COMPENSATION OF THE INSERTION DEVICES EFFECT IN ELECTRON STORAGE RINGS

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Abstract

The method of designing of the local compensation schemes for suppression of wigglers and undulators affects on lattice functions of low emittance storage rings is described. The method is based on the analysis and optimization of a transport matrix of the insertion device section. The features of magnetic lattices permitting to compensate effects of various wiggler and undulator types are discussed.

The effects of the insertion devices to lattice functions and parameters of storage ring UNK Kharkov are discussed. The schemes of compensation are presented.

1 INTRODUCTION

Nowadays, the beams of photons obtained from insertion devices (wiggler, undulator) (ID), installed on storage rings - sources of a synchrotron radiation (SR), became the necessary tool for realization of researches in science and technology. Owing to this reason SR sources of the third generation are oriented on magnetic lattices with the great amount of ID [1]. As the ID installed in a storage ring affects on the electron beam, there is a problem of suppression of ID effect on a beam dynamics in a ring. The methods of compensation of ID effect on particles dynamics in a ring should be universal and effective.

In this report the technique of designing of the schemes of compensation based on use of a matrix formalism and optimization of elements of a transport matrix is offered. Compensation is carry out on a section of "insertion", where ID is disposed, in such a manner on a remaining ring of a focussing function are not changed, thus the effect of ID is localized on a section of "insertion" [2].

With use of this technique we have designed variants of the scheme of local compensation of effect of flat wiggler for UNK Kharkov storage ring [3]. In this report we consider effects, to which the installation of flat wiggler on an UNK Kharkov are resulted and we reduce outcomes of application of the schemes of compensation.

2 EFFECT OF ID ON PARAMETERS OF STORAGE RINGS LATTICES

The ideal ID in electron storage ring bring a modification of a focussing functions, frequencies of oscillations and increase of emittance and energy spread, emerging of a horizontal dispersion on a ID space. The field of spiral ID call coupling of horizontal and vertical oscillations, that changes focusing properties of a lattice and results in increase of vertical phase volume in a ring. This coupling of oscillations should be localized on a space of an insertion.

When in ID there are only transverse fields the changes of focussing functions and tunes of betatron oscillations are caused by a edge-focussing effects of coils of these devices. The tune shifts and change β-functions can be calculated by a method of transport matrixes. The field of a ideal flat wiggler is well describe by a matrix of a rectangular magnet. The matrix models of other types of devices also can be created.

In a lattice of UNK Kharkov the installation of super-conducting horizontal three-polar wiggler with a maximum field up to 7 T and length 0.62 m is stipulated [4]. We evaluated a tune shift of vertical oscillations, change of horizontal emittance ε_x, distortion β - functions of UNK Kharkov depending on a field value in wiggler B_W by use of the application package DeCA [5]. The field in wiggler was changed from 0 up to 7 T. Results of calculations are indicated in table 1 and on fig.1.

Table 1.

Number in fig.1	B_w [T]	Emittance ε_x [m*rad]	Q_z
1	0.00	$2.480*10^{-8}$	4.25739
2	5.00	$2.850*10^{-8}$	4.35516
3	5.50	$3.130*10^{-8}$	4.38047
4	6.00	$3.534*10^{-8}$	4.41436
5	6.25	$3.706*10^{-8}$	4.42998
6	6.50	$4.090*10^{-8}$	4.51322
	7.00	Motion unstable	

Obviously, that for providing of normal work of a ring when the magnetic field in wiggler is big it is necessary to localize effect of ID on a space of "insertion" or to suppress it by anyone methods. The scheme of compensation should ensure normal work of a ring for any modification of magnitude of a field in ID.

3 DESIGN OF THE SCHEMES OF LOCAL COMPENSATION

It is possible to describe the focusing properties of the ID by a transport matrix M_{WU} by a size 6*6 [6,7]. By making a combination from matrixes $M_{WU\,1}$, $M_{WU\,2}$, . . . , M_{WU} of ID sections and matrixes M_{comp1} , M_{comp2} . . . M_{comp_i} of groups of compensatory elements we should receive a resulting matrix of an insertion ID. It will be noted as follows:

$$M_{comp_i} * M_{WU\,i} \ldots M_{comp2} * M_{WU\,1} * M_{comp1} = M_{ID} \qquad (1)$$

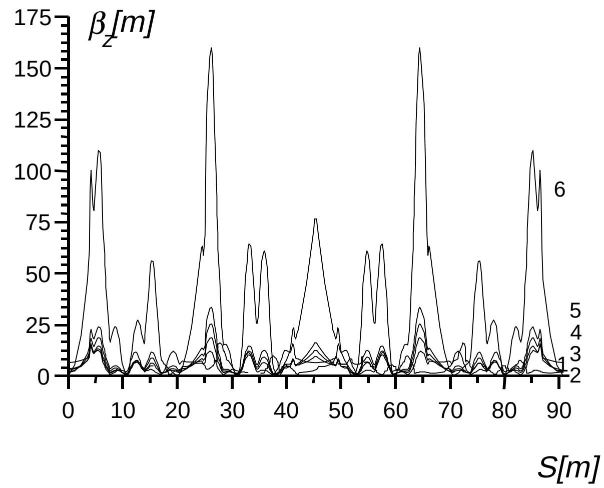

Figure 1. β-function of UNK Kharkov with ID without compensation.

(1) represents a system from 20 equations. When taking into account conditions of stability of particles motion in a storage ring [8]:

$$Det\left|M_{ID}\right|_x = 1, \ Det\left|M_{ID}\right|_z = 1, \quad (2)$$

we receive a system of 18 independent equations, for sufficing of that is necessary to have 18 independent parameters. Such parameters can be forces of quadrupole lenses, lengths of drift spaces, turn angles in dipole magnets, rotation angles of quadrupole lenses. In depending from kind of resulting matrix of a section of an insertion that we want to receive and what type ID we use, the number of the equations can be reduce.

The transport matrix of flat wiggler with *n* poles is the matrix of *n* rectangular magnets. Combining this matrix with matrixes of compensatory sections, when considering a condition (2) received a system of 10 equations. Thus, for suppression of flat wiggler effect it is necessary to make a magnetic lattice with 10 varied parameters, to impose requests on focusing properties of a transport matrix of an insertion M_{ID} and to decide this system. If requests to compensation of dispersion function are not to impose then amount of the equations and elements, required for compensation, is reduced up to 6.

Most simple configuration of insertion lattice permitting to compensate focusing properties of flat wiggler, receive, if to surround wiggler by a system from quadrupole lenses. In this case (1) has a kind:

$$M_{comp2*} \ M_{WU*} \ M_{comp1} \quad M_{ID}. \quad (3)$$

The requests to focusing properties of M_{ID} can be arbitrary and are determined by real conditions of a storage ring lattice and soluble problems. However most natural are the variants, when the transport matrix of an insertion is represented as a matrix of drift space or the matrixes of a focusing section, where ID is disposed. In these cases all properties of lattices of storage rings in a linear approximation will be saved, and the effects of ID will be localized on a section of an insertion.

4 COMPENSATION SHEMES FOR UNK KHARKOV STORAGE RING

In a fig. 2 the layout of an insertion consisting from wiggler and compensatory a structures permitting to receive arbitrary matrix of a focussing is shown.

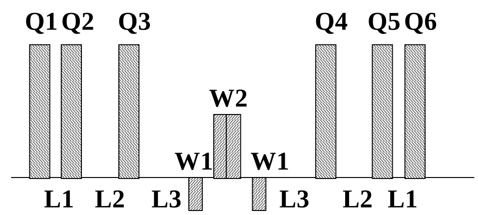

Figure 2: Layout of compensatory insertion.

We designed two variants of compensatory structures for UNK Kharkov. First variant (I) realized a transport matrix of an insertion appropriate to length of drift space, where it is disposed, and uses 6 additional quadrupole lenses. Second variant (II) realized a transport matrix appropriate to a focusing matrix of long straight section of a storage ring, in which wiggler is situated. In table 2 the parameters of elements of an insertion for two variants of a transport matrix are indicated.

Table 2.

	***K1* [T/m], *B* [T]**		***L*[M]**	
	I	**II**	**I**	**II**
Q1	K1=-44.616	K1=2.8997	0.2	0.2
Q2	K1=100.152	K1=-1.9405	0.2	0.2
Q3	K1=-160.76	K1=14.8653	0.2	0.2
Q4	K1=-132.98	K1=14.8653	0.2	0.2
Q5	K1=98.909	K1=-1.9405	0.2	0.2
Q6	K1=-54.539	K1=2.8997	0.2	0.2
W1	B=-3.5 ,	B=-3.5	0.2067	0.2067
W2	B=7.0	B=7.0	0.2067	0.2067
L1			0.4614	0.3
L2			0.1204	0.2
L3			0.2682	3.34953

where $K1 = \frac{1}{B\rho}\frac{\partial B}{\partial x}$, B – magnetic field, L – elements length.

For keeping of a kind of transport matrix when value of a field in wiggler is vary gradients of quadrupole lenses are changing directly as a field in wiggler.

The amplitude functions of UNK Kharkov without ID and with taken into lattice of compensatory insertion and ID are shown in a fig. 3. In a result of an operation of an insertion the horizontal tune of betatron oscillations is not changed, and the vertical tune is increased on 1 and they are Q_x = 7.21114, Q_z = 5.25832. In a result of magnification of energy losses on a SR the energy spread has increased from $1.085*10^{-3}$ up to $1.258*10^{-3}$, and emittance from $2.48*10^{-8}$ m*rad up to $3.76*10^{-8}$ m*rad. At the same time, horizontal β_x - function at centre of wiggler has decreased almost twice (from 11.123 m up to 6.842 m), that allows to compensate effect of growth of emittance and energy spread on a horizontal size of a beam.

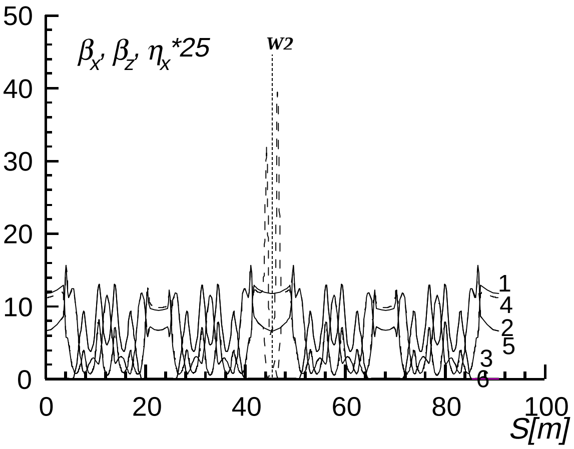

Figure 3:. 1 - β_x – B_W=0 T, 2 - β_z – B_W=0 T, 3 - η_x – B_W=0 T, 4 - β_x – B_W=7 T insertion I switch on, 5 - β_z – B_W=7 T insertion I switch on, 6 - η_x – B_W=7 T insertion I switch on, *W2* – centre of wiggler magnet.

We also calculated the dynamic aperture (DA) of a UNK Kharkov. The calculations of the DA with and without of insertion with taken into account only transverse motion and longitudinal motion with chromatic aberration too were conducted. The DA in a vertical plane not was changed, as the tune of betatron oscillations was not actually changed, and the amplitude functions in a vertical plane also was changed a little (fig. 4). The minor diminution of area of stability in a horizontal plane is caused by an amplification of sextupole lenses in bending sections of lattice that compensate the natural chromaticity. The taking into account of longitudinal motion of particles and chromatic aberrations show that without insertion they do not have essential influence on area of stable motion of particles. However, when magnetic elements of the insertion switch on the influence of chromatic aberrations are increased and DA decrease on ± 5 mm. Despite of it, the DA at center of wiggler remain rather large (± 12 mm), that it is quite enough for realization of injection in a ring.

The amplitude functions of a storage ring with taking into account of an insertion and without it and for normal mode of quadrupole lenses of straight section for variant II of insertion are shown on fig.4. The effect of an insertion to amplitude functions in a ring is unsignificant. On a section of an insertion β_z will increase up to 55,9 ì, and β_x up to 13 m is increased. The tune of horizontal and vertical betatron oscillations practically is not changed and they are Q_x = 7.22598, Q_z = 4.18371. In a result of increase of energy losses on a SR the energy spread has increased up to $1.258*10^{-3}$, and emittance up to $4.407*10^{-8}$ m*rad.

The calculations of the DA with taking into account only transverse motion and also longitudinal motion and chromatic aberrations were conducted. As the tune of betatron oscillations after including of insertion in lattice was provided were not actually changed, the DA not was changed. The minor magnification of area of stability in a vertical direction is caused by slack of sextupole lenses in bending section of a lattice, and remove of tune of vertical oscillations from a resonance Qz/4. The effect of chromatic aberrations on particles motion less essential, than in case of an insertion as drift space and the magnitude of the DA is changed unsignificantly.

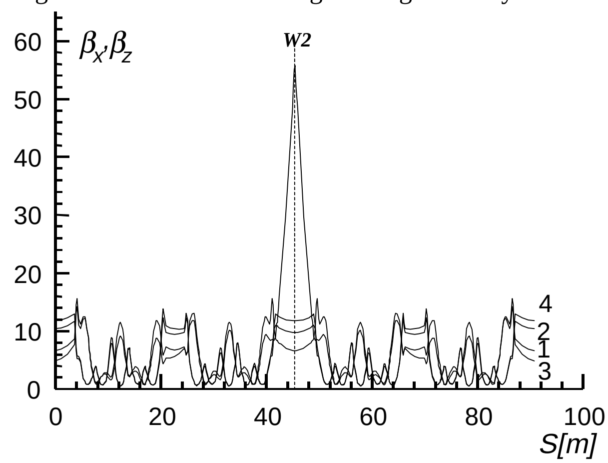

Figure 4 :. 1 - β_x – B_W=0 T, 2 - β_z – B_W=0 T, 3 - β_x – B_W=7 T insertion II switch on, 4 - β_z – B_W=7 T insertion II switch on, *W2* – center of wiggler magnet.

5 CONCLUSION

The results of calculations of a compensatory insertion show that the theory of transport matrixes allows calculating parameters of structures compensatory the ID effects in storage rings. The designed compensatory schemes will be used in a storage ring UNK Kharkov.

REFERENCES

[1] SPRING-8 Project, Facility Design 1991, August 1991.

[2] A. Ando, S.Date, K. Soutome et all. “A local compensation scheme for insertion devices in the 8 GeV storage ring SPRING-8”, EPAC 94, v.1, pp. 660-662

[3] E.Bulyak, A.Dovbnya, P.Gladkikh, “A multipurpose accelerator facility for Kharkov national scientific center”, Conference SR-98 Novosibirsk, July, 1998, to be published.

[4] P. Gladkikh, I. Karnaukhov, A. Mytsykov, “The effect of superconducting wiggler on the DA ISI-800”, EPAC 96, v.1, pp.656-658, 1996

[5] A.Zelinsky, P.Gladkikh, M. Strelkov, New version 3.3 of the DeCA code, Proceeding of the 3 EPAC, 1992, v.1, pp. 685-687.

[6] A Zelinsky, I.. Karnaukhov, A. Shcherbakov, “Compensation of coupling caused by solenoid”, Preprint KPTI 88-47, Moskow-CNIIatominform-1988, pp. 12.(In Russ)

[7]V. Kartashev, V.I. Kotov, “The base of magnetic optic of charge particles”, Paris, 1966.(In Russ)

[8] A. Bruck, “Accelerateurs Circulaitares de Particules”, Moskow: Atomizdat, 1970.(In Russ)