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Structural Analysis of the Beam Window for RI Beam Line in KOMAC

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1. Introduction

A 100-MeV proton linac in KOMAC (Korea Multi-purpose Accelerator Complex) is providing users with high energy proton beam for various applications. Currently, two target rooms are available and a new target room (TR101) for RI (radioactive isotope) production such as Sr-82 and Cu-67 is under construction. At the end of the beam line, there is a beam window to extract the proton beam from the vacuum beam pipe. When proton beam pass through the beam window, some fraction of beam power is lost in the beam window, which results in temperature increase of the beam window. In addition, beam window is put under vacuum pressure loading. Therefore, the material of a beam window should be robust under the changes of temperature and the radioactive circumstance. We chose an alloy of aluminum and beryllium (AlBeMet 162) as the material of the beam window because it can maintain its strength even in the above extreme circumstance. The thickness of the beam window is determined to be 0.5 mm and 99.4% of 100 MeV proton beam can penetrate the beam window [1]. The main mechanical properties of AlBeMet 162 are shown in Table 1.

Table 1. Properties of AlBeMet 162

Properties	Unit	
Density	kg/m^3	2100
Thermal Conductivity	W/m·℃	212
Young's Modulus	GPa	193
Ultimate Tensile Strength	MPa	413
Yield Strength	MPa	314
Elongation	%	7.0
Poisson's Ration		0.17
Chemical Composition	%	Al ≒ 38 Be ≒ 62

Before making the beam window, the structural analyses were performed by using a finite element code to calculate the deformation and stress of the beam window under thermal and vacuum loading. We examined the mechanical stability with various boundary conditions.

2. Analysis and Results

The beam window is designed to be a shell with 100 mm in diameter and 0.5 mm in thickness, which is a part of a sphere with 500-mm radius, considering that the size and radioactivity of target and the penetrability of proton beams [1]. A 2D model for the structural analysis including beam window and supporting structure is generated with those parameters as shown in Fig. 1.

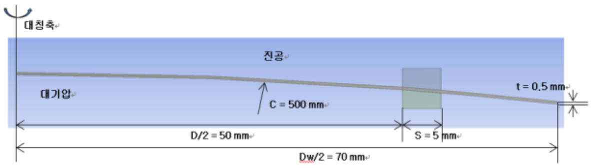

Fig 1. A 2D model for structural analysis

The Structural Analysis was performed by using ANSYS code. Its analytical conditions were summarized in Table 2.

Table 2. Analysis Condition

Analysis Type	Linear
	Non-linear (Large Deflection)
Pressure	Atmospheric pressure (0.101325MPa)
Contacts	frictionless (μ=0)
	frictional (μ=0.1~1.0)
	bonded
	no separation

When linear analysis is applied, the maximum deformation turned out to be 0.164 mm, which is as large as 33% of the thickness of the beam window. So, non-linear analysis by using the Large deflection Option should be activated for better results. Table 3 shows the results of non-linear structural analyses.

Table 3. Results of non-linear structural analysis

Contacts at Supports	**Axial Deformation (mm)**	**Maximum Principal Stress (MPa)**
Frictionless (μ=0)	0.68595	200.67
Frictional (μ=0.1)	No convergence	No convergence
Frictional (μ=0.2)	0.46309	154.34
Frictional (μ=0.3)	0.42925	146.43
Frictional (μ=0.4)	0.40377	140.55
Frictional (μ=0.5)	0.38200	135.60
Frictional (μ=0.6)	0.36244	131.77
Frictional (μ=0.7)	0.34442	128.30
Frictional (μ=0.8)	0.32777	125.12
Frictional (μ=0.9)	0.31229	122.18
Frictional (μ=1.0)	0.29791	119.86
Bonded	0.26427	131.53
No Separation	0.68322	201.56

Because AlBeMet 162 is a brittle material, the maximum principal stress is better criterion than von Mises stress for stability assessment [2].

As the friction coefficient μ increases, the deformation and stress of the beam window decrease. The fixing level seems to be a direct cause of variation in the amount of deformation and stress. Judging from the Yield Strength of AlBeMet 162, all these conditions are safe in structural aspects except the case of μ=0.1. In that case, there is a little friction between the beam window and the supports. So, the beam window may move and the result of analysis cannot be converged. The minimum value of stress was obtained when the friction coefficient μ is 1.0. The location of the maximum principal stress is at the inner part of the support in the atmospheric contacted surface. Figure 2 shows the deformation shape and Fig. 3 shows the location of the maximum principal stress in that case.

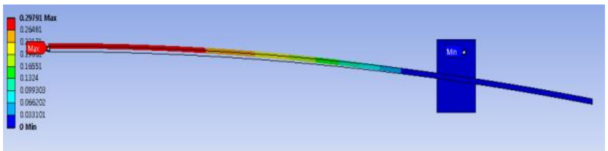

Fig 2. Deformation (μ=1.0)

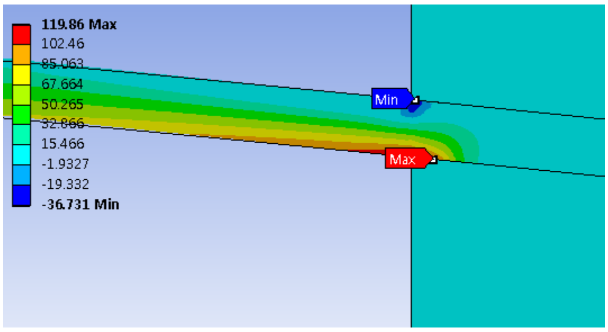

Fig 3. Principal Stress (μ=1.0)

3. Conclusion

The structural analyses were performed with various boundary conditions by using ANSYS code. As a result, it is confirmed that the beam window is structurally stable under most frictional contact conditions. Though fixed supports are most favorable to minimize the deformation and stress level, the ease of making and assembling should be also considered. Therefore, the supports of the beam window will be made with high practicality and will be installed at the RI beam line.

Acknowledgements

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REFERENCES

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[2] Mechanics of Solid, Roger T. Fenner, CRC Press, 1999