

IMPEDANCE STUDY FOR A SLOTTED-PIPE KICKER MODEL

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ABSTRACT

This paper introduces the principle of a new slotted pipe kicker for upgrading BEPC, which is made by using vacuum pipe itself with proper slits as current conductors. The wakefields of the present kicker and the new slotted-pipe one are compared, and the typical results show that the wakefield of the new one is greatly decreased. Its impedance and the loss factor are studied in detail by using analytical method and modelling of 3-D MAFIA. Calculations present that the inductance of such new kicker is about 0.06nH.

1 INTRODUCTION

For further luminosity upgrading of BEPC(Beijing Electron Positron Collider), several approaches were proposed, among which Mini-Beta insertion was the most promising. However, the crucial factor to realize this scheme is the reduction of the bunch length from the present 6 cm to 3 cm. Obviously, finding an approach to shorten the bunch length becomes an important subject. It is understood that decreasing the beam impedance is one of the approaches for shortening beam length. According to our measurements, four injection kickers and forty bellows cavities contribute more to the total impedance. Thus, it is necessary to develop new injection kickers to replace the current conventional air-coil injection kickers.

2 PRINCIPLE OF THE NEW SLOTTED-PIPE KICKER MODEL

The present kicker in BEPC are the conventional air-coil magnet which has two metallic current plates surrounded by a large vacuum tank. Experiment shows that the impedance of this type of kicker comes from the tapers and the two ends of metallic plates. The new slotted-pipe kicker model is principally based on the vacuum pipe itself with properly arranged slits as current conductors. Its schematic diagram and cross section are shown in Fig.1. These two parallel conductors on both sides of the beam axis form an inductive loop, and the six slits between the conductors are connected to ground, which is one of the most important features different from the current injection kickers. Due to the racetrack beam pipe, the central metallic plates are the nearest to the moving beam and carry most of image current. Obviously, the impedance of this new kicker is reduced significantly.

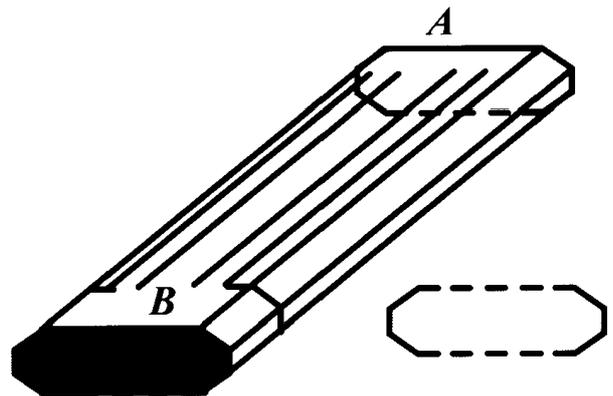


Figure 1 Schematic map of the slotted-pipe kicker

3 WAKEFIELD COMPARISON BETWEEN THE PRESENT KICKER AND THE NEW ONE

One can simulate the wakefields of the new slotted-pipe kicker model and the present one by using 3-D code MAFIA, as shown in Fig.2 and Fig.3, respectively.

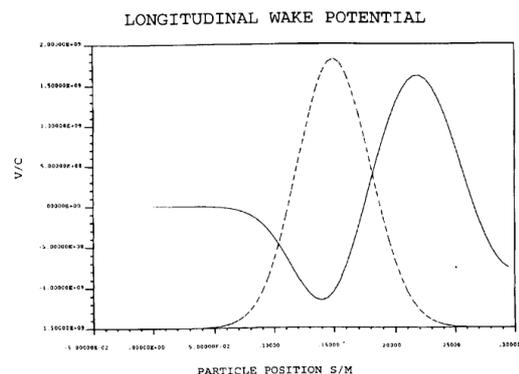


Figure 2 The wakefield of the slotted-pipe kicker

Evidently, the wakefield of the new kicker model is reduced about one order of magnitudes. One can also find from the plot of the wakefield that the new kicker is inductive. The loss factors of the two kickers are also compared, as given in Table 1.

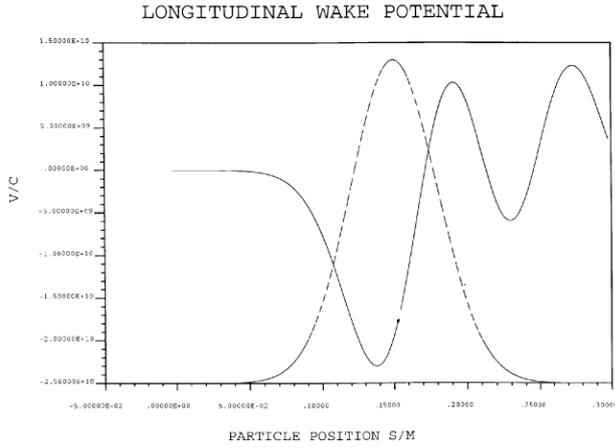


Figure 3. The wakefield of the present kicker in BEPC

Table 1. the loss factors of the two kickers with bunch length, k_1 and k_2 represent the loss factors of the present kicker and the new one, respectively.

σ (cm)	k_1 (V / PC)	K_2 (V / PC)
1	6.98×10^{-2}	2.88×10^{-3}
3	1.01×10^{-2}	5.59×10^{-4}

4 IMPEDANCE CALCULATION

One can see in Fig.1 that the complete beam pipe A and B are connected with the two ends of the vacuum tank, respectively. Thus, its contributions to the impedance come from the eight longitudinal slots and the two transverse slots for separating high voltage from the ground. Supposed that the cross talk among these slots is neglected, hence, its total impedance is the summation of these longitudinal slots and two transverse slots. In order to calculate the impedance of the eight longitudinal slots, one can approximate the racetrack pipe as the circular one, which has the radius of the short semi-axes for upper estimation. Applied for Kurennoy's formula[1], the impedance of the slot can be written as

$$Z(\omega) = -i \frac{Z_0}{C} \frac{\alpha_e + \alpha_m}{4\pi^2 b^2} \quad (1)$$

where α_e, α_m are the electric and magnetic polarizabilities of the slots, respectively, b the radius of the beam pipe. Notice that this formula only applies for such slot whose length l and width w are smaller than the radius of pipe b . For the slotted-pipe kicker, its length l is much larger than the radius of the beam pipe b .

Clearly, our case violates the above condition. However, one can extend the formula to the condition, length l larger than the radius of pipe b . (w is still smaller than b)[3]. Study shows that the impedance of the slots oriented in the beam only comes from the ends of the slots, not from their lengths. For a round-end slots oriented in the beam,

$$\alpha_e + \alpha_m = w^3 \left(0.1334 - 0.05 \frac{w}{l} \right). \quad (2)$$

Substituting the actual dimensions of the longitudinal slots, i.e., four slots with 7mm width and another four slots with 9mm width, one can obtain their inductance $L=0.004\text{nH}$ (pessimistic value). The impedance of its two transverse slots can be estimated as follows

$$\alpha_e + \alpha_m = \frac{\pi}{3} \frac{1}{24 \left(\ln \frac{8l}{w} + \frac{\pi t}{2w} - \frac{7}{3} \right)} \quad (3)$$

where electric polarizability is smaller than the longitudinal magnetic polarizability by an order of magnitude and thus can be overlooked. Here, due to the elliptical pipe, we also make it equivalent to the circular pipe which has radius $r = \sqrt{ab}$, where a and b are the short and long semi-axes of the elliptical pipe. For convenient calculation, one can replace the circular pipe

by the regular octagon with side $d = \frac{\pi}{4} r$, where three

sides are not cut into slots. In other words, two transversal and three tilted slots of the octagon are cut into slots according to the dimensions of the kicker model. The three tilted transverse slots can be equivalent to one and a half transverse. Thus, there are three and a half transverse slots, and each slot is 10mm in width and 33 mm in length. According to the equation(3), one can easily obtain their inductance $L=0.056\text{nH}$. The total inductance of this slotted-pipe kicker is the additivity of the eight longitudinal slots and two transverse slots, i.e., $L=0.06\text{nH}$. One can check the above analytical result by extracting the inductance from the wakefield obtained by the 3-D MAFIA, as shown in Fig.2., $L=0.052\text{nH}$, which agrees roughly well with the analytical result.

5 CONCLUSION

The slotted-pipe kicker has smaller impedance than that of the present kicker in BEPC. At the low frequency, this new kicker behaves inductive characteristics.

6 ACKNOWLEDGEMENTS

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