CERAMIC CHAMBER USED IN SuperKEKB HIGH ENERGY RING BEAM ABORT SYSTEM

T. Mimashi, N. Iida, M. Kikuchi, T. Mori, K. Kodama, KEK, Tsukuba Ibaraki Japan
K. Abe, Hitachi Haramachi Electronics Co., Hitachi Ibaraki Japan

Abstract

The design beam current of SuperKEKB High Energy Ring (HER) is 2.6A with the 2500 bunches operation. The design bunch length is 5mm. The power dissipation due to the image currents is measured in SuperKEKB Phase I operation. About 870mA beam current has been stored in HER at the Phase I operation. [1] The water cooled ceramic chamber is chosen for SuperKEKB abort kicker systems. It has a thin Ti conducting layer deposited on the inner wall of ceramic. Total 9 pieces of 500mm long ceramic tubes are used for the beam abort kicker magnets. These chambers show enough cooling power.

INTRODUCTION

Several kicker magnets are installed in the SuperKEKB main ring. Since the design beam current is large, the water cooled ceramic chambers are chosen for these kicker magnets. The horizontal abort kicker magnets are required to have very fast rise time and large current, the gap of kicker magnet must be as small as possible. [2] The compact new water cooled ceramic chambers are developed for the HER beam abort kicker. They are used for SuperKEKB phase I operation.

CERAMIC CHAMBER

Ceramic chambers are used for injection kicker magnets, beam abort kicker magnets and the vertical kicker magnets for the beam diagnostic. They allow external time varying magnetic field to penetrate the vacuum chamber. A thin metallic coating is required to carry the beam image current and to protect external component from the beam fields. The total heating is produced by the two types of induced currents. One is the image currents of beam and the other is the eddy currents induced by the pulsed kicker field. In case of ceramic chambers used in SuperKEKB, the power dissipation due to beam image current is dominant. It was estimated using the KEKB data to be an order of 1.8 kW. Table 1 shows the dimension of SuperKEKB abort system ceramic chamber. The ceramic chamber has racetrack type inner wall. Almina ceramic was chosen as vacuum chamber because of its greater mechanical strength and best braze metallization. Kovar was chosen as metal brazes ring. It provides low stress hermetic seal to ceramic and flexible transition between ceramic and massive flange. And Kovar also matches expansion coefficient of ceramic reasonably well. Kovar for vacuum seal and cooling water seal were brazed separately, because when one of them had damage, it won't give any damage to the other braze. The Cu flange has been chosen to minimize heating from image beam current. The electron beam welding is used to connect Cu flange and Kovar sleeve to avoid annealing Cu flange. The dimensional accuracy was required to the inner wall of inner ceramic. It was ground so that the flatness of inner wall surface is less than 0.1 mm in 10-mm square area. In order to match the level at the junction of ceramic and kovar less than +-0.2 mm difference, taper structure was chosen.

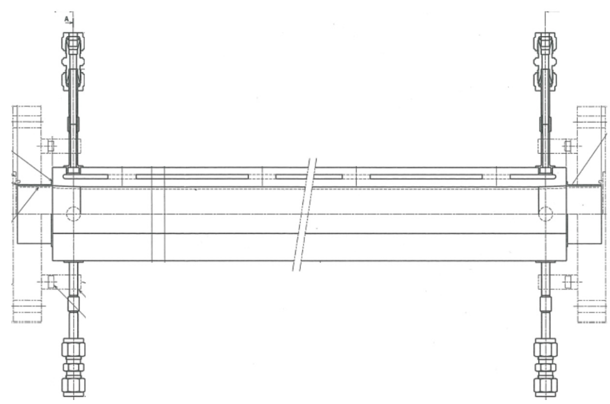

Figure 1: Structure of the ceramic chamber of HER Injection kicker.

Table 1: Dimension of the Abort System Ceramic Chamber

	Type I	Type II
Length (mm)	580	1128.3
Height of ceramic(mm)	67.5	
Width of ceramic(mm)	87.5	
Length of ceramic (mm)	500	500 x 2
Ceramic inner wall size (mm)	40 x 60	
Number of used	8	1
Coating	Ti	
Ti Coating thickness (μ m)	5	
Type	Straw	
Braze Metallization	Ti	
Braze	Ag-Cu	
Ceramic	Almina ceramic	

Structure of Ceramic Tube

Two types of ceramic chambers were developed for the beam abort system. One is used for the vertical kicker magnet and the other is used for horizontal kicker magnets. The length of the vertical kicker ceramic chamber is 580 mm and has 500 mm long ceramic tube with a thin Ti conduction layer deposited on the inner wall. The ceramic is connected to the Cu flange through kovar sleeve. The ceramic chamber for horizontal kicker magnet contains two pieces of the ceramic tubes with Ti coating. Each ceramic is combined through kovar, and total length of the chamber is 1128.3 mm. Figure 2 shows ceramic chambers installed in HER. The structure of 500mm long hollow type ceramic is shown in Figure 1. The ceramic tube includes cooling water path inside. The inner diameter of the chamber is 60mm in horizontal and 40 mm in vertical. The cooling water flows into the ceramic tube upper and lower pipes of one side and gets out from the other side. The ceramic chamber made from one piece of ceramic so that it has simple structure and relatively easy to assemble. The simple structure make the ceramic chamber compact. As the result, the gap of horizontal kicker magnet can be reduced from 90mm (KEKB) to 70mm (SuperKEKB).

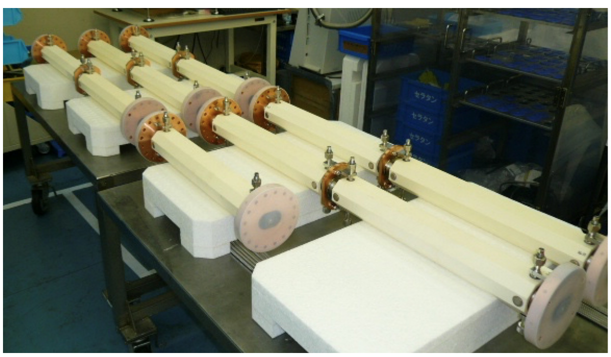

Figure 2: Ceramic chamber for abort kicker magnets.

Braze Metallization

Although Mo-Mn is the typical braze metallization of the ceramic chamber, it is weak against water, so that Ti with activated metallize method has been chosen. Its braze metallization method had no troubles more than 10 years.

Ti Coating Inside of Ceramic Tube

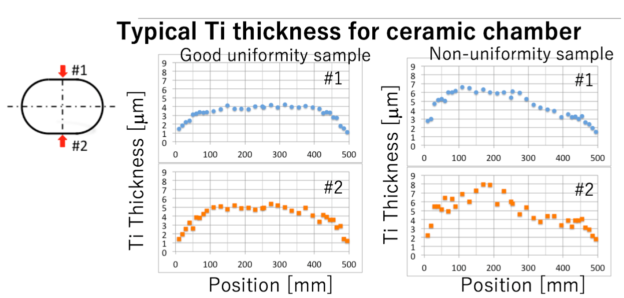

Figure 3: Ti corting thickness distribution innner wall of the ceramic anong the beam longitudinal direction.

The Ti metallization of ceramic inner wall was produced by DC magnetron sputtering. Argon gas is chosen to make plasma between the cathode and the anode. Figure 4 shows the picture of sputtering machine. Ti cathode and stainless steel anode screen are used. Ti coating uniformity has been checked with an eddy current film thickness meter. Target value of Ti coating thickness is set to 5μm. Ti coating is relatively thick in the middle of ceramic tube and thin near the edge. (Figure 3) When the target value is set to 5μm, minimum 1μm Ti coating is guaranteed.

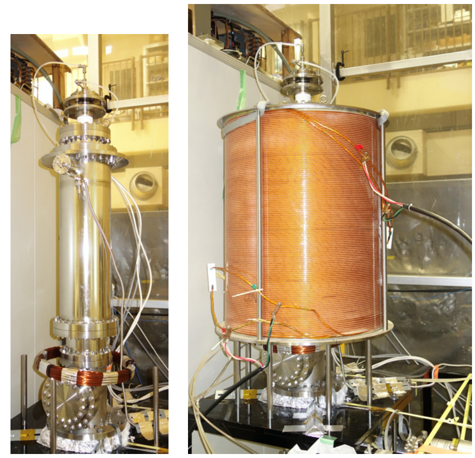

Figure 4: Sputtering machine for Ti coating.

Cu Conducting Layer for Kovar Sleeve

The copper electroforming is applied to deposit the 100 μm thickness Cu conducting layer on the inner wall of Kovar sleeve. (Figure 5) The Cu conducting layer reduce the heat generated by beam image current on the Kovar braze ring.

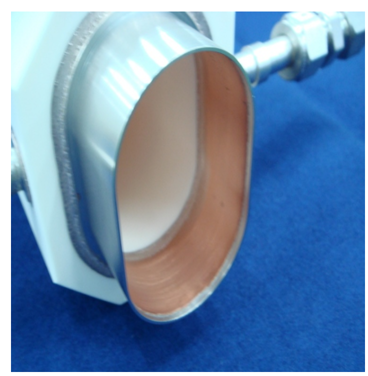

Figure 5: Cu conducting layer inner wall of Kovar sleeve.

Bench Test of Ceramic Chamber

The penetration of kicker magnetic field and cooling capacity are investigated with the test bench. The rise time of horizontal kicker magnetic field is measured with integrating the signal from pick up coil placed in kicker magnet. Figure 6 shows power supply output current and magnetic field with/without Ti coated ceramic chamber. The rise time is less than 200 nsec that satisfy the requirement.

The cooling capacity was tested with test bench system. [Figure 7] Heater is inserted into the ceramic chamber and heat up the chamber up to 5kW. The temperature was measured on the ceramic chamber. No local temperature rise is observed. There are some ceramic supports in the

ISBN 978-3-95450-182-3

cooling water path. [Figure 7] The temperature difference between on and off the support is 3 degree at 2kW deposit.

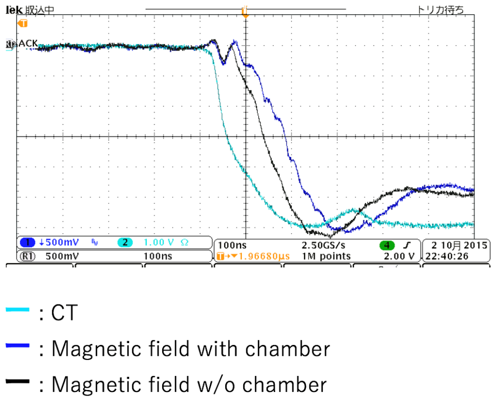

Figure 6: Kicker field penetration test.

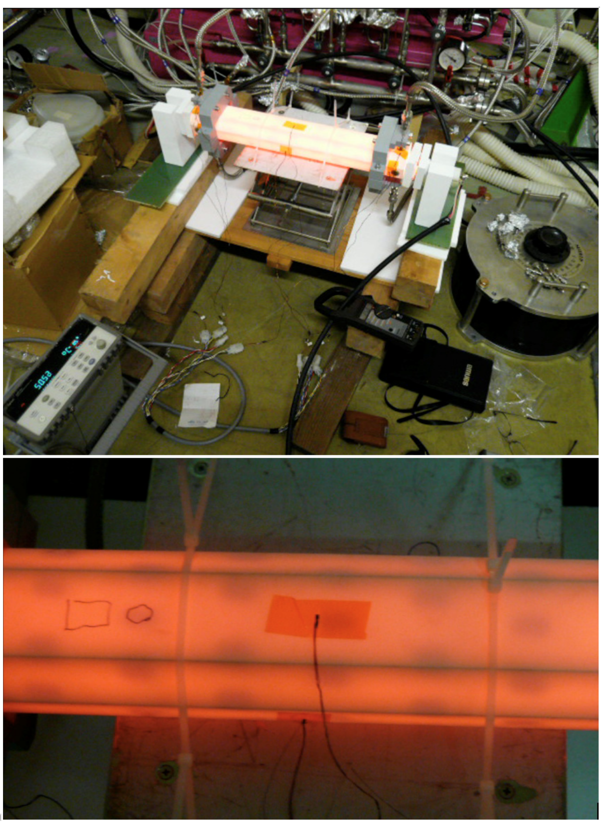

Figure 7: Ceramic chamber heat test.

SUPERKEKB OPERATION

Four ceramic chambers for the horizontal abort kickers and one ceramic chamber for vertical kicker are installed on HER beam abort system. [Figure 8]

In 2016 Phase I operation, the 870mA of total beam current were stored in 1576 bunches of HER. And the design bunch length is 5mm. Temperature rise at the ceramic surface is 1.4 degree under the condition of 3 litter/minute of cooling water flow. The power dissipation due to image current was estimated to be around 290 W. Since ohmic loss of the beam image current in the ceramic surface is linear to the number of bunches and the square of bunch current, temperature rise at the 2.6A in 2500 bunches operation will be 8.4 degree. The power dissipation due to image current will be 1.8kW. The ceramic chambers give enough cooling capacity. The temperature of Kovar sleeve surface is also measured. AT the 870 mA beam current, temperature rise is around 3 degree. It corresponds 18 degree rise at full current operation. It is acceptable.

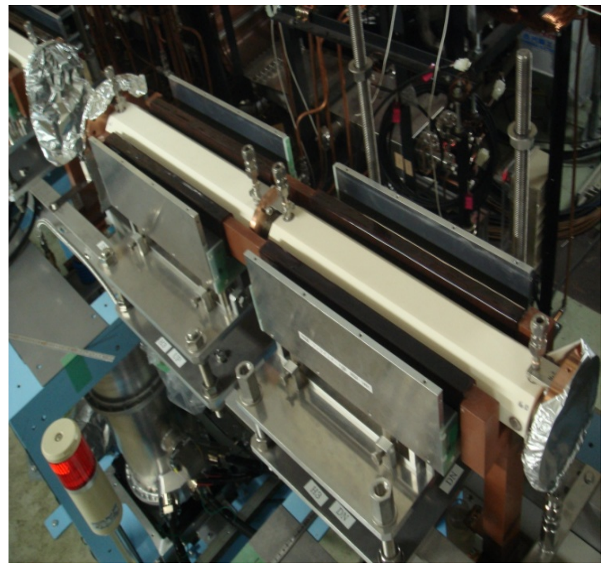

Figure 8: Installation of the ceramic chamber for the horizontal abort kicker magnet.

The kicker field penetration is checked with the beam in HER. The single bunch beam is aborted and using the alumina fluorescent screen behind the extraction window, it is tested if the aborted beam pass the window. From this measurement, the abort gap can be reduced down to 160 nsec which satisfy the requirement.

CONCLUSION

Two kinds of water cooling ceramic chambers were developed and fabricated for SuperKEKB HER beam abort system. In phase I operation 870 mA beam current were stored in HER. That water cooled ceramic chamber shows sufficient cooling capacity. Abort kicker magnetic penetrate in the ceramic chamber. The rise time of the magnetic field is around 160nsec.

REFERENCES

[1] Y. Funakoshi et al, "Beam Commissioning of SuperKEKB", IPAC'2016, Busan, Korea, May 2016, TUOBA01, p.1019.

[2] T. Mimashi et al, "SuperKEKB Beam Abort System", IPAC'2014, Dresden, Germany, June 2014, MOPRO023, p.2444.