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Analysis of Heat Transfer in RFT-30 Cyclotron Ga Target System

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1. Introduction

The cooling performance of the target system in accelerators is essential for improving production yield and ensuring stable production. The RFT-30 30 MeV cyclotron consists of four beamlines: beamline 1-1, 1-2, 2-1, and 2-2. Three of them, except for beamline 2-2, have different roles. For example, beamline 1-1 is for PET RI Production. In case of beamline 2-2 is being prepared for Ge-68 production. It is the reason is why need high current. The distinctive feature of the target system applied to this beamline is that the target can be transported through vacuum pipelines, making it detachable. Therefore, the design to the target entrance structure and the flow structural configuration of helium cooling were implemented to enhance the cooling capability [1,2]. This cooling system employs two methods: helium cooling at the front-facing direction from the beam and water cooling at the back part. During accelerator operation, it is essential to conduct coupled analysis that combines fluid flow within the cooling system and heat transfer to the target in order to evaluate the thermal integrity of the target.

In this study, CFD(Computational Fluid Dynamis) numerical analysis was conducted to evaluate the effectiveness of the enhanced cooling performance for the beamline 2-2 target system [3]. Additionally, a fluid-structure integrated analysis was performed. The CFD simulations were carried out using ANSYS Fluent. Flow analysis was performed for both water cooling and helium cooling. And heat transfer analysis was conducted for the solid target material. The result in this study shows the validation of the target's structural integrity with the implementation of the enhanced design.

2. Methods and Results

2.1 Modeling

CFD simulations were conducted using the commercial software Ansys Fluent. The geometry for analysis was modeled using Ansys SpaceClaim, as shown in Fig. 1. The solid target consists of gallium target and niobium foil. The basic design parameters of target system are given in Table 1.

The target system is categorized into two groups: the water cooling and the helium cooling. Cooling the target from both directions is an efficient approach. In the case of the helium cooling, the structural design of the flow path aims to induce vortex in the proximity of the target. This design demonstrates its effectiveness in enhancing the cooling performance on the target's surface.

The mesh was generated more densely in the depth direction of the target to calculate the temperature distribution on the target and the cooling system that affects it more accurately.

Simulations were conducted for various current conditions of 40, 60, 80, 100, and 120 μA, based on a beam diameter of 25 mm and a beam energy of 30 MeV.

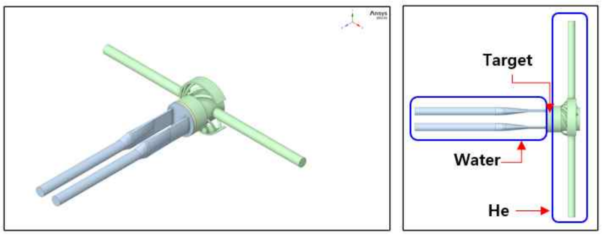

Fig. 1. Modeling of the target system

Table 1. Design parameters of target system

Parameters		Values
Thickness of target	Nb foil	0.1 mm
	Ga	2.3 mm
Flow rate of cooling	Water	20 L/min
	Helium	130 L/min

2.2 Numerical methods

Inlet velocities were applied for both water cooling and helium cooling cases. The flow rate of the water cooling was determined based on an inlet velocity of 20 L/min. For the helium cooling, a flow rate of 130 L/min was used for calculation. For turbulence analysis, the turbulence model employed was the k-ω model. The heat generation in the target was calculated and applied based on beam energy of 30 MeV, beam diameter of 25 mm, and current conditions of 40, 60, 80, 100, and 120 μA.

2.3 Results

To conduct a comprehensive heat transfer analysis of the beamline 2-2 target system, simulations were carried out utilizing the mentioned boundary conditions. These simulations enabled the examination of the temperature distribution across the depth direction of the target.

Fig. 2 shows the velocity vector of the helium cooling, revealing the occurrence of vortex near the vicinity of the target. This demonstrates that the design intent has been well reflected.

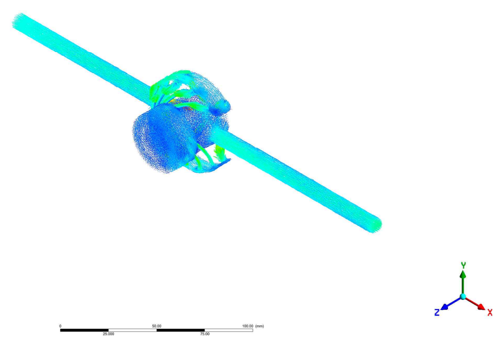

Fig. 2. Velocity vector of the helium cooling

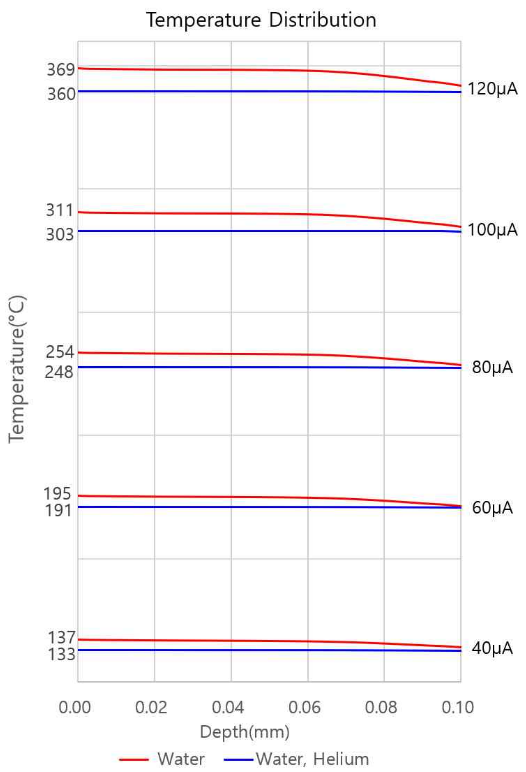

Fig. 3. Temperature distribution of capsule target foil (Nb)

Temperature distributions for a 0.1mm thickness capsule target foil which is made by niobium were examined under various current conditions. This analysis was conducted for cases involving water-only cooling and the combined application of water and helium cooling. The results demonstrate that the utilization of both water and helium cooling leads to lower temperatures on the target surface. Under various current conditions, the cooling effectiveness is shown to improve to 2-3%, as given in Figure 3.

Figure 4 demonstrates the comparison of temperature distributions between the case with water cooling only and the case with combined water and helium cooling. It shows the gradual temperature variation on the target foil surface in contact with helium.

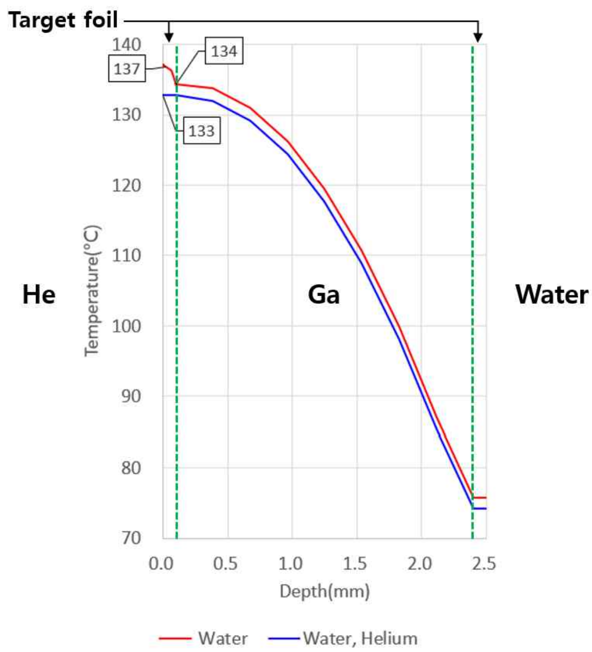

Fig. 4. Comparison of Temperature distribution at 40 μA

3. Conclusions

In this study, the temperature distribution in RFT-30 cyclotron Ga target system is presented. The analysis was conducted both fluid and solid, to evaluate the target system which is consisted of the cooling and solid target parts. The CFD simulation were conducted using ANSYS Fluent. The helium cooling was designed to generate a vortex when it comes to contact with the Ga target. The improved structural configuration of the target system was validated for cooling performance through this study.

To further validate the structural integrity of the target, it is necessary to conduct research on the thermal-induced deformation of the target's structure.

ACKNOWLEDGMENT

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