Vacuum system for the SAMURAI spectrometer†

Y. Shimizu,*1 H. Otsu,*1 T. Kobayashi,*1,*2 T. Kubo,*1 T. Motobayashi,*1 H. Sato,*1 and K. Yoneda*1

The first commissioning experiment of the SAMURAI spectrometer[1)] and its beam line was performed in March, 2012. The vacuum system for the SAMURAI spectrometer includes its beam line and the SAMURAI vacuum chamber with the windows for detecting neutrons and charged particles.

The window for neutrons is made of 3 mm-thick stainless steel designed in the shape of a partial cylinder to support itself against atmospheric pressure. The deflection of the window caused by the pressure difference and the induced stress are calculated using the general purpose finite element analysis program code ANSYS[2)]. Figure 1 shows the ANSYS calculation result. The calculated displacement by the atmospheric pressure at the central region and the maximum induced stress are 0.17 mm and 44 MPa, respectively. It should be noted that the latter is smaller than 1/10 of the tensile strength. This window is achieved a safety factor of 12.

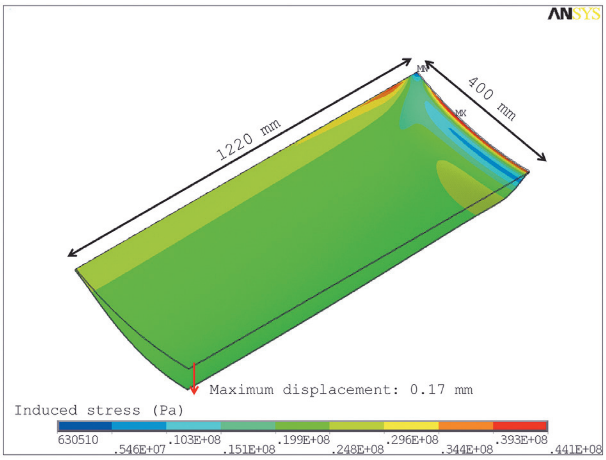

Fig. 1. ANSYS calculation result for the shape of a partial cylinder with a thickness of 3 mm.

The window for charged particles was composed of a combination of Kevlar and Mylar with thicknesses of 280 and 75 μm, respectively. The Kevlar and Mylar were glued with an Araldite® to the top of the window frame, which is made of SUS304. The open geometry of the exit window of the vacuum chamber is 2800 $\times$ 800 mm^2, while a 2800 $\times$ 400 mm^2 window was used in the commissioning experiment. This was a result of tradeoff between the experimental requirement and the safety and risk management for the breaking of the window. The deflection and stress for the Kevlar textile are calculated by ANSYS. Since the elastic properties of the Kevlar textile are not known, they are determined to reproduce the vacuum test[3)]. In order to reduce the displacement and elongation of the Kevlar textile, we performed a calculation considering a flexure of 193 mm in the initial condition. The result is shown in Fig. 2. The displacement and elongation of the Kevlar textile are 73 mm and 6.3%, respectively.

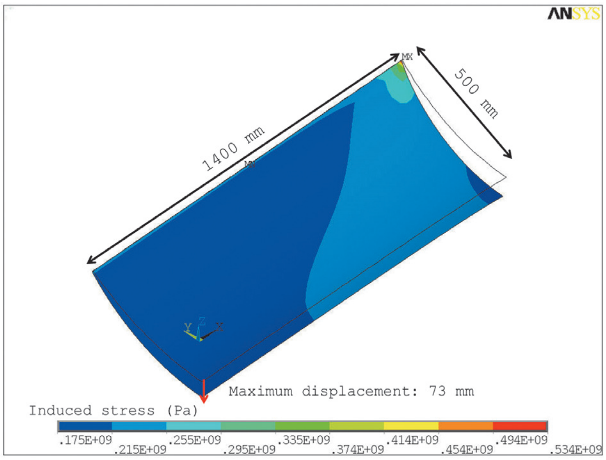

Fig. 2. ANSYS calculation result for Kevlar textile with a flexure of 193 mm in the initial condition.

In order to have a flexure of 40 mm around the center region in the initial condition, both sides of the Kevlar and Mylar were slacked by about 5 mm. The flexure of 40 mm was determined to be the maximum flexure without inducing wrinkles in the Mylar at the corners. The maximum deflection around the center region was estimated to be approximately 60 mm. This indicates that the Mylar elongated about 3.2% due to air pressure, which was 1/3 smaller than that of the tensile elongation at the break. Since this window is achieved a safety factor of only 2.8, the window materials have to be replaced every year for reasons of safety.

The deflections of these windows by visual observation were consistent with the ANSYS calculation results. The pressure in the SAMURAI vacuum chamber was successfully maintained at a few Pa during the commissioning experiment without any problems caused by the windows.

References

1) Y. Shimizu *et al.*, J. Phys.: Conf. Ser. **312**, 052022 (2011).
2) URL: http://www.ansys.com/
3) Y. Shimizu *et al.*, RIKEN Accel. Prog. Rep. **44**, 154 (2011).

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*1 RIKEN Nishina Center
*2 Department of Physics, Tohoku University