Thermal model simulation of high-power rotating target for BigRIPS separator

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A realistic thermal-model simulation is particularly important to evaluate the beam-power tolerance of the high-power rotating target system of BigRIPS separator,[1,2)] which has been successfully operating at RIBF since 2007. The target system was designed to withstand a beam power of 82 kW, which corresponds to the goal beam intensity of 1 particle μA (pμA) for a ^{238}U beam at 345 MeV/nucleon. The available beam intensity at RIBF was 13 kW so far, less than 20% of the goal. Therefore, thermal-model simulations were utilized to estimate the thermal behavior of the target system for high-intensity beams from the observation at lower beam intensities.

Many efforts[1–5)] have been devoted to the thermal model simulations of the target systems with finite-element ANSYS code. In the simulations, the rotating target was modeled using a mass transport option of ANSYS[6)] to describe the rotating motion. The model worked fine at the design stage[4)] but has been less usable because a recent version of ANSYS limits the use of mass transport only for motion slower than the thermal diffusion speed. Since the rotating target distributes the heat load by a fast rotating motion, the restriction prevents the simulation in the operational condition of the rotating target.

A new model of the rotating target was developed to avoid the restrictions. In the new model, the target itself is fixed, and a heat source moves along the circumference of the target. As shown in Fig. 1, many heat sources with a square shape of 1 mm by 1 mm were defined along the circle of the beam trajectory, and each source was excited by a heat load at a slightly different timing along the trajectory. Thus, the rotation of the heat source was successfully accounted for in the transient thermal calculation of ANSYS. In order to obtain the temperature distribution of a rotating target at the steady state, we have to simulate whole thermal equilibration process starting with the room-temperature target. More than 400 rotations of a spot heat source were necessary to obtain the saturation of the temperature. This process can be shortened by starting with the temperature distribution of a time-averaged heat source, which was calculated by steady-state thermal calculations with a time-averaged circular heat source. A nearly steady temperature distribution was obtained after 3–4 rotations of the spot heat source in this case.

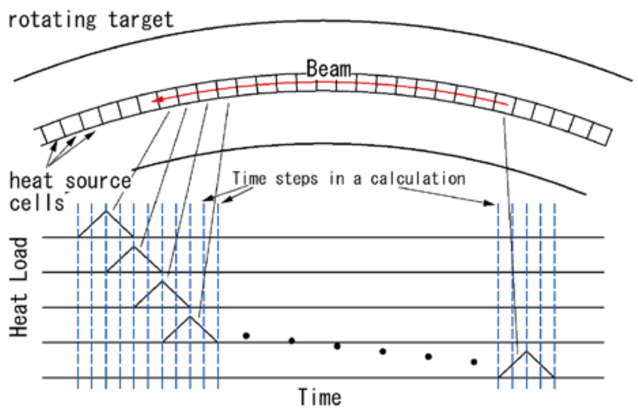

Fig. 1. Model of the rotating target. Graphs are the time structure of heat loads applied to heat source cells.

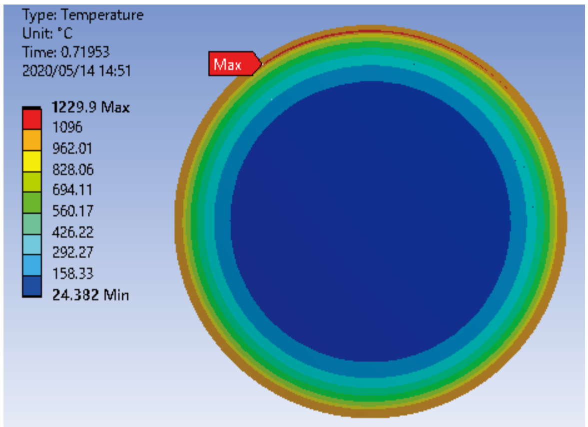

Fig. 2. Temperature distribution of the rotating target for irradiation with a ^{238}U beam at 345 MeV/nucleon, 1 pμA.

A simulation for the case of a ^{238}U beam at an energy of 345 MeV/n and 1 pμA impinging on a 2-mm-thick Be target was performed, and the resulting temperature distribution is shown in Fig. 2. Heat transfer coefficients of 10.5 and 3 kW/m^2 K were used for thermal contacts between the cooling water and cooling disk and between the cooling disk and Be target, respectively. As shown in Fig. 2, the highest temperature of 1230°C indicated by the "Max" label was obtained at the beam spot. Starting at the beam spot, the high-temperature region was spread along the beam trajectory. The calculation shows that the Be target does not melt in the heat of the beam since the melting point of Be is 1287°C. The maximum temperature of the calculation for ^{238}U beam at 30 pnA was 66°C, which is consistent with the measured temperature of 63.6°C at RIBF. Thermo-mechanical calculations are in progress to check the thermal deformation or destruction of the target.

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References

1) A. Yoshida *et al.*, Nucl. Instrum. Methods Phys. Res. A **521**, 65 (2004).
2) A. Yoshida *et al.*, Nucl. Instrum. Methods Phys. Res. A **590**, 204 (2008).
3) A. Yoshida *et al.*, RIKEN Accel. Prog. Rep. **35**, 152 (2002).
4) A. Yoshida *et al.*, RIKEN Accel. Prog. Rep. **37**, 295 (2004).
5) Z. Korkulu *et al.*, RIKEN Accel. Prog. Rep. **52**, 132 (2019).
6) ANSYS. Inc Product Release 19.