DESIGN OF LOW IMPEDANCE ELECTROSTATIC SEPARATORS FOR BEPC II

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Abstract

The multi bunch train collision is adopted in BEPC II. There are 4 horizontal electrostatic separators in the main ring to generate close-orbit displacement as "pretzels" which allow the electrons and positrons to be stored in the same vacuum chamber simultaneously without unwanted destructive collisions. In the separator the beam current (576mA) and the gap voltage (220 kV) are both very high. So there are five key problems that must be handled well: To reduce the beam impedance and loss factor; To absorb the high order modes (HOMs); To reduce the leakage of RF EM field; To extract the heats due to the HOMs losses and the SR power; To reduce the spark rate. Their analysis and the solutions are presented in this paper.

1 CONSIDERATIONS OF IMPEDANCE

The separator always presents relatively higher beam impedance comparable with a single RF cavity cell. The frequency region of HOMs for BEPC II separator covers from f_l=57.7MHz to f_c=408MHz. When a bunch passes through the separator, it leaves energy behind in the form of RF EM field. This field energy generates local RF heating which might reach a few kW. So the impedance must be reduced as low as possible. The basic idea is to make the beam image current can pass through the separator as smoothly as possible.

The design of impedance is based on the design of CESR separator and DELTA slotted-pipe kicker. The ground electrodes are added into the zero potential planes to reduce the impedance, as well as by tapering and contouring the vacuum chamber outer wall as shown in Figure 1. The ground electrodes are part of the original vacuum pipe and they carry the dominating fraction of the mirror currents travelling with the beam along the vacuum pipe. The fine electrical contact and smooth interior between both ends of the ground electrodes and the vacuum chamber are extremely important and should be done well. The transition curve of ground electrodes at both ends along the longitudinal direction is shown in Fig 2. The width of HV electrode and the diameter of vacuum tank should be reduced as possible. The shape of the end parts of HV electrode is tapering and also smooth. The electric field plot and distribution of horizontal separator are shown in Figure 3 and Figure 4.

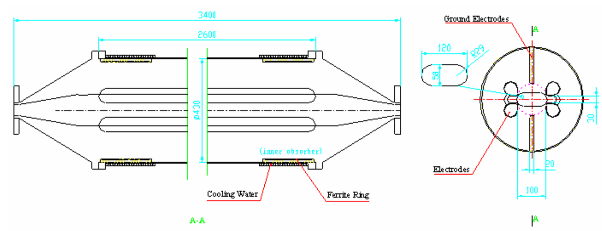


Figure 1: Vertical section of horizontal

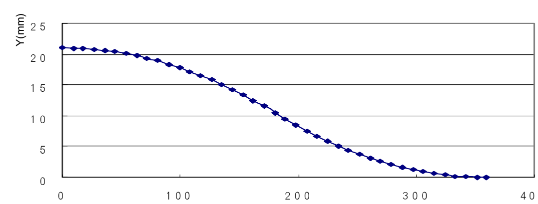
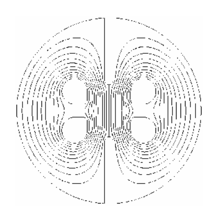


Figure 2: The end transition curve of ground electrodes



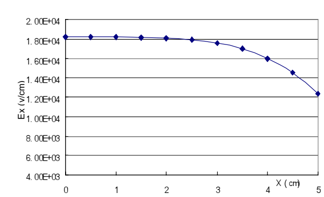


Figure 3: The equipotential line plot of separators

Figure 4: The electric field distribution of separators

2 ABSORPTION OF BROAD BAND RF POWER

2.1 Absorbers

Although various methods to reduce the impedance and the loss factor are adopted, there is still a great deal of HOM power in the separators. If there is no absorber, the RF field will build up internally to very high level and in case RF break down may occur. It is necessary to install broad band RF absorbers to absorb the unavoidable HOMs.

2.2 Outer absorber

The outer absorbers are located around the HV feedthrough and outside the vacuum tank of the separators. These absorbers are built up with ferrite tube and resistor to form a compound lossy transmission line. The resistor in series with HV inner conductor acts as a lossy transmission line. The role of ferrite is equivalent to a resister that also forms as a lossy transmission line. The equivalent circuit of the absorber is shown in Figure 5.

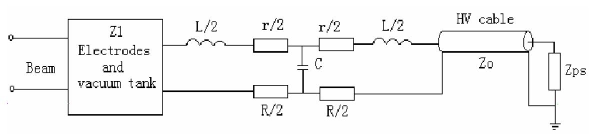
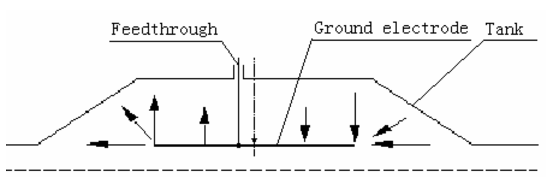


Figure 5: Equivalent circuit of outer absorber

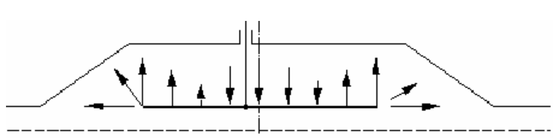
Z_1 is impedance at electrode and vacuum tank. L is inductance between inner and outer conductors. C is capacitance between inner and outer conductors. r is a resistor in series with inner conductor. R is equivalent resistor of ferrite HOM loads. Z_0 is impedance of HV cable. Z_{ps} is impedance of power supply.

2.3 Increasing the absorption efficiency of the outer absorber

By means of Using the asymmetrical joint between feedthrough and HV electrode from the middle point of the electrode, make both odd and even order modes TEM waves can be coupled to the HV cable outside the separator and damped as shown in Figure 6. This may increase the efficiency of HOMs coupling and absorption.



(a) Field distribution of TEM wave when n=1, the field is zero at the middle



(b) Field distribution of TEM wave when n=2, the field is max. at the middle point

Figure 6: Possibility of coupling to feedthrough at the middle point of electrode for odd and even modes

2.4 Inner absorber

The inner absorber consists of a ferrite ring and a copper bushing. It is placed on the inner surface at the ends of vacuum tank as the HOM loads that can transform the wake field energy into heats directly. It is shown in Fig. 1.

3 THE DESIGN OF EMC

The design of EMC is considered in two aspects:

How to absorb the RF energy?

How to prevent the RF fields from leaking out of the system?

The shielding tasks are carried out by the designs of feedthrough and absorbers.

The key points on design of feedthrough and outer absorber are follows:

- The coaxial structure of absorber should be chosen.
- The broad band absorption ferrite should be chosen and also be designed as a long and thin tube with thick wall.
- To add high conductivity layers in the absorption material.
- To adopt double layers of absorption materiel with different μ_r. see Figure7.
- All of the holes and ports on the box of absorber are designed as cut-off wave-guides, referring to Figure7.
- At all of the link planes of the box of absorber add the electromagnetic gaskets.

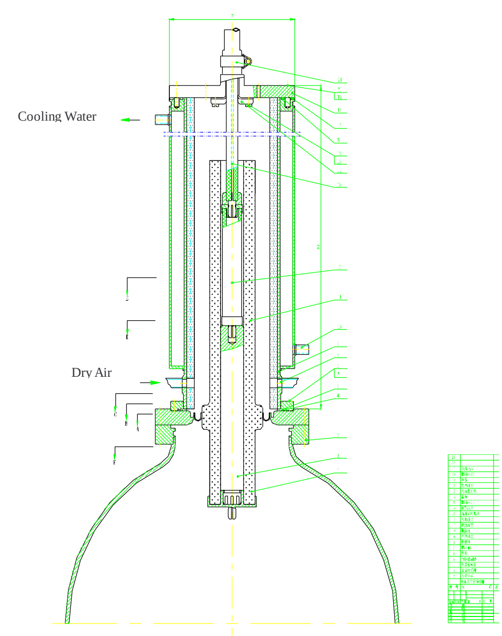


Figure 7: Feedthrough with outer absorber

Above technologies were used in the modified absorber of BEPC separator. The noise level was reduced sharply from 800mV to 3 mV. Especially for the low frequency range the noises were attenuated 60-99dB.

4 HEATS AND EXTRACTION METHODS

The heat in separator results from synchrotron radiation striking and high order modes losses in absorbers, electrodes, feedthroughs and vacuum tank.

Table2: Extraction methods of heat

Heats	Methods of extraction
In outer absorber	(1).Water cooling (2).Forced air-cooling
In inner absorber	Cooler made of copper tube
On the electrodes	Dielectric liquid CFC113

5 METHOD TO REDUCE THE SPARK RATE

Sparking is also a very important problem. SR may cause sparks in some case. Spark often causes beam loss. So does scattered SR.

Methods to reduce the spark rate:

- HV feedthroughs and supporters of electrode are arranged under the electrodes to avoid the SR.
- Using masks to obstruct the SR.
- To limit the maximum field strength on the ends and the edges of electrodes.

6 CONCLUSION

The requirements imposed on the electrostatic beam separators, namely operating at high field in the environment of the beam and the associated electron and ion clouds, are technically very demanding. This technology can only be acquired by practical experience. A prototype separator needs to be built and operated both on the bunch and in BEPCI as early as possible. Separators are not needed in a double-ring design.

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