COOLING PROPERTIES OF HOM ABSORBER MODEL FOR CERL IN JAPAN

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Abstract

Two types of the HOM absorber models were designed and fabricated according to results of ferrites and ceramic properties measurement at low temperature. One without HIP ferrite was used to measure thermal property and the other with HIP ferrite to confirm HOM absorption property and thermal tolerance against cooling cycle. Measurement of thermal resistance in inadequate position of comb-type RF bridge suggested that the comb teeth should be modified to reduce the thermal transmission. The HIP ferrite attached to our 9-cell ERL model cavity sufficiently damped HOMs. Several cracks were observed during cooling cycle test.

INTRODUCTION

HOM damping is important for superconducting cavities, especially for high current CW machines such as ERLs. The lower Q-values of HOMs lead to the smaller capacity of a refrigeration system and the higher threshold current against the beam breakup (BBU). Enlarged beam pipes, which have lower cutoff frequencies, are effective to damp monopole and dipole HOMs [1] and the eccentric-fluted beam pipe is effective to damp quadrupole HOMs [2]. Propagating HOMs through the beam pipe are absorbed and damped by the HOM absorbers. Since the HOM absorbers are connected to the superconducting cavities in a cryomodule as shown in Fig. 1, the operating temperature of the HOM absorbers is near liquid nitrogen temperature. The HOM absorbers are required to have high thermal resistance between liquid nitrogen temperature and liquid helium temperature parts to reduce the heat load into the superconducting cavity. The HOM absorption materials are required to have good HOM absorption property as well as good tolerance against cooling cycle.

The HOM absorber models were designed and fabricated to confirm the thermal property and tolerance at liquid nitrogen temperature.

The present paper describes the measured results of thermal property and tolerance at low temperature and HOM absorption property at room temperature .

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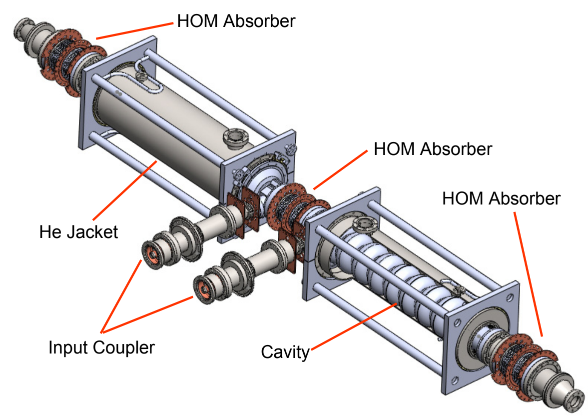

Fig. 1: Layout of HOM absorbers in the cryomodule.

HOM ABSORBER MODELS

The HOM absorber can be divided into three parts. The center part consists of the RF absorber and the 80K-anchor connected to the liquid-nitrogen-temperature line. Both end parts consist of the flange connected to the superconducting cavity and the 5K-anchor. The center part and the end part are connected with a bellows.

HIPped (Hot Isostatic Press) ferrite is attached on the inner surface of the copper base. Since HIP can bond between the ferrite and the copper base firmly, HIP process is adopted to prevent from the ferrite falling off from the copper base. The comb-type RF bridge is adopted at the beam pipe connection between the center and the end parts [3]. The comb-type RF bridge has the advantages of low impedance and small heat conductance compared with the finger-type RF connector. The bellows is used to increase allowance of the flange connection and the heat shrink. The bellows is also used to reduce the heat transmission to the superconducting cavity when the ferrite temperature rises due to HOM power absorption.

Two types of the HOM absorber models were designed and fabricated. One was almost same structure of the HOM absorber except the HIP ferrite (Fig, 2 upper) and the other was a center part with HIP ferrite before machining for teeth of the comb-type RF bridge and the 80K-anchor (Fig. 2 lower). The former was used to measure the thermal property at 80K and the latter to measure the HOM absorption property and the cooling cycle tolerance.

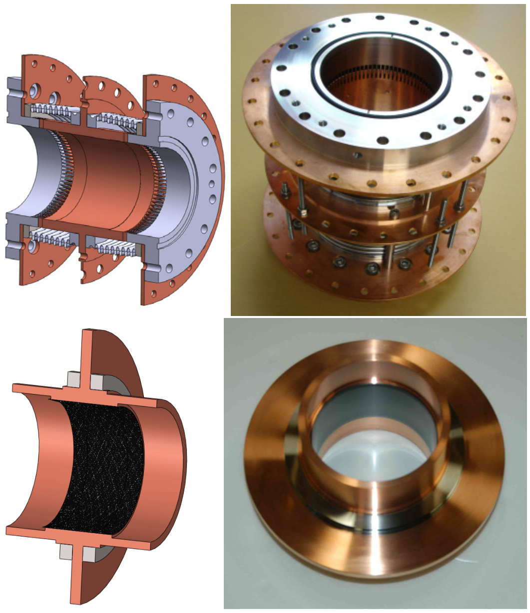

Fig. 2: Schematic views and photographs of HOM absorber models without HIP ferrite (upper) and center part with HIP ferrite (lower).

THERMAL PROPERTY

The HOM absorber model without HIP ferrite was cooled to the liquid nitrogen temperature in an adiabatic vacuum chamber. The results were presented elsewhere [4]. The thermal resistance was also measured in inadequate position where the opposite comb teeth contacted longitudinally or at a tilt. Figure 3 shows the results of thermal resistances. Though radiation can not be ignored near room temperature and small temperature changes make hard to measure accurately at low temperature, the results near middle temperature can be considered to be precise. The thermal resistances of longitudinal and tilted contact were about 1/6 and 1/2 times lower than that in the adequate position. The reason of these bad thermal resistances was considered to be caused by simple cutting of comb teeth. The comb teeth were square cut at the top and radially cut at the side. In these cases contact section is apt to increase when opposite comb teeth contact as shown in Fig. 4 left. To decrease the thermal transmission by contact with comb teeth, the shape of comb teeth should be modified to tilted cut at the top and parallel cut at the sides as shown in Fig. 4 right

HOM ABSORPTION PROPERTY

The HOM absorber model with HIP ferrite was attached to our 9-cell ERL model cavity to confirm HOM absorption property as shown in Fig. 5. The resonant peaks were searched with a network analyzer and Q-values were measured under two conditions with and without the HOM absorber model with HIP ferrite.

The resonant peaks and their Q-values are shown in Fig. 6. It indicates that the HOM absorber model with HIP ferrite sufficiently decreases the Q-values of both monopole and dipole modes. Some Q-values were too low to be measured with the network analyzer as plotted with blue dot only and no red dot in Fig. 6 lower.

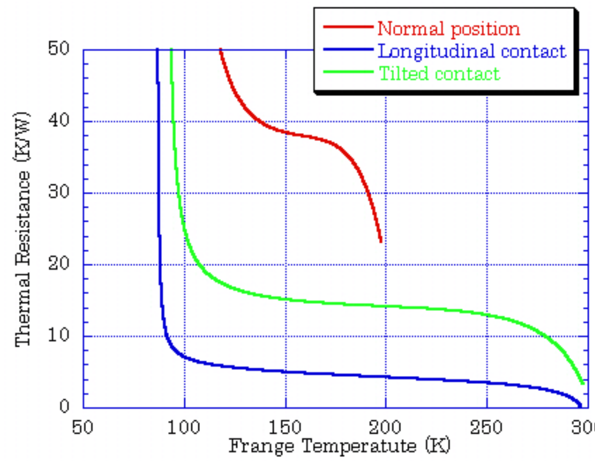

Fig. 3: Thermal resistances in the normal position, with longitudinal and tilted contact.

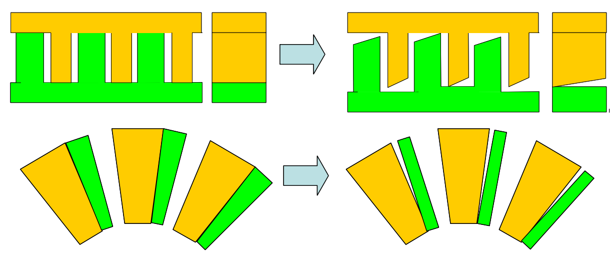

Fig. 4: Schematic views of comb teeth shape cut before (left) and after (right) modification.

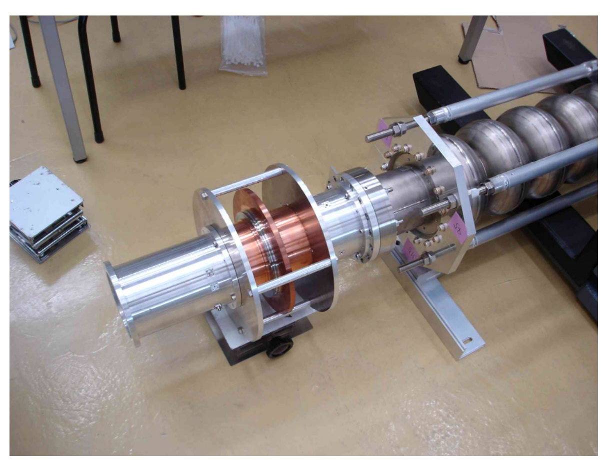

Fig. 5: Setup of HOM absorption measurement with our 9-cell ERL model cavity.

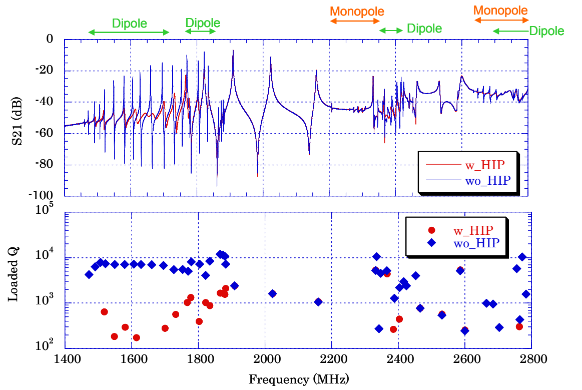

Fig. 6: HOM peaks and Q-values with and without HIP ferrite.

COOLING CYCLE TEST

The coefficients of thermal expansion are different between ferrite and copper. When the HOM absorber is cooled down to liquid nitrogen temperature, the different coefficients of thermal expansion may cause the stress and damage to the HIP ferrite. Cooling cycle test was performed to check tolerance of the HIP ferrite. The HOM absorber model with HIP ferrite was cooled and heated by a GM refrigerator between room temperature and 80K while controlling the speed of temperature change. Figure 7 shows a schematic view of the cooling cycle test setup. Two HOM absorber models with HIP ferrite were used for the cooling cycle test. It took 2.5 days each for the models to cool and heat between room temperature and 80K to make the temperature difference between the copper base and the ferrite as low as possible.

The surface of the HIP ferrite was observed with a closeup CCD camera. The HIP ferrites initially had some linear cracks. After the first cooling cycle test, several linear cracks were observed mainly near the ferrite edge where the ferrite was tapered as shown in Fig. 8. Though one of two models with HIP ferrite chipped off a small piece of ferrite after the 2nd cooling cycle as shown in Fig. 9, the other was not observed to chip off during the five times of cooling cycle. Further inspections with ultrasonic echo will be carried out to investigate the other cracks inside the ferrite.

CONCLUSION

Two types of the HOM absorber models were fabricated and cold tests were performed. With the results of thermal resistance of the comb-type RF bridge, the shape of comb teeth is going to be modified to reduce the heat transmission. The other HOM absorber model with HIP ferrite was attached to our 9-cell ERL model cavity and both monopole and dipole HOMs were sufficiently damped. During cooling cycle test, linear cracks and small trails of chipped-off ferrite were observed. More detail inspection of ferrite surface as well as inside will be carried out.

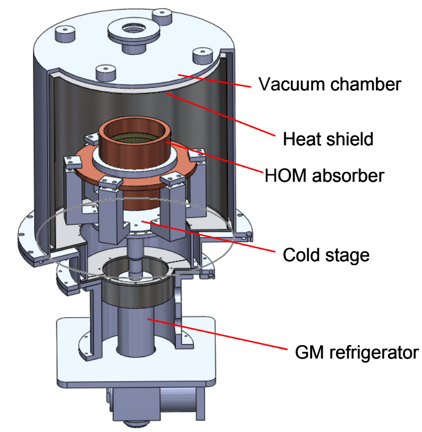

Fig. 7: Schematic view of cooling cycle setup for HOM absorber model with HIP ferrite.

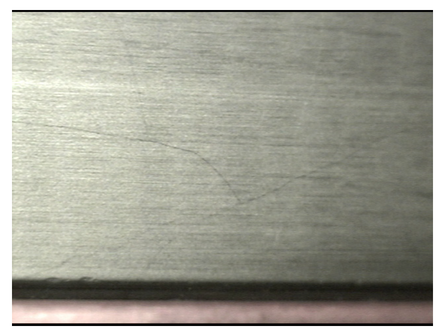

Fig. 8: Linear cracks observed near the tapered ferrite edge.

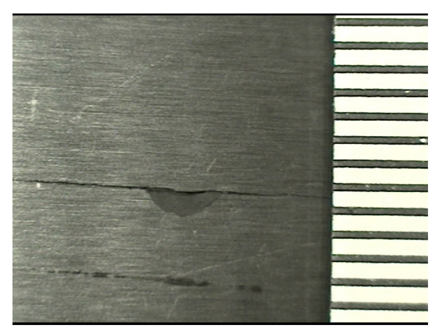

Fig. 9: Trail of chipped-off piece (left) and 1mm-scale (right).

REFERENCES

[1] K. Umemori et al., "Design of L-Band Superconducting Cavity for Energy Recovery Linacs", Proc. of APAC2007, 570-572 (2007)
[2] M. Sawamura et al., "Eccentric-fluted beam pipes to damp quadrupole higher-order modes", Phys. Rev. ST Accel. Beams 13, 022003 (2010)
[3] Y.Suetsugu, et al., Proceedings of the 5th Annual Meeting of Particle Accelerator Society of Japan and the 33rd Linear Accelerator Meeting in Japan, August 6-8, 2008, pp. 200-202 (in Japanese)
[4] M. Sawamura et al., "Cooling Test of ERL HOM Absorber", Proc. of IPAC2010, 2344-2346 (2010)