HGC Window Test - Double Layered Kevlar-Mylar with Epoxy Coating

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As part of the prototyping process for the SoLID Heavy Gas Cherenkov detector (HGC), a suitable material for the entrance window must be found. The HGC will be filled with gas at a pressure of approximately 1.5 atm, or 22.0 psi (that is, 0.5 atm or 7.35 psi overpressure), and must fit in the SoLID assembly at Jefferson Lab Hall A. As such the material must not only withstand the pressure difference, but do so with minimal bulging (no more than approximately 10 cm). In this trial a window consisting of two layers each of Kevlar and Mylar, with an epoxy resin coating, was tested.

1 Procedure

Mylar and Kevlar samples have been aquired from Challenge Sailcloth [1]. The Mylar has a thickness of 5 mil and is crosshatched with strands of carbon and glass fiber. The Kevlar has a thickness of 12 mil and comes with an adhesive backing, which has been used to bind the layers. Two layers of Mylar were bound between two layers of Kevlar. The material was cut to fit a 35.6 by 28 cm acrylic window frame. Previous testing [2] indicates that epoxy may increase the tensile strength of the material, so LePage Speed-Set epoxy resin was then applied to the material and given 24 hours to set. The material was then mounted on the prototype frame. The material with the resin was still flexible, and was mounted to be flat and taut while un-inflated.

The window was then fixed to a steel plate with vacuum grease to provide an airtight seal. A ruler was fixed above the window in an apparatus which allows the ruler to slide up and down, resting against the window. Air was pumped through a hole in the under side of the plate using a bicycle pump attached to a pressure gauge and valve. The entire apparatus is shown in Fig. 1.

Measurements were taken by closing the vavle at desired pressure values, and reading the ruler against the ruler's holding apparatus. The initial reading at zero pressure is taken to be a deflection of 0 cm.

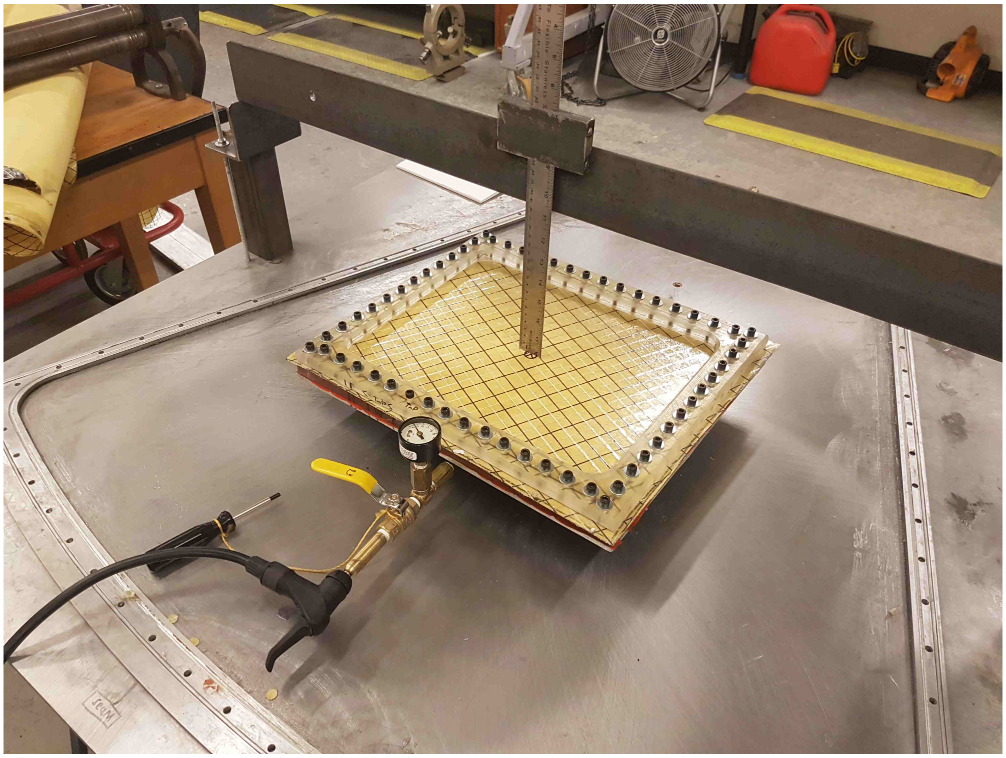

Figure 1: Photograph of experimental setup.

2 Results

Air was pumped in until the pressure reached 20 psi, where the window had deflected to 2.7 cm. At this point, the pressure was noted to be decreasing while the valve was closed. Several leak points were found around the circumference. The deflection versus pressure up to this point is shown in Fig. 2 by the red points.

The window was disassembled and adjusted to eliminate the leak. It was then left at a pressure of 10 psi overnight to ensure it was holding pressure. The window was then inflated to higher pressure. The deflection versus pressure is shown in Fig. 2 by the green points. At a pressure of 50 psi and a deflection of 4.6 cm, the window began leaking again, though much more rapidly. At this point the deformation in the frame, shown in Fig Figs. 3 and 4, was noted.

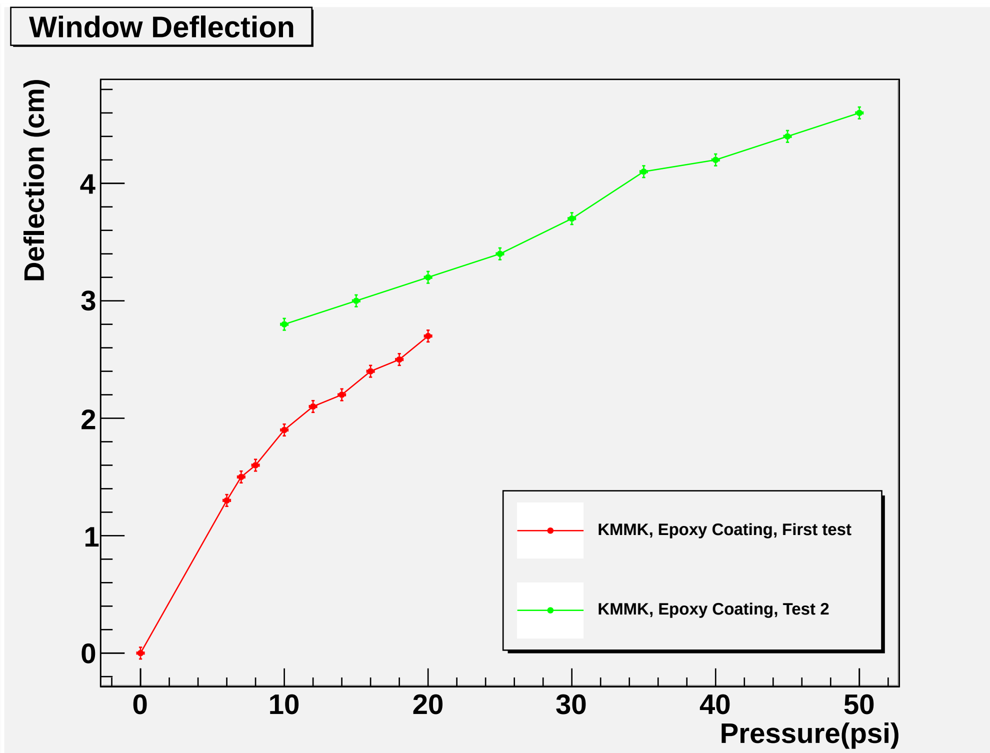

Figure 2: Graph showing height of the bulge in the window versus pressure both before and after correcting the leak.

Figure 3: Side view of the window frame and plate, showing the upward deformation at 50 psi.

Figure 4: Inward deformation at the side of the window at 50 psi. A straight steel rod provides a reference.

The deflection has been related to the deflection observed in previous tests on the full size window frame by normalization to the width at the measurement point, along the shortest axis. This width is 28 cm for the small window, and 83 cm for the full size window. The results are shown in Fig 5.

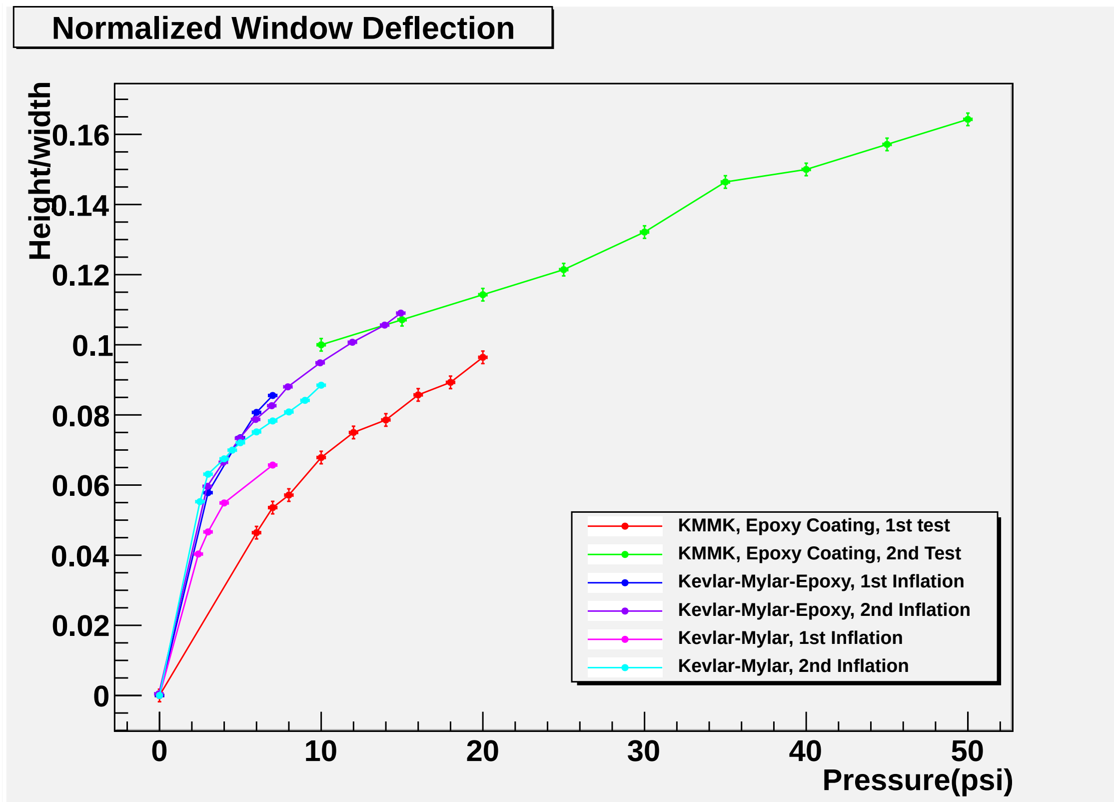

Figure 5: Comparison of window deflection, normalized by window width, for this test and previous tests on the full size window. Red and green lines indicate the tests described in this report, on the scaled down window. All other lines indicate previous tests performed on the full size window.

The tension in the material may also be calculated from the deflection, width, and pressure of the window. Approximating the surface as spherical, the radius of curvature is:

$$r = \frac{w^2}{8h} + \frac{h}{2} \tag{1}$$

for height h, and width w. The tension at pressure P is then:

$$T = Pr \tag{2}$$

The results for this calculation are shown in Fig. 6.

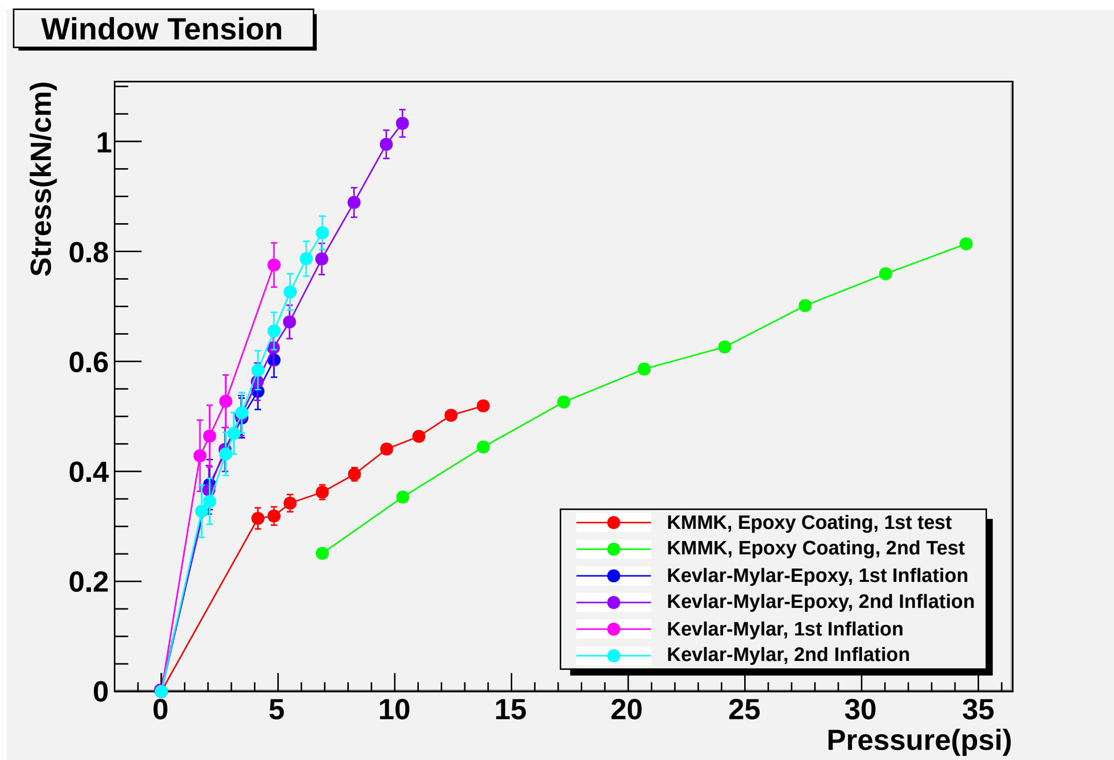

Figure 6: Comparison of window tension for this test and previous tests on the full size window. Red and green lines indicate the tests described in this report, on the scaled down window. All other lines indicate previous tests performed on the full size window.

3 Conclusion

The miniature version of the window was shown to be a promising method for testing of window materials, at a lower material cost. However several flaws in the design have been highlighted and need to be addressed before proceeding. The small scale window had no sealing o-ring, and no clamping wire, as in the design of the full window. The window should also be mounted to a thicker plate to avoid the deformation shown in Figs. 3 and 4.

The doubling of the layers of window material appear to give greatly improved deflection over previous tests on initial inflation. However, the second inflation (after repairs) shows much more comparable deflection at equal pressures. It is not currently clear why this is the case. It is possible that the height of the deflection does not simply scale linearly with the size of the window, as has been assumed here. Further testing of different window materials should be performed using a consistently sized window to eliminate the need for such assumptions.

References

[1] Challenge Sailcloth, Inc. 711 W 17th St, Cosa Mesa, CA 92627-4345. 949-722-7448

[2] Evans, R. S., et al. Heavy Gas Cherenkov Detector: Window Material Pressure Test, *Unpublished* (2016).