Thermal Load Estimation in a Tungsten Target for the Korea Spallation Neutron Source

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1. Introduction

KOrea Multi-purpose Accelerator Complex (KOMAC) has been operating a 100 MeV linear accelerator to provide users with proton beam since 2013. Recently, we are planning to upgrade the beam energy for the spallation neutron source. In order to achieve the desired neutronic performance, a simulation-driven target design is required in advance. In this report, a general-purpose Monte Carlo N-Particle(MCNP) simulation code was used to estimate the thermal load distribution within the spallation neutron target. The calculated data will be used for the mechanical analysis related to stress and deformation.

2. MCNP Modeling

A horizontal section view of the split target blocks is shown in Fig. 1. The MCNP modeling reflected the geometry of the tantalum clad tungsten target with separated plates. The split plates will be aligned normal to the incident proton beam direction with narrow channels between them to allow cooling water to pass. At high temperature and under certain moist atmosphere, unclad tungsten vaporize and could be separated from the solid tungsten. So, a typical plate with tantalum clad protects the tungsten from corrosion by cooling water. The target was designed based on the high-power neutron production targets of the accelerator based facilities around the world[1,2,3]. Lessons learned from those experiences in the facilities are helpful to decide the design for the high power stationary solid target.

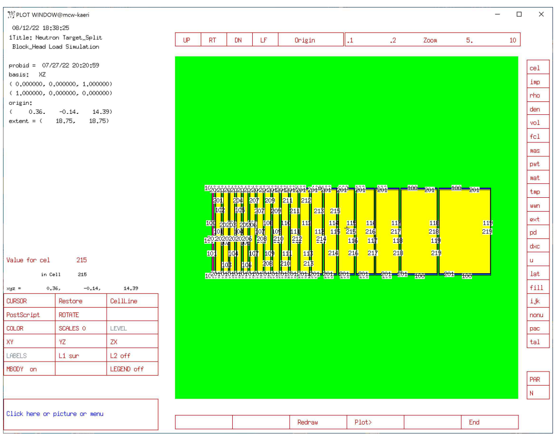

Fig. 1. MCNP modeling of the target plates. Tantalum clad tungsten regions shown in yellow.(source: 1.3 GeV, proton, uniform area 8.6 x 3.5 cm^2)

3. Heating Rate Estimation

Fig. 2 shows the simulated thermal load distribution image within the target plates and Table I indicates volumetric heating rate in plates. The full block target need to split into plates to control temperature and thermal stress. On the other hand, the dynamic response associated with stress and deformation can be acquired by thermal-hydraulic analysis based on the MCNP heat load data. Furthermore, design criteria for the peak surface temperature on the tantalum, the peak tungsten temperature, and thermal stress need to be established. In order to reduce the stress, target temperature should be below threshold for tungsten vaporization.

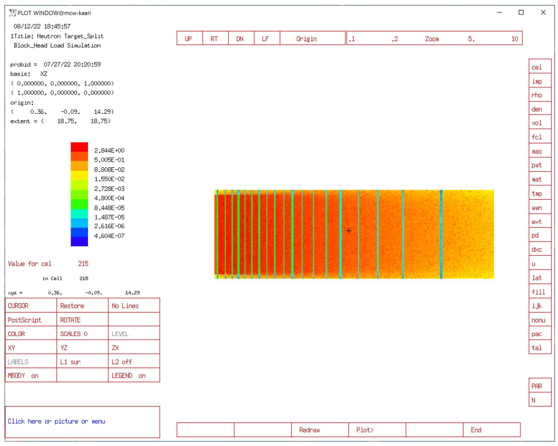

Fig. 2. Simulated heat load distribution in the target plates. The beam power and the unit in legend of color-map are 500 kW and MeV/cm^3, respectively.

Table I: Volumetric Heating Rate in Split Plates

Split plate number	Thickness (cm)	Heating rate (W/cm^3)	Reference (W/cm^3)
1	0.7	540.17	624.10
2	0.6	537.15	638.53
3	0.57	521.85	637.69
4	0.57	502.16	627.29
5	0.57	479.73	610.17
6	0.65	456.28	587.20
7	0.7	429.84	558.83
8	0.7	401.53	527.82
9	0.8	371.91	494.59
10	0.83	344.09	459.70
11	0.9	314.59	424.59
12	1.1	282.80	387.09

13	1.25	248.30	346.66
14	1.4	214.16	304.35
15	1.8	178.50	256.72
16	2.0	143.35	204.15
17	2.6	107.39	149.06
18	4.0	70.58	97.64
19	5.7	36.84	34.50

4. Summary

In this study, we calculated thermal load in a tungsten target for the spallation neutron source. There is a difference between the reference data that is based on analytic polynomial function of the proposed earlier SNS solid tungsten target and our simulation result. We have not yet fully understood the reason. After the specification of the accelerator related to the beam profile and energy is decided, the number and thickness of the target plates will be optimized for the system. In future, further studies will be conducted to apply this thermal analysis data to calculate stress and deformation.

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