SUPERCONDUCTING CRAB CAVITY FOR KEKB

K. Hosoyama, K. Hara, A. Kabe, Y. Kojima, Y. Morita, H. NakaiI, Li Shao Peng
K. Ohkubo*, H. Hattori*, and M. Inoue*
KEK High Energy Accelerator Research Organization
* Mitsubishi Heavy Industries Ltd.

Abstract

After R&D study of 1/3 scale 1.5 GHz non-axially symmetric squashed cell shape superconducting Nb crab cavities, a full scale 508 MHz squashed cell shape superconducting Nb crab cavity for KEKB has been designed and fabricated. At the same time test stands for these cavities with RF measurement systems and vertical cryostats have been constructed. The cold test of the full scale 508 MHz cavity in 4.2 K vertical cryostat was carried out and the surface electric peak field Esp could exceed its design value of 21 MV/m and reached to 32 MV/m.

1 INTRODUCTION

KEKB - a high luminosity asymmetric 8 x 3.5 GeV electron-positron collider at KEK - adopts finite angle crossing scheme of 2 x 11 mrad to reduce the background rates and to simplify beam optics at interaction region [1]. By this scheme the luminosity reduction due to geometrical effect and the possibility of beam-beam instability by synchrotron-betatron coupling resonances will be anticipated. The crab crossing scheme shown in Fig. 1 was proposed [2,3] to eliminate these effects. In this scheme bunches of electrons and positrons to the interaction point are tilted by time-dependent transverse kick in the superconducting crab cavities and head-on collide. After the collision these bunches are kicked back to the original orientations by another crab cavties.

The R&D program of the KEKB superconducting crab cavity was started in 1994. We have adopted the squashed cell shape cavity for the base line design of the KEKB superconducting crab cavity. This type of the cavity was designed and studied extensively at Cornell in 1991 and 1992 for CESR-B under KEK-Cornell collaboration[4]. At the first stage of the R&D three 1/3

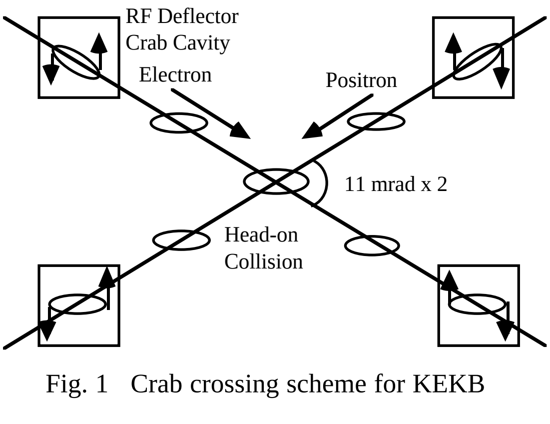

Fig. 1 Crab crossing scheme for KEKB

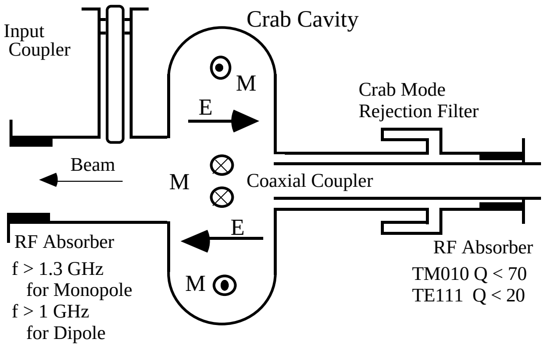

Fig. 2 Conceptual design of the crab cavity

scale 1.5 GHz squashed cell shape niobium model cavities were designed and fabricated to establish fabrication and surface treatment techniques of the non-axially symmetric structure [5]. One of these cavities was cold tested at 1.8K. The maximum electric surface peak field of the cavity could exceed the design values of Esp = 21 MV/m and reach to Esp = 43 MeV/m [6]. The fabrication of a full scale 508 MHz squashed cell shape superconducting crab cavity has been started in 1996 [7]. At the same time the test stand for this cavity with RF measurement system and vertical cryostat for cold test has been constructed.

2 DESIGN OF CRAB CAVITY FOR KEKB

The TM110 like mode in the squashed cell shape cavity is used to get time-dependent transverse kick for the crab crossing. Figure 2 shows the conceptional design of the crab cavity. The time-dependent magnetic field on the beam axis of the cell is used to give the transverse kick to the beam bunch. Table 1 lists the selected parameters of the crab crossing for KEKB.

An unwanted lower TM010 mode and higher modes in the crab cavity are extracted from the cavity through a large aperture beam pipe and a coaxial beam pipe and absorbed by RF absorbers attached on the beam pipes at room temperature. A crab mode rejection notch filter is

Table 1. Selected parameters of KEKB crab crossing

	LER	HER
Beam Energy [GeV]	3.5	8.0
RF Frequency [MHz]	508.887	
CrossingAngle [mrad]	11 x 2	
βx	0.33	0.33
$\beta crab$	20	20
Req.Kick Volt. [MV]	1.41	1.44

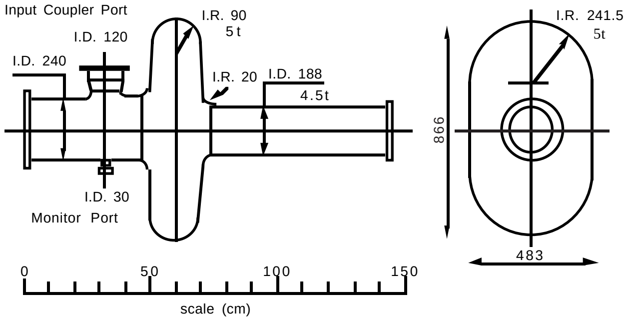

Fig. 3 Squshed cell type crab cavity for KEKB

set in the middle of the coaxial structure to prevent flowing out the crabing mode from the cavity due to incorrect positioning of the coaxial coupler in the cavity.

By adopting the squashed cell shape design we can push the resonance frequency of the unwanted one other polization mode of the TM110 upward, higher than the cut-off frequency of the coaxial beam pipe and extract to the RF absorber at the end of the coaxial pipe. On the other hand in case of the round cell shape cavity this mode with almost same frequency of the crabing mode is remained trapped in the cavity.

The dimensions of the 508 MHz squashed cell shape Nb crab cavity for KEKB are shown in Fig. 3. The RF characteristics of non-axially symmetric squashed cell shape crab cavity was calculated by 3-dimensional computer code MAFIA. Table 2 shows the calculated characteristic parameters of the cavity. The maximum surface electric field Esp is located at the iris part of the larger beam pipe. The design maximum electric surface peak field Esp which correspond to required kick voltage of 1.44 MV for KEKB crab cavity is about 21 MV/m. The mechanical design of the crab cavity was performed using the finite element softwares ANSYS and MARC [5]. The cavity wall thickness of more than 4 mm is required to withstand the external pressure of 0.13 MPa at room temperature. In this design four reinforcing ribs are attached to the iris part of the cavity to reduce the stress concentration at these part due to the non-axially symmetric cell structure.

3 FABRICTION AND SURFACE TREATMENT OF NB CRAB CAVITIES

Before fabrication of the full scale 508 MHz Nb crab cavity, we have fabricate three 1/3 scale 1.5 GHz squashed cell shape model cavities to establish the fabrication and surface treatment techniques for non-axially symmetric Nb cavity. The fabrication and surface treatment procedures for the full scale model are completely same as that of 1/3 scale model. The half-cell of the cavity were hydroformed out of 5 mm thick Nb sheet with RRR=190 supplied from Tokyo Denkai. Inner surface of the half cell was buff-polished to remove the scars on it. After the equator and iris parts of the cell were trimmed mechanically, the cell and the beam pipes were assembled into a cavity by electron beam welding.

Table 2. RF properties of 508 MHz KEKB crab cavity

R / Qo	48.9 [Ω]
Γ	227
Esp/Vkick	14.4 [MV/m/MV]
Hsp/Vkick	415 [Oe/MV]

The electron beam welded equator part of the cell was ground by specially designed grinding tool. Inner surface of the cavity especially equator part was barrel polished [8] more than about 200μm and then electropolished about 100μm by horizontal rotational electropolishing system developed and used for TRISTAN super conducting cavity [9]. After rinsing by ultra pure water the cavity was installed in titanium box and annealed in vacuum furnace at 700^{o}C for 3 hours to evacuate hydrogen gas from the cavity which was included during electropolishing. Before the cavity is assembled into vacuum system for the cold test, inner surface of the cavity was high pressure rinsed by 8 MPa ultra pure water for about 45 minutes

4 TEST STANDS FOR CRAB CAVITIES

We have constructed the test stands for the 1.5 GHz 1/3 scale and 508 MHz full scale model crab cavities. The test stands have vertical cryostats of 400 mm, 1100 mm in diameters and 2.5 m, 3.5 m in heights for the 1/3 scale model cavity 1.8 K and full scale model cavity 4.2 K cold tests respectively. The test stand of the full scale crab cavity was constructed beside the existing cold box of the large helium refrigeration system [10] with 8 kW cooling capacity at 4.4 K which was used for cooling of the TRISTAN superconducting acceleration cavities. Liquid helium of more than 5000 L for the cold rest of the cavity was fed directory from the 12000 L liquid helium Dewar. The RF measurements and its display are performed by using computer with Labview language program.

5 TEST RESULTS

The cold tests of the 1/3 scale model 1.5 GHz crab cavity was carried out at 1.8 K. Figure 4 shows the cold test results of it. After the tests in which the maximum surface peak Esp = 36 MV/m was attained, we warm up the cavity and leaked the air into the cavity without filter. The micro-particles in the air is introduced into the cavity and the cavity performance degraded as shown in Fig.4 and x-ray radiation increase dramatically. After warm up we disassembled the cavity and performed the high pressure rinsing with 8 MPa ultra pure water to remove the micro-particle on the surface. The RF performance of the cavity was recovered and Esp reached 43 MV/m without the x-ray radiation.

The test results of the 508 MHz crab cavity in the 4.2 K vertical cryostat are shown in Figs. 5, 6. In the first cold test the Qo values degraded at around Esp = 13

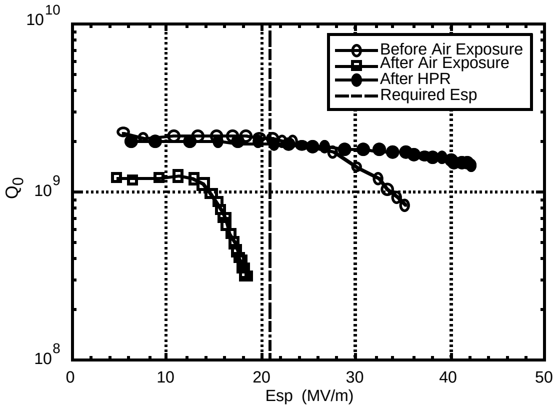

Fig. 4 Test results of 1/3 scale crab cavity

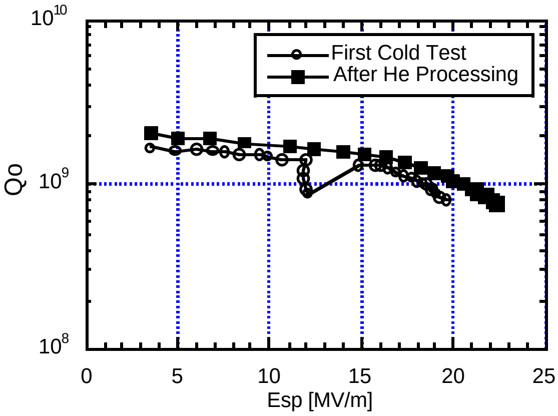

Fig. 5 The first test of full scale KEKB crab cavity

MV/m as shown in Fig. 5, this was overcome by short duration of the RF processing and reached about 20 MV/m with field emission loading. We carried out helium processing for about 20 minuets by introducing helium gas about 10^{-5} Torr into the cavity. By this processing Esp exceeded design values of 21 MV/m and reached 23 MV/m as shown in Fig. 5. This cavity was disassembled and about 5 µm of surface layer was removed by slight electopolishing followed by high pressure rinsing, and cold tested again. The Qo values of the cavity decreased and surface peak field Esp was limited by heavy electron loading due to contamination of the micro-particles from the ion pump which were introduced into the cavity by mishandle of the valve of the vacuum pumping system. By the helium processing this degradation was cured and Esp could reached to 25 MV/m as shown in Fig. 6. We tried the high pressure rinsing to this cavity to remove the micro particle in the cavity and carried out cold test again. By this processing the Qo values recovered and Esp exceeded 30 MV/m and x-ray radiation decreased drastically. The maximum Esp was limited by the capacity of the RF power source.

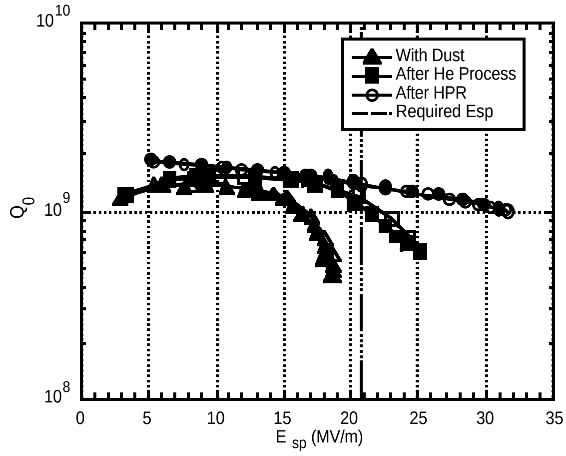

Fig. 6 Test results of full scale KEKB crab cavity after helium processing and HPR

6 SUMMARY

We could establish the fabrication and the surface treatment techniques of non-axially symmetric squashed cell shape superconducting Nb crab cavities for the KEKB. At the same time we found the high pressure rinsing by ultra pure water is essential to get good cavity surface and the helium processing is very effective to cure RF performance of the degraded cavity contaminated by the micro particles.

7 ACKNOWLEDGMENT

The authors wish to express their gratitude to Professors S.Kurokawa, E.Ezura, Y.Yamazaki for their continuous support. Thanks are also due to staffs of cryogenic group and of superconducting cavity group for their devoted support and useful suggestions and comments.

8 REFERENCES

[1] "KEKB B-Factory Design Report", KEK Report 95-7, August 1995, A
[2] R. B. Palmer, SLAC-PUB 4707 (1988)
[3] K. Oide and K. Yokoya, Phy. Rev. A40 p.315 (1989)
[4] K. Akai et al. Proc. IEEE Part. Accel. Conf. (1993)
[5] K. Hosoyama et al. Proc. of the 7th workshop on RF superconductivity p.671 (1995)
[6] Y. Morita et al. Proc. of the 8th workshop on RF superconductivity (1997)
[7] K. Hosoyama et al. Proc. of the 8th workshop on RF superconductivity (1997)
[8] T. Higuchi et al.Proc. of the 7th workshop on RF superconductivity p.723 (1995)
[9] K. Saito et al. Proc. of the 4th workshop on RF superconductivity p.635 (1990)
[10] K. Hosoyama etal. Advances in Cryogenic Engineering Vol.37 p.683 (1992)