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Mechanical Design of a 1-kW Neutron Production Target at KOMAC

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1. Introduction

At the Korea Multi-purpose Accelerator Complex (KOMAC) of Korea Atomic Energy Research Institute (KAERI), we are studying a neutron-production target system based on the 100-MeV proton linear accelerator of KOMAC[1] as a preliminary study of a future high-power neutron source driven by a proton accelerator[2]. In the concept of the neutron source, high-energy neutrons are generated by using a 100-MeV proton beam on a heavy-metal target in a target chamber. Here, we describe the mechanical design of the 1-kW neutron production target system at KOMAC.

2. Concept of 1 kW Neutron Source

2.1 Target Material

In the past, many targets made of uranium have been used in several spallation neutron facilities at 3-160 kW proton-beam powers [3]. However, uranium is no longer used as a spallation-target material, instead non-actinide heavy metals such as tantalum, tungsten, and lead are adopted for neutron-production targets. For example, solid tungsten target has been operated at ISIS facility and LANL (Los Alamos National Lab) LANSCE (Los Alamos Neutron Science Center) facility. Both facilities have used tantalum-cladded tungsten to minimize corrosion by hot water [4]. In order to avoid technical issues related to tantalum-tungsten metal joint, tantalum was selected as target material because of its advantages: tantalum is resistant to hydrogen blistering and water corrosion, and it has a neutron yield similar to tungsten.

2.2 Target Assembly

A present target assembly is composed of a stainless-steel flange, a water-cooled 12 mm-thick tantalum disc, and cooling chamber. In the design of a target assembly, proton-beam irradiation condition is assumed to be as follows: a 100-MeV proton beam at the average power of 1 kW with the diameter of 3 cm at the entrance of a proton-beam window and the maximum irradiation time of 8 hours/day. The diameter of the proton beam incident on the target is assumed to be 3 cm, giving the thermal load of 1.4 MW/m^2. Since it is not a small amount, the target assembly is designed and assessed based on the results of thermal analysis on the design. The mechanical design of the target assembly is shown in Fig. 1. This is a part that needs to be further improved. A special flange was designed to completely isolate a proton beam line and target chamber while minimizing the energy loss of the proton beam irradiated to the target. A 2 mm-thick SUS316L plate is considered to be a proton beam window (PBW). The energy loss of the proton beam in the PBW is about 8.2 MeV, and the rest of the beam energy is deposited in the Ta disc. Fig. 2 shows thermal load along the beam axis calculated using MCNP6 [5]. The thermal load has a volume within the Ta disc. Because of the radioactivity issue of coolant, water will flow in a closed loop which is separated from the established accelerator cooling system.

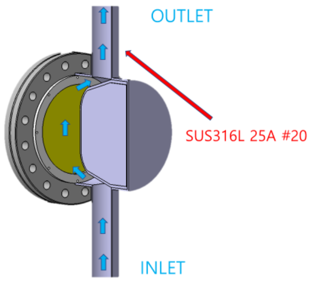

Fig. 1. The present version of a target assembly for neutron production. Water flow velocity on a target disc side was made stronger by making the cross section area of the disc smaller than the cross section area of the pipe. Inlet and outlet pipes of 25A schedule #20 was used to withstand coolant water pressure up to 3.5 MPa.

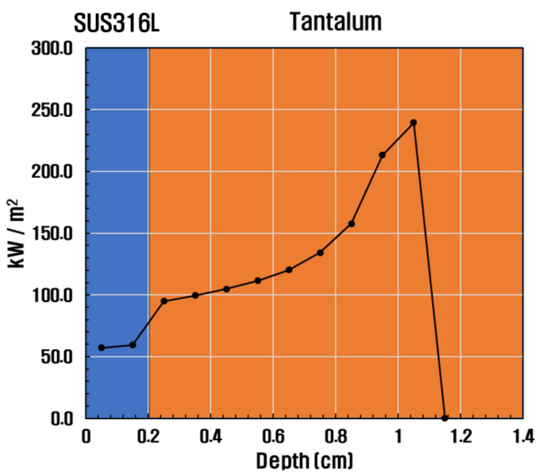

Fig. 2. Calculation of thermal load in a target disc induced by a proton beam. Calculation was done with MCNP6. The

thermal load induced by the proton beam in the stainless and tantalum area is about 8% and 92% of the total beam power, respectively.

2.3 Biological Shielding Design

In the neutron-irradiation experiment, personnel or users need to access to a sample station located near the target assembly, which is expected to be highly radioactive. Biological shielding is designed to protect personnel or users against radiations. It was designed in the form of enclosing a neutron-production target with lead, high-density polyethylene (HDPE), and cadmium. Lead is used for gamma ray shielding on the innermost part, and HDPE is used on the outer side of a lead layer to moderate fast neutrons that do not go in the forward direction. In addition, a cadmium layer was added around the HDPE layer to reduce thermal neutron flux escaping the biological shielding. And two neutron-beam guides were made at the downstream of the target assembly for neutron-beam extraction. The biological shielding was designed so that it can be movable for maintenance. The estimated weight of the shielding materials, i.e. lead and HDPE, except supporting frame is 499 kg.

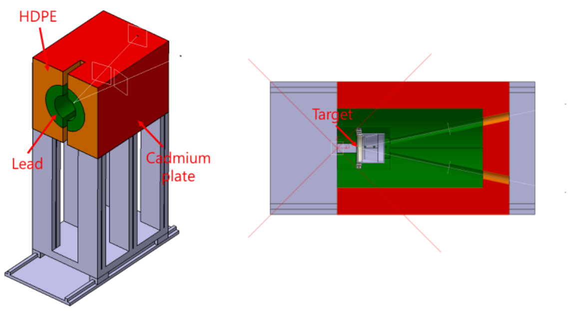

Fig. 3. The 3D modeling of biological shielding. It was designed in the form of enclosing a neutron-production target with lead, high-density polyethylene (HDPE), and cadmium.

3. Summary

A 1-kW neutron-production target including biological shielding was designed to generate a neutron beam using the 100-MeV proton accelerator in KOMAC. The target-system design is not fixed yet, and it still needs to be improved. Especially, we will put a lot of effort into increasing cooling efficiency. With further improvements, every components of the target system could be fabricated until the end of 2021, then a new 1-kW neutron source could be installed and operated at KOMAC in the next year.

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