $\Delta B/B$, dipole and quadrupole misalignments in horizontal Δx and vertical Δz planes are considered as a source of the distortions. Moreover the influences of quadrupole gradient errors $\Delta G/G$, longitudinal quadrupole misalignments Δs, dipole tilts around horizontal axis $\Delta\theta$ and quadrupole turns around longitudinal axis $\Delta\alpha$ on the closed orbit and tune shifts are taken into account. The simulation has been done for both individual and total contribution of the imperfections. The imperfection amplitudes are presented in Table 1 and Table 2. A 6x6 matrices have been used in order to take into account transverse coupling due to the rotation $\Delta\alpha$.

Simulation results

The distributions of the closed orbit maximum deviation have been obtained as a result of simulation. These distributions in horizontal plane are shown in Fig. 1. The first and second moments of the deviation distribution are presented in Table 1. The spectra of the closed orbit distortions in horizontal plane received from the averaging of total number of simulation realization are shown in Fig. 2. These spectra have maximum on harmonic number n=2 because the tune value is Q_x=1.875 for slow extraction mode and Q_x=2.165 for fast extraction mode.

Table 1

Type of errors	slow extraction		fast extraction	
	x,z, mm	$\sigma_{x,z}$, mm	x,z, mm	$\sigma_{x,z}$, mm
dipole				
$\Delta B/B = 10^{-4}$	2.78	1.19	3.44	1.68
$\Delta x = 10^{-4}$ m	1.84	0.87	2.29	1.19
$\Delta z = 10^{-4}$ m	0.35	0.15	0.30	0.17
quadrupole				
$\Delta x = 10^{-4}$ m	0.12	0.05	1.37	0.69
$\Delta z = 10^{-4}$ m	0.19	0.09	1.25	0.78
all errors				
x-plane	3.29	1.50	4.31	2.23
z-plane	0.54	0.29	1.32	0.80

The distributions of the betatron tune value are shown in Fig. 3. R.m.s. tune shifts $\Delta Q_{x,z}$ are presented in Table 2.

Table 2

Type of errors	slow extraction		fast extraction	
	$\Delta Q_x \times 10^5$	$\Delta Q_z \times 10^5$	$\Delta Q_x \times 10^5$	$\Delta Q_z \times 10^5$
dipole				
$\Delta \theta = 10^{-5}$rad	1.80		8.28	
quadrupole				
$\Delta G/G = 10^{-4}$	0.53	0.73	8.22	13.4
$\Delta s = 10^{-4}$ m	0.04	0.03	4.93	2.28
$\Delta \alpha = 10^{-5}$rad	0.01	0.02	0.42	1.08
all errors	1.88	0.74	12.5	13.5

Conclusions

Main sources of the closed orbit distortions are dipole field errors and dipole misalignments but the quadrupole misalignments should be taken into account for fast extraction mode. The harmonic numbers from n=1 to n=10 are considerably excited. The betatron tune shifts do not exceed of $5 \cdot 10^{-4}$ in both horizontal and vertical planes. The results of simulation will be used in order to place diagnostics devices around storage ring and to choice proper closed orbit correction algorithm.

References

[1] M. I. Grachev et al, "Moscow Meson Factory Proton Storage Ring," in Proceeding of the XIII International Conference on High Energy Accelerators, Novosibirsk, USSR, 1987,vol. 1, pp. 264-269.

[2] P. Schmuser, "Basic course on accelerator optics," in Proceeding of the 1986 CERN Accelerator School, 1987, pp. 1-44.

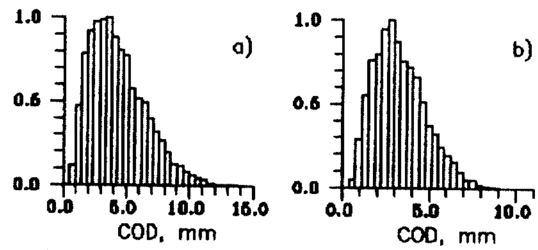

FIG. 1 Distribution of the COD maximum:
a) fast extraction, b) slow extraction.

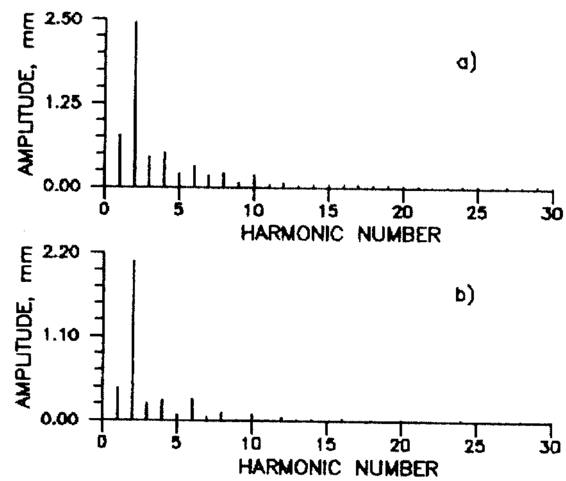

FIG. 2 Averaged spectrum of the COD:
a) fast extraction, b) slow extraction

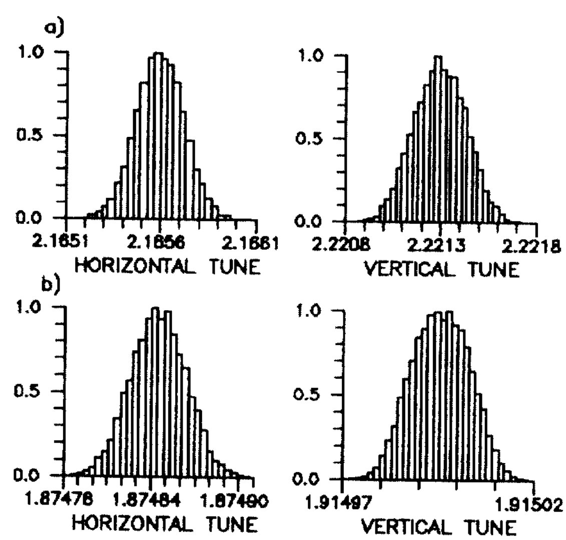

FIG. 3 Tune distributions:
a) fast extraction, b) slow extraction