IMPEDANCE OF THE BEPCII ELECTROSTATIC SEPARATORS*

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Abstract

One option to upgrade Beijing Electron Positron Collider (BEPC), namely BEPCII, is to adopt multi-bunch collision in a single ring with a pretzel orbit. Thus 4 horizontal and 2 vertical electrostatic separators are needed. They have large contribution to the impedance budget of the storage ring. In this paper, ways to minimize the impedance of the separators are introduced, and the primary results of 3D modelling are presented.

1 INTRODUCTION

Beijing Electron Positron Collider (BEPC), a single ring e^+, e^- collider serving for both high energy physics experiments and synchrotron radiation application, has been well operated for over 10 years since it was put into operation in 1988. To upgrade the luminosity of BEPC by more than 10 times, known as BEPCII[1], is considered as a practical and economical way to continue exploring the rich physics at J/ψ energy range and has been approved as the future project in the coming years at IHEP. A baseline design of the accelerator to realize the increment on the luminosity is to adopt multi-bunch collision with pretzel orbit in a single ring meantime to reduce the β_y^* from the present value of 5cm to 1.0~1.5cm. The schematic layout of the pretzel orbit is as shown in Fig.1 and the main parameters of the storage ring are listed in Table 1.

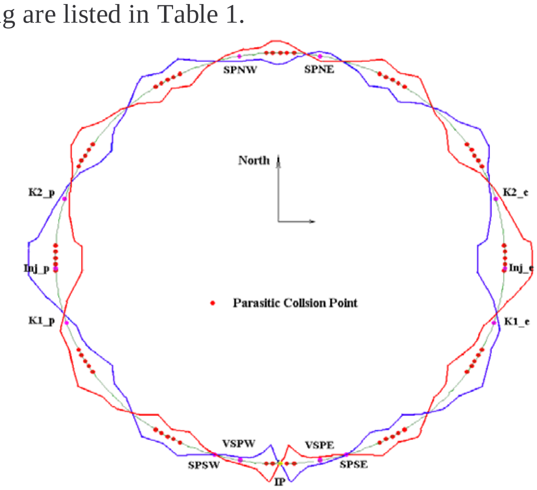

Figure 1: Schematic drawing of the pretzel orbit for e^+ and e^- beams in BEPCII.

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The pretzel orbit lies in the horizontal plane and is anti-symmetric with respect to the diameter that includes the IP. Thus two horizontal separators (SPNW, SPNE) located symmetrically around the present north interaction point of BEPC (NIP) are needed to yield the pretzel orbit. The horizontal betatron phase advance between each separator and NIP is matched to $\pi/2$, so an adjusting of the separator voltage brings the two beam into collision at the south IP while preserving their separation elsewhere. A pair of horizontal anti-symmetrically powered separators (SPSW, SPSE) located symmetrically around the south IP with betatron phase advance of 2π between them is used to adjust the crossing angle of collision. The pair of vertical separators (VSPW, VSPE) is used for the separation of beam orbit at the IP during injection.

Table 1: The main parameters of BEPCII in comparison with BEPC at J/ψ energy range.

Parameters	BEPCII	BEPC
Energy (GeV)	1.55	1.55
Circumference (m)	240.4	240.4
β_x^*/β_y^* (cm)	90/1.5	120/5.0
Tune(ν_x/ν_y) ν_s	6.58/7.64 0.067	5.8/6.7 0.02
No. of separators (vertical/horizontal)	2/4	2/0
Bunch number	2×6×3	2×1
Bunch current (mA)	16	22
Bunch length (cm)	~1.0	~5.0
Impedance $(Z/n)_0$	~0.2	~4.0
Crossing angle (mrad)	±5.5	0
Beam lifetime (h.)	~2.9	6-8
Lum. ($10^{31}cm^{-2}s^{-1}$)	38	0.5

There are 6 separators in total in the BEPCII single ring scheme, which are main sources of impedance. From table 1, to suppress the bunch length to about 1cm at bunch current of 16mA, the impedance should be well controlled, say $(Z/n)_0<0.2\Omega$. Study [2] has been carried out to design separators with low impedance. We can refer to the CESR experience [3] to reduce the loss factor of the separators by introducing ground electrode to confine the electromagnetic fields that travel along with the bunch between the electrodes so as to reduce the energy loss of the beam, and also tapering the connection between the vacuum tank and the beam pipe. It's helpful too that the high voltage electrode (plate) be shaped with tapered ends and tapered thickness [4], as that sketched in Fig. 2, since the tapering would minimize the microwave generation.

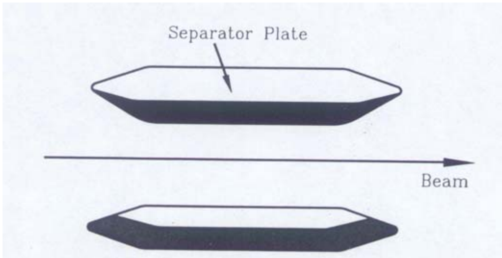

Figure 2: Schematic drawing of the metallic plates with tapered ends.

The physical design of the separator is described in detail in [2]. In this paper focus is on the calculation of the impedance of separator using MAFIA [5] code. The simulation method and result are reported.

2 MODELING OF HSP AND VSP

2.1 Simplified model

The length of each separator is about 2.6 meters, and the radius of the vacuum tank containing the high voltage electrode is about 0.22m. Thus, to calculate the wake potential generated by 1cm bunch, the number of meshes is too large. However, due to the symmetry of the structure, we can use 1/4 solid model as the first step of simplification.

Since it is the wake filed generated at the discontinuous structures that mostly affect the longitudinal motion of the bunch, the tapering part between the vacuum tank and the beam pipe dominant the impedance. To verify this, we have calculated the wake potential of a 4cm bunch (to reduce the mesh number) in difference cases by varying the length of the high voltage electrode. The results are almost the same when the length is changed from 0.2m to 2.0m, as shown in Fig. 3. So in MAFIA simulation we can build the 1/4 solid model with 1/10 length of high voltage plate instead of the full structure of the separators to save computer memory and CPU time.

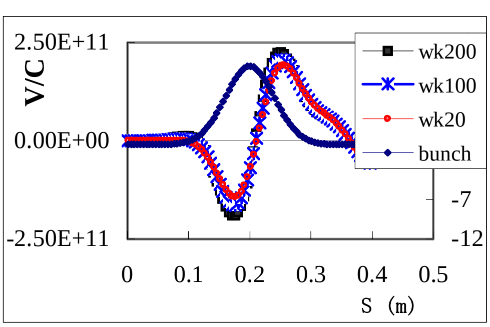

Figure 3: Wake potential vs length of the high voltage plates, wk200, wk100, wk20 refers to its length of 20cm, 100cm and 200cm, respectively.

2.2 Indirect method

In MAFIA calculation, to avoid the numerical noise, the indirect method is preferred by integrating the wake field generated in a cavity-like structure. But in the separator case, the electrode intrudes into the beam pipe. Though the direct method can be used, an alternate way [6] is by introducing artificial beam pipes at the ends to convert them to cavity-like structure. Then the indirect method is applied twice, one on the structure with the electrodes as shown in Fig. 4(a) and the other without the electrodes as Fig. 4(b), to obtain the wake field by subtraction. Fig. 5 shows the subtraction result of the wake potential of a Gaussian distribution bunch with σ_0=1cm due to the vertical separator. The wake potential shows most resistive with small inductance. For horizontal separators, the wake potential shows the similar property.

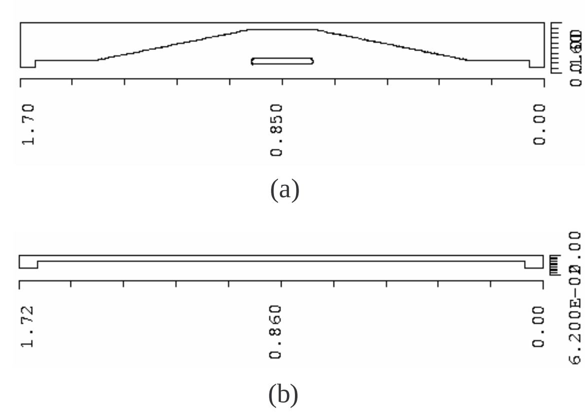

Figure 4: The two cavity-like structures used to get the wake field by subtraction. (a) with electrode, (b) without electrode.

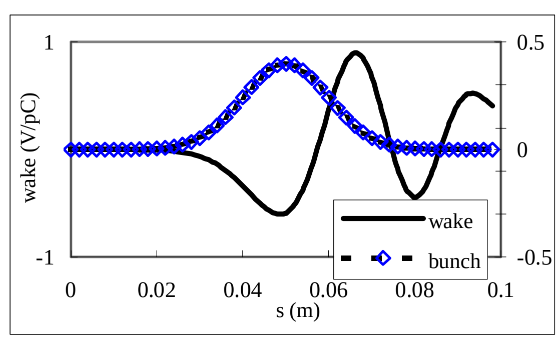

Figure 5: Wake potential of a σ_0=1cm bunch.

3 PRELIMINARY RESULT

To study the effect on reducing the longitudinal broadband impedance by importing the ground electrodes and 3D tapering the high voltage electrodes, simulation has been done in the cases of with no ground electrodes (g.e.), with g.e., and with both g.e. and 3D tapering of the electrodes, respectively. Primary results of the vertical and horizontal separators have been obtained. The comparison between the results of the vertical separator in the above 3 cases is listed in Table 2.

Table 2: Impedance of VSP.

	L (nH)	kl (V/pC)
No tapering, no g.e.	8.6	1.05
Partially tapering +g.e.	3.8	0.55
3D tapering + g.e	1.93	0.25

From Table 2, it can be seen that the loss factor is halved due to the ground electrode. Another half reduce of loss factor comes from the 3D tapering of the voltage plate. The result of the horizontal separators shows the similar property, as Table 3.

Table 3: Impedance of HSP.

	L (nH)	kl (V/pC)
No tapering, no g.e.	13.9	1.02
3D tapering + g.e	2.59	0.38

The HOM power generated by the beam can be calculated as,

$$P_{HOM} = k_l (eN_e)^2 n_b f_{rev} = k_l I_b{}^2 n_b / f_{rev}$$

where N_e is the electron number in a bunch, I_b the bunch current, n_b the bunch number, f_{rev} the revolution frequency. In BEPCII case, I_b=16mA, there are 6×3 bunches for e+, e- respectively, so the HOM power is more than 2kW. Thus, microwave absorber (ferrite or SiC) should be adopted, which has been included in the design [2]. Previous study [7] showed that resonant modes may be generated in the separators, ways to extract these modes effectively have been also considered [2].

4 CONCLUSION AND DISCUSSION

It's an effective way to reduce the impedance of separators by importing the ground electrode and 3D tapering the high voltage electrode. However, the inductance is still larger than expected. Optimisation of the width of high voltage plates, the shape of the ground electrode and the tapering at two ends are still under way. For the vertical separator, SR may hit on the ground electrode if it's introduced, so an alternative way should be investigated to reduce impedance while meantime to shield the SR to an acceptable level. The possible HOM trapped in the vacuum tank is being studied. If the R&D work continues, a prototype that has the similar shape of the separators will be made to measure the impedance on mockup so as to verify the calculation and optimise the design.

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