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DEVELOPMENT OF HOM ABSORBERS FOR CW SUPERCONDUCTING CAVITIES IN ENERGY RECOVERY LINAC

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Abstract

Higher Order Modes (HOM) absorbers for Superconducting cavities in energy recovery linac (ERL) have been developing at TOSHIBA in collaboration with High Energy Accelerator Research Organization (KEK) since 2015. A prototype HOM absorber for 1.3 GHz 9-cell superconducting cavity was fabricated. An aluminum nitride based lossy dielectrics (AlN) cylinder was brazed in a copper cylinder. Stainless steel flanges were joined on either end of the copper cylinder by electron beam welding to fabricate a whole prototype HOM absorber. AlN/Cu brazing tests and Cu/SUS welding tests were carried out before fabricating the prototype. Fabrication process of the prototype HOM absorber will be presented in this paper.

INTRODUCTION

KEK has been designing the 10 mA class ERL-FEL light source accelerator. The main linac uses 9-cell cavities with beam line type HOM absorbers. The target accelerating gradient is 12.5 MV/m. The 9-cell cavity is designed from experience of the KEK compact ERL (cERL) main linac [1]. HOM absorbers are one of the key components to determine the ERL cavity performance to reduce the HOM problem for the high current operation. The absorption heat of HOM absorber is estimated to about 10 W. The use of the AlN is planned as HOM absorber material because it has high RF absorption at 80 K. Permittivities and Permeabilities of AlN were measured at room temperature and 80K. It was confirmed that 80 K data keep high value at high frequency [2]. Shape of HOM absorber has been designed [3].

TESTS BEFORE FABRICATING A PROTOTYPE HOM ABSORBER

Brazing Tests

Brazing tests between AlN and Cu were carried out before fabricating a prototype HOM absorber. An AlN cylinder was brazed in a copper cylinder, which has lattice-like slots on the inner surface. The size of an AlN cylinder and a copper cylinder used for the tests are shown in Table 1. The outer surface of an AlN cylinder was Mo-Mn metalized and Ni plated. Brazing conditions are shown in Table 2. Figure 1 shows a test piece after brazing. Ultrasonic testing of the test piece in the water bath was carried out to check their good adhesions. It was found that the AlN cylinder was partially touched the copper cylinder. To confirm the mechanical properties of the brazed connection during thermal cycling, the test piece was cooled down to 80 K with nitrogen gas. After cooling, cracks occurred in the AlN cylinder (see Fig. 2). The test piece was cooled in one hour from room temperature to 80 K. It was too fast to cool the test piece uniformly.

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Table 1: Test Pieces for Brazing

Material	Inner Diameter	Thickness	Length
AlN	100 mm	10 mm	20 mm
Copper	120 mm	6.5 mm	69 mm

Table 2: Brazing Conditions

Brazing material	Silver
Process temperature	750 ºC
Furnace atmosphere	Hydrogen

Figure 1: Test piece of brazing.

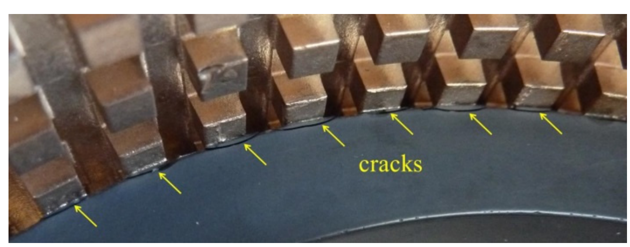

Figure 2: Cracks occurred in AlN cylinder.

Welding Tests

Welding tests between Cu and SUS were carried out. Stainless steel flanges were joined on both ends of a copper cylinder by electron beam welding (EBW). The size of a copper cylinder and stainless steel flanges used for the tests are shown in Table 3. They are the same size as the prototype. Conditions of EBW are shown in Table 4. Figure 3 shows the test piece after welding. Back side of the flange and the copper cylinder was welded to

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reinforce. Figure 4 shows the micro structure of the cross-section of the welded parts. The temperature of the copper cylinder was measured with thermocouples during welding. Consequently, temperature of the copper cylinder brazed an AlN cylinder was less than 100 °C.

The thermal cycles of the test piece of Cu/SUS between 80 K and room temperature were carried out five times. After the thermal cycles, the leak test was carried out and there was no problem.

Table 3: Test Pieces of Welding

Part	Material	Size[mm]
Cylinder	Copper	I.D. 120, t 6.5, L 126
Flange	Stainless steel	O.D. 215, T 22

Table 4: Conditions of EBW

Acceleration voltage	125 kV
Beam current	30 mA
Welding speed	750 mm/min

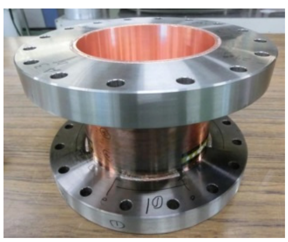

Figure 3: Test piece of welding.

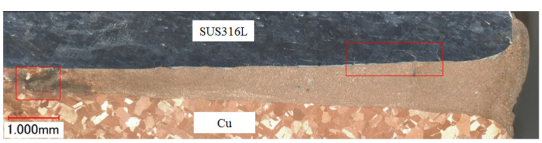

Figure 4: Micro structure of the cross-section.

FABRICATION OF A PROTOTYPE HOM ABSORBER

Specifications

Main specifications of the prototype HOM absorber are shown in Table 5. The drawing of the prototype HOM absorber is shown in Fig. 5.

Table 5: Prototype HOM Absorber Specifications

Frequency	1.3 GHz
Type	Beam line type
Inner diameter	100 mm
Working temperature	80 K
RF absorbing material	AlN (Sienna tec., STL-150D)
Flanges material	Stainless steel (SUS316L)

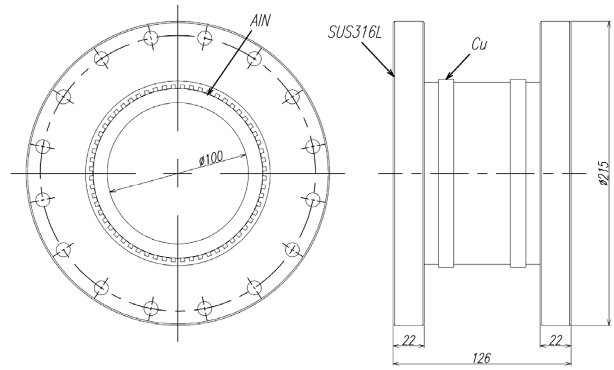

Figure 5: Drawing of the prototype HOM absorber.

Fabrication Process

The parts used for a prototype HOM absorber are shown in Table 6. An AlN cylinder was brazed in a copper cylinder under the same conditions as the tests (see Table 2). Figure 6 shows a copper cylinder brazed with an AlN cylinder. Outer periphery of the copper cylinder was cut and its thickness was thinned to reduce the forces after cooling down. An 80 K anchor will be attached around the copper cylinder at the cooling tests.

After brazing, stainless steel flanges were welded on both ends of the AlN/Cu cylinder under the same conditions as the tests (see Table 4). Figure 7 shows the completed the prototype HOM absorber.

Table 6: Parts of the Prototype HOM Absorber

Parts	Size[mm]	remarks
Copper Cylinder	I.D. 120, t 6.5, L 126	Lattice-like slots on the inner surface
AlN	I.D. 100, t 10, L 20	Mo-Mn metalized and Ni plated on the outer surface
Stainless steel Flange	O.D. 215, t 22	

Figure 6: A copper cylinder brazed with an AlN cylinder.

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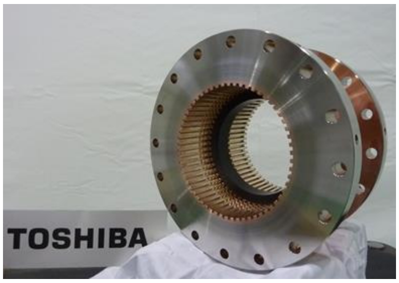


Figure 7: Prototype HOM absorber.

Ultrasonic Tests

Ultrasonic testing of the HOM absorber prototype in the water bath was carried out. Figure 8 shows a set up for the ultrasonic testing. The test results are shown in Fig. 9. Point A in Fig. 9 (1) is outside of AlN. It has two peaks as shown Fig. 9 (2). The first peak at 67 µm means that the boundary of water and copper cylinder outside reflects the ultrasonic wave. The second peak at 69 µm means that the boundary the copper cylinder inside and water reflects the ultrasonic wave. Point B in Fig. 9 (1) doesn't have the second peak around 69µm as shown Fig. 9 (3). It means that AlN and copper are completely touched. Point C in Fig. 9 (4) has the small peak around 69µm. It means that AlN and copper are not completely touched. The color of scanning image shows the echo height. Completely touched points of AlN and copper as point B are dark in Fig. 9 (1). Not at all touched points as point A are bright. Incompletely touched points as Point C are slightly brighter than point B. It is considered that about 40 % of the brazed area is not completely in the scanning image. Considering the color of the scanning image, touched area of AlN and copper is considered to be about 60 % of the brazed area.

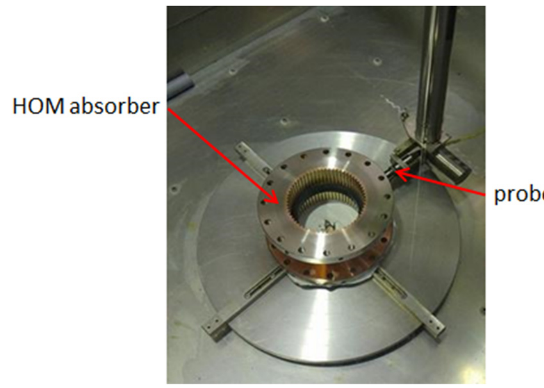
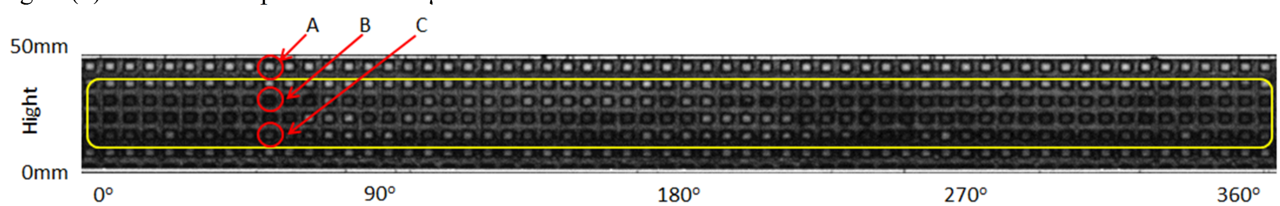
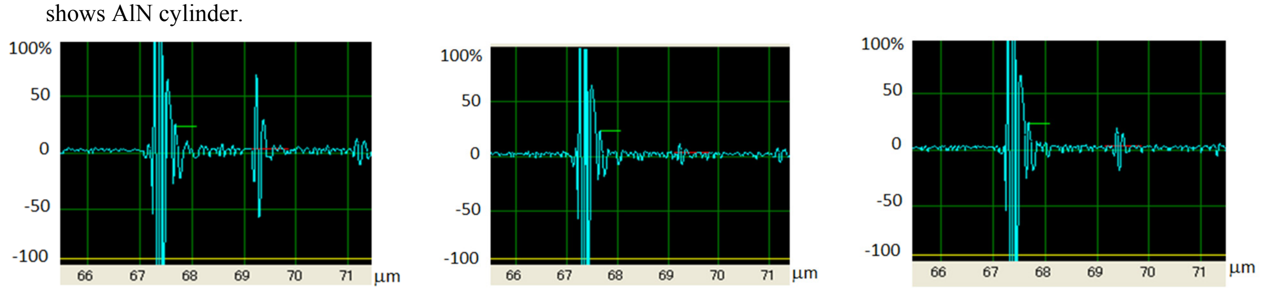


Figure 8: Set up for ultrasonic testing in water.



(1) The scanning image of the HOM absorber. It shows the scanning image width 50 mm of the coppTer cylinder. Yellow lines area shows AlN cylinder.



(2) Echo waveforms at point A in the figure above. (3) Echo waveforms at point B in the figure above. (4) Echo waveforms at point C in the figure above.

Figure 9: Ultrasonic testing results.

CONCLUSION

The prototype HOM absorber for 1.3 GHz 9-cell superconducting cavity was fabricated. Ultrasonic testing of the HOM absorber was carried out. Consequently, touched area of AlN and copper is considered to be about 60 % of the brazed area. As one of means for extending touched area, it is considered to form a fillet brazed joint. The shape of grooves of a copper cylinder should be considered to form the fillet.

RF performance measurements of this prototype HOM absorber at room temperature and 80 K will be carried out at KEK.

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