Calculation of effective area

Reference data

$p_{nom} := 100\ MPa$

$A_{0nom} := 1.90290 \cdot 10^{-6}\ m^2$

$\lambda_{nom} := 7.79 \cdot 10^{-13} \cdot Pa^{-1}$

$A_{ref100} := A_{0nom} \cdot (1 + \lambda_{nom} \cdot p_{nom}) = (1.903048 \cdot 10^{-6})\ m^2$

$A_{res} := 1.903052 \cdot 10^{-6}\ m^2$

$g := 9.809273 \cdot m \cdot s^{-2}$

$\rho_a := 1.2$

$t_{ref} := 20\ °C$

$\sigma := 31 \cdot 10^{-3}\ N \cdot m^{-1}$

$\Delta h := -0.073\ m$

$\rho_l := 912.5\ kg \cdot m^{-3}$

Reference p/c data

$A_0 := 1.903118 \cdot 10^{-6}\ m^2$

$\lambda := .743 \cdot 10^{-6} \cdot MPa^{-1}$

$m_{cpr} := .2000038 \cdot kg$

$\rho_p := 8030$

$m_{pr} := \dfrac{m_{cpr}}{1 - \left(\dfrac{1}{\rho_p} - \dfrac{1}{8000}\right) \cdot 1.2} = 0.2000037\ kg$

$m_{cbr} := .800007 \cdot kg$

$\rho_b := 5058$

$m_{br} := \dfrac{m_{cbr}}{1 - \left(\dfrac{1}{\rho_b} - \dfrac{1}{8000}\right) \cdot 1.2} = 0.8000768\ kg$

$\alpha_p := 4.5 \cdot 10^{-6}\ K^{-1}$

$\alpha_c := \alpha_p$

$c := \sqrt{\dfrac{A_0}{\pi}} = (7.783 \cdot 10^{-4})\ m$

Object p/c data

$m_{cpo} := 0.199996 \cdot kg$ $\quad$ $m_{po} := \frac{m_{cpo}}{1 - \left(\frac{1}{\rho_p} - \frac{1}{8000}\right) \cdot 1.2} = 0.199996\ kg$

$m_{cbo} := 0.7999962 \cdot kg$ $\quad$ $m_{bo} := \frac{m_{cbo}}{1 - \left(\frac{1}{\rho_b} - \frac{1}{8000}\right) \cdot 1.2} = 0.800066\ kg$

1. Reference pressure calculation

$t_r := 19.21\ °C$

$\rho_m := 7920$

$m_{cr} := \begin{bmatrix} 3.999996 \\ 4.9999857 \\ 4.9999928 \\ 4.9999939 \\ .001950 \end{bmatrix} \cdot kg$ $\quad$ $m_r := \frac{m_{cr}}{1 - \left(\frac{1}{\rho_m} - \frac{1}{8000}\right) \cdot 1.2} = \begin{bmatrix} 4.00000 \\ 4.99999 \\ 5.00000 \\ 5.00000 \\ 0.00195 \end{bmatrix} kg$

$m_{tr} := \sum m_r \cdot \left(1 - \frac{\rho_a}{\rho_m}\right) + m_{pr} \cdot \left(1 - \frac{\rho_a}{\rho_p}\right) + m_{br} \cdot \left(1 - \frac{\rho_a}{\rho_b}\right)$

$p_r := \frac{m_{tr} \cdot g + \sigma \cdot c}{A_0 \cdot (1 + \lambda \cdot p_{nom}) \cdot (1 + (\alpha_p + \alpha_c) \cdot (t_r - t_{ref}))} + \rho_l \cdot g \cdot \Delta h = (1.030732 \cdot 10^8)\ Pa$

$p_0 := p_r$

Object p/c data

$t_o := 20.41\ °C$

$$m_{co} := \begin{bmatrix} 3.9999608 \\ 4.999989 \\ 4.9999886 \\ 4.9999928 \end{bmatrix} \cdot kg \qquad m_o := \frac{m_{co}}{1 - \left(\frac{1}{\rho_m} - \frac{1}{8000}\right) \cdot 1.2} = \begin{bmatrix} 3.9999669 \\ 4.9999966 \\ 4.9999962 \\ 5.0000004 \end{bmatrix} kg$$

$$m_{co} := \sum m_o \cdot \left(1 - \frac{\rho_a}{\rho_m}\right) + m_{po} \cdot \left(1 - \frac{\rho_a}{\rho_p}\right) + m_{bo} \cdot \left(1 - \frac{\rho_a}{\rho_b}\right) = 19.99692\ kg$$

$$A_{p_1} := \frac{m_{co} \cdot g + \sigma \cdot c}{p_r \cdot \left(1 + \left(\alpha_p + \alpha_c\right) \cdot \left(t_o - t_{ref}\right)\right)} = \left(1.9030601 \cdot 10^{-6}\right)\ m^2$$

2. Reference pressure calculation

$t_r := 20.36\ °C$

$\rho_m := 7920$

$$m_{cr} := \begin{bmatrix} 3.999996 \\ 4.9999857 \\ 4.9999928 \\ 4.9999939 \\ .002100 \end{bmatrix} \cdot kg \qquad m_r := \frac{m_{cr}}{1 - \left(\frac{1}{\rho_m} - \frac{1}{8000}\right) \cdot 1.2} = \begin{bmatrix} 4.00000 \\ 4.99999 \\ 5.00000 \\ 5.00000 \\ 0.00210 \end{bmatrix} kg$$

$$m_{tr} := \sum m_r \cdot \left(1 - \frac{\rho_a}{\rho_m}\right) + m_{pr} \cdot \left(1 - \frac{\rho_a}{\rho_p}\right) + m_{br} \cdot \left(1 - \frac{\rho_a}{\rho_b}\right) = 19.99908\ kg$$

$$p_r := \frac{m_{tr} \cdot g + \sigma \cdot c}{A_0 \cdot \left(1 + \lambda \cdot p_{nom}\right) \cdot \left(1 + \left(\alpha_p + \alpha_c\right) \cdot \left(t_r - t_{ref}\right)\right)} + \rho_l \cdot g \cdot \Delta h = \left(1.0307295 \cdot 10^8\right)\ Pa$$

$p_1 := p_r$

2. Object p/c data

$t_o := 21.93\ °C$

$$A_{p_2} := \frac{m_{co} \cdot g + \sigma \cdot c}{p_r \cdot \left(1 + \left(\alpha_p + \alpha_c\right) \cdot \left(t_o - t_{ref}\right)\right)} = \left(1.9030394 \cdot 10^{-6}\right)\ m^2$$

3. Reference pressure calculation

$t_r := 20.68\ °C$

$$m_{cr} := \begin{bmatrix} 3.999996 \\ 4.9999857 \\ 4.9999928 \\ 4.9999939 \\ .002250 \end{bmatrix} \cdot kg \qquad m_r := \frac{m_{cr}}{1 - \left(\frac{1}{\rho_m} - \frac{1}{8000}\right) \cdot 1.2} = \begin{bmatrix} 4.00000 \\ 4.99999 \\ 5.00000 \\ 5.00000 \\ 0.00225 \end{bmatrix}\ kg$$

$\sum m_r = 19.00225\ kg$

$$m_{tr} := \sum m_r \cdot \left(1 - \frac{\rho_a}{\rho_m}\right) + m_{pr} \cdot \left(1 - \frac{\rho_a}{\rho_p}\right) + m_{br} \cdot \left(1 - \frac{\rho_a}{\rho_b}\right) = 19.99923\ kg$$

$$p_r := \frac{m_{tr} \cdot g + \sigma \cdot c}{A_0 \cdot \left(1 + \lambda \cdot p_{nom}\right) \cdot \left(1 + \left(\alpha_p + \alpha_c\right) \cdot \left(t_r - t_{ref}\right)\right)} + \rho_l \cdot g \cdot \Delta h = \left(1.030734 \cdot 10^8\right)\ Pa$$

$p_2 := p_r$

3. Object p/c data

$t_o := 21.64\ °C$

$$A_{p_3} := \frac{m_{co} \cdot g + \sigma \cdot c}{p_r \cdot \left(1 + \left(\alpha_p + \alpha_c\right) \cdot \left(t_o - t_{ref}\right)\right)} = \left(1.9030356 \cdot 10^{-6}\right)\ m^2$$

4. Reference pressure calculation

$t_r := 22.81\ °C$

$$m_{cr} := \begin{bmatrix} 3.999996 \\ 4.9999857 \\ 4.9999928 \\ 4.9999939 \\ .002700 \end{bmatrix} \cdot kg \qquad m_r := \frac{m_{cr}}{1 - \left(\frac{1}{\rho_m} - \frac{1}{8000}\right) \cdot 1.2} = \begin{bmatrix} 4.00000 \\ 4.99999 \\ 5.00000 \\ 5.00000 \\ 0.00270 \end{bmatrix}\ kg$$

$\sum m_r = 19.0027\ kg$

$$m_{tr} := \sum m_r \cdot \left(1 - \frac{\rho_a}{\rho_m}\right) + m_{pr} \cdot \left(1 - \frac{\rho_a}{\rho_p}\right) + m_{br} \cdot \left(1 - \frac{\rho_a}{\rho_b}\right) = 19.99968\ kg$$

$$p_r := \frac{m_{tr} \cdot g + \sigma \cdot c}{A_0 \cdot \left(1 + \lambda \cdot p_{nom}\right) \cdot \left(1 + \left(\alpha_p + \alpha_c\right) \cdot \left(t_r - t_{ref}\right)\right)} + \rho_l \cdot g \cdot \Delta h = \left(1.030738 \cdot 10^8\right)\ Pa$$

$p_3 := p_r$

4. Object p/c data

$t_o := 20.42\ °C$

$$A_{p_4} := \frac{m_{co} \cdot g + \sigma \cdot c}{p_r \cdot \left(1 + \left(\alpha_p + \alpha_c\right) \cdot \left(t_o - t_{ref}\right)\right)} = \left(1.9030502 \cdot 10^{-6}\right)\ m^2$$

5. Reference pressure calculation

$t_r := 20.53\ °C$

$$m_{cr} := \begin{bmatrix} 3.999996 \\ 4.9999857 \\ 4.9999928 \\ 4.9999939 \\ .002250 \end{bmatrix} \cdot kg \qquad m_r := \frac{m_{cr}}{1 - \left(\frac{1}{\rho_m} - \frac{1}{8000}\right) \cdot 1.2} = \begin{bmatrix} 4.00000 \\ 4.99999 \\ 5.00000 \\ 5.00000 \\ 0.00225 \end{bmatrix} kg$$

$\sum m_r = 19.00225\ kg$

$$m_{tr} := \sum m_r \cdot \left(1 - \frac{\rho_a}{\rho_m}\right) + m_{pr} \cdot \left(1 - \frac{\rho_a}{\rho_p}\right) + m_{br} \cdot \left(1 - \frac{\rho_a}{\rho_b}\right) = 19.99923\ kg$$

$$p_r := \frac{m_{tr} \cdot g + \sigma \cdot c}{A_0 \cdot (1 + \lambda \cdot p_{nom}) \cdot (1 + (\alpha_p + \alpha_c) \cdot (t_r - t_{ref}))} + \rho_l \cdot g \cdot \Delta h = \left(1.030736 \cdot 10^8\right) Pa$$

$p_4 := p_r$

5. Object p/c data

$t_o := 21.18\ °C$

$$A_{p_5} := \frac{m_{co} \cdot g + \sigma \cdot c}{p_r \cdot (1 + (\alpha_p + \alpha_c) \cdot (t_o - t_{ref}))} = \left(1.9030409 \cdot 10^{-6}\right) m^2$$

$A_p := \sum A_p \cdot 0.2 = \left(1.9030452 \cdot 10^{-6}\right) m^2$

$$p = \begin{bmatrix} 1.0307325 \cdot 10^8 \\ 1.0307295 \cdot 10^8 \\ 1.0307343 \cdot 10^8 \\ 1.0307377 \cdot 10^8 \\ 1.0307357 \cdot 10^8 \end{bmatrix} Pa \qquad p_{mean} := \text{mean}(p) = \left(1.03073 \cdot 10^8\right) Pa$$