IN SITU DEGASSING OF THE FERRITE CORES IN THE EXTRACTION KICKER MAGNETS OF THE J-PARC RCS

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Abstract

This report aims to propose a new in situ degassing method by which only the kicker magnets were baked out without raising the temperature of the vacuum chamber by installing heat source and heat shield between the kicker magnet and the chamber wall. The target temperature of the ferrites in the kicker magnet is above 100 ^{o}C, while keeping the temperature rise of the vacuum chamber less than 20 ^{o}C in order to prevent the heat expansion of the vacuum chamber. After checking the operability of this method by thermal analysis with simple model, the experimental measurement was performed by using a RCS kicker magnet. The results showed that the target temperature was able to be achieved by this degassing method.

INTRODUCTION

The role of kicker magnets in J-PARC 3GeV synchrotron (RCS) is to extract an accelerated 3 GeV proton beam to a downstream beam transport line [1]. They are first pulse magnets whose magnetic field rise time is about 300 ns. The voltage of 30 kV is applied from the power supply to the magnets. The kicker magnets are installed in vacuum to prevent the discharge. 3 and 5 kicker magnets are located in vacuum chambers, whose length is 3 and 5 m, respectively. Ni-Zn ferrites are used for the magnetic cores of the kicker magnets. So far, we have made efforts to reduce the outgassing from ferrite cores, whose outgassing rate is orders of magnitude comparing with other materials [2, 3]. It was found that the main outgassing component was absorbed water molecules and they were able to be effectively removed by a bake-out above 100 ^{o}C in vacuum. These past efforts were devoted to reduce the outgassing of the ferrites before assembling the kicker magnets. It is also very important to develop an in situ degassing method after installing the kicker magnets in the beam line because the vacuum quality may become poor after repeated exposures to air. However, it is undesirable to use a normal baking method like baking the vacuum chamber of the kicker magnets because the large heat expansion of the vacuum chamber, which will be 5 mm with a temperature rise of 100 ^{o}C for a chamber of 5 m length, will break nearby equipments such as alumina ceramics ducts.

This report aims to propose a new in situ degassing method by which only the kicker magnet is heated without raising the temperature of the vacuum chamber. The target temperature of the ferrites is above 100 ^{o}C, while keeping the temperature rise of the vacuum chamber less than 20 ^{o}C. The principles of the method are as follows. Heat source is installed between a kicker magnet and a chamber wall. Heat shields are installed between the heat source and the chamber wall. By locating the heat source and heat shields in ideal position, it is possible to direct the most amount of radiant energy to the kicker magnet.

In this report, we will first examine the operability of the new degassing method by thermal analysis. Second, we will show the experimental setup and results. Finally we will mention about future subjects for applying this method to the kicker magnets in the RCS beam line.

THERMAL ANALYSIS

Before starting the experiments, it is important to perform the operability assessment of the new degassing method by calculation. Therefore we calculated the temperature of each material by changing the location of heater, number of the heat shielding panels, heater powers, and so on. In this report, we mention about the calculation for the heater power dependence with fixing other parameters.

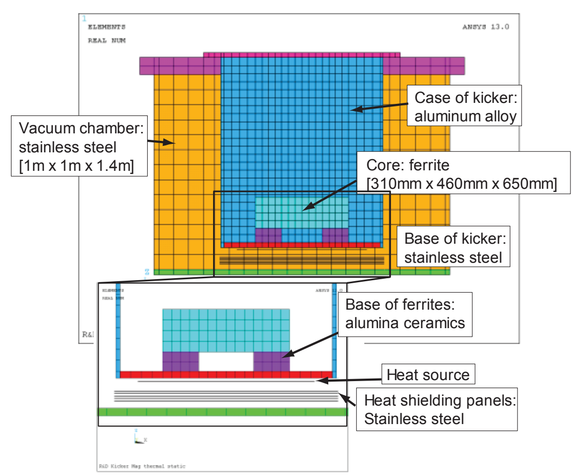

Figure 1: Calculation model for the thermal analysis.

Table 1: Material properties used in the calculation

	Ferrite	Aluminum alloy	Stainless steel	Alumina ceramics
Density [g/cm^3]	4.8	2.8	7.9	3.9
Specific heat [J/kg·K]	754	779	499	847
Thermal conductivity [W/m·K]	15.9	130	16	36
Emissivity	0.5	0.04	0.15	0.71

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The code ANSYS was used for the thermal analysis. A single kicker magnet and vacuum chamber are simulated as shown in Figure 1. This model is based on the experimental setup, which is mentioned in the following section. In this model, the ferrites are simulated by a simple block, which is put on the alumina ceramics base. Calorific power per unit volume was input to the elements, which occupy the volume of the heat source. The number of the heat shielding panels was fixed to 5. Table 1 summarizes material properties, which were used in the calculation. The temperature dependence of the material properties was not concerned in this analysis. The cases for the heater power of 750, 850, and 1000 W were calculated.

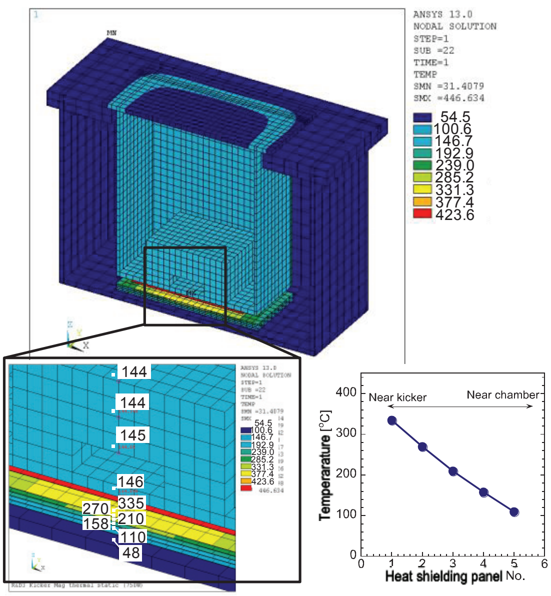

Figure 2: Typical temperature distribution of a kicker magnet and vacuum chamber. This is the case of heater power of 850 W.

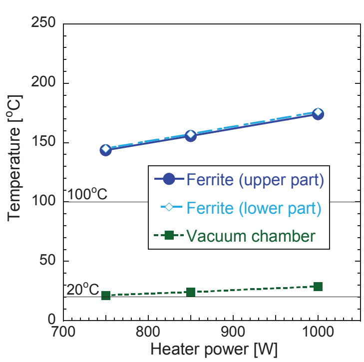

Figure 3: Heater power dependence of the ferrites and the vacuum chamber temperatures.

Figure 2 shows a typical temperature distribution. It is noticed that multi-layer panels effectively shield the radiant energy to the vacuum chamber. Figure 3 shows the calculated temperature of each part depending on the heater power. The absolute temperature is important for desorption of water vapor from the ferrites, while the difference from the room temperatures is necessary to estimate the heat expansion of the vacuum chamber. Therefore, the absolute values for the ferrites and the differences from room temperature for the vacuum chamber are plotted in Figure 2. There is a linear relation between the heater power and temperatures. The ferrite was easily heated up above 100 ^{o}C. The temperature rise of the vacuum chamber was 21, 24, and 29 ^{o}C in the case of 750, 850, 1000 W, respectively. Although the above simulation is simple case, we can expect that the target temperature be achieved by this degassing method.

EXPERIMENT

Principle of Experiment

Figure 4 shows the conceptual diagram of experimental setup for examining the in situ degassing method for a kicker magnet. A 0.8 m long sheath heater, whose maximum permissive power is 1600 W, was bent in the 0.7 m×0.8 m area below a kicker magnet. The 5 heat shielding panels of combination of stainless steel and aluminum alloy were installed between the heater and chamber wall. The vacuum chamber size is 1 m high, 1 m wide, and 1.4 m long. A turbo molecular pump with exhaust velocity of 0.42 m^3/s was used as a main pump. The vacuum chamber and the turbo molecular pump were connected with a pipe of 0.54 m^3/s conductance. Total and partial pressure are measured by a Bayard-Alpert gauge and a quadrupole mass spectrum analyzer, respectively.

The measurements were performed at the heater power of 750, 850, and 1000 W. The measured thermometric points are also shown in Figure 4.

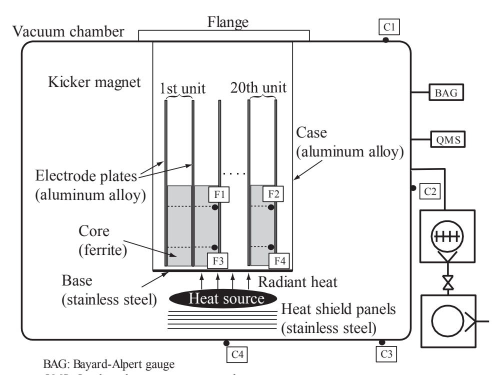

Figure 4: Concept of experimental setup. F1-4 and C1-4 represent the thermometric points.

The measured temperatures of each point are shown in Figure 5. As is the case in Figure 2, the absolute values and the differences from room temperatures are plotted for the ferrites and the vacuum chamber, respectively. The ferrite temperatures are almost equivalent to the calculated results shown in Figure 2. The measured temperatures do not linearly depend on the heater power. It is because the ferrites temperatures are slightly affected by the room temperature in spite of being in vacuum. The temperatures of the vacuum chamber are less than the calculated ones. The reason is considered to be that the

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heat transfer coefficient from SUS304 to the air used in the calculation is different from the real value. Anyway, it is possible to conclude that the ferrite can be baked out above 100 ^{o}C with keeping the temperature raise of the vacuum chamber below 20 ^{o}C.

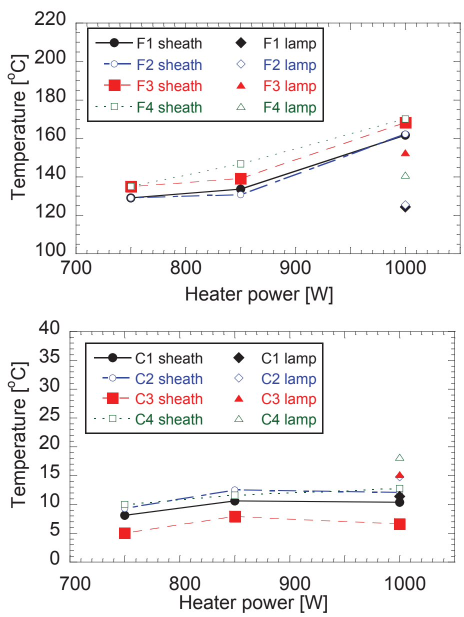

Figure 5: Measured temperatures of each point. F1-4 and C1-4 represent the thermometric points in Fig. 4.

Improvement for Practical System

For the practical degassing system, which will be installed in the RCS beam line, it is preferable to make the heater size as small as possible for the maintenance and/or the replacement of the heater. The desirable size is less than 133 mm in diameter, which is the inner diameter of a general purpose port located in the chamber wall bellow a kicker magnet. Therefore we selected a circular halogen lamp heater of 113 mm diameter (Fig. 6). Measurements of the temperature and pressure were performed with this lamp heater. The temperature results are plotted in Fig. 5. Although the ferrite temperatures become lower by miniaturization of heater size, the target temperatures of the ferrites can be achieved. Figure 7 shows the result of the outgassing reduction by the bake-out using the circular lamp heater. The outgassing rate and partial pressure of water vapor were able to be reduced by two orders.

Figure 6: A circular halogen lamp heater. The main gas (Ar) is filled in the circular glass tube.

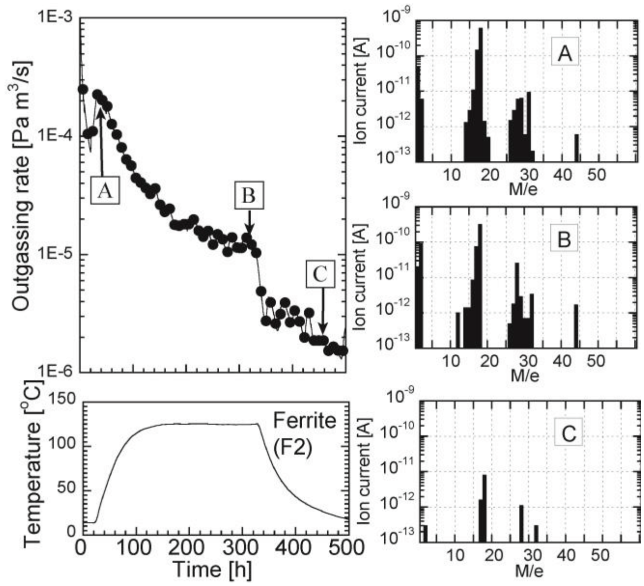

Figure 7: Results of the outgassing reduction by using the circular lamp heater. The applied heater power is 1000 W.

SUMMARY AND FUTURE PLAN

We developed a new in situ degassing method for a kicker magnet. The ferrite cores of the kicker magnet were able to be baked out above 100 ^{o}C without raising the vacuum chamber temperatures over 20 ^{o}C. This target temperature was achieved by the practical small heater.

The technical issues for applying this method to the practical kicker magnet in the beam line are as follows.

1. More reliable heater: Because lamp heater is relatively fragile, it is necessary to select the indestructible heater.
2. Layout and install method: It is necessary to consider the layout of heaters, heat shielding panels, and power cables in the more limited space in the practical vacuum chamber.

For the issue 1, we will perform the experimental measurement by using some types of heaters. For the issue 2, we will verify the realistic locations by making a mock-up of the same size as the practical kicker and vacuum chamber.

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