DEVELOPMENTS OF HOM DAMPERS FOR SUPERKEKB SUPERCONDUCTING CAVITY

M. Nishiwaki#, K. Akai, T.Furuya, A. Kabe, S. Mitsunobu and Y. Morita
KEK, Tsukuba, Japan

Abstract

Eight superconducting accelerating cavities were stably operated under a high beam current and a large beam induced HOM power in KEKB electron ring. The HOM power of 16 kW at the beam current of 1.4 A was absorbed in two ferrite dampers attached to each cavity. In SuperKEKB, that is the upgrade machine of KEKB, the design beam current is 2.60 A. The HOM power of higher than 40 kW is expected to be induced. To cope with the large HOM power, precise evaluations of HOM power loads including HOM dampers were carried out. Then, new ferrite dampers with reinforced water cooling were developed and high-power tested. On the other hand, the evaluation indicated that an additional HOM damper can absorb significant amount of HOM power. Additional damper is effective to reduce each ferrite damper load. In this report, we will describe the results of high power tests of the new ferrite dampers, studies for additional dampers, and an installation plan for SuperKEKB.

INTRODUCTION

SuperKEKB that is an upgrade machine of KEKB and an asymmetric energy electron-positron double-ring collider is under construction. The commissioning run will start in early 2015. The design luminosity is 40 times higher than that of KEKB [1]. In order to achieve the high luminosity, stored beam currents will be twice higher compared with those of KEKB as one of the important factors in the upgrade design. In an electron ring (high energy ring, HER), the design beam current is 2.60 A.

In KEKB, eight superconducting (SC) accelerating cavity modules were operated with the maximum beam current of 1.4 A in the HER. The large current beam induced a large higher-order-mode (HOM) power in the cavity. To absorb the HOM power, two ferrite dampers were installed at both side of the cavity beam pipes, called small beam pipe (SBP) and large beam pipe (LBP) as shown in Fig.1. In the KEKB type ferrite damper, the ferrite was sintered on copper base pipe by the hot isostatic press (HIP) method. The thickness of the ferrite was chosen as 4 mm in consideration of Q value and thermal conductivity of ferrite material [2]. In KEKB, the HOM power of 16 kW at the beam current of 1.4 A was successfully absorbed with two ferrite dampers without any problems [3]. In the upgrade plan for SuperKEKB, those eight cavity modules will be used with some reinforcements.

Table 1 shows SC cavity-related machine parameters of HER of KEKB and SuperKEKB. The loss factor of the cavity is calculated as 1.2 V/pC from the parameters of SuperKEKB. The expected HOM power induced in the cavity is 31 kW. The damper loads including the self losses are estimated to be 26 and 20 kW for LBP and SBP dampers, respectively. Therefore, the total heat load will be 46 kW per cavity.

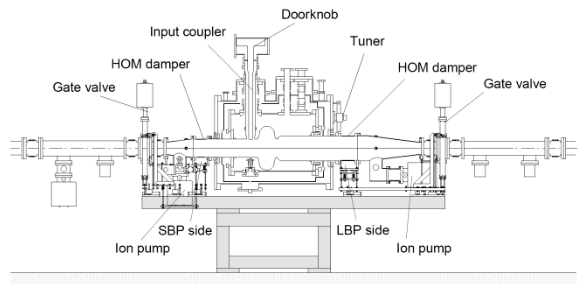

Figure 1: Cross-section drawing of the superconducting cavity module of KEKB.

Table 1: SC cavity-related Machine Parameters of HER in KEKB and SuperKEKB.

Parameters	**KEKB** (achieved)	**SuperKEKB** (design)
Beam Energy [GeV]	8.0	7.0
Beam Current [A]	1.4	2.60
Number of Bunches	1400	2500
Bunch Length [mm]	6	5
Beam Power [kW/cavity]	350~400	400
RF Voltage [MV/cavity]	1.2~2	1.5

One of the most important issues to cope with the large load of current ferrite dampers is large outgas from the ferrite surface because high voltage breakdown of the cavity is triggered by the outgas from the ferrite. In KEKB operation, the ferrite temperature was around 80 ^{o}C. On the other hand, the ferrite temperature will be 170~190 ^{o}C at the beam operation of 2.6 A. In the severe condition, the outgas rate is estimated to increase by a factor of 10 or more compared with KEKB conditions [3]. There are also issues in the water cooling system. The copper tube for cooling water is wound on the outer surface of copper base pipe. The water temperature must be maintained less than 60 ^{o}C to prevent vapor bubbles.

#michiru.nishiwaki@kek.jp

ISBN 978-3-95450-143-4

And the flow rate should be less than 8 L/min. to prevent erosion-corrosion of the copper tubes. To solve those issues, we developed new ferrite dampers with reinforced cooling system. Furthermore, in order to get more effective absorption of the HOM power, we carried out new simulation of power flow for the SC cavity module including dampers. This simulation indicated that additional dampers can absorb HOM powers effectively.

In this report, we will describe the development and RF test of new ferrite dampers and the simulation study of additional dampers.

NEW FERRITE DAMPERS

To suppress the surface temperature rise of ferrite, the new dampers that have a thinner ferrite tile and double channel water cooling tubes were developed, denoted as 3t-2ch (fig.2). In the new type, the ferrite thickness of 3 mm was adopted to get better thermal conduction. By using the thinner ferrite, we guessed the reduction of the self loss factor of the damper. Enhanced cooling effect was expected by using doubled cooling channel. The new type dampers were tested with RF high power of 509 MHz with 6, 8 and 10 L/min. of the flow rates for each channel. The copper base pipe temperature was maintained less than 60 ^{o}C.

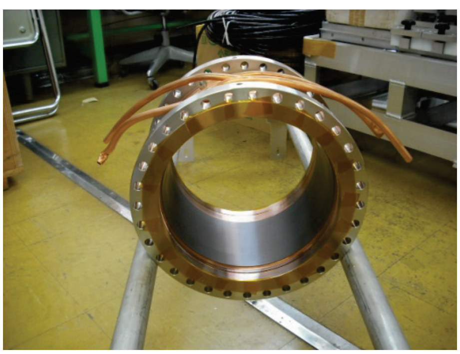

Figure 2: New type damper with 3-mm thickness of ferrite and doubled cooling channels, 3t-2ch damper.

The high power tests results of the new type (3t-2ch) LBP and SBP dampers are shown in Fig.3(a) and (b), respectively. It was found that the both dampers could absorb the expected HOM power in SuperKEKB. But the ferrite temperatures rose up to around 170 ^{o}C at the maximum absorption power. The summary of the relations between the maximum absorbed power and the ferrite temperature of dampers is shown in Table 2. From the summary, we could not see significant difference between the KEKB type and the new types. When the dampers are replaced with others, there is a risk that the cavity surface is contaminated by the air exposure and the cavity performance will degrade. Thus, there are no merits to replace the present dampers with the new types. Additionally, the 3t-type dampers cracked during the high power test. The tensile strength of the ferrite thickness of 3 mm would not enough. As a result, we should consider other measure to deal with the large HOM power along with studies on further development of the ferrite damper.

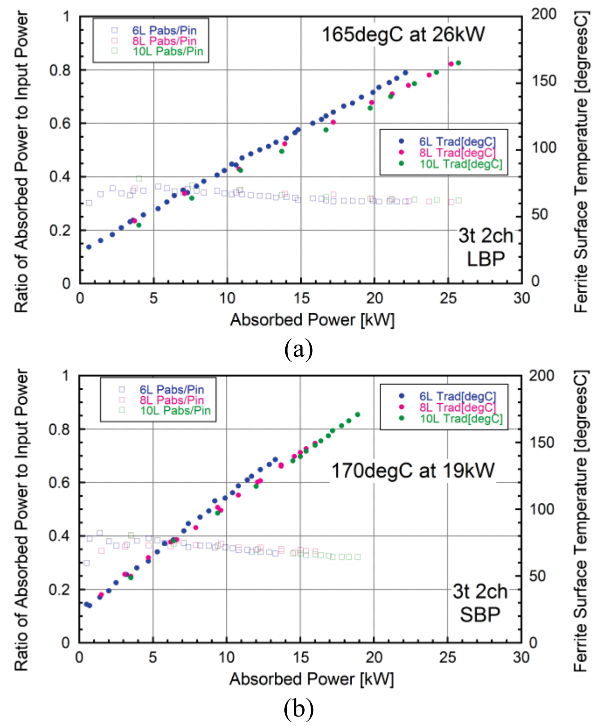

Figure 3: High power tests results of new type (3t-2ch) (a) LBP and (b) SBP dampers.

Table 2: Summary of absorbed power and ferrite temperature in high power tests of ferrite dampers. 4t-1ch denotes 4 mm thick ferrite with single channel water cooling.

Damper type		Max. Absorbed Power [kW]	Ferrite Temperature [degrees C]
LBP	KEKB (4t-1ch)	26	170
	New1 (3t-2ch)	24	160
	New2 (3t-2ch)	26	165
SBP	KEKB (4t-1ch)	19	190
	New1 (3t-2ch)	18	150
	New2 (3t-2ch)	19	170

POWER FLOW SIMULATION

In order to consider the HOM power in the large beam current operation, we have established new calculation method with power flow monitor of wake-field simulation using CST-Particle Studio. In this method, the HOM loads of each part can be obtained by the total loss factor calculation and the area and time integral of power flow monitored at each part in the model of the SC cavity module.

Figure 4 shows a model of the SC cavity module for this calculation. The loss factor is calculated as 1.41 V/pC for the bunch length of 5 mm. The total energy that is a

ISBN 978-3-95450-143-4

sum of integrated power flows at each part is consistent with the energy deposit calculated from the loss factor. Equivalent loss factors and HOM loads of each part in 2.6-A beam operation are summarized in Table 3. The equivalent loss factors are estimated from the loss factor and a ratio of the integrated power flow at each part to the total energy. This simulation showed the loads of dampers are smaller than expected and can be absorbed by present dampers. However, the large energy that is higher than 30% of the total energy is emitted through the LBP side outlet. The outlet energy becomes additional load to the downstream cavities. Therefore the outlet energy must be absorbed by other additional dampers.

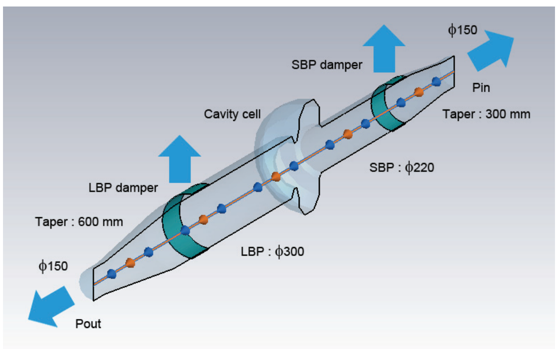

Figure 4: Calculation model of the SC cavity module. Bunched beam comes from Pin side.

As the additional damper, a SiC damper that was used in the SC Crab cavity and the normal conducting cavity ARES in KEKB, was considered. The SiC damper is added downstream of the gate valve of the cavity module. As a result, SiC damper absorbs effectively outlet energy and reduces the loads of ferrite dampers as shown in Table 3. For our cavity, the SiC length of 240 mm is optimum because the outlet energy becomes considerably small. In the condition with SiC damper, the ferrite temperature will become around 100 ^{o}C. The temperature is acceptable to the outgas rate and the cooling capacity even though the remained outlet energy is added to the load of the downstream cavity. In addition, the SiC damper can be added without exposing the cavity inside to the air. That is the great advantage to avoid degradation of the cavity performance. Two prototype SiC dampers have been fabricated as shown in Fig.5. In consideration to the condition of the cooling capacity, the damper length is designed to be 120 mm to divide the heat load. The high power tests of SiC dampers are ongoing. Further fine simulations are necessary in order to verify the effect of the additional SiC damper.

SUMMARY

In order to absorb large HOM power in the superconducting cavity modules in SuperKEKB, new HOM dampers were developed and tested. The new dampers with thinner ferrite tile and doubled cooling water channels, however, have not effect to reduce the temperature rise. A new HOM power calculation method showed the outlet energy to the downstream cavities is large. Additional SiC damper would be effectively absorb the outlet energy. In addition, it was found that the current cavity modules are workable in the 2.6-A beam operation without opening the cavity and replacing current ferrite dampers. The high power tests of the SiC dampers are in progress. The more fine simulations are also needed to verify the effect of the additional SiC damper. In the next year, we plan to install SiC dampers in the SuperKEKB ring.

Table 3: Summary of equivalent loss factors (Eq.LF) and HOM loads at 2.6-A beam operation.

Part	Without SiC		With 240-mm SiC	
	Eq.LF [V/pC]	HOM Load [kW]	Eq.LF [V/pC]	HOM Load [kW]
Inlet	0.08	2.2	0.09	2.4
Outlet	0.46	12.5	0.22	5.9
SBP damper	0.37	10.1	0.31	8.4
LBP damper	0.49	13.3	0.44	11.9
SiC damper	-	-	1.10	29.7
Total	1.41	38.2	2.16	58.4

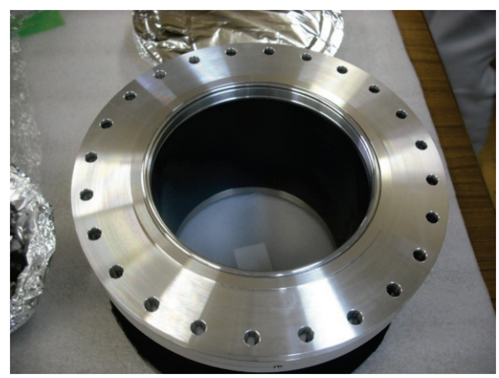

Figure 5: First prototype of SiC damper.

REFERENCES

[1] K. Akai, et al., "Design Progress and Construction Status of SuperKEKB," IPAC2012, New Orleans, May 2012, TUPPR006, p. 1822 (2012); http://accelconf.web.cern.ch/accelconf/IPAC2012/papers/tuppr006.pdf
[2] T. Tajima, "Development of Higher-Order-Mode (HOM) Absorbers for KEKB Superconducting Cavities," KEK Report 2000-10 (2000).
[3] Y. Morita, et al., "Status of KEKB Superconducting Cavities and Study for Future SKEKB," SRF2009, Berlin, September 2009, TUPPO022, p. 236 (2009); http://accelconf.web.cern.ch/AccelConf/srf2009/papers/tuppo022.pdf