PERFORMANCES OF THE SOLEIL LATTICE IN THE PRESENCE OF ERRORS[1]

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Abstract

The SOLEIL storage ring lattice has been designed in order to obtain large dynamic aperture and energy acceptance. The aim of this work is to investigate the effect of various errors on these performances. First of all, the effect of the residual closed orbit and focusing errors on the optics and dynamic aperture has been evaluated. Then, multipolar components, deduced from magnet design computation, have been introduced in the lattice and special attention was paid to the components added by the presence of dipolar correctors in sextupoles.

INTRODUCTION

The high brilliance lattice for SOLEIL has been optimized in order to reach small beam emittance (ε_x = 3 nm.rad) and a large dynamic aperture up to $\Delta p/p = \pm 6$ % [1]. The nominal tunes are $\nu_x = 18.28$ and $\nu_z = 8.38$. The performances of this lattice depend on the effect of errors. The focusing errors are due to the residual closed orbit after correction, to the quadrupole gradient reproducibility, to the sextupole horizontal displacement and also to a residual index in dipoles. The multipolar components of fields, deduced from 2D calculations, have been tested on dynamic aperture. There are sextupolar, decapolar and 14-pole in the dipoles, octupolar and dodecapolar in the quadrupoles. In sextupole magnets, in addition to systematic 18-pole and 30-pole, there are decapolar and 14-pole generated by the presence of dipolar correctors. The effect of these errors has been tested independently for each type of errors and then together. Tune shifts and chromaticity variations have been compensated if necessary. All the calculations have been performed with the BETA code [2].

1. FOCUSING ERRORS

1.1. Residual closed orbit errors

The closed orbit correction scheme was described in [3]. The maximum rms values after correction using only 48 horizontal and 32 vertical correctors are 0.17 mm in horizontal plane and 0.14 mm in vertical plane. The effect on dynamic aperture is given on Fig. 1, showing that the dynamic aperture is reduced for some samples. Note that the use of the total number of correctors (112) restores exactly the nominal dynamic aperture.

1.2. Quadrupole gradient reproducibility

The reproducibility usually required for quadrupole gradient is $(\Delta\int G d\ell / \int G_o d\ell) = 1\ 10^{-3}$. Random errors have been generated and statistical results over 20 samples give rms tune shifts of $\Delta\nu_x = 0.010$ and $\Delta\nu_z = 0.006$. The dynamic aperture can be severely affected for particular samples. So we planned to compensate for this type of errors (which will be defined after magnetic measurements) by using the quadrupole independent power supplies.

1.3. Sextupole horizontal displacement

A horizontal displacement of sextupoles with a rms value of 0.1 mm leads to horizontal and vertical rms tune shifts of $\Delta\nu_x = 0.0075$ and $\Delta\nu_z = 0.006$. The result dynamic aperture is sufficient for injection. The correction of the tune shifts on the stored beam will restore the dynamic aperture and consequently the Touschek beam lifetime. Note that sextupoles will be aligned on girders within 30 μm-rms, the girder being aligned itself within 50 μm-rms. So the rms horizontal displacement of sextupoles will be probably close to 60 μm instead of 100 μm.

1.4. Index in dipoles

The field index is created when the gap height (37 mm) varies along the pole width (108.6 mm), due to the switch-on of the power supplies. The variation of the gap height is 0.02 mm which corresponds to $\Delta B/B_o = -2\ 10^{-4}$ at $x_o = \pm 20$ mm. This systematic error leads to the following tune shifts : $\Delta\nu_x = -0.003$ and $\Delta\nu_z = 0.08$. The strong variation of ν_z is due to the large value of β_z in dipoles (β_z = 18 m). These tune shifts can be compensated with small variations of quadrupole strengths (-0.2 % on defocusing quadrupoles and –0.06 % on focusing ones). After compensation, dynamic aperture and optical functions are restored, and the natural vertical chromaticity is slightly increased ($\Delta\xi_z = \Delta\nu_z/\Delta p/p = 0.1$). This variation is easily compensated with small variations of sextupole strengths.

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2. EFFECTS OF MULTIPOLAR COMPONENTS

All the multipolar components are given as $\Delta B/B_o$ values at the limit of the good field region, $x_o = \pm 30$ mm for quadrupoles and sextupoles and x_o ± 20 mm for dipoles (Table 1). They have been deduced from 2D calculations by a polynomial fit for the dipole field and harmonic analysis for the quadrupole and sextupole fields. The simulations use the following definition for the 2n-pole thin lens strength :

$$A_{2n} = \frac{1}{(n-1)!} \frac{\partial^{n-1} B_z}{\partial x^{n-1}} \frac{L}{B\rho}$$

(where $B\rho$ is the magnetic rigidity and L the multipole length).

Table 1. Multipolar components.

	Dipoles	Quadrupoles	Sextupoles
B_o	$B(x = 0)$	$G_o\, x_o$	$H_o\, x_o^2$
Hexapole	$-1.75\ 10^{-4}$		
Octupole		$-1.5\ 10^{-5}$	
Decapole	$-1.4\ 10^{-4}$		$2.4\ 10^{-2}$
Dodecapole		$-1.2\ 10^{-4}$	
14-pole	$-4.75\ 10^{-5}$		$2.7\ 10^{-3}$
18-pole			$-1.2\ 10^{-4}$
30-pole			$-4.1\ 10^{-3}$

2.1. In the dipole

The hexapolar and decapolar components reduce slightly the vertical aperture, but the 14-pole component has a rather strong effect on vertical aperture and excites resonances in horizontal plane. When all components are tested together, the vertical aperture is less reduced and the horizontal aperture remains unchanged.

2.2. In the quadrupole

The systematic errors are octupolar (the yoke is open for photon beamlines) and dodecapolar. The octupolar component, very small, has no effect on dynamic aperture. The dodecapolar component modifies strongly the horizontal tune shift for large amplitudes but reduces only slightly the dynamic aperture.

2.3. In the sextupole

In addition to 18-pole and 30-pole systematic components, we have to take into account, the systematic multipoles due to the dipolar correctors located in sextupoles, which are decapolar and 14-pole. The hexapolar component has been cancelled by choosing appropriate currents in steering coils [4]. The effect of decapolar and 14-pole components has been tested with 10 samples of dipolar correctors which correct both horizontal and vertical closed orbits. The decapolar component reduces the dynamic aperture significantly for several samples. The effect of the 14-pole component is negligible.

The 18-pole component has been minimized during magnetic optimization in order to reduce its strong effect on dynamic aperture.

The 30-pole component remains strong and its effect on horizontal aperture is drastic (Fig. 2). The particles are lost in the SX4 sextupole family where the β_x function and the sextupole strength are very large. The instability is not due to resonance excitation and the tune shift with amplitude is not modified for small amplitudes. Then it is not possible to compensate this bad effect by acting on sextupole strengths.

2.4. Effect of all multipolar errors together

When multipoles of dipoles and quadrupoles are tested together, with a compensation of the focusing due to index in dipoles, the small aperture reduction is given by the effect of the dodecapolar.

When all systematic multipolar errors are tested together, the dynamic aperture is reduced significantly (Fig. 3) due to the strong effect of the 30-pole in sextupoles. If this component can be decreased significantly, the dynamic aperture will be acceptable (Fig. 4).

2.5. Off-momentum dynamic aperture

The performances of the real machine in terms of lifetime depend on the dynamic aperture for off-momentum particles. First results have shown a strong reduction of the dynamic aperture for $|\Delta p/p| \geq 4$ %, which is still due to the 30-pole in sextupoles. This confirms that it is essential to minimize this component.

CONCLUSION

The effect of systematic errors, deduced from magnetic designs, on dynamic aperture and optics, has been tested for the operating point of SOLEIL. The defaults are acceptable except for the 30-pole component of the sextupole field. Tune shifts and chromaticity variations are easily compensated with small variations of quadrupoles and sextupoles respectively, restoring optical functions and dynamic aperture. This work has shown that the nominal lattice optimization remains valid only if the 30-pole component of sextupoles is strongly decreased. In particular, off-momentum dynamic apertures will be large enough to maintain the good Touschek lifetime [1]. Further developments will concern the effect of all skew multipolar components and particularly the ones due to the skew quadrupole fields created in sextupoles.

REFERENCES

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[3] A. Nadji et al., EPAC 96, Vol. 1, pp. 673-675.
[4] A. Nadji et al., this conference (TUP06C).

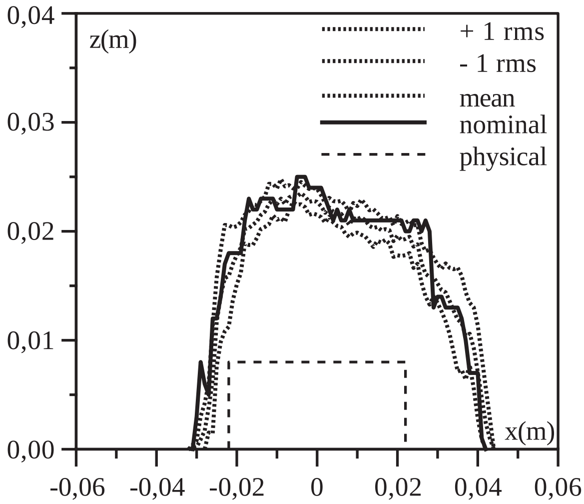

Fig. 1. Effect of the residual closed orbit on dynamic aperture.

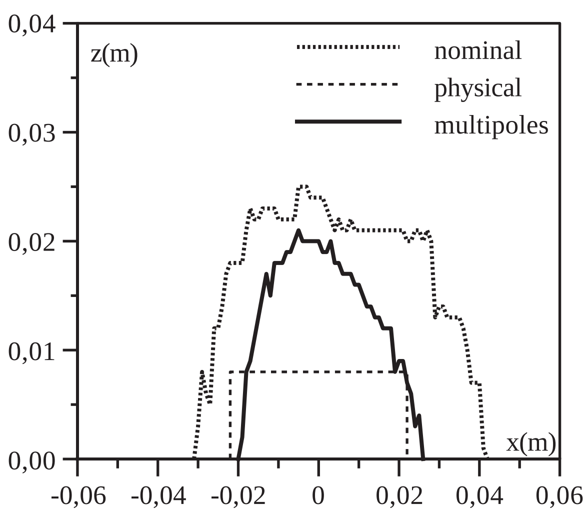

Fig. 2. Effect of multipolar components of sextupoles on dynamic aperture.

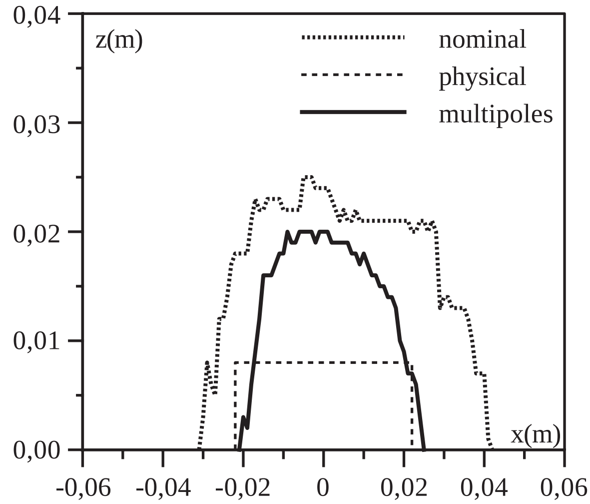

Fig. 3. Effect of all the multipolar components on dynamic aperture.

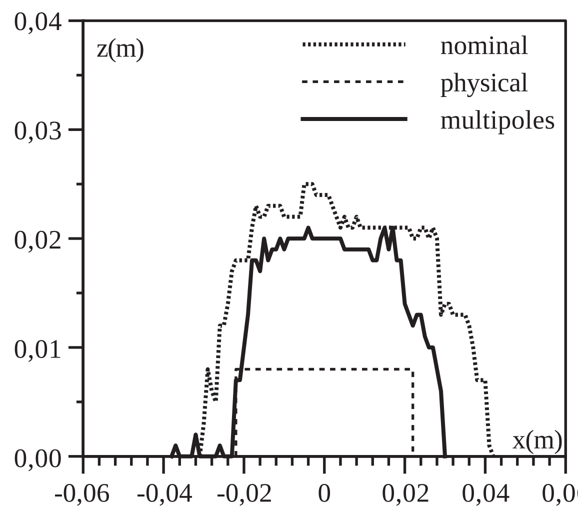

Fig. 4. Effect of all the multipolar components **except** the 30-pole component of sextupole.