Water Cooling Ceramic Chamber for KEKB Kicker Magnet

T. Mimashi, N. Iida, M. Kikuchi, H. Nakayama, K. Satoh, KEK, Tsukuba Ibaraki Japan
Y. Ashihara, K. Iwamoto, Kyocera Co. Gamo-Gun Shiga Japan
T. Nagayama, K. Abe, Hitachi Haramachi Electronics Co., Hitachi Ibaraki Japan

Abstract

The design beam current of KEKB is 2.6A at the low energy ring and 1.1A at the high energy ring with the 4mm bunch length. The power dissipation due to the image currents is studied with the TRISTAN accumulator ring and estimated for the case of KEKB ring. The water cooling ceramic chamber is chosen for KEKB kicker systems and the two types of water cooling ceramic chambers are developed with a thin Ti conducting layer deposited on the inner wall of ceramic. Total 19 ceramic chambers are used for the injection kicker magnets, the beam abort kicker magnets and the vertical kicker magnets for beam diagnostic.

1 INTRODUCTION

Several kicker magnets are installed in the KEKB main ring, the injection kicker magnets, kicker magnets for the beam abort systems and vertical kicker magnets for the beam diagnostic. For these kicker magnets, water cooling ceramic chambers is developed. Total length of ceramic chambers in HER is 7160mm. It contains 5880mm ceramic tubes with a thin Ti conducting coating layer. And total length of ceramic chambers in LER is 6700mm containing 4620mm ceramics.

2 CERAMIC CHAMBER R&D

Ceramic chambers are used to allow external time varying 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. They are the heating due to the image currents of beam and the heating due to the eddy currents induced by the pulsed kicker field. The power dissipation due to image currents of beam in KEKB was estimated to be an order of 1 kW for 6μm Ti coating. The image current power dissipation was measured in the TRISTAN accumulator ring, and then it was extrapolated to the case of KEKB.

The power dissipation due to the eddy current and penetration of the kicker pulse are measured at the test bench system of the kicker and ceramic chamber. The power dissipation is around 20-50W under 50Hz repetition rate.

Two kinds of water cooling ceramic chambers are developed and fabricated for KEKB kicker system. (Figure 1,Figure 2) The ceramic chamber for KEKB kicker system 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 ceramics reasonably well. Fe-Ni-Co alloy was used. Kovar for vacuum seal and cooling water seal were brazed separately, because when one of them had a damage, it won't give any damage to the other braze.

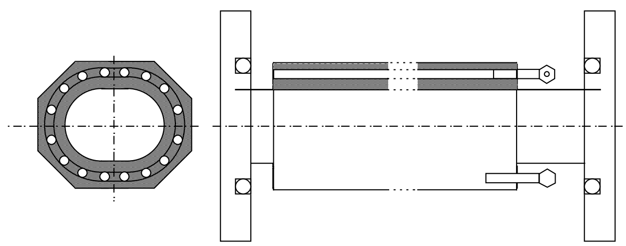

Figure 1: Structure of the ceramic chamber of HER injection kicker

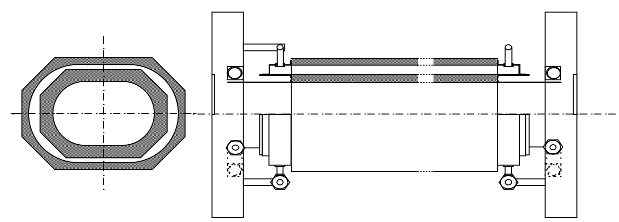

Figure 2: Structure of the ceramic chamber of LER injection kicker

Ti-Mn coating uniformity has been checked with a microscope. Coating was done using Ti-Mn wire. Since the ceramic chamber is racetrack type, Ti coating is relatively thick in upper and lower side of the chamber (Figure 3-A) and thin in the side arc (Figure 3-B). If we coat Ti in 6 μm thickness, minimum 3.5μm Ti coating is guaranteed. The surface resistance is 89.1μΩcm for 6μm Ti coating.

2.1 HER Ceramic Chambers

Two types of ceramic chambers were developed. One is used for the injection kicker magnets and vertical kicker magnet of the beam abort system. (Type A) [1] The other is used for horizontal kicker of the beam abort system. (Type B) The type A chamber is 520mm long and has 420mm ceramic with a thin Ti conduction layer deposited on the inner wall. The ceramic is connected to the flange through kovar. The type B chamber contains three pieces of 420mm ceramic with Ti coating. Each ceramic is combined through kovar, and total length of the chamber is 1500mm. The structure of type A chamber is shown in Figure 1. The 16 holes go through the ceramic and cooling water flows through these holes. They flow into the chamber from upper and lower pipes and after going back and forth twice, it gets out from water pipe in the left and right side. These types of ceramic chamber need only one piece of ceramic and relatively easy to assemble. Eight pieces of the type A ceramic chamber and two pieces of the type B ceramic chamber are installed on HER.

	HER Type A	HER Type B	LER Type C	LER Type D
Length (mm)	520	1500	520	1540
Height of ceramic	84	84	84	84
Width of ceramic	101	101	122	122
Length of ceramic	420	420 x 3	420	420 x 3
Ceramic inner wall	24 x 65	24 x 65	24 x 76	24 x 76
Number of used	8	2	8	1
Coating	Ti-Mo	Ti-Mo	Ti-Mo	Ti-Mo
Coating thickness (μm)	6	6	6	6
Resistance (μΩm)	90	90	90	90
Type	Straw	Straw	Double ceramic	Double ceramic
Braze Metalization	W+Mn +Ni	W+Mn +Ni	Ti	Ti
Braze	Ag-Cu	Ag-Cu	Ag-Cu	Ag-Cu
Ceramic	Almina ceramic	Almina ceramic	Almina ceramic	Almina ceramic

Table 1: Dimension of Ceramic chamber

The cooling capacity was estimated by simulation. Figure 4 shows temperature distribution of ceramic. They are calculated assuming 2.5kW of uniform heating whole ceramic inner wall. The highest temperature in the surface of ceramic is the center of ceramic chamber in the side plane. This is consistent with a result from a heating bench test. The heating test bench system was built by implementing a heater inside the ceramic chamber. The temperature of ceramic surface was measured at many points. All point temperature is lower than the temperature of output cooling water. No local heart up is observed. Although Mo-Mn is the typical braze metallization of the ceramic chamber, it is weak for water, W-Mn with nickel plane on fired metallizing is chosen. Ceramic and flange are connected through kovar. The dimensional accuracy is required to the inner wall of ceramic. It was ground so that the flatness of inner wall surface was less than 0.1mm in 10mm square area.

In order to match the level at the junction of ceramic and kovar less than +-0.2mm difference, taper structure was chosen.

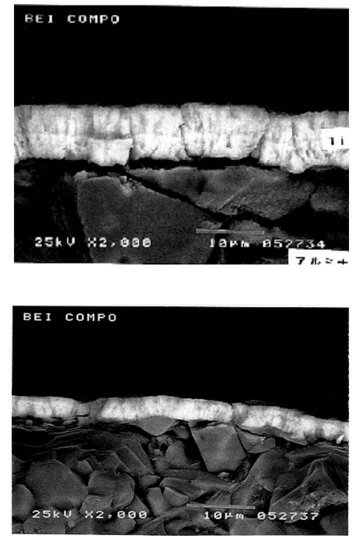

Figure 3: Ti coating thickness (Upper: 3-A Lower: 3-B)

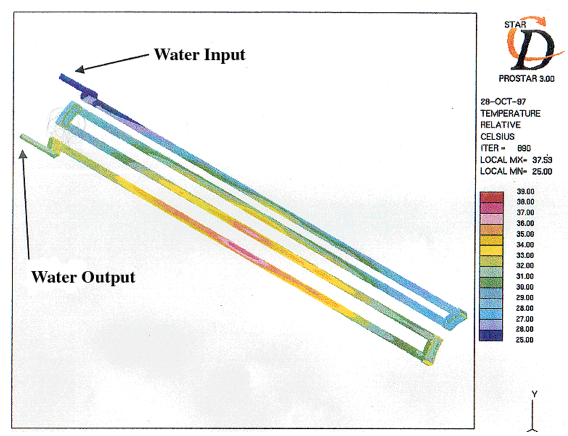

Figure 4A:Cooling water temperature

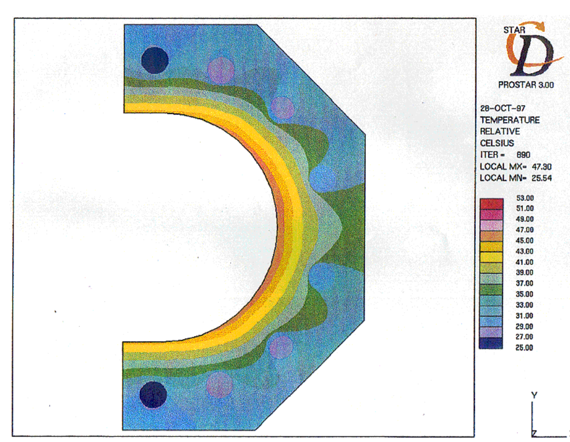

Figure 4B:Temperature of ceramic

Figure 4: Simulation of ceramic chamber heat distribution

2.2 LER Ceramic Chamber

Two types of water cooling ceramic chambers are also developed for the LER injection kickers (Type C) and the horizontal kicker of LER beam abort system. (Type D) Length of the type D ceramic chamber is 1540mm and the length of the type C ceramic chambers is 520mm. As same as HER type B chamber, the type D chamber contains three pieces of 420mm ceramic with Ti coating. A type D chamber and eight pieces of type C chambers are used in LER.

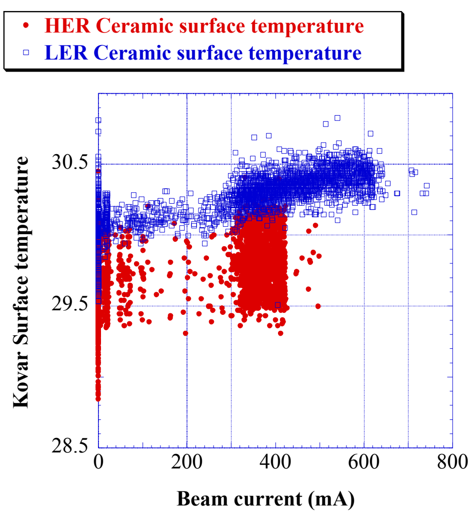

Figure 5: Temperature of ceramic surface

LER ceramic chamber has a double tube structure. Simple schematic is shown in Figure 2. Cooling water flows between inner and outer ceramic pipes. Thus an inner and an outer ceramic pipes are completely separated by cooling water. LER ceramic chamber has fairly good cooling ability, but it needs two pieces of ceramic tubes. As braze metallization, Ti with activated metallize method has been chosen. Inner wall of inner ceramic was ground so that the flatness of inner wall surface is less than 0.1mm in 10mm square area as same as HER ceramic chamber. At the junction of ceramic and kovar, the level matching accuracy is less than +-0.2mm.

4 KEKB OPERATION

In June 2000, the 750mA and 500mA beam currents were stored in LER and HER respectively. Temperature rise is less than 1 degree at the ceramic surface. So far the ceramic chambers give an enough cooling capacity. (Figure 5) The problem was temperature rise in the surface of kovar. As shown in Figure 6 temperature of kovar surface rise more than 10 degrees at the 600mA in LER, we added another cooling water path to the flange. This makes the temperature of kovar 6-7 degree down. (Figure 6) The flow rate of cooling water is about 4 liters/minute and the temperature of the cooling water rises about 0.5 degree at the beam current 600mA. The power dissipation due to image current was estimated to be around 150W. Total current will be increased 4.3 times as big as we have now. Bunch length seems to be relatively longer than designed value so that power dissipation will be larger if the bunch length becomes shorter. Finally the power dissipation due to image current will be 800W-1000W. Further more, we sometimes observe extra temperature rise of the ceramic chamber. It may be caused by synchrotron light when the orbit changes.

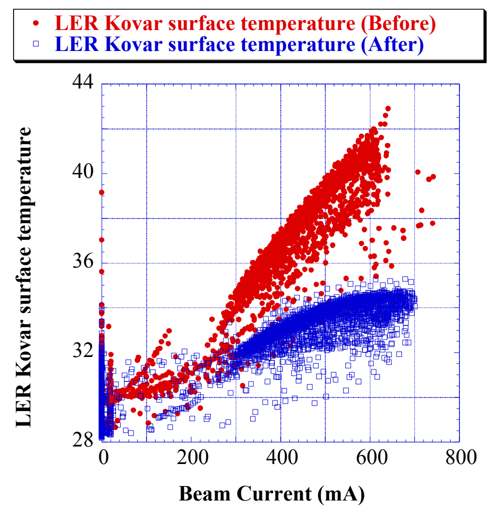

Figure 6: Kovar surface temperature

5 CONCLUSION

Two different structures of water cooling ceramic chambers are developed and fabricated for KEKB kicker systems. They are used in HER and LER respectively. So far 750mA beam current was stored in LER and 500mA beam current was stored in HER. Both types of the water cooling ceramic chambers show a sufficient cooling capability.

REFERENCES

[1]N.Iida et al, “Abort System for the KEKB”, EPAC2000,Vienna, Austria, June 2000