Magnetic Performance of Prototype Bump Magnet for the SPring-8 Storage Ring

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1. Introduction

The 8 GeV electron or positron beams from the synchrotron through the transport beam line are injected into the storage ring with septum magnets and two pairs of bump magnets situated on both sides of the injection section (Fig. 1).

In the off-axis mode operation, the amplitude of the bump orbit at the injection point is 16.2 mm from the reference orbit and the injected beam is guided at 24.5 mm from the reference orbit. To perform on-axis injection at the storage ring commissioning, the amplitude of the bump orbit is tunable up to 24.5 mm.

The design of the bump magnets and their power supplies has been completed. We have constructed a prototype bump magnet and a power supply and measured its electrical and magnetic performances.

2. Design of Prototype Bump Magnet

2-1) Magnet Core

A cross sectional view of the prototype bump magnet with a ceramic chamber is shown in Fig. 2. The magnet core having C-shaped structure is made of 0.1-mm-thick laminations stamped from thin silicon steel plates and welded together. The plates are insulated each other by an inorganic coating. The core has higher magnetic saturation field and the manufacturing is easier than that by the use of a ferrite core. The frequency characteristics of the laminated core are not as good but sufficient for our purposes. Further, these characteristics are useful for the suppression of magnetic field oscillations which are caused by reflection of the current between the power supply and the magnet. The end plates are made of stainless steel.

2-2) Structure of the Coil

When the bump magnet is excited, the applied voltage between the coil conductor and the core becomes approximately 35 kV. Mica epoxy-resin insulation has a high stand-off voltage, is corona discharge-proof, with good mechanical properties and thermal stability.

The conductor is wound with a reconstituted mica tape of 0.13 mm thickness and thus a layer of about 3 mm thickness is formed. The surface of the layer is also wrapped with a semi-conducting tape. The end surface of the coil leaving the core is wrapped with high resistance tape. Finally the coil is impregnated with epoxy resin under vacuum. The coil made on this process can endure up to 120 kV of impulse voltage [1], and the bump coil can withstand the applied voltage even when the deterioration with use is considered. To minimize gap between the coil surface and the core, the coil is fixed tightly to the core by clamps.

2-3) Ceramic Chamber

A ceramic of a 99% Al_2O_3 grade was employed as material of the chamber. Ti was deposited onto the inner surface of the chamber.

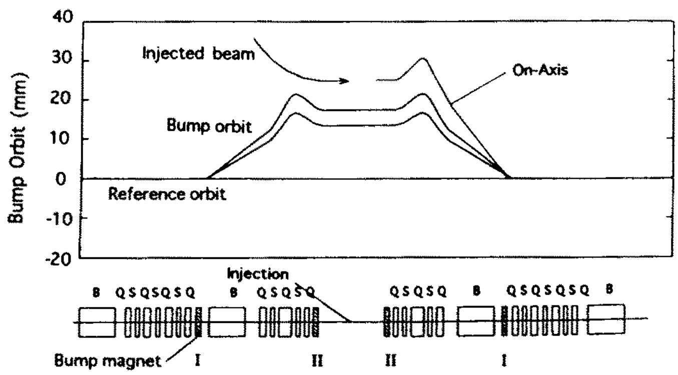

Fig.1. Envelop for the injected and bumped beam at the injection straight section.

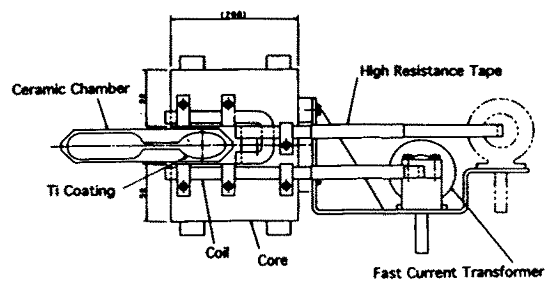

Fig.2. Cross sectional view of the prototype bump magnet.

2-4) Power Supply

The magnet was excited by a capacitor discharge circuit as shown in Fig. 3. The circuit produces half-sine-wave pulse of 6 μsec width by firing Thyratron.

The repeated stability of the peak current was within the accuracy of ±1%. Since the power supply and the magnet are located 20 m apart with each other, they are connected by two coaxial cables. A resistance and a capacitor for impedance matching are installed at the output terminals of the power supply.

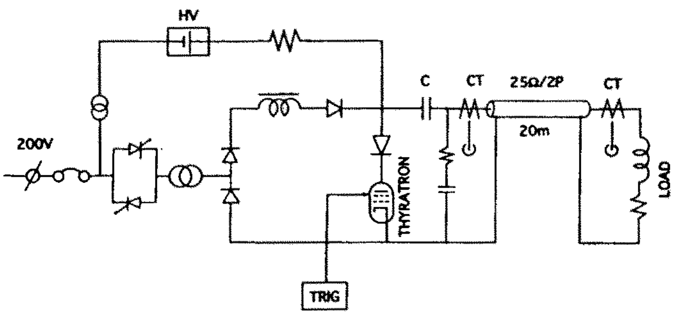

Fig.3. Diagram of the power supply.

3. Results of the Measurement

3-1) Methods of the Measurement

Magnetic fields were measured by a 5-turn search coil having a diameter of 8.3 mm, wound with 0.1 mm diameter copper wire. Magnetic fields were estimated by integrating the voltage induced in the search coil with a 8 bit digitizing oscilloscope.

3-2) Evaluation of the Insulation of the Coil

The maximum surge voltage on the magnet coil reaches about 35 kV. The coil withstood the voltage, but a glow corona discharge was observed at a certain point on the coil. The average resistance between the surface of the coil and the core was about 5 kΩ, but in the case where the glow corona discharge is observed, the resistance was above 100 kΩ. The cross section of the coil and its equivalent circuit are shown in Fig. 4.

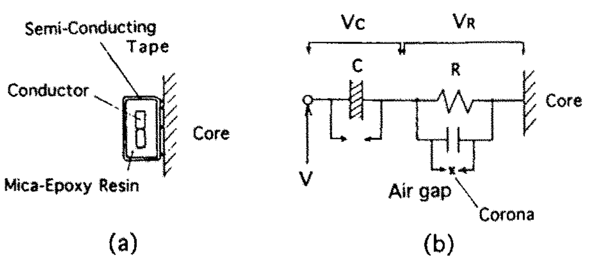

Fig.4. (a) Structure of the coil, and (b) its equivalent circuit. C: Capacitance between the conductor and the semi-conducting tape. R: Resistance of the semi-conducting tape. Air gap: the no contact point between the semi-conducting tape and core.

High resistance makes long impressed voltages between the coil and the core. The phenomena seems to be a cause of the corona discharge.

The corona discharge disappeared when the semi-conducting coat was painted on the surface of the coil. To avoid the discharge, the surface of the coil must have a proper resistance.

3-3) Field Measurement

Figure 5 shows the relation between the peak current and magnetic field with and without the chamber in the magnet gap. The magnetic field increases proportionally with the peak excitation current. The dotted line shows the calculated magnetic field in the case of a static field. The strength of the field decreases compared to the static calculation results because of the frequency characteristics of the core and the eddy currents induced in the metal coating of the ceramic chamber.

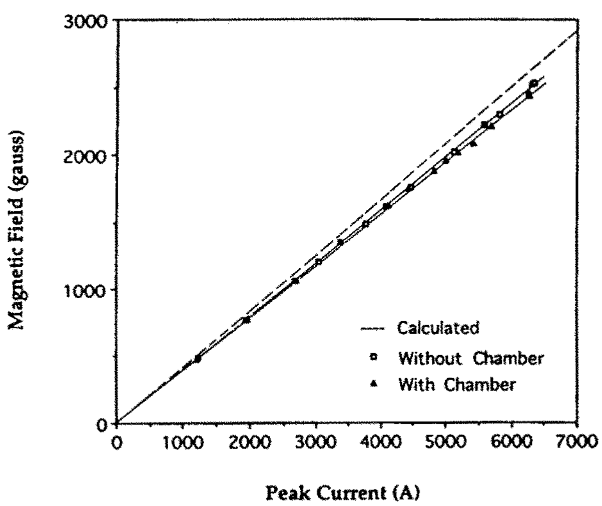

Fig.5. Relation between peak current and magnetic field.

4. Conclusion

The prototype of the bump magnets for the injection of the Spring-8 storage ring was constructed and tested. There are some problems to be improved slightly but experimental results that satisfy roughly the specification of the bump magnet were obtained. The construction of the actual bump magnets and their power supply are in progress.

References

[1] Technical report of the Institute of Electrical Engineers of Japan, **96**, 45 (1970).