DEVELOPMENT OF HOM DAMPER FOR B-FACTORY (KEKB) SUPERCONDUCTING CAVITIES

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I. INTRODUCTION

Higher Order Mode (HOM) power excited in Superconducting Cavities (SCC) can be on the order of kW in the B-factory due to high current. To extract this power, cavities are designed so that HOM can travel out through beam pipes and be absorbed in a lossy material [1]. Ferrite has been investigated as a candidate material for the absorber [2,3]. Due to its low tensile strength, bonding of tiles has been a problem. To solve this problem, we started R&D on the sinter-bonding of ferrite powder directly on the inner surface of a copper pipe using Hot Isostatic Press (HIP). In this paper, we describe the manufacturing process, low power test, high power test and outgassing rate measurement of the manufactured dampers.

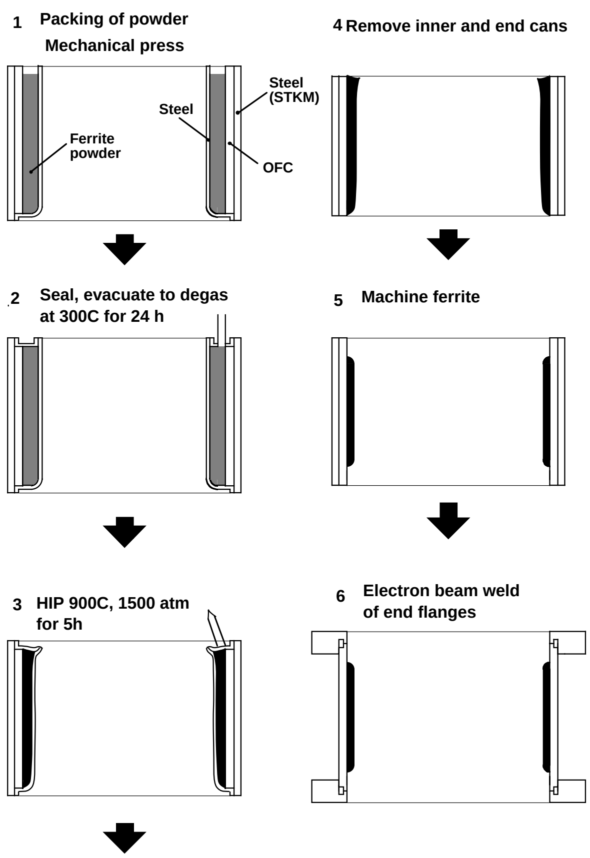

Figure 1: Manufacture process of full size damper.

II. MANUFACTURING [4]

In the design of the SCC for KEKB, there are two dampers on up stream and down stream side of the cavity. Their sizes of ferrite layer are 220 mm and 300 mm in outer diameter, 120 mm and 150 mm in length, respectively. The thickness of both dampers is 4 mm. The latest design has 25 mm tapers at the front and rear end, starting with 1 mm-thick ferrite, to lower the surface temperature as will be shown later. Figure 1 shows the process of manufacturing of full size HOM damper. The process is as follows : 1) pack ferrite powder between inner can and outer copper pipe using mechanical press, 2) TIG weld cans and lid, evacuate and degas ferrite at 300 °C for 24 h, 3) chip off and HIP with Ar at 1500 atm x 900 °C for 5 h, 4) remove inner can with lathe, 5) machine ferrite with diamond grinder, 6) electron-beam weld end flanges and 7) machine a cooling channel on the outer surface of copper, then press-insert the copper pipe in the channel. Figure 2 shows the finished damper. The problems we have faced so far are 1) crack of ferrite when stainless steel ring was HIPped together, 2) voids that appear after ferrite machining and 3) delamination of ferrite. Elimination of stainless steel solved the first problem. The second problem was solved by raising HIP pressure from 1000 to 1500 atm, together with lengthening of the degassing time. The third problem, delamination, has become less by elimination of stainless steel and raising HIP pressure, but, still occurs sometimes. We are planning to lower the ramping

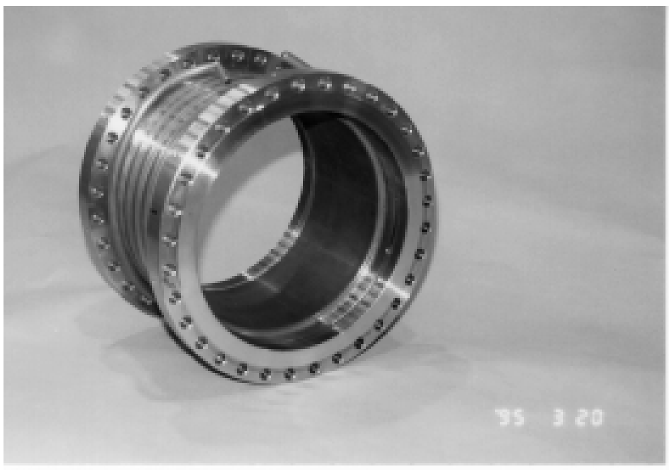

Figure 2: HOM damper . Ferrite size : 220 mm o.d. x 120 mm long x 4 mm thick. Cooling pipe is 3/8" copper pipe pressed in the channel.

rate so that the thermal stress in the ferrite upon cooling down can be less.

III. LOW POWER TEST

A. Mode damping

Damping of each mode has been measured using an aluminum model cavity with a network analyzer [5]. Figure 3 shows the comparison between the cavities with HOM damper and without it. As shown in the figure, most modes were successfully damped. Detailed check of each mode is under way.

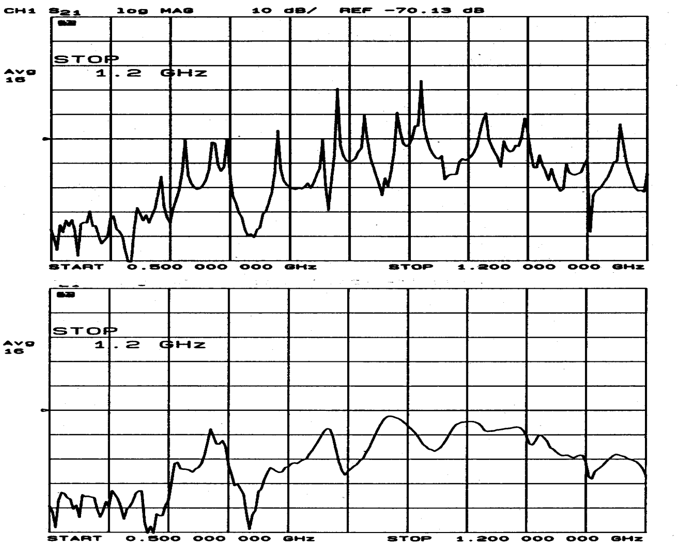

Figure 3: Mode damping with ferrite (lower). 0.5 - 1.2 GHz.

B. Loss factor of ferrite pipe

Loss factor of ferrite pipe alone has been measured by a wire method, so-called synthetic pulse method [6]. 3 mm-diam. inner conductor was set on the central axis, then loss factor was calculated by comparing the inversely Fourier transformed S21 data of the pipes with and without damper. Figure 4 shows the measured loss factor of small damper (220 mm o.d. x 120 mm long) as a function of bunch length. The data for the bunch length shorter than 11 mm is not accurate due to strong reflection for the frequencies corresponding to these data.

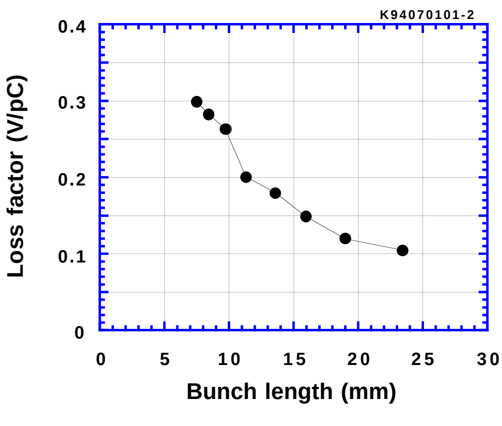

Figure 4: Loss factor of small damper (220 mm o.d. x 120 mm long x 4 mm thick ferrite).

IV. HIGH POWER TEST

We have performed 2 types of high power test as shown below. In both types, tests were performed in air.

A. TM01 mode at 2.45 GHz

Using the smaller diameter model, TM01 mode high power test was performed. The ferrite size was 109 mm o.d. x 150 mm long x 4 mm thick. A 2.45 GHz c.w. magnetron power source (5 kW) was used. The inner surface temperature distribution of ferrite was measured with thermo-labels , i.e., whose white spots change into black at specified temperatures. We tried 3 shapes, without taper and 2 types of tapers as shown in Fig. 5. The max. absorbed power was 3.95 kW and average power density was 8.3 W/cm^2. Assuming the exponential decay of power, the estimated max power density was about 29 W/cm^2 at the leading edge of the ferrite. Figure 5 also shows the temperature distribution. As shown in the figure, introducing a taper was proved to be effective to reduce the surface temperature, which is important to reduce outgas from ferrite. Cooling water flow rate was 3 l/min.

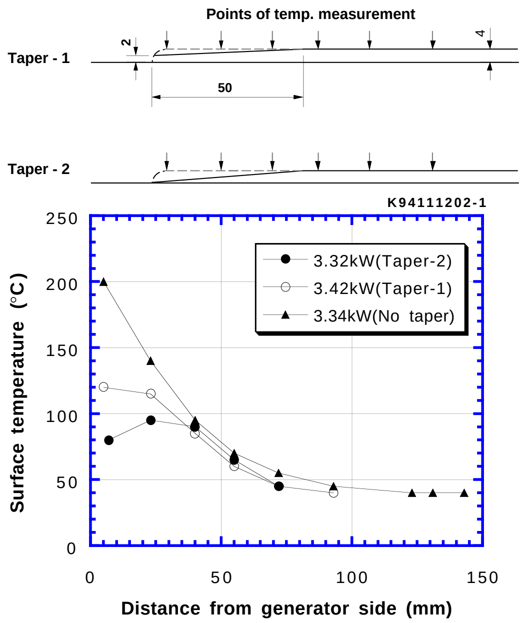

Figure 5: Tapers used in the test (above) and ferrite surface temperature distribution.

B. Coaxial line at 508 MHz

To test power handling capability of full size damper, we started using coaxial line with 508 MHz Klystron. We have tested 2 dampers, both small and large, so far. Small one was tested up to an absorbed power of 11.7 kW and the average power density was 14.6 W/cm^2. Temperature distribution along the pipe axis was rather flat and the max. temperature was 140 - 149 °C at 10.4 l/min of cooling water flow.

Large damper was tested up to 14.8 kW and the average power density was 10.8 W/cm^2. The surface temperature was lowered with the power density.

In both tests, there was no damage on the ferrite. In the next tests, higher power will be fed to know the limit power if possible.

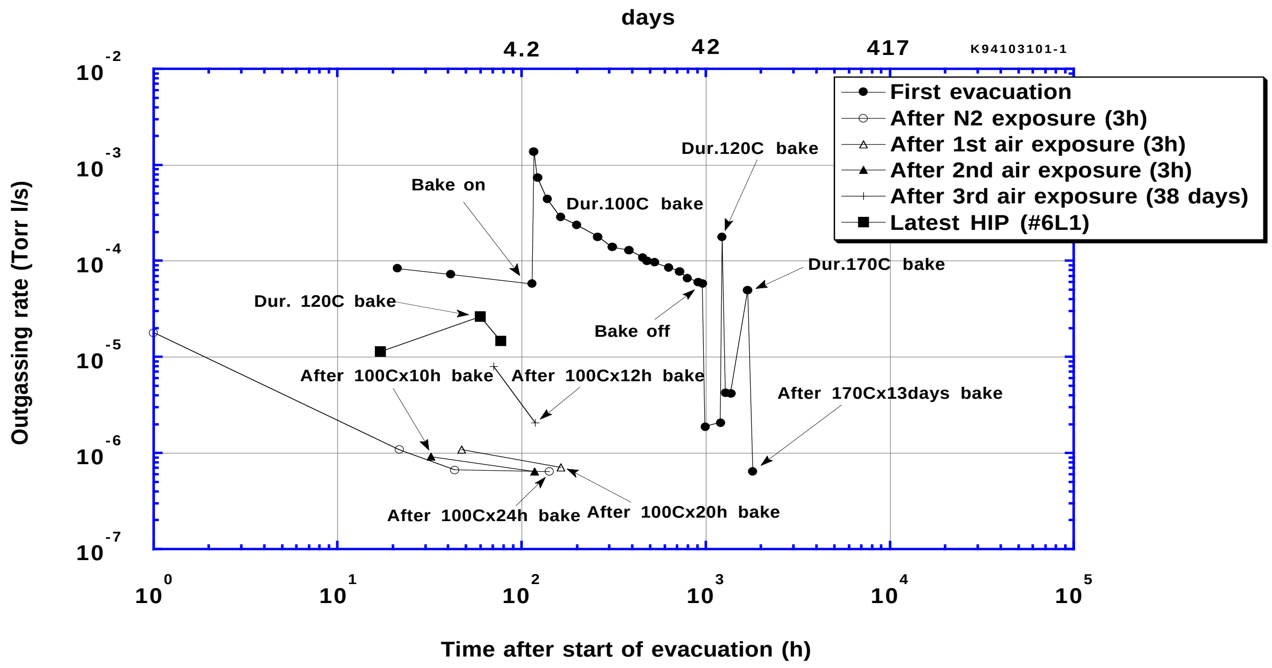

Figure 6: Outgassing rate of large damper. The data except for solid squares were taken from the same damper. #6L1 is the damper that was recently HIPped after improvement of powder degassing. The effects of exposure to N_2 and air are also shown.

V. OUTGAS RATE

Vacuum in the KEKB should be lower than 1 x 10^{-9} Torr to get sufficient beam life time. Also, for SCC, since the condensed gas on the Nb surface seems to play a significant role on the trips, the outgassing rate from HOM dampers should be low enough not to cause any problem. The vacuum before cooling down should be at least 1 x 10^{-8} Torr.

A. Sample test

Outgas rate of commercial ferrite tile (80 mm x 80 mm x 4 mm), TDK IB-004, was measured to be about 5 x 10^{-11} Torr l/scm^2 at room temperature after 140°C x 25 h bake [5].

B. Full size damper

Full size dampers have been measured with through-put method, i.e. the pressure difference between the ferrite chamber and the pump chamber was multiplied with the given conductance to obtain the outgassing rate [4,5]. Figure 6 shows the results of large damper. The ferrite area of large damper is about 1380 cm^2. As shown with solid circles, the outgassing rate was more than an order of magnitude higher than the sample result even after more than one month of baking. However, once it is baked, it can reach the final rate in a few days after 3 h of air exposure. From the fact that the major gas species was water and that the adsorbed gas on the surface can be easily removed, it was concluded that the gas source was the trapped water vapor in the ferrite. Recently, we tried to degas the powder at about 300 °C in dry nitrogen gas before packing. The solid square in Fig. 6 shows the result of the powder-degassed damper. As one can see, the outgassing rate before baking was lowered about an order of magnitude. With this outgassing rate, we can probably reach a vacuum lower than 1 x 10^{-8} Torr before cool down with a pump having effective pumping speed of 100 l/s.

VI. CONCLUSIONS

HOM damper has been manufactured by HIPping of ferrite powder on copper. The small and large dampers were high power tested with 508 MHz coaxial line up to 11.7 kW and 14.8 kW, respectively. There was no damage on the ferrite. The outgassing rate can be sufficiently low to obtain a pressure lower than 1 x 10^{-8} Torr before cooling down of SCC.

A beam test of large damper as well as 1.3 GHz TM01 mode high power test in vacuum will be performed soon.

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