APPLICATION OF COMB-TYPE RF SHIELD TO BELLOWS CHAMBERS AND GATE VALVES

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Abstract

A comb-type RF shield has been applied to bellows chambers and gate valves in a chain of R&D for future high intensity accelerators. The comb-type RF shield has a structure of nested comb teeth, and has higher thermal strength and lower impedance than the conventional finger-type one. Various types of seven bellows chambers have been installed in the KEK B-Factory (KEKB) positron ring since 2003 in series. The temperature of corrugation decreased by a factor of 3 - 6 in most cases. No significant problem has been found in these bellows chamber up to a stored beam current of 1.7 A (1.3 mA/bunch). A circular-type gate valve was also installed in the ring in January, 2005, and promising results were obtained.

INTRODUCTION

Several vacuum components in accelerators, like bellows chambers and gate valves, are usually equipped with RF-shield structures inside. The RF shield bridges a transverse gap or a hole to reduce beam impedance and to avoid heating due to higher order modes (HOM) excited there. One difficulty of RF shields in bellows chambers and gate valves is that they should be able to expand or contract to some extent while keeping a good electric contact. A conventional RF shield is the finger-type consisting of lots of fingers [1]. Recent high-current accelerators, however, put much severer thermal and electrical conditions than ever before on the RF-shield structure [2]. The comb-type RF shield, which was proposed recently in KEK, has better RF property and higher thermal strength compared to the conventional one [3, 4]. The shield was applied to bellows chambers and gate valves, and tested at the KEK B-Factory (KEKB) positron ring with an intense beam up to 1.7 A [5]. Here these results of beam tests are presented and discussed.

COMB-TYPE RF SHIELD

The comb type RF-shield consists of no more than thin fingers, but nested comb teeth [3, 4]. Typical sizes of a tooth are 10 mm in length, 1 mm in width and 10 mm in depth. The gap between adjacent teeth is 2 mm. In principle, the high-frequency wall current accompanied by a bunched beam flows via capacitance between the nested teeth (a gap of 0.5 mm). To ensure the flow of DC or low-frequency wall current, small fingers (back fingers) are prepared at the outer half between the nested teeth. In most of the bellows chambers, an extra RF contact (back shield) was additionally prepared at just outside of the nested teeth to make sure the shield. For the gate valve, however, the sliding of back fingers between teeth can be a source of dust, which could deteriorate the vacuum sealing property. The back finger, therefore, was omitted and only the back shield was prepared.

Advantages of the comb-type RF-shield are as follows: (1) The RF shield, i.e. the copper teeth, has a high thermal strength compared to thin fingers. (2) There is no transverse step at inside surface in principle, and the shield has low impedance. (3) The TE-mode like HOM, which can easily couple with the finger-type RF shield, hardly goes through due to the large radial thickness of teeth. (4) There is no sliding point on the inner surface of beam duct, which otherwise could be a source of arcing. (5) The RF shield can fit for beam ducts with various cross sections. The potential disadvantages compared to the finger-type RF shield, on the other hand, are the limited stroke of expansion/contraction, typically ±4 mm, and the small bending angle, ±30 mrad at most.

APPLICATION TO BELLOWS CHAMBER

Circular Bellows Chamber

The first test model had a circular cross section with a diameter of 94 mm [4]. The nominal (natural) length is 160 mm. The RF shield was made of pure copper (C1011) and other parts, bellows itself and flanges etc., were made of stainless steel (SS316). The test bellows chamber has two cooling water paths around the body. A thermocouple inserted into the inside of teeth can measure the temperature of the RF shield itself.

Two test bellows chamber were manufactured and installed into the ring in 2003. They were placed just at the downstream side of a movable mask (collimator). The movable mask is a big HOM source in the ring [6], and several bellows chambers with the finger-type RF

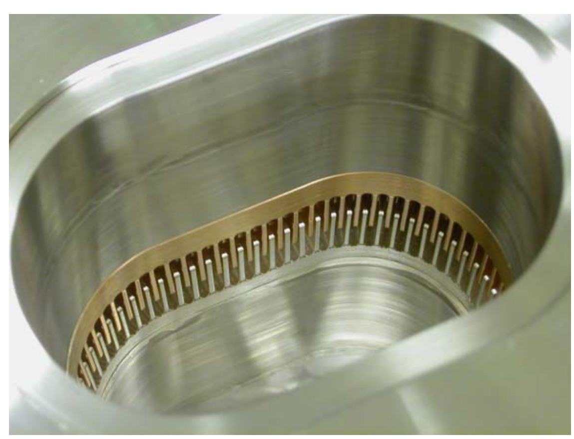

Figure 1: Racetrack bellows chamber with comb-type RF shield.

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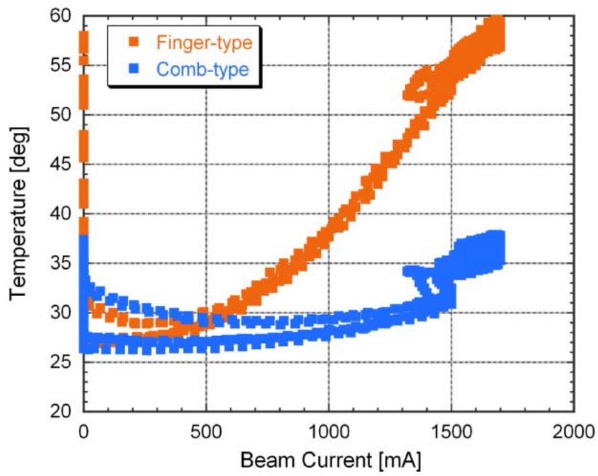

Figure 2: Average temperatures of corrugations of four bellows with comb-type and finger-type RF shield. The data include those during several beam injection cycles.

shield near to the masks had suffered damages from the excess heating [7]. Actually the excited HOM power is estimate as about 11 kW for a 1.7 A beam (1284 bunches, 6 mm bunch length). The temperature of flanges and corrugations of bellows, and the vacuum pressures near to the bellows chamber were measured during the usual beam operation.

The temperature of the corrugation was about 35°C (ΔT = 11°C) at the beam current of 1.5 A (1.2 mA/bunch) without a cooling fan. The temperature rise decreased to 1/6 compared to that of the finger-type one. The temperature was almost the same as that of flanges. On the other hand, the temperature of the tooth itself was about 50°C (ΔT = 26°C), which causes no problem structurally. The temperature, furthermore, was much insensitive to the bunch fill pattern compared to that of the finger-type. These mean that little HOM leaks through the comb-type RF shield. Any trace of arcing, such as burst of pressures, and any structural damages have not been observed for these 2 years.

Racetrack Bellows Chamber

As a next step, a bellows chamber with a small racetrack shape (76 mm in width × 48 mm in height) was produced as shown in Fig.1. It was also installed in the KEKB positron ring. The aperture is the narrowest one in the ring and the wall current is the severest as a result. In this bellows chamber, as a test, the back shield was omitted and only the back fingers were prepared. The materials were the same as the previous circular one.

The temperature of corrugation was about 45°C (ΔT = 21°C) without a cooling fan at the beam current of 1.7 A (1.3 mA/bunch). The temperature, however, was almost the same as that of a bellows chamber with the finger-type RF shield. Further investigation including the mode of HOM excited there will be necessary, but the result indicates that the comb-type RF shield with only the back finger has not so different RF-shielding effect from the finger-type. That is different from the calculation for the TE modes [3]. The back shield will improve the RF-shield property. No trace of vacuum arcing has been observed for one year.

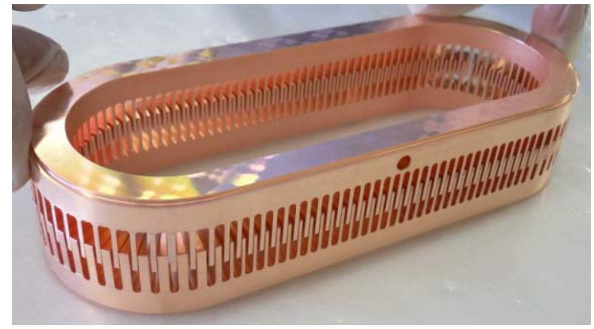

Figure 3: Trial model of racetrack comb-type RF shield without back fingers.

Circular Bellows for Movable Masks

A movable mask itself uses four bellows at both sides [6]. These bellows, however, have to be able to bend up to 20 mrad to adjust the position of mask head. The comb-type RF shield, which can be bent up to about 30 mrad in principle, was then applied to these bellows. The aperture is circular (ϕ94 mm) and installed into the positron ring in 2004. Both the back finger and the back shield were prepared in this case.

As shown in Fig.2, the average temperature of four corrugations decreased from 58°C (ΔT = 32°C) to 37°C (ΔT = 11°C) at the beam current of 1.7 A. The temperature rise decreased to about 1/3. Note here that only the bellows chambers with finger-type RF shield was cooled by fans. The temperature of corrugation was almost the same as that of flanges. The temperature was insensitive to the bunch fill patterns for the comb-type RF shield. There was no trouble for this one year's operation.

Next Step

The first plan is to apply it to the bellows chamber near to the interaction region of the KEKB, where the intense HOM is also generated due to the complex structure of beam ducts. The bellows chamber has a larger racetrack shape compared to the previous one, 150 mm in width × 50 mm in height. The RF shield under manufacturing is presented in Fig.3. In this case, as a test, the back finger will be omitted as that of gate valve described below, and only the back shield will be prepared.

Another plan is to apply it to the beam duct for future high current machine. In this case, to manage the intense synchrotron radiation, the cross section of beam duct becomes complicated such as a beam duct with antechambers [8]. The cross section of the RF shield has the same cross section as a result.

Figure 4: Comb-type RF shield for gate valve.

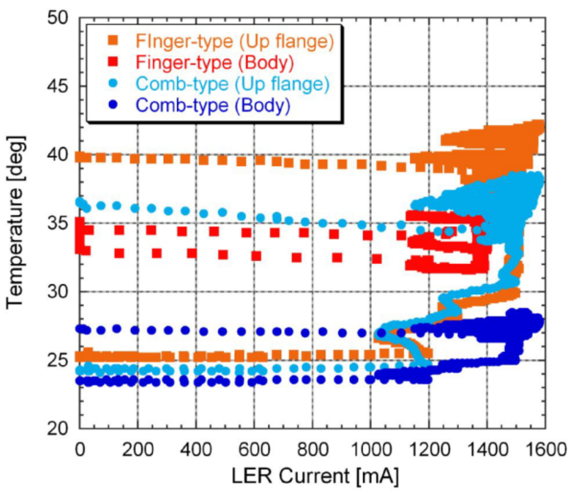

Figure 5: Temperatures at connection flange and body of gate valves with comb-type and finger-type RF shield. The data include those during several beam injection cycles. Small decreases of temperatures at low beam currents are due to the large heat capacity of gate valve.

These bellows chambers will be installed in the electron or position ring of the KEKB this summer and tested with beam.

APPLICATION TO GATE VALVE

The gate valve has the similar problem as the bellows chamber. The gate valve for accelerator has usually an RF-shield structure and the conventional one is the finger-type. The heating and the resultant excess gas desorption has been already observed in KEKB as the bellows chamber. The R&D to apply the comb-type RF shield to gate valves was tried under the collaboration with VAT Vakuumventile AG [9].

Circular Gate Valve

One test model with a diameter of 94 mm and the width of 95 mm was manufactured. The inside view is shown in Fig.4. The base design of the valve, such as the vacuum sealing mechanism, was the same as the standard one, and only the RF-shield part was modified to the comb-type RF shield. The gate valve was installed at the arc section of the KEKB positron ring, near to the movable masks. The tooth was made of pure copper and other parts are made of stainless steel (SS304). As described above, the back finger was omitted to avoid the generation of dust due to abrasion during open/close motion.

The temperatures around the connection flange and the body of gate valve were measured. The pressure near to the gate valve was also observed during the operation. The temperatures are shown in Fig.5 for the cases of the comb-type and the finger-type RF shields. The temperature decreased from 42°C (ΔT = 18°C) to 38°C (ΔT = 14°C) at the flange and from 36°C (ΔT = 12°C) to 28°C (ΔT = 4°C) at the body of gate valve at 1.6 A. The large decrease of temperature rise at the body means the decrease of HOM intruding inside. A little reduction of the temperature rise at flanges is explained by that the stainless-steel flange is also a main source of heating. No trace of arcing has been observed for one year. These mean the RF shield is working well, even without the back finger. The omission of the back finger practically simplifies the structure of the comb-type RF shield. For the gate valve, however, only the expansion and the contraction are required in principle. The possibility to omit the back finger even for the bellows chamber should be tested separately, where the bending and some offsets are to be considered.

Next Step

As a next step, a gate valve with a racetrack shape will be manufactured and tested with beam at the electron ring of KEKB. The design is undergoing and a trial model will be installed in the early stage of 2006.

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