MATERION

TECH BRIEF

Electrofusion Beryllium Window Thickness Guidelines

Beryllium X-ray windows frequently operate in differential pressure situations with atmospheric pressure on one side and vacuum on the other. The following equations are suggested as a means of computing stress on X-ray windows in typical differential pressure installation conditions. Beryllium foil is not characterized for its mechanical properties but a design strength of 40,000 psi or 275 MPa is typical. Note that appropriate safety factors should be employed in all calculations.

Determining Deflection and Stress

The procedure to determine deflection and stress at any given foil thickness is to use a math program or spreadsheet to solve for deflection "y" in the first equation.

$$\frac{qr^4}{Et^4} = K_1 \frac{y}{t} + K_2\left(\frac{y}{t}\right)^3$$

Equation 1 – Deflection

Then, use that value to solve for maximum stress "σ" in the second equation. This analysis considers X-ray windows to be flat, circular plates with the edges held and fixed, as would be the case for diffusion bonded window assemblies. These formulas take into account shear stress and diaphragm stress, which is the stress in the material carried as tension, so it is valid for windows even if they undergo a deflection larger than half the material thickness. Although intended for use on circular apertures, if applications require rectangular apertures, a practical approximation is to use the following guideline: substitute the small dimension of the rectangle for the diameter of the aperture.

$$\frac{\sigma r^2}{Et^2} = K_3 \frac{y}{t} + K_4\left(\frac{y}{t}\right)^2$$

Equation 2 – Maximum Stress

These equations are from pages 477 & 478, Roark's Formulas for Stress & Strain by Warren C. Young, 6th Edition, (1989) McGraw-Hill.

Solve for: y = Maximum deflection (solve for this first)
σ = Maximum stress due to bending and tension

Variables: t = Beryllium thickness
r = Radius of aperture (inches or meters)
q = Unit lateral pressure, typically 15 psi or 101 kPa for 1 ATM

Constants: ν = Poisson's Ratio for Be = 0.03 — 0.08
E = Young's Modulus for Be = 44 msi, (44×10^6 psi), or (303 GPa)
$K = 5.33/(1-\nu^2)$
$K_2 = 2.6/(1-\nu)$
$K_3 = 2/(1-\nu)$ {at center}
$K_4 = 0.976$ {at center}
$K_3 = 4/(1-\nu^2)$ {at edge}
$K_4 = 0.476$ {at edge}

Health and Safety Note

Processing beryllium-containing alloys poses a health risk if safe practices are not followed. Inhalation of airborne beryllium can cause serious lung diseases in some individuals. Occupational safety and health regulatory agencies worldwide have set mandatory limits on occupational respiratory exposures. Read and follow the guidance in the Safety Data Sheet (SDS) before working with this material. The SDS and additional important beryllium health and safety information and guidance can be found at https://berylliumsafety.com, https://berylliumsafety.eu and https://Materion.com. For questions on safe practices for beryllium-containing alloys, contact the Materion Product Stewardship Group at +1.800.862.4118 or contact us by email at Materion-PS@Materion.com.

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