ABORT SYSTEMS FOR THE KEKB

N. Iida, T. Mimashi, H. Nakayama, K. Satoh, KEK, Tsukuba, Ibaraki 305-0801, Japan
A. Tokuchi, S. Naitoh, Nichicon Co., Kusatsu, Shiga 525-0053, Japan

Abstract

A beam abort system is imperative from a requirement of radiation safety and saving sensitive components in BELLE detector. This system is composed of kicker magnets, a Lambertson septum magnet and a beam dump. The kickers are composed of two parts, horizontal and vertical ones. A single power supply with a single switching device excites both parts of kickers so that we can prevent either kicker from mis-firing. The kicker magnets are conventional windowframe type magnets with ferrite core. Actual waveforms of magnetic fields in ceramic vacuum chambers inside kicker magnets are measured.

1 INTRODUCTION

The KEKB accelerator is a high luminosity colliding machine for electron and positron. In the high energy ring(HER), electron beams of 8.0GeV are stored to a maximum current of 1.1A. While in the low energy ring(LER), positron beams with 3.5GeV are stored to a maximum current of 2.6A. Both rings are usually refilled once about two hours. The revolution period is 10μsec. Whenever beams are to be aborted for some reasons, they should be dumped into a special place for beam dump, which prevents spewing beams everywhere in the ring. Beam abort systems are installed both KEKB rings for the purpose above.

The beam abort system is composed of kicker magnets, a Lambertson DC septum magnet and a beam dump. The kicker magnets are pulse magnets which kick out the beam horizontally and vertically. The former is called the horizontal kicker and the latter the vertical kicker in this paper. Both of kickers are connected to the same power supply with one switching device so that we can prevent either kicker from mis-firing. Beams are kicked away horizontally from the ring by the kickers, then deflected downward by the Lambertson DC septum magnet and led into the dump prepared for beam abort. In this paper, a design of kicker magnets and power supply and the actual magnetic fields measured are presented.

2 KEKB ABORT SYSTEM

2.1 A fast rise time of kicker magnet

Fig. 1 shows the layout of the beam abort system of HER. Circulating beams are kicked away horizontally by horizontal kickers with a fast rise time, about 1μsec. The beams are passed through a Ti window at 12m downstream and then deflected about 100 mrad to the downward by the horizontal magnetic field of a Lambertson DC septum magnet and dumped to a dump. As mentioned above, because the beam abort systems are equipped for radiation safety and protection of BELLE detector, beams are never failed to put into the dump at the abort.

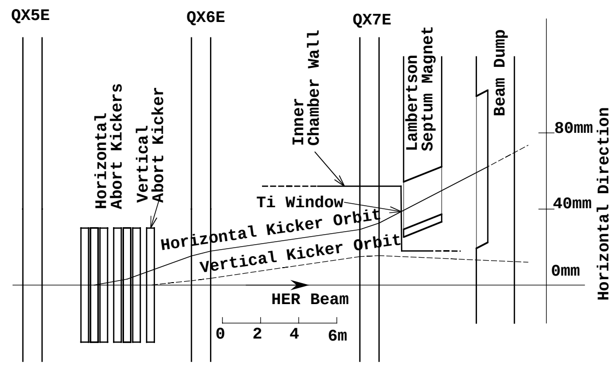

Figure 1: The orbit of aborted particles from HER.

We paid attention to two points below. One is that the rise time of horizontal kickers are made short as possible. It is about 1μsec now. If beams exist in the rise time of kicker magnets, they can not be led into the dump and scattered out somewhere in the tunnel. For this reason, KEKB beams have a gap of 1μsec in 10μsec of the beam revolution period.

2.2 Heating at the Ti window

Another one is a problem from heating at the Ti window. This is a more serious subject in LER whose beam current is higher. To avoid melting the extraction Ti window and the beam dump by the high beam current, the extracted beam cross section on the window is effectively enlarged by additional deflection with a vertical kicker having a slower rise time than 10μsec. Because the cross section of beam is very thin vertically and wide sideway, this vertical beam moving is effective to diffuse heat on the window. To enlarge this area more, the magnetic fields of horizontal kickers are ringed in an amplitude of $\pm 10\%$ after the fast rising kick. When beam with 2.6A passes through the window, the maximum heating reaches 660°C, where the beam size is 500μm in horizontal and 100μm in vertical.

A Lambertson septum magnet is a DC magnet which makes a horizontal magnetic field just outside the KEKB vacuum chamber without affecting the beam circulating in the ring. Field for both HER and LER is 1Tesla.

A beam dump is made of iron, lead and concrete surrounding them. It confines γ-rays and reduces the velocity of neutrons. The beam abort into the dump was confirmed

Table 1: Parameters of kickers for beam abort system

		HER-H	HER-V	LER-H	LER-V
E_{beam}	(GeV)	8.0	8.0	3.5	3.5
$B\rho$	(Tm)	28.02	28.02	12.34	12.34
Deflection Angle	(mrad)	-3.75	1.2	-1.93	1.4
Bl	(Tm)	10.5e-2	3.36e-2	2.38e-2	1.73e-2
Magnetic flux density	(T)	5.00e-2	9.61e-2	2.27e-2	4.94e-2
No. of turn×Current	(AT)	3584	8027	1625	4910
No. of turn		2	3	1	4
Current	(A)	3584	2676	1625	1228
Inductance	(mH)	5.7	8.64	4.4	11.6
Junction of Coils		3series-2parallel	1	3series	1
Gap	(mm)	90	105	90	125
Width	(mm)	160	176	160	170
Length of Ferrite	(mH)	900×2	300	900	300
Length of Ceramic Chamber	(mm)	1500×2	520	1540	520

by looking beam spot on a screen monitor at the entrance of the dump.

3 ABORT KICKERS

3.1 Kicker magnet

The kicker magnet in the abort system is of a purely inductance type and the structure is conventional windowframe ferrite core magnet. The ceramic vacuum chambers with a thin Ti conducting layer deposited on the inner wall are used. The layer thickness is chosen so that the dynamic magnetic field can pass through. Heat generated dominantly by the circulating beam is cooled down with water flowing through in the ceramic chamber wall. Details are reported in a reference [1].

Kicker magnets both for HER and LER have two types, horizontal and vertical deflections. Each parameter is listed in Table 1. One magnet unit with a ferrite core of 300mm long holds a ceramic vacuum chamber of 420mm long. The “3series” of an item “Junction of Coils” in the table expresses that the three unit of kicker magnets are connected in series and are excited by a single coil of 1500 mm. The parameters are given by the beam energy and deflection angles. Especially because the horizontal kicker magnets in HER should deflect high energy particles with a large angle, six units of kicker magnets are needed. To keep the rise time of the horizontal magnet fast, inductances of these magnets should be small as possible. As a result, the number of coil turns should be one or two, especially for HER magnets, where two “3series” coils are connected in parallel.

3.2 Power supply

A schematic picture of the circuit of a power supply for kicker magnets is shown in Fig. 2. As an example, the power supply only for HER will be mentioned below. The $\mathbf{L_H}$ and $\mathbf{L_V}$ in the figure express coils of the horizontal magnet and vertical one, respectively. In this circuit, only magnets are installed in the tunnel. The power supply provides currents via coaxial cables of about 30m long to the tunnel. The power crawbar circuit is located on the ground to avoid damaging caused by radiation.

This circuit is composed of two resonance units. Each coil($\mathbf{L_H}$ or $\mathbf{L_V}$) is connected to a capacitor($\mathbf{C_H}$ or $\mathbf{C_V}$) in parallel. The values of L and C are small for horizontal magnet, while those are large for vertical one. $\mathbf{T_{MAIN}}$ expresses coaxial cables of 50m long. $\mathbf{C_{MAIN}}$ is a main capacitor which is usually charged at a high voltage of 35kV. $\mathbf{C_{PC}}$ and $\mathbf{D_{PC}}$ compose a power crawbar circuit which keeps the flat top of the magnetic field in the horizontal magnets. $\mathbf{C_{PC}}$ is usually charged 1600V.

THY is a thyratron which is only one switching element. After **THY** is closed by a trigger pulse, $\mathbf{C_{MAIN}}$ begins discharging and at first the current flows the circuit as $\mathbf{I_H}$ in the figure. The charge stored in the transmission line $\mathbf{T_{MAIN}}$ is reflected at its end where the potential is raised up 35kV by $\mathbf{C_{MAIN}}$, and twice amount of current

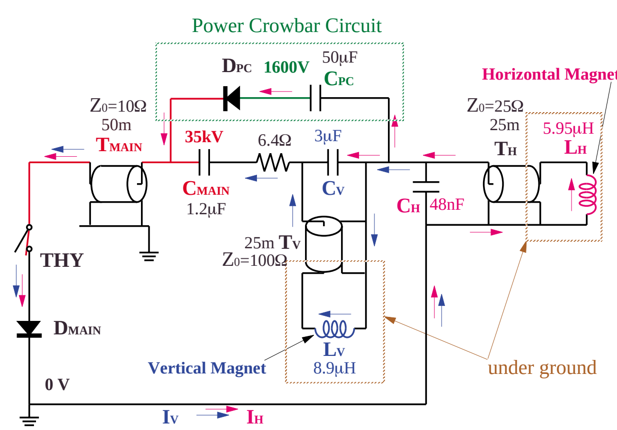

Figure 2: The circuit of a power supply for HER kicker magnets

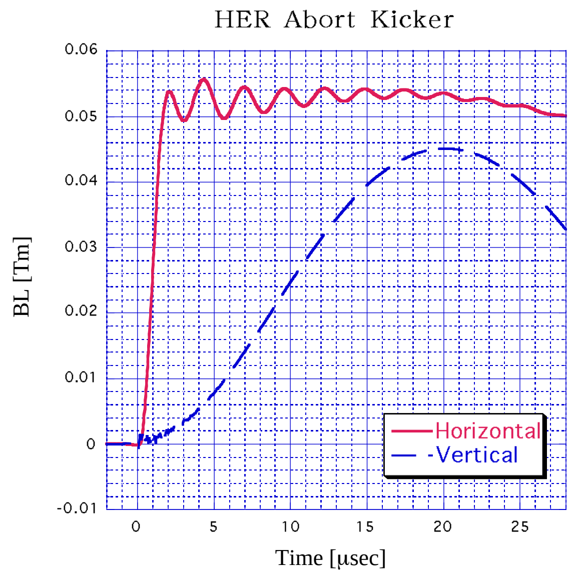

Figure 3: The measured pulse fields in the HER kicker magnet with ceramic chambers.

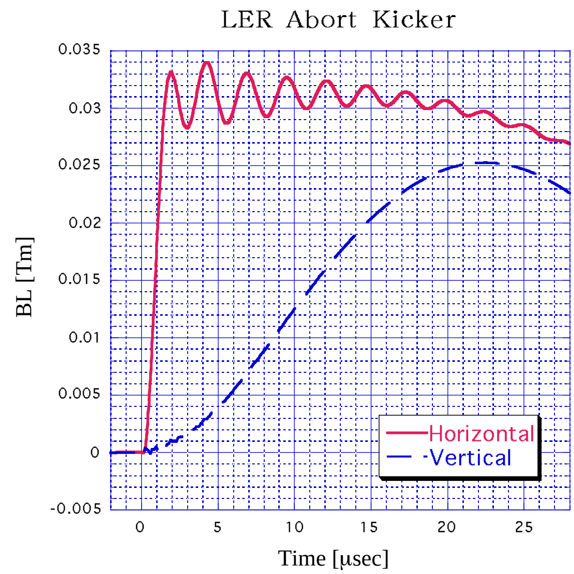

Figure 4: The measured pulse fields in the LER kicker magnet with ceramic chambers.

flows along $\mathbf{I_H}$, which produces high current during a rise time of $\mathbf{L_H}$. The rise time is also dependent on the capacitance of $\mathbf{C_H}$. These two points give fast rise time and high current to the horizontal magnets. From those the horizontal magnets should tolerate a voltage of $\pm$35kV. The current $\mathbf{I_H}$ is partly supplied by all charge stored in $\mathbf{C_{PS}}$ discharged 100μsec. Meanwhile the current flowing $\mathbf{L_H}$ is ringing with a resonant frequency determined by $\mathbf{C_H}$ and $\mathbf{L_H}$. The frequency is about 4μsec with which horizontal magnetic fields vibrate.

On the other hand, $\mathbf{C_V}$ and $\mathbf{L_V}$ resonate at a lower frequency. The rise time for $\mathbf{L_V}$ is slow ($\sim$10μsec). The current flow is $\mathbf{I_V}$ in the figure.

3.3 Measurement of the magnetic fields

The integrated magnetic fields along the beam direction in kicker magnets are measured in the ceramic chambers. Fig. 3 and 4 shows the results. The horizontal axis shows the time starting at the trigger. The vertical axis corresponds to the measured magnetic fields. The rise times of horizontal fields are about 1μsec. The ringing at the flat top can be seen for 10μsec. The maximum strength of fields are larger enough than those shown in Table 1. (Because the horizontal magnets are composed with two coils in parallel, the strength measured in one magnet is half of that in Table 1.)

The vertical fields rise slowly in more than 10μsec. The strength of fields 10μsec after trigger is about 75% of design value in Table 1 for both figures. We have already improved the rise time of vertical magnets by changing $\mathbf{C_V}$ value and connecting an additional resistance in parallel. Now the fields of the vertical magnets raise up to the design values 10μsec after trigger.

4 CONCLUSION AND FUTURE

The beam abort system for KEKB is designed and installed in both rings, HER and LER. The pulse fields of the kickers with ceramic chambers are measured. The beam abort systems work well in the KEKB operation.

Now both rings have an abort gap of 1μsec which is corresponding to a rise time of the horizontal kicker magnets. Now the maximum currents stored in HER and LER are about 500mA and 700mA, respectively. When the design currents are stored in near future, kickers with a faster rise time should be required. It would be a very important subject for abort systems.

REFERENCES

[1] T. Mimashi et al.,"Water Cooling Ceramic Chamber for KEKB Kicker Magnet", Proceedings of the EPAC2000