Simulation of correction for PSR-2000 Dynamic aperture.

Andrey Zelinsky, Ivan Karnaukhov, Stanislav Kononenko, Michael Strelkov, Aleksander Tarasenko

Kharkov Institute of Physics and Technology, 310108 Kharkov, Ukraine

Abstract

6-D numerical simulation results for the dynamic aperture of the Pulse Stretcher Ring PSR-2000 with taking into account the aperture correction are given. The sextupole and octupole magnets correcting the aperture value were used in addition. In calculation the reference orbit distortions and the magnetic field perturbations up to the third order were considered.

The calculations were performed with the DeCA code.

1. INTRODUCTION

The lattice of the electron pulse stretcher ring PSR-2000, designed at the Kharkov Institute of Physics & Technology [1], provides for the generation of synchrotron radiation of high brightness [2] with the PSR-2000 operating in the mode of low radiation emittance (LRE). This is achieved by increasing the rigidity of the magnetic system with the result that the chromaticity increases, to compensate the latter, it is necessary to enhance the sextupole lens power in the non-zero dispersion sections, thereby substantially decreasing the dynamic aperture (DA), defined as a bucket boundary of betatron oscillations.

Preliminary studies of the PSR-2000 DA, which were performed through analytical estimation and computer simulation [3,4] under all operation conditions have shown that:

i) the DA for the PSR operating at Qx=7.22, Qz=7.27 (injection with inflector) is larger than the geometric aperture and requires no additional correction;

ii) The DA for the PSR operation at Qx=8.26, Qz=7.17 (injection with a "bump") is smaller than the geometric aperture. The computer simulation studies of the DA value [4] with taking into account the reference orbit perturbations and the influence of sextupole end octupole magnetic field perturbations have shown that in the operating frequency range Qx=8.17 . . . 8.35 the DA is smaller than the geometrical aperture and its increase would require some special correction, since the correction by means of additional sextupole lenses does not give any significant increase in the DA (20% increase), besides, in the frequency range considered the DA size strongly depends on the tune point.

2. RESULTS OF CALCULATIONS.

On developing the design, we have modified the focusing structure to meet the technical requirements for the disposition of the equipment, and to comply with symmetrization of the curvilinear superperiod sections geometry. These modifications have resulted in new operation conditions for LRE in the frequency range Qx=7.21 to 7.37 with injection by the "bump", providing the emittance ε between 2 and $21.33 \cdot 10^{-8}$ m•rad in the energy range between 0.8 and 2.33 GeV. Figure 1 shows the superperiod structure, amplitude and dispersion focusing functions. The natural chromaticity $\xi x=-20$, $\xi z=-15$ is compensated by four sextupole lenses in the curvilinear superperiod section.

These operation conditions permit the DA correction without installing additional sextupole lenses (we use the sextupole lenses providing the beam extraction at the third-order resonance, they are located in the achromatic part of the orbit, see Fig.1).

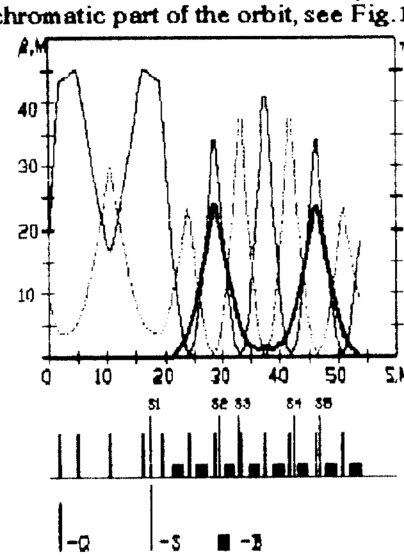

Figure 1.

The present paper is concerned with the studies of the DA in the vicinity of the tune point Qx=8.3(8.21 to 8.34) under different operation conditions, viz., in the ideal structure, with the sextupole lens correction, with due account of reference orbit perturbations (misalignment of the magnetic elements), with due account of the reference orbit correction, with taking into account sextupole and octupole storage-ring magnetic field perturbations.

The field values of the correcting sextupole lenses were chosen from the minimization condition of the coefficients of nonlinear frequency shift from the oscillation amplitude due to the sextupole field effect [5]. Based on this choice, a computer simulation was made to calculate the DA value. No longitudinal motion of particles was taken into account in the simulation. All computations were made with the DeCA code [6].

The simulation procedure was as follows: five hundred particles with the coordinates x,z and the tilt angle x'=0., z'=0, uniformly distributed in across the aperture, were injected on the azimuth with the zero values of $\beta x'$, $\beta z'$. The particles were considered as lost if the amplitude of their oscillations exceeded the fixed boundary value. The boundary was chosen equal to 8m in x and 8m in z direction. In the phase map X and $ show the initial coordinates of the particles after they have passed the assigned number of turns (100 in our case) (X: the particle is out, $: the particle motion is stable). Knowing the initial particle coordinates and having calculated the β-functions, we can obtain the DA on any azimuth of the ring.

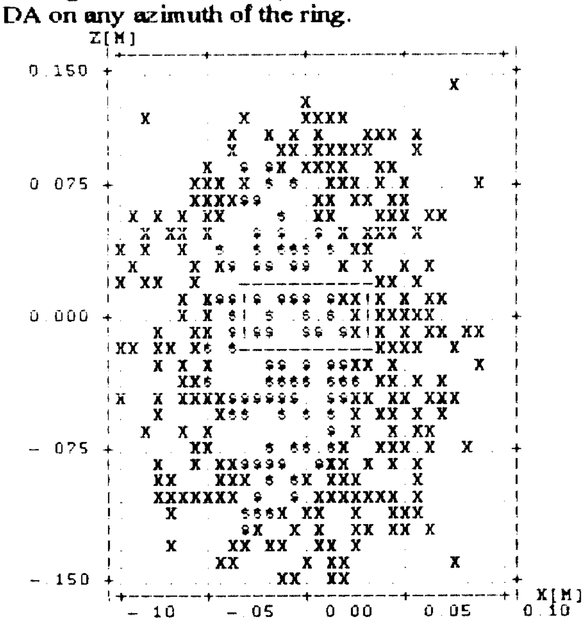

Figure 2

Fig. 2 Shows the phase map of the beam for the case of an ideal reference orbit without any nonlinear field perturbations and without correcting sextupole lenses. Fig. 3 depicts the DA for the same case but with the correcting sextupole lenses included. The solid line in the figures shows the geometrical aperture (GA) of the storage ring chamber (x=0.05 m, z=0.02 m).

As can be seen from the figures, the DA without the correcting sextupoles is smaller than the GA. After performing the correction, the DA becomes appreciably larger than the GA (x from -0.113 m to 0.123 m and z from -0.106 m to 0.137 m).

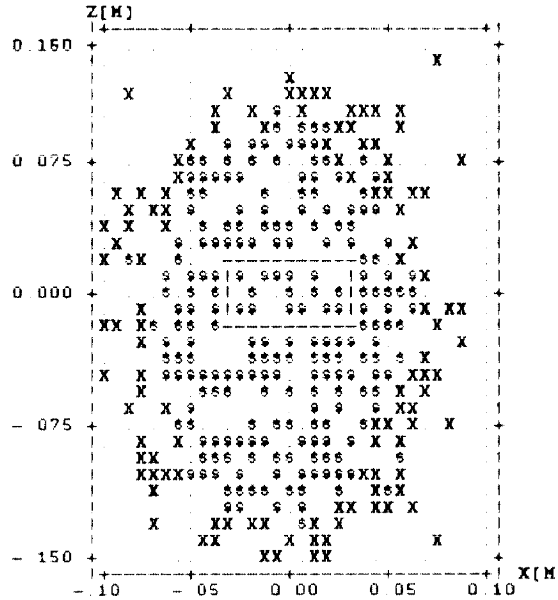

Figure 3

Fig. 4(a,b) shows the DA for the case of a perturbed reference orbit with the correcting sextupoles included (without (a) and with (b) the correction of the reference orbit).

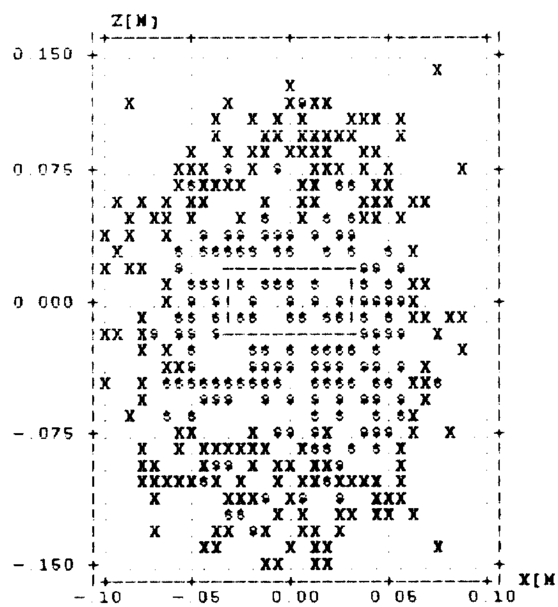

Figure 4a

The errors in the PSR-2000 magnet element alignment were $x=10^{-4}$m, $x'=10^{-4}$rad, $z=10^{-4}$m, $z'=10^{-4}$ rad, $s=10^{-4}$m, $s'=10^{-4}$rad. The RMS orbit deflections were $x_{rms}=6\cdot10^{-4}$m, $z_{rms}=10^{-3}$m before the correction and $x_{rms}=6\cdot10^{-5}$ m, $z_{rms}=10^{-5}$m after the correction.

It seen from the figures that with the reference orbit distortion the DA decreases by ~ 15% and ~40% in the x and z coordinates, respectively. After the reference orbit is corrected, the DA is practically equal to the DA in the no-perturbation case (see Fig.3).

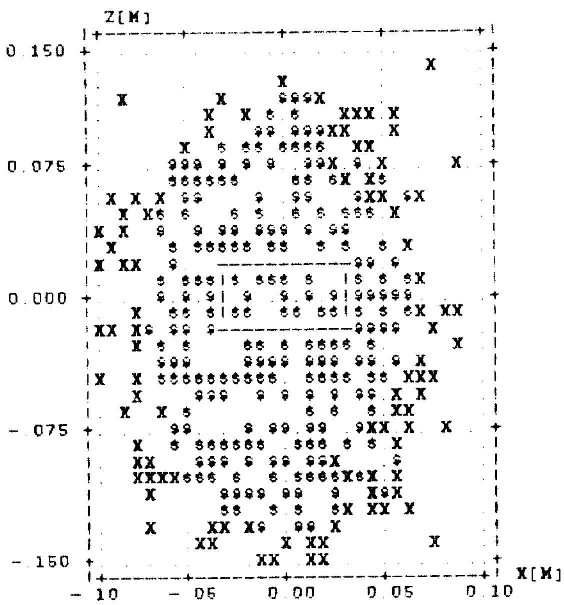

Figure 4b

Studies were also made for the DA in the operating frequency range Qx= 7.21 to 7.37 with perturbed and corrected orbits and with the correcting sextupole lenses included. The computations have shown a ~ 10% variation of the DA in this frequency range.

Fig. 5 illustrates the DA for the case of a perturbed reference orbit with its subsequent correction, with the correcting sextupole lenses included and with taking into account the sextupole and octupole magnetic field perturbations. The perturbation values for were chosen to be 0.2% of the guide field values for the sextupole and octupole components, the fields varied in the limits of 0.5 and 1.1 T in the quadrupole lenses and dipole magnets, respectively.

It seen from Fig.5 that the DA decrease in the x-coordinate is ~ 20%, and its largest values for the operating frequency range are from -0.103 to 0.082 for x, and from -0.127 to 0.095 for z.

Thus, the undertaken studies have revealed that in the frequency range 7.21 to 7.37 the DA correction by the sextupole lenses with taking into account the linear reference orbit distortions and the nonlinear magnetic field perturbations substantially increases the DA value.

The highest value of the DA is twice as large as that of the geometrical aperture in the x-coordinate and 5 times greater in the z-coordinate. This allows us to state that under the chosen operation conditions the effects associated with the DA will not essentially influence the beam lifetime.

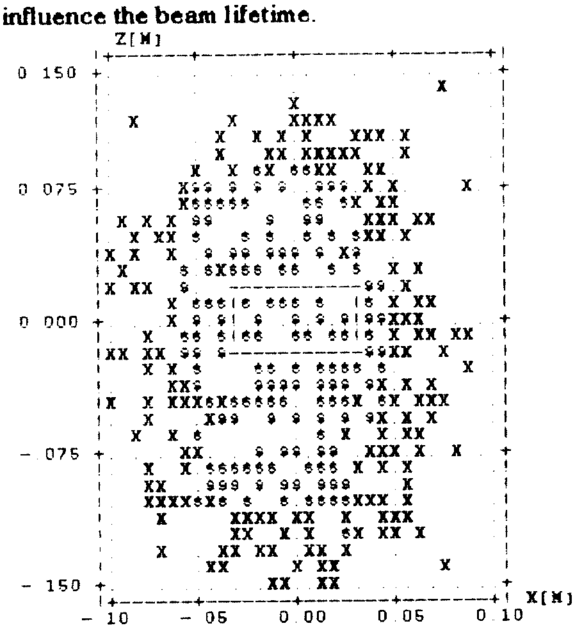

Figure 5

3. REFERENCES:

[1] Gladkikh P.I., Gonchar V.Yu., Grigor'ev Yu.N. et al. "PSR-2000. The pulse stretcher ring for the Kharkov linear electron accelerator", Preprint KFTI 90-22, Moscow, TcNIIAtominform,1990, 34p.

[2] Boldyshev V.P., Gladkikh P.I., Grigor'ev Yu.N. et al. "The Kharkov 3 GeV pulse stretcher ring as a source of synchrotron radiation", Nucl.Inst.&Meth., A282(1989), pp.390-391

[3] Gladkikh P.I., Karnaukhov I.M., Kononenko S.G. et al. "Dynamic aperture of the pulse stretcher ring PSR-2000 for operation in the low radiation emittance regime", Particle Accelarators, v.28(1990), Part III, pp. 11-17

[4] Zelinsky A.Yu.,Karnaukhov I.M., Kononenko S.G., Tarasenko A.S."Dynamic aperture of the PSR-2000 for operation in the low radiation emittance regime", Preprint KFTI 91-40, Moscow, TcNIIAtominform,1991, 7 p.

[5] Ryutaro Nagaoka, Katsuhisa Yoshida and Masahiro Hara "Nonlinear dynamics with sextupoles in low-emittance light source storage rings". Nucl.Instr.&Meth., A302(1991),pp.9-26

[6] Gladkikh P.I., Zelinsky A.Yu., Strelkov M.A. "DeCA -code for analysing and designing of cyclic Accelerators", Proceeding of the EPAC - 2, vol. 2, pp 1234-1236, 1991.