COOLING TEST OF ERL HOM ABSORBER

M. Sawamura#, JAEA, Tokai, Ibaraki 319-1195, Japan
T. Furuya, H. Sakai, K. Umemori, KEK, Tsukuba, Ibaraki 305-0801, Japan
K. Shinoe, ISSP, University of Tokyo, Kashiwa, Chiba 277-8581, Japan

Abstract

HOM absorbers are one of the key components to determine the energy-recovery linac (ERL) cavity performance to reduce the higher-order mode (HOM) problem for the high current operation. Since the HOM absorbers are installed inside the cryomodule, the HOM absorbers must be cooled down to liquid nitrogen temperature. The HOM absorbers are required to have good thermal properties such as thermal resistance and thermal transmission. The HOM absorber test model was designed and fabricated to test the cooling and temperature properties were measured.

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 of the beam breakup (BBU). Enlarged beam pipes, which have lower cutoff frequencies, are effective to damp monopole and dipole HOMs and the eccentric-fluted beam pipe is effective to damp quadrupole HOMs [1]. Propagating HOMs through the beam pipe are absorbed and damped by the HOM absorbers. Since the HOM absorbers are connected to the superconducting cavities 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 the parts of liquid nitrogen temperature and those of liquid helium temperature to reduce the heat load into the superconducting cavity. The HOM absorbers are also required to have good thermal transmission properties to effectively remove the HOM absorption power. The HOM absorber test model was designed and fabricated to confirm the thermal properties by cold test at liquid nitrogen temperature. The thermal simulation calculation was also performed

The present paper describes the results of measurement and calculation of the HOM absorber test model at low temperature.

HOM ABSORBER TEST MODEL

The HOM absorber test model was designed and fabricated with the results of the measurement of ferrites and ceramic properties at low temperature [2]. Figure 2 shows schematic view of the HOM absorber test model. The HOM absorber test model 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 to connect with 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 HOM absorber. 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 are used to increase allowance of the flange connection and the heat shrink. The bellows are also used to reduce the heat transmission to the superconducting cavity when the ferrite temperature rises due to HOM power absorption.

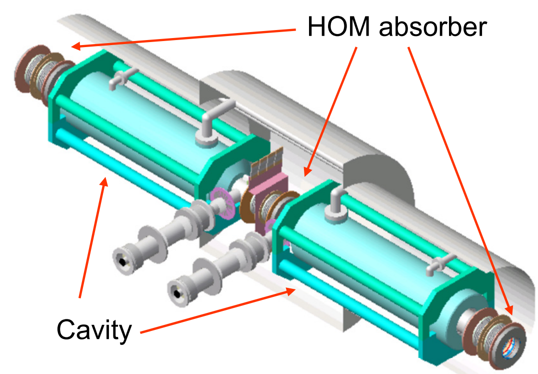

Figure 1: Layout of HOM absorbers in the cryomodule

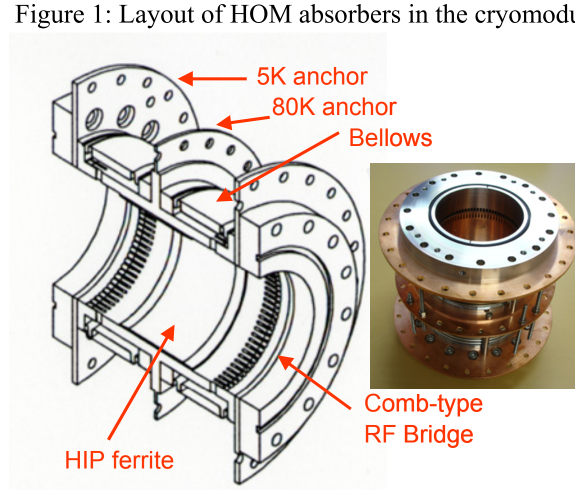

Figure 2: Schematic view and photograph of HOM absorber

#sawamura.masaru@jaea.go.jp

SETUP FOR COLD TEST

The HOM absorber test model was cooled at the liquid nitrogen temperature in an adiabatic vacuum chamber as shown in Fig.3. Inside the chamber a liquid nitrogen tank was set and connected to the HOM absorber test model with the four blade lines. Each blade line has 100 mm^2 cross-section and 200 mm long. The connection copper plates were used to connect the blade lines to 80K-ancher plate. The connection plates will be used to support the HOM absorber inside the cryomodule. An aluminum heat shield box was connected with the liquid nitrogen tank and surrounded by the super-insulator. It was used to prevent from the heat radiation from the chamber body. The HOM absorber test model was adiabatically fixed inside the heat shield box with the teflon rods. The heat shield box was also supported by the teflon rods inside the chamber.

A ribbon heater was installed on the base metal where the ferrite should be attached to estimate the temperature rise due to the HOM power absorption,

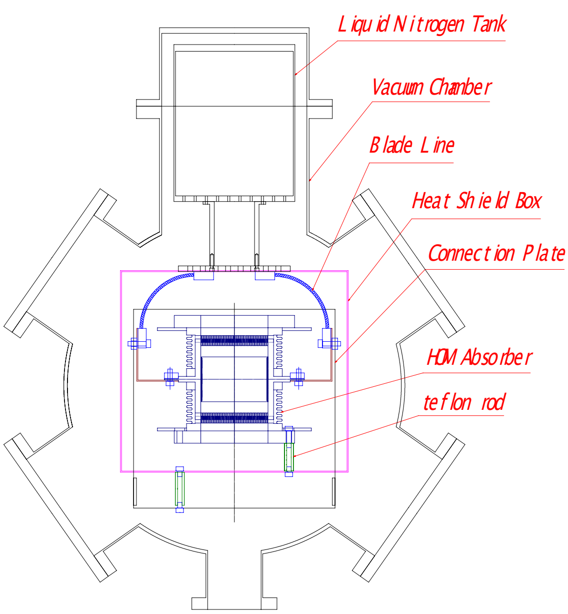

Figure 3: Setup of HOM absorber test model in vacuum chamber for cold test

MEASUREMENT OF THERMAL PROPERTIES

Figure 4 shows the measured temperature of the 80K anchor and both flanges at the cooling process.

The thermal resistance can be estimated as following. Assume that a body with mass of m and specific heat of C is connected with material of thermal resistance R with temperature of both ends of θ_0 and θ. When the temperature θ changes $d\theta$ at an interval of dt, the thermal resistance can be expressed as

$$R = \frac{\int (\theta - \theta_0) dt}{m \int C d\theta} . \qquad (1)$$

With the result of measurement the thermal resistance of bellows between the 80K anchor and the flange can be estimated as shown in Fig.5.

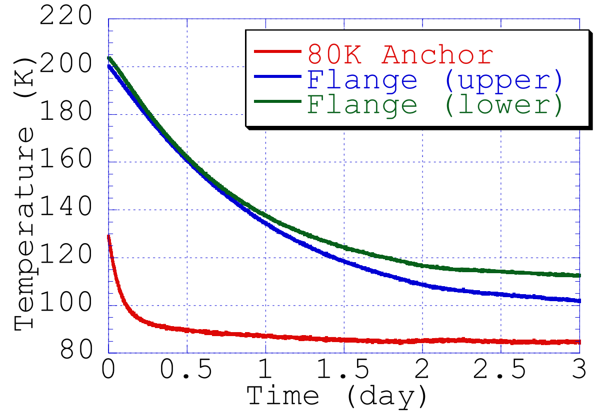

Figure 4: Measured temperature of HOM absorber test model

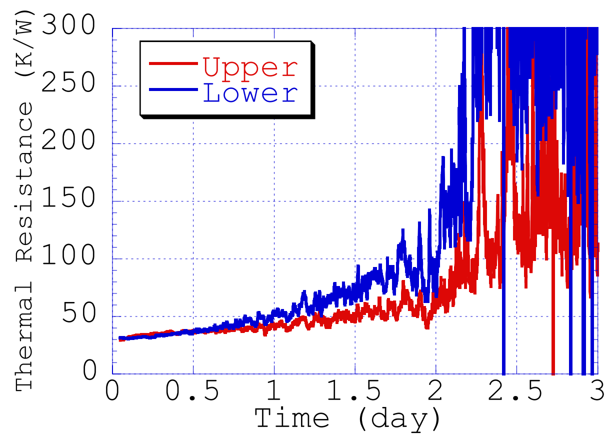

Figure 5: Measured thermal resistance of bellows of HOM absorber test model

CALCULATION OF THERMAL PROPERTIES

The thermal resistance through the bellows was also estimated by heat transfer simulation code ABAQUS. The axisymmetric 2D model was used for simplicity since the HOM absorber itself can be considered as axisymmetric and the blade lines and connection plate can keep the thermal property by changing the thickness according to the radius to keep their cross-section. Though the parameters such as heat conductivity, density and specific heat necessary to solve the transient problem are functions of temperature, the calculation was performed with the constant values at room temperature for simplicity. Figure 6 shows the temperature of 80K-anchor and 5K-anchor as a function of elapsed time from the beginning of cooling.

With the Eq.(1) the thermal resistance was calculated as shown in Fig.7. The thermal resistance of the bellows is 150 K/W

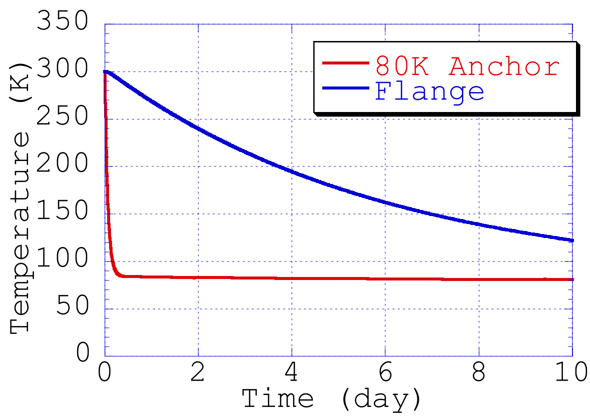

Figure 6: Calculated temperature of HOM absorber test model

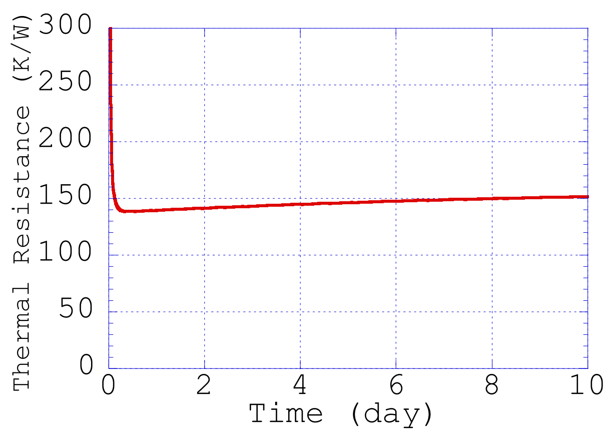

Figure 7: Calculated thermal resistance of bellows of HOM absorber test model

COMPARISON WITH MEASUREMENT AND CALCULATION

The measured thermal resistance was smaller than the calculated one and increased with time. The small thermal resistance can be considered to have some heat transmission paths besides the bellows. Two kinds of heat radiation can be considered to be included in the measured thermal resistance.

The first is the heat radiation between the teeth of the comb-type RF bridge. The comb-type RF bridge is equipped as each tooth is stuck in between teeth of opposite comb-type RF bridge. The surface area of the teeth of the comb-type RF bridge is 0.021 m^2. When temperature of the 80K-anchor is 80 K and that of flange 130 K, the heat radiation is estimated as 0.147 W and the thermal resistance is converted to be 340 K/W.

The second is the heat radiation between the flange and its surroundings such as the liquid nitrogen tank and the heat shield box. When the tank is filled with liquid nitrogen, the blade lines, the connection plates and the heat shield box are cooled much faster than the flange as shown in Fig.4 and Fig.6. The surface area of the flange is 0.048 m^2 and the heat radiation is estimated at 0.334 W when temperature of the flange is 130 K and that of surrounding parts 80 K. The thermal resistance is converted to be 150 K/W. When the temperature difference between the flange and 80K-anchor decreases, the heat radiation also decreases and the heat resistance increases. Since the flange will be connected to the superconducting cavity and cooled at 4 K, the heat radiation between the teeth of comb-type RF bridge can be ignored for the actual module setup.

HEATER TEST

The HOM power absorption test was performed by turning on the heater installed inside the HOM absorber test model. By measuring the temperature differences between the connection parts such as the blade line, the connection plate and 80K anchor, the temperature rise can be estimated when 100W HOM absorption occurred. Table 1 shows the result of measurement of heater power of 38.5 W. The major temperature difference was between the both ends of the blade lines. When the length is shortened and number of the blade line increases, the temperature difference will decrease.

Table 1. Temperature difference of connection of heat transmission line

Measured Point	ΔT (K)
Liq. N_2 Tank - Blade Line	10.1
Blade Line	40.8
Blade Line - Connection Plate	4.1
Connection Plate	8.1
Connection Plate - 80K Anchor	2.9

CONCLUSION

The HOM absorber test model without ferrite was fabricated and cold test was performed. Some temperature properties such as the heat resistance of the bellows and the temperature rise at the HOM absorption condition are estimated. With these results the heat transmission and heat load will be used to design more in detail for the cryomodule design.

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