MICE Beryllium Window pressure stress evaluation

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Case #1a: using linear material properties as input.

Input material properties for Beryllium:

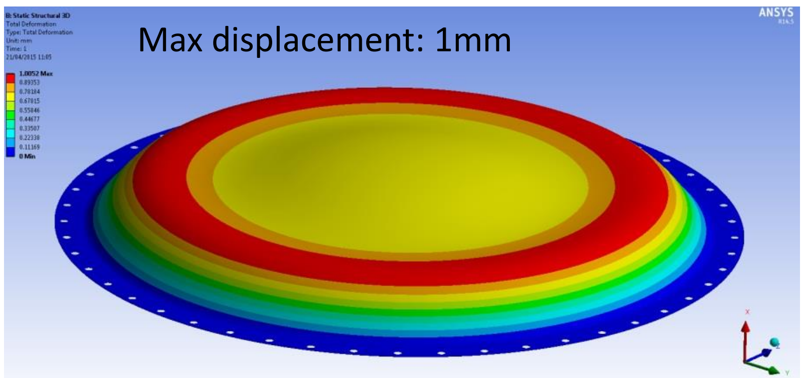
- Density: 1850 kg/m^3;
- E: 287, 000 MPa;
- v: 0.03

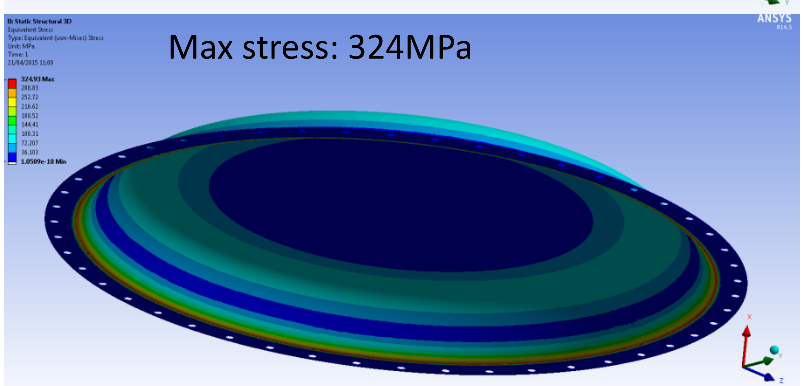
Beryllium window geometry as per CAD model received from Allan DeMello on the 17th of April, 2015.

Positive pressure load: 0.01 MPa (0.1 bar);

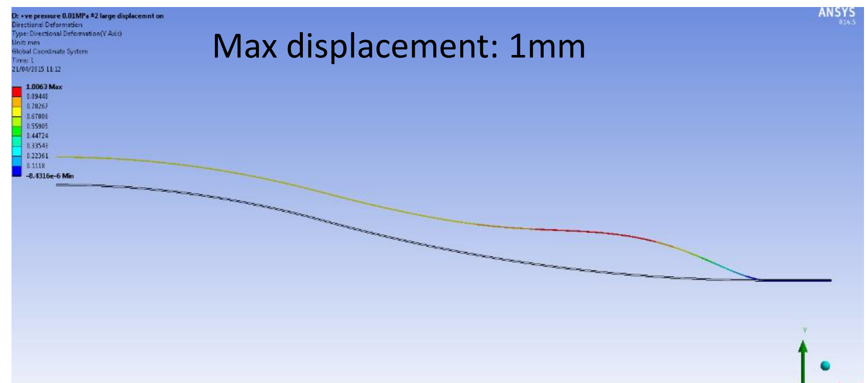
Step loading run – this takes into account of large displacement effect ;

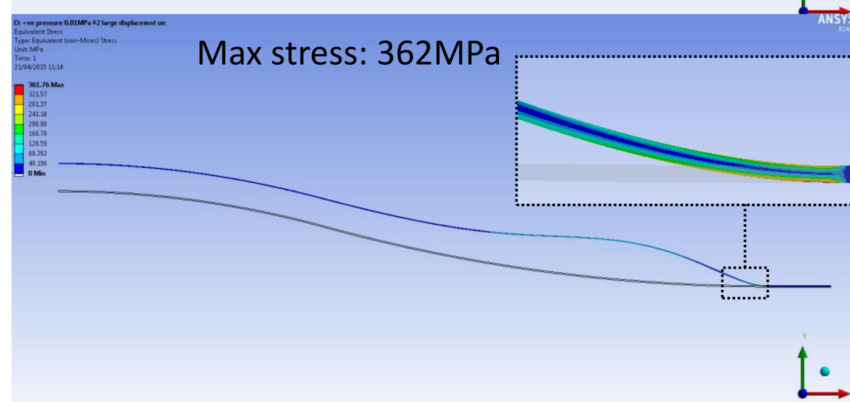
3D model:





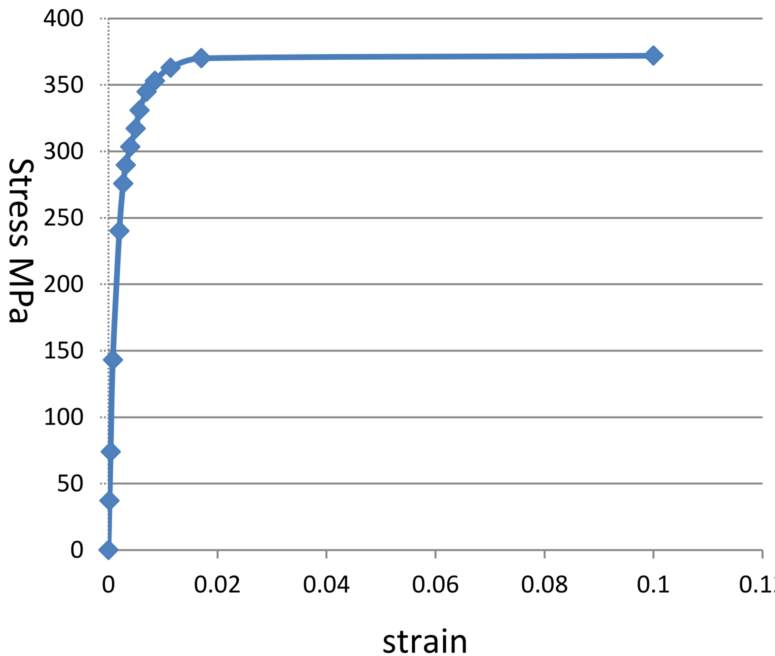
2D axisymmetric model





Case #2: using nonlinear material properties as input

Assumed Beryllium stress strain curve

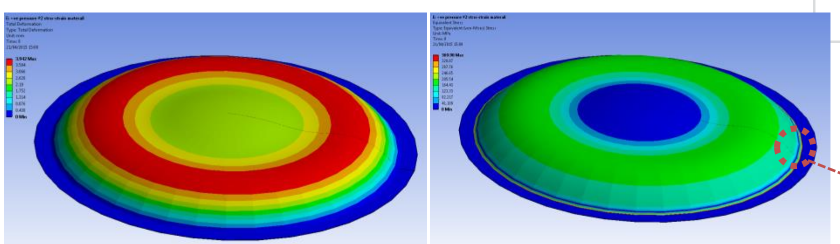


Assumed Beryllium properties of:

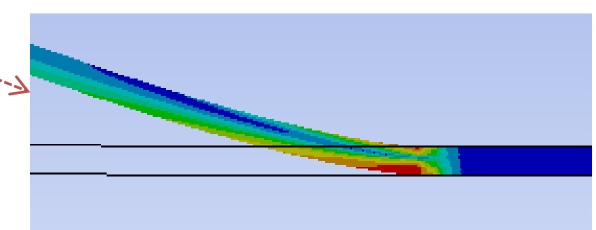
- Yield strength: 240 MPa;
- Tensile strength: 370MPa;

Result summary:

pressure load (bar)	max stress MPa	max displacement mm
0.005	19.565	0.183
0.010	36.887	0.343
0.050	136.010	1.076
0.100	204.830	1.583
0.250	311.820	2.506
0.500	365.860	3.570
0.550	368.970	3.761
0.600	369.980	3.942



3D view of the 2D model axisymmetric model result



Remarks:

Unlike the AFC Absorber window, the Beryllium window has a uniform thickness throughout the entire window. This makes it very weak in sustaining any pressure load.

The linear elastic analysis (Case #1) using linear material properties shows peak stress of 362 MPa on a pressure load of as low as 0.1 bar near the outer rim where it is joined to the window flange.

A flat circular of the similar geometry as the window was studied using close-form solution to double check that the FE results are in the same ball-park figure. This is in Appendix 1. The result shows that a flat window would yield at 0.01 bar pressure which is about 6 times lower that the Beryllium window – helped by the curved geometry.

A non-linear elastic-plastic analysis (Case #2), taking into account of large displacement effect shows the window reaching a UTS value of nearly 370MPa (using a standard stress-strain curve on Beryllium) on a pressure load of 0.6 Bar. We suspect this reflects the burst pressure of the window.

Remarks:

Obviously, we could estimate the “safe” working pressure of the window from the calculated burst pressure.

If we accept this argument, then the following evaluation applies:

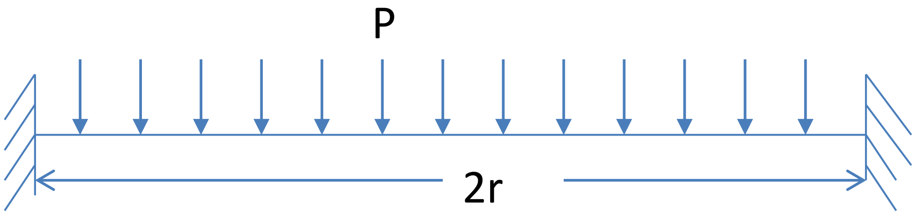
Section UG-101-m-2ain Div 1 of ASME VIII suggested that the burst pressure P_b should be:

$P_b = 5 \times P \times S_t/S_w$ *where S_t and S_m are the min. tensile stress at test and working temperature respectively.*

If we assume $S_t = S_w$ to be the same, then Max. working pressure, P, of the window = $P_b/5$ = 0.6bar / 5 = 0.12 bar **which is still very low**.

In this analysis, we have, in absence of any specific material data on Beryllium, used a typical stress-strain relationship for the FE analysis. On the assumption that the applied material properties are correct, the window is not capable of sustain any pressure load more than **0.12 bar.**

Appendix 1 -- Max Pressure for a flat circular plate



Max. Bending Moment at the outer rim of the clamped circular plate is:

$M = P * r^2 / 8$ ------- (1)   r = radius of window = 210mm

Bending stress in the circular plate is: $\sigma = 6 M / t^2$ ---------------- (2)

t is the plate thickness = 0.381mm

(1) & (2) ➔ $t^2 * \sigma / 6 = P * r^2 / 8$ ➔ $p = 1.33 * t^2 * r^2 / \sigma$

For a yield stress of, say, 240 MPa (max. allowable bending stress = yield), the max. pressure is

$P = 1.33 * 0.381 * 0.381 * 240{,}000{,}000 / 210 * 210$

$= 1050$ Pa = 0.001 MPa or <u>0.01bar</u>

The Beryllium window yield at around 0.1 bar. So, the result is in the right ball-park figure.