Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 19-20, 2022

Thermal Stability Evaluation of Graphite target through Induction Heating

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1. Introduction

With an increasing number of experiments in high-energy physics, demand of experiments with particle accelerators grows more and more. Globally, new accelerators have been designed and constructed competitively. For accelerator facilities in purpose of high-energy physics experiments, graphite is a material that is frequently used as a target material [1,2]. In the design of targets, it is an important requirement not to be broken even at high temperature caused by reaction heat. In the previous study [2], we validated its temperature distribution by using ANSYS mechanical software. It needed to be compared to the validation experiment. The most precise way to validate the calculation result is to perform the experiment in the same condition to the operation. However, the experiment has some problem that a lot of radiation which can damage to surroundings (e.g., gamma-ray, neutrons, protons, and a sort of heavy-ions). Secondary radiations also make the measurement of the local temperature of the target much difficult. Our idea is that the local temperature of the target can be compared to the ANSYS calculation result by heating the target in the same power using induction coil. In this paper, the ANSYS calculation process is described and validated by comparing to the induction heating experiment.

2. Induction heating by copper coil

When a high frequency alternating current (AC) flow through an induction coil, the rapidly alternating magnetic field generates eddy currents in surroundings. The eddy currents flow through the resistance of the material and heat the material. Using induction coil to heat the target has a few advantages to the experiment with operation beam from accelerator. First, copper coil can be so easily bended that the target can be heated in desired local position. Second, there is no radiation contamination. We can analyze the target damage after the experiment. Lastly, we can use thermocouples or thermal imaging cameras to measure the target temperature.

3. Induction heating experiment with graphite target

The experiment was performed with the test chamber for IF facility in RAON. The graphite target was placed in vacuum and the induction copper coil was placed in the 7 mm higher than the target. The experiment condition was described in Table I and Figure 1..

Table I: Problem Description

	Value
Current [A]	8
Voltage [V]	134
Frequency [kHz]	350.4

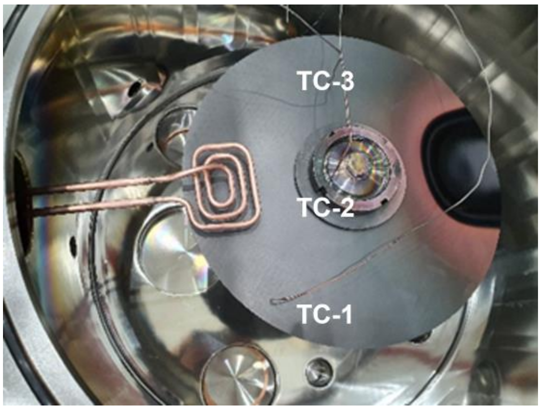

Fig. 1. Induction heating experiment setting.

4. Heat generation rate calculation by ANSYS MAXWELL

In order to calculate the temperature distribution of the target, the amount of the heat generation by eddy currents was calculated first by ANSYS MAXWELL software [3]. For the calculation efficiency, vacuum chamber and some detailed parts were excluded and only target, and induction coil was applied in the ANSYS MAXWELL calculation. The geometry which was applied to the calculation was described in Fig. 2.

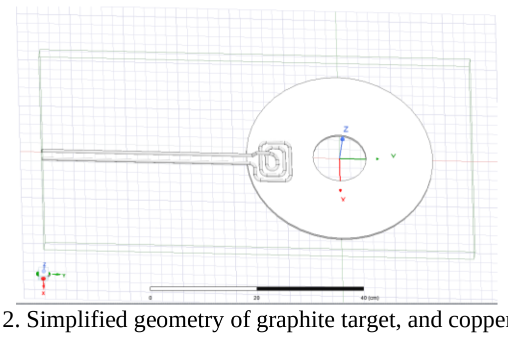
Fig. 2. Simplified geometry of graphite target, and copper coil

5. Local temperature calculation by ANSYS Mechanical

ANSYS MAXWELL shares the calculation result with various ANSYS modules through ANSYS Workbench. The calculated heat generation rate from ANSYS MAXWELL was applied to ANSYS Mechanical with a scaling [4]. The material properties of each graphite vary widely. The calculation with default graphite properties shows underestimated heat generation rate. We scaled the heat generation rate in ANSYS Mechanical calculation to desired power, 1 kW. The entire experiment system was applied but simplified for calculation efficiency. The applied geometry is described in Fig. 3.

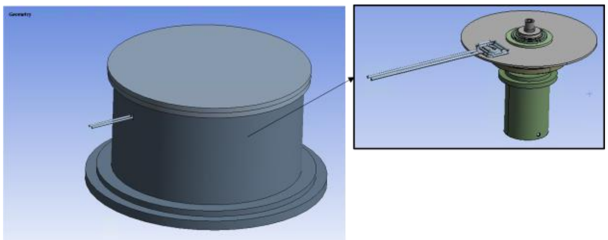

Fig. 3. Chamber geometry (Left) Graphite target, copper coil, and detailed parts (Right)

6. Results and Discussion

In the experiment, the local temperature was converged after 60 minutes as described in Fig. 4.

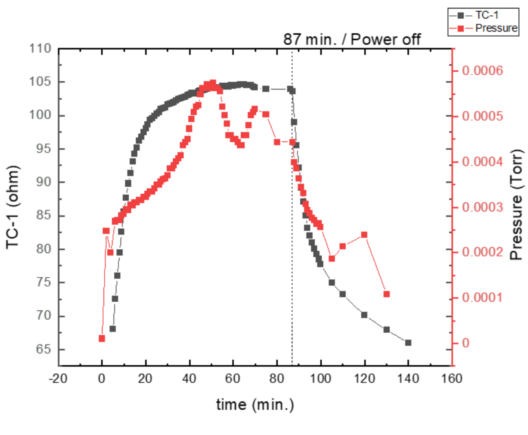

Fig. 4. Measured thermocouple resistance per minute (Black) Internal pressure in vacuum chamber (Red)

Internal pressure seems to increase as the target is heated up. It is presumed to be because the gas inside the target escapes from the target during heating. In the after study, it is expected that the material properties of the target can be kept constant when the gas in the target is discharged in advance through pre-heating.

The calculated local temperature at the three points was compared to the calculation result in Table III.

Table III: Problem Description

Temperature (°C)	Experiment	ANSYS Mechanical
TC-1	721.69	725.64
TC-2	784.36	783.26
TC-3	630.66	648.01

The results show the good agreement within 2 % difference. This result shows that ANSYS calculation can predict the material temperature when operating. This experiment will be improved and performed with the target in μSR facility before operating. Viewport and thermal imaging camera will be installed to measure overall temperature of the target.

6. Acknowledgement

This work was supported by the Rare Isotope Science Project of the Institute for Basic Science funded by the Ministry of Science and ICT and the NRF of Korea (2013M7A1A1075764).

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