

DESIGN OF THE BEAM DUMP FOR LOW FLUX BEAMLINE IN KOMAC

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Abstract

A linac in KOMAC (Korea Multi-purpose Accelerator Complex) is providing users 100-MeV proton beam for various applications. A new beamline for low flux density of proton beam will be constructed in 2016. The beam dump is an important part of this beamline and must be designed to stop 100 MeV beams with a maximum power of 8 kW. Incepting the waste of beam increases the temperature of the beam dump, which can make a structural problem. Therefore, the material of it should be robust under the high temperature and the radioactive circumstance. To ensure safety, thermal analyses have been performed for a few materials using a finite element code. The beam dump will be fabricated based on the analysis results.

INTRODUCTION

A linac in KOMAC (Korea Multi-purpose Accelerator Complex) is providing users with 100-MeV proton beam. Currently, a new beamline for low flux density of proton beam is under construction for development of measuring instruments and copy of space radiation. The beam dump of this beam line will be installed to sharply reduce the flux of proton beam. So, it should be designed to stop 100 MeV beams and to endure a maximum power of 8 kW, which results in a temperature increase of the beam dump. Moreover, it should be able to withstand radioactive circumstances. Therefore we verified the thermo-mechanical stability of the beam dump prior to fabrications. The location of the beam dump is shown in Figure 1.

ANALYSIS AND RESULTS

To ensure safety under the high temperature and the radioactive circumstance, thermal analyses have been performed for a few materials using ANSYS code [1].

Design Features

The beam dump is designed to be a conical geometry with 10 ~ 200 mm in internal diameter, 358.2 mm in length and 20 mm in thickness, which is covered with SUS304 case as shown in Figure 2.

Thermal Load

The beam is assumed a Gaussian round beam with $\sigma_R=15$ mm and the total beam power is 8 kW.

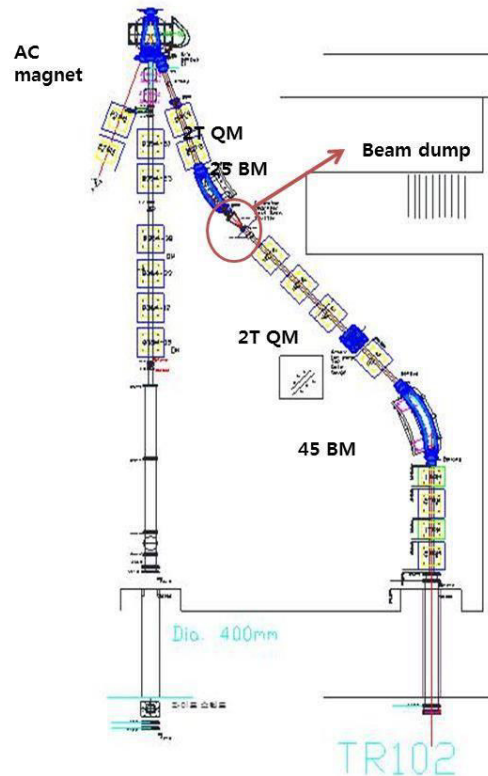


Figure 1: Location of beam dump in Low flux beamline.

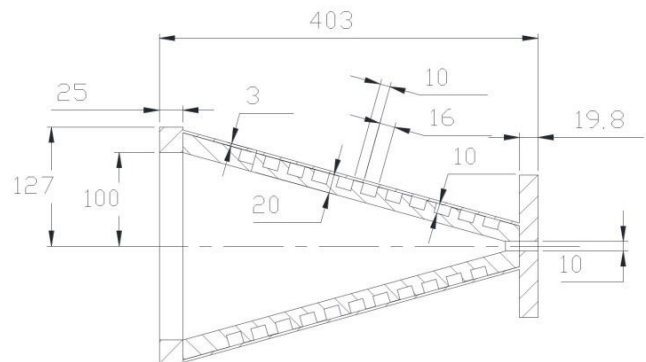


Figure 2: Cross section of beam dump.

Cooling Condition

The beam dump has cooling system based on 27°C liquid water flowing with a velocity of 2.5m/s through a helical channel of 16 x 10 mm² cross section. In the above coolant's condition, the heat transfer coefficient was calculated considering Rectangular ducts' Turbulent Flow [2].

- Hydraulic diameter:

$$D_h = \frac{4ab}{2(a + b)}$$

- Reynolds number:

$$Re_{e,D_h} = \frac{\rho u_m D_h}{\mu}$$

- Nusselt number:

$$Nu = \frac{2}{3} Nu_{slug} + 0.015 Pe^{0.8}$$

- Heat transfer coefficient:

$$HTC = \frac{k}{D_h} \cdot Nu$$

The Nu_{slug} is the Nusselt number corresponding to slug flow ($Pr = 0$) through rectangular ducts, which is given in Figure 3 as a function of α^* for rectangular ducts under the boundary conditions.

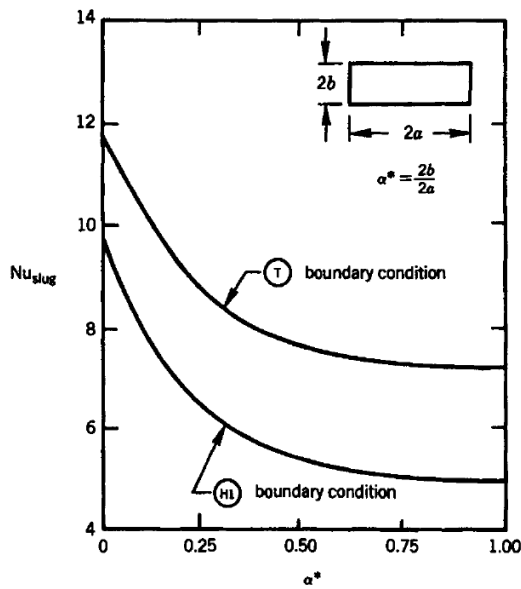


Figure 3: Slug flow Nusselt numbers for rectangular ducts [3].

The α^* is 0.625, then the Nu_{slug} is 7.5. The Reynolds number is 35880 and the Pe is the Peclet number, which is represented by the product of Reynolds number and Prandtl number. The Nusselt number 275.7 and the heat transfer coefficient 13730 W/m²·K.

Materials

The beam facing material should be chosen by considering thermal conductivity, structural strength and residual radioactivity in the above condition. So, copper and graphite were compared. The properties of them are shown in Table 1. The residual radioactivity is calculated after the irradiation of 100 MeV, 1 uA proton beam for 1hour.

Table 1: Properties of Materials [4]

Properties	Copper	Graphite
Thermal conductivity (W/m-K)	385	24.0
CTE (µm/m-K)	16.4	0.60-4.3
Yield Strength (MPa)	33.3	-
Residual radioactivity (Bq) @128h	1.26E7	1.88E7

Analysis Results

As the results, the maximum temperature is located at the center of the beam dump where the maximum thermal load is applied. As shown in Figure 4 and Figure 5, the maximum temperature is about 90 °C in the copper beam dump and about 540 °C in the graphite beam dump. If the limit temperature is 100 °C to prevent coolant from boiling, graphite is not suitable due to the large increase of temperature.

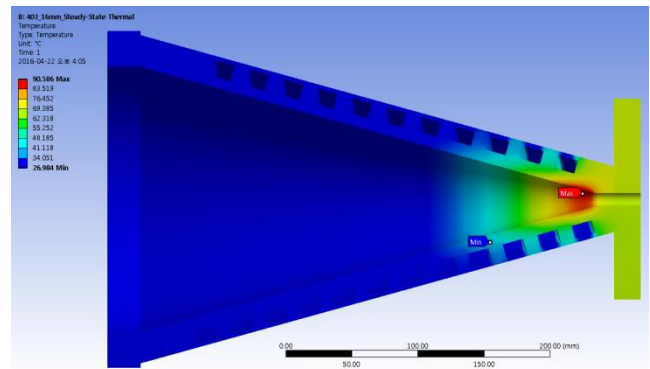


Figure 4: Temperature of copper beam dump.

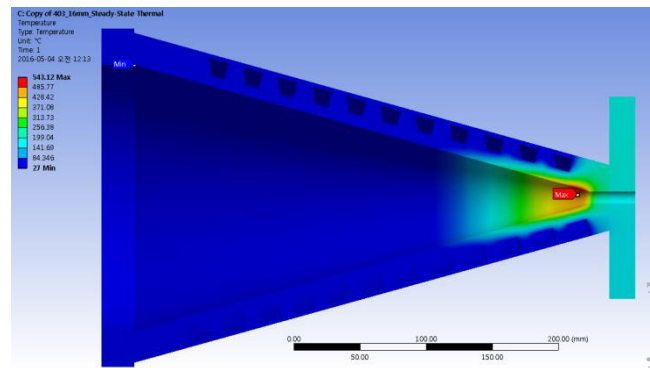


Figure 5: Temperature of graphite beam dump.

To reduce the beam flux of the low flux density of proton beamline at KOMAC to 0.1%, the beam will be further bent and will not hit the center of the beam dump. In other words, the edge of beam profile will be used.

Assuming the beams offset 40 mm against the center of the beam dump, the thermal analysis results are shown in Figure 6 and Figure 7. Because the area of the maximum beam power deposition hits the beam dump, the maximum temperature of the beam dump due to 40mm-offset beam will be higher than no-offset beam. But the temperature does not exceed the boiling point 100°C though the

40mm-offset beams hit it on. So the beam dump is safe in this case also.

peated loads on the beam dump. Therefore, additional fatigue analyses are needed.

CONCLUSION

The beam dump was designed for the Low flux density of proton beamline at KOMAC. The beam is assumed a Gaussian round beam with $\sigma_R=15$ mm and the total beam power 8 kW. Considering the beam’s properties, the beam dump was a cone with 10 ~ 200 mm in internal diameter, 358.2 mm in length and 20 mm in thickness. When comparing the analysis results using ANSYS code, copper is a reasonable choice as the material of the beam dump. Checking the maximum temperatures of each case, it is confirmed that the beam dump is thermo-mechanically stable in case of the 40mm-offset beam as well as the no-offset beam. The beam dump will be fabricated based on these results and installed in the Low flux density of proton beamline.

ACKNOWLEDGEMENT

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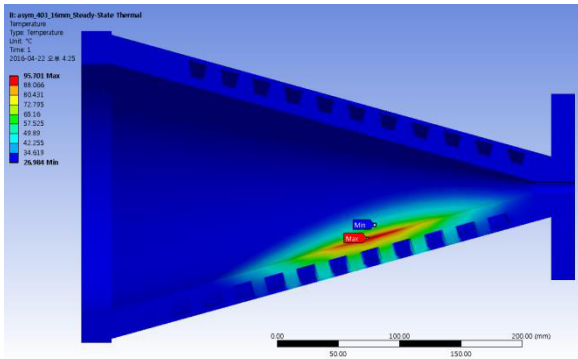


Figure 6: Temperature of 40 mm-offset beam. (side)

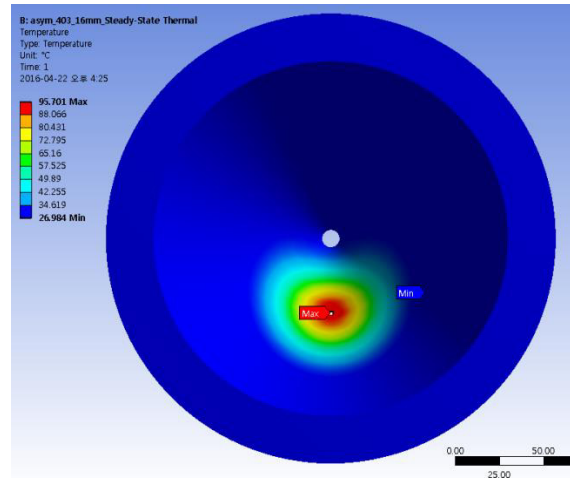


Figure 7: Temperature of 40 mm-offset beam. (front)

But when using the edge of beam profile, the thermal stress is larger than using no-offset beam. Because of the pulsed beam hitting, the thermal stress could lead to re-