PRELIMINARY DESIGN OF FAST KICKER SYSTEM FOR BEPC II

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Abstract

With in BEPC II injection system there are two sets injection lines in storage ring each consisting of a pair of kicker magnets and one Lambertson magnet for e^+ and e^- injection respectively. The incoming beam is injected horizontally inside the storage ring. The linac provides the short pulsed bunch train of 3 micro bunches. There are six e^+ and six e^- bunch trains countermove in a same ring. The single bunch train injection is chosen. The duration of bunch train is 16ns. The kick of field is 130 Gauss-meter. The type of lumped ferrite inductance magnet with ceramic vacuum chamber is chosen. Per magnet consists of four modules each of 30 cm long, The field strength of magnet is 108 gauss. Excitation current is 631 A .The pulse field of magnet is a trapezoidal wave with duration less than 110ns, rise / fall time of K1 and fall / rise time of K2 is 33ns / 50ns respectively. The lumped LC network with impedance of 30ohm and voltage of 38kV is chosen as a pulser. The stray inductance of lead is controlled to be small enough by an air-insulated coaxial construction. Field rise time is reduced by the compensating capacitance and the fall time is reduced by second switch and saturable reactor. A ZVS PWM type of high voltage power supply is chosen as the charger for PFN. The details are described in this paper.

1 KICKER MAGNT

1. 1 Comparative of magnet type

The main features of kicker magnet are very fast rise and fall time of field and low beam impedance. The slotted–pipe magnet is simple and cheap, but field gain is very low. So the current of magnet and the voltage of the generator are all very high and the rise time of current is long. The travelling wave magnet is the best for the rise and fall time of field, but it is very complex. It appears better that the lumped ferrite inductance magnet can operate in air and also give the fast rise time and need a lowest voltage. In order to reduce the beam impedance the ceramic vacuum chambers with metallic coating are needed for the ferrite magnet.

1. 2 magnet

A lumped ferrite inductance magnet is chosen. A cross section of the magnet is shown in Figure1. It is constructed with Nickel-Zinc ferrite around a ceramic vacuum chamber. The type of CMD-5005 ferrite may be chosen. Per magnet is cut into four separate modules each of 30cm long, with Lm the inductance of 750nH to reduce the transmission time in magnet length. The field plot and the distribution of magnet without vacuum chamber are shown in Figure 2 and Figure 3.

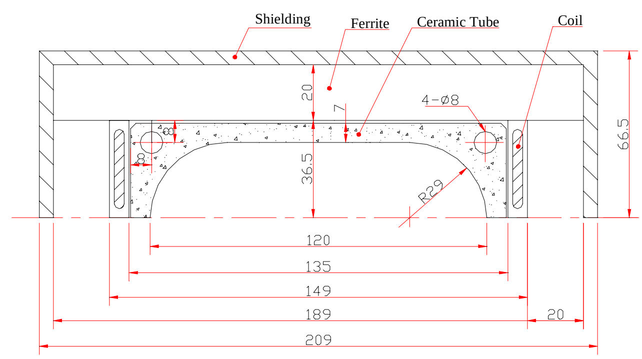

Figure 1: Cross section of ferrite window magnet

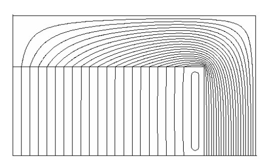

Figure 2: Field plot of magnet

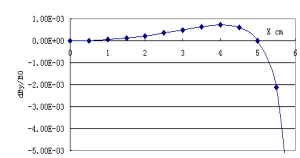

Figure 3: Field distribution of magnet without vacuum chamber

2 CERAMIC VACUUM CHAMBER

2. 1 Structure of the ceramic vacuum chamber

The ceramic vacuum chamber consists of a ceramic tube, two parts of transition metal and two flanges, it is shown in Figure 4. There is a metallic coating on the inner surface of ceramic beam pipe. It serves to carry the beam image current through the kicker system smoothly, to minimize the high-order mode losses in this region, as well as to shield against the electromagnetic field of the beam, while still allowing the pulsed magnetic field to penetrate the tube with minimum attenuation. There are four water holes in the wall of ceramic pipe to extract the heats generated by the beam image currents and the eddy currents inducted by the pulsed magnetic field in the coating. The ceramic pipe is also hit by synchrotron light. The most dangerous regions are at the transition metal of both ends of ceramic pipe shown in Figure 4. Masks are used to obstruct the synchrotron lights to protect the transition metal parts.

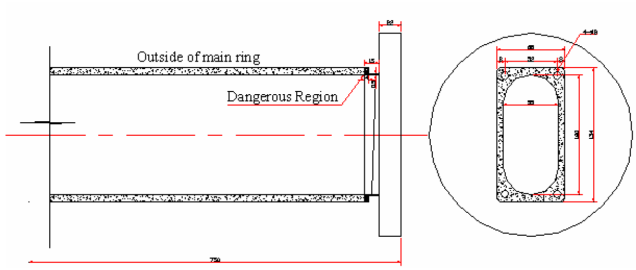

Figure 4: The diagram of ceramic vacuum chamber

2.2 Calculations of coating

The calculated results of power dissipation due to image currents and eddy currents are shown in Figure 5. The optimum resistivity of coating is about 0.235Ω /sq from the point of view of power loss. But the field penetration time through the coating τ is 130ns, because the resistivity is low. In this case, the field rise and fall time will be too long.

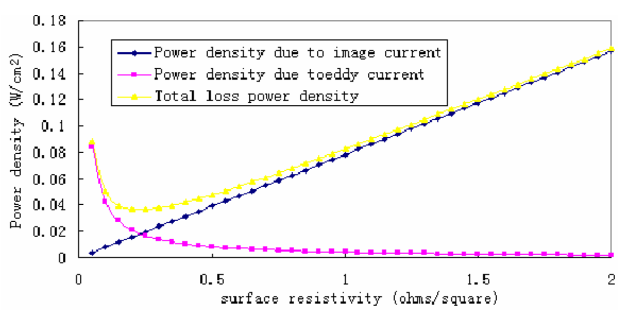

Figure 5: The calculated results of power density of loss in the coating of ceramic chamber

The penetration time τ is related to R_{sq}, the surface resistivity of the coating.

$$\tau = \frac{\mu_0 r}{2R_{sq}} = 6.28\,[\text{ns}]\ r\ [\text{cm}]/R_{sq}\ [\Omega/\text{sq}]$$

Here r is the equivalent radius of ceramic chamber. R_{sq} depending on the material and thickness of coating. For example, assuming that Titanium is chosen as coating material. The calculated results are listed in Table 1.

Table 1 Calculated results of coating.

R_{sq} (Ω/sq)	0.235	1	3.05	6.1
τ (ns)	130	30.6	10	5.02
t_c (μm)	1.68	0.42	0.1377	0.06885
P_{id} (w/cm^2)	0.019	0.0766	0.234	0.46716
P_{ed} (w/cm^2)	0.009	0.0023	0.0008	0.0004
P_t (w)	50	181	538	1073
Q l/min	0.15	0.52	1.5	3.1

τ is penetration time, t_c is thickness of coating, P_{id} is power density due to image currents, P_{ed} is power density due to eddy currents, P_t is total power of loss, Q is volume of cooling water.

The influence of the resistivity of the coating on the pulse shape is shown in Figure 6. If the resistivity R_{sq} is chosen to be 6Ω /sq. τ is about 5ns. The requirement of field rise time can be met. The sum of power dissipation is about 1073W each ceramic tube. This volume seems very high. The longitudinally striped coating is adoped. In this case, the problem of field rise time and dissipation power both can be solved.

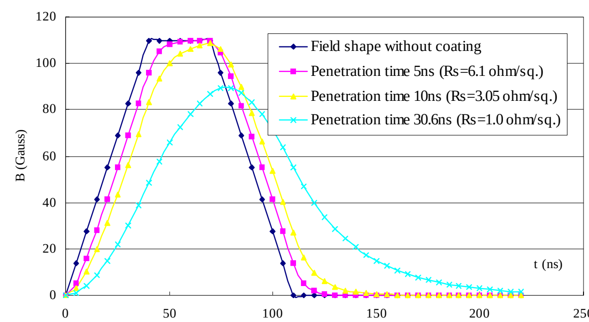

Figure 6: Influence of resistivity of coating for field shape

3 PULSE GENERATOR

A Pulse forming network with n_c cells and with L_c and C_c the cell inductance and capacitance respectively, the pulse duration is

$$T_0 = 2n_c\sqrt{L_c C_c}$$

If the pulsed field waveform is a trapezoidal shape, then n_c>1. Since the pulse duration is short, L_c and C_c are all very small. The inductance of lead seems large compared with L_c. So, it is a tradition that the cables are employed as PFL for a short pulse.

We may consider lumped parameter for pulse forming network as another option. As the pulse duration of current is very short, C_c and L_c the capacitance and inductance per cell are all small. Since L_t=$n_c L_c$ the total inductance of generator is also not very large, we may assume that L_t is provided by an air-insulated coaxial construction. The inductance and capacitance of the air-insulated coaxial body are:

$$L = 2\times10^{-7}\times\ln(d_2/d_1)\times l_g \ \text{(H)}$$

$$C = \frac{\varepsilon_r \cdot \varepsilon_0 \cdot l_g}{\log(d_2/d_1)} \ \text{(F)}$$

Where d_1 and d_2 are the inner and outer conductor diameters respectively and l_g the length of coaxial construction. By increasing d_2/d_1, we can get the required value of L_t. Though the C will become very small at the same time, there is no problem. The lumped condensers are inserted between the inner and outer conductors at the intervals to form a LC ladder network. The stray inductance of lead is farthest reduced, but the ineluctable inductance of lead is used in this construction. The primary assembly drawing is shown in Figure 7. The equivalent circuit is shown in Figure 8. The type of CX1154 thyratron is chosen as switch and the cathode is grounded. The current waveform is shown in Figure 9.The calculated results of current are rise time of 28ns, fall time of 41ns and flat top of 30ns.The requirements of K1 would be met. The field falls from top to 8% in time of 33ns. It closes to the field fall time required of K2. The fall time can be reduced further by Saturable reactor in series with main switch. The flat top width of pulsed field can be adjusted by second switch.

The features of this design are:

1. Most of HV coaxial cables and their connectors can be economized.
2. The construction of PFN will be very simple.
3. There are more methods to adjust the current waveform.
4. PFN's volume is much smaller than PFL.
5. As the structure of PFN is a coaxial body, a same tube can covers the thyratron, the LC network and the terminator. It favors the designs of EMC and matching impedance.

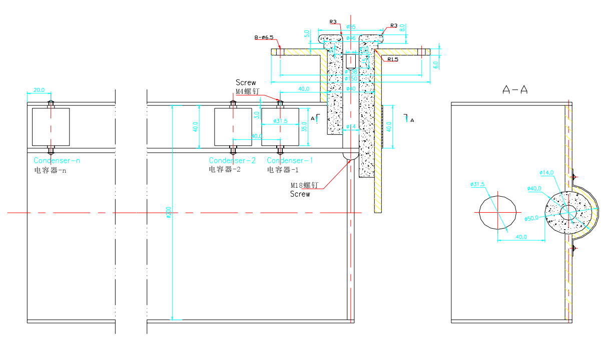

Figure 7: Lumped LC ladder network (PFN)

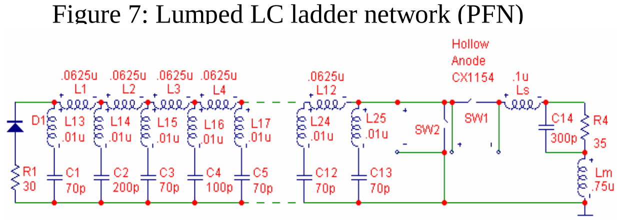

Figure 8: The equivalent circuit of the PFN

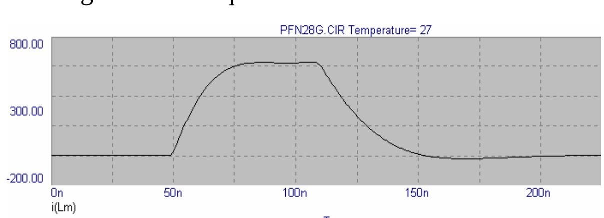

Figure 9: Pulsed current waveform of magnet

4 CHARGER

The charger is a 40kV DC charging power supply for PFN. The PWM ZVS converter is adopted. Its features show high efficiency, high stability and reliability, low price and reduced volume. The EMI will be weak because the ZVS.

5 CONCLUTION

We prefer the ferrite window magnet. Although its connatural rise time is slower than travelling wave magnet, it can come true for fast rise time after taking some measures. Lumped LC ladder network with second switch and saturable reactor can meet the requirements of field rise and fall time.

6 ACKNOWLEDGEMENTS

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