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

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Since 2007, a water-cooled high-power rotating disk target made of beryllium or tungsten has been used as the production target at the in-flight radioactive-isotope (RI) beam separator BigRIPS.[1,2] The diameter of the rotational disk is 30 cm while the thickness can be optimized according to the atomic number and the energy of the selected projectile. To obtain a variety in thickness, the circumference edge of each disk has two steps to realize less thicknesses. The rotational disk target system was designed to withstand the maximum beam intensity of ^{238}U at 345 MeV/nucleon and 1 particle μA. Although only about 20% of the goal beam intensity of 82 kW has been achieved, the high-power rotating target system has been successfully operated with various beams. Because the present primary beam intensity is much lower than the goal value, the requirement that Be could withstand the goal intensity cannot be experimentally commissioned. Therefore, we started to develop simulations based on ANSYS Parametric Design Language (APDL)[3] to calculate the beam spot temperature at various conditions. Earlier, a prototype target system was designed and constructed using the same simulation code.[4,5]

In the analysis, a complete model built by APDL was used. The primary beam was focused at a diameter of 1 mm (FWHM) with Gaussian beam distribution. The power deposition in beryllium material was calculated with the LISE++ simulation code.[6] To include the effect of radiation cooling, the emissivity of 0.57 was used for the surface of the Be disk.[5] The target disk was tightly fixed with screws on the water-cooled aluminum plate (see Fig. 1) and the boundary temperature for the cooling water was fixed at 25°C. The heat transfer coefficient, calculated by JAERI formula,[7] was found to be 10.5 kW/m^2 K at 25°C. Because the beam spot temperature varied with time, the temperature-dependent thermal conductivity of Be and Al was used for temperatures between 25 and 1200°C and 25 and 700°C, respectively.

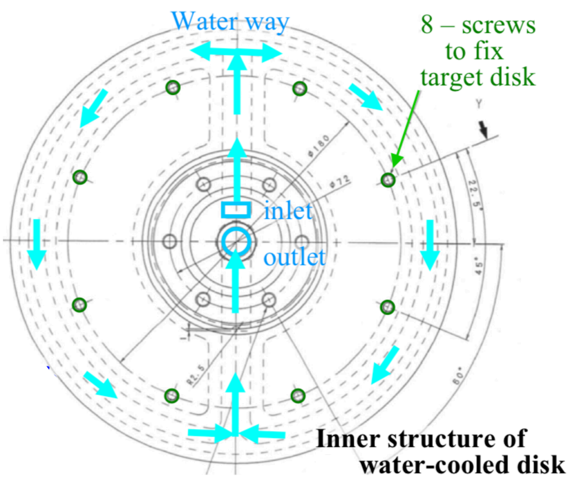

Fig. 1. Cooling-water is introduced to the aluminum disk through a double-piped shaft.

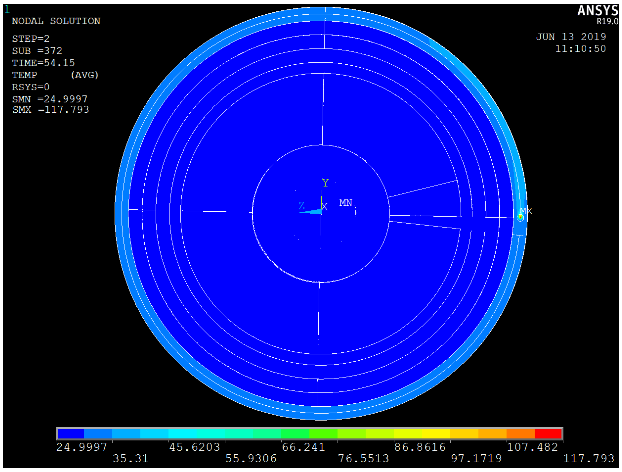

Fig. 2. A ^{48}Ca primary beam at 345 MeV/nucleon with 470 pnA (7.8 kW in beam power) onto the beryllium target of 10 mm thickness. The heat deposited in the target was 0.96 kW for a beam spot size with a diameter and rotation speed of 1 mm and 10 rpm, respectively. The maximum beam spot temperature is approximately 118°C.

In our simulations, the heat source was fixed and the target model moved across it based on the mass transport option of ANSYS. To capture the effect of temperature variation occurring in the model, the applied mesh size must be small enough. Although the beam spot temperature became constant after several rotations, this complex model required a few hours of the CPU time. The initial analysis was performed with low rotational speed, from 1 to 10 rotations per minute (rpm), in several steps to confirm the reliability of our simulation code.

The present status of simulated heat distribution with 10 rpm is reported in Fig. 2. Further simulation studies are under way to optimize a small mesh size that can increase the rotation speed of the disk target up to the required velocity of 100 to 1000 rpm.

References

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