Thermal Analysis for 100 MeV Proton Beam Dump in the Target room

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1. Introduction

The Proton Engineering Frontier Project (PEFP) has constructing a 100-MeV proton linear accelerator and to supply 20-MeV or 100-MeV proton beams to users who want to utilize a proton beam for their research and development. To meet user's demand, the PEFP will construct ten target rooms, each of which has its own characteristic purpose. There are five target rooms for 100 MeV proton beam utilization (For example, TR 101, 102, 103, 104, 105). The beam dump is one of the essential components of the beam irradiation facility in the target room, that prevent proton beam to meet other components in the target room, such as the concrete wall of target room, support frame and etc. Therefore, the beam dump have to withstand against the radiation damage and the thermal damage induced by intensive proton beam [1].

2. Methods and Results

2.1. Material selection of beam dump

The beam dump should have low residual radio-activity after proton beam irradiation to minimize the radiation dose or to protect radiation workers from radiation hazards. Therefore, the material of beam dump was selected by aluminum alloy. Figure 1 shows the residual radio-activities of several materials which was estimated by MCNPX simulation [2].

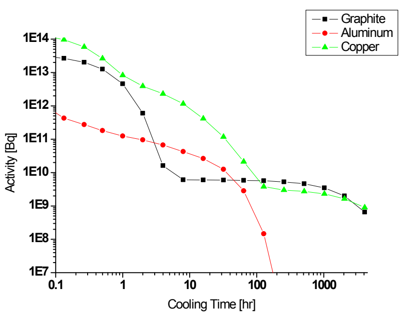


Fig. 1. The residual radio-activity of several materials (100 MeV, 300 μA, 1 hour irradiation)

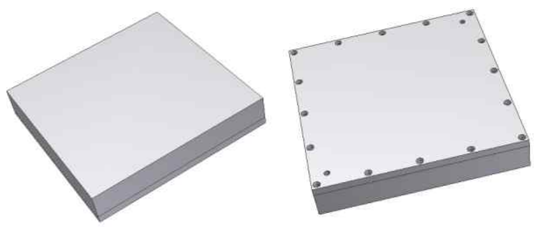
2.2 Mechanical Design of beam dump

The aluminum beam dump was designed for the cooling of 30 kW heat load and the coolant was assumed by ordinary water. The beam dump was consisted of two plates of 40 cm by 40 cm and its total thickness was 7 cm. The cooling channel of beam dump have rectangular shape and its size was 14 mm × 12 mm. Figure 2 shows the cooling jacket and cooling channel of designed beam dump and its upper cover.

(a) Cooling jacket (b) Beam dump cover

Fig. 2. Schematics of the designed beam dump.

Figure 2 shows the fabrication of aluminum beam dump. The inlet and outlet of coolant was placed at the rear side of beam dump.



(a) Front side (b) Rear side

Fig. 3. The fabrication of the aluminum beam dump.

2.3 1-D Thermal Analysis for the beam dump

The brief description for thermal analysis was tabulated at Table 1. When the maximum beam current was 300 μA, the maximum heat generation was 30 kW. And if the beam size of incident proton beam was 30 cm diameter, the maximum heat flux was 424413 W/m^2. The spatial distribution of incident proton beam was assumed as uniform. Figure 4 shows 1-D calculation model of beam dump. The results of the 1-D calculation show, the flow velocity has to be above 1 m/sec to prevent boiling of coolant.

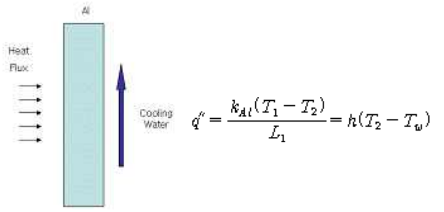


Fig. 4. 1-D calculation model of beam dump

Table 1. Brief description for thermal analysis

Max. heat generation	30 kW
Max. heat flux	424413 W/m^2
Coolant	Ordinary water
Criteria	Max. Temp. of beam dump < 660°C (prevent melting of aluminum) Coolant temp. < 90 °C (prevent boiling of water)

Table 2. Temperature evaluation as function of flow velocity

Velocity [m/sec]	Reynold N.O.	Heat transfer coefficient [W/m^2-k]	T_1 [°C]	T_2 [°C]
0.5	18582	4258	192.6	124
1	39023	7708	148	80
1.5	55156	10167	134.6	66.7
2	74330	12907	125.8	56.6

2.4 Thermal analysis by using CFD method

To verify the results which was estimated by 1-D thermal analysis, CFD(Computational fluid dynamics) method was applied by using ANSYS-CFX 12 [3]. Figure 5 shows 3-D model and meshed model for CFX calculation

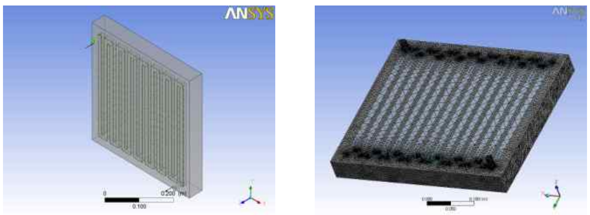


Figure 5. Calculation model for CFX calculation

Figure 6 shows temperature distribution of heating surface when the flow velocity of inlet was 2 m/sec. the temperature at the central region of beam dump was 124 °C. That result shows good agreement with that of 1-D calculation. but the maximum temperature at the edge of beam dump was 199 °C. It is considered that the result was caused by rising of the coolant temperature. The coolant temperature gradually rise from 25 °C up to 77 °C during the flowing in the cooling channel of beam dump. Therefore, the flow velocity has to be above 2 m/sec to prevent boiling of coolant. Figure 7 shows temperature distribution of coolant.

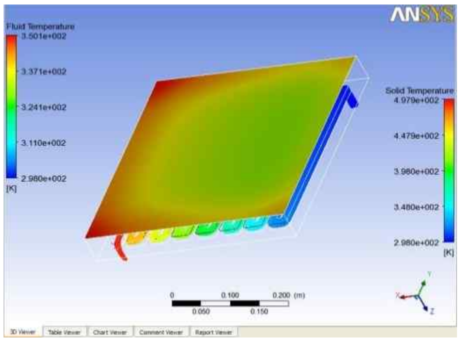


Fig. 6. The temperature distribution of heating surface (flow velocity : 2 m/sec)

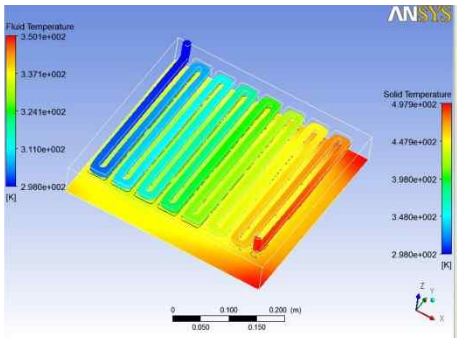


Fig. 7. The temperature distribution of coolant (flow velocity : 2 m/sec)

3. Conclusions

The thermal analysis was conducted by using 1-D calculation and CFD method (ANSYS-CFX 12). The results of thermal analysis shows, the flow velocity have to be above 2 m/sec to prevent boiling of coolant against 30 kW of heat load induced by 100 MeV proton beam.

REFERENCES

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[3] http://www.ansys.com, “ANSYS CFX TUTORIAL”, ANSYS, Inc. 2009.