PEEK material properties, unfilled

yield strength, room temp — elastic modulus

$S_{y\_peek\_23C} := 97 \cdot 10^6 \text{Pa}$ $S_{y\_peek\_23C} = 1.407 \times 10^4 \text{psi}$ $E_{peek} := 3.7 \cdot 10^9 \text{Pa}$ $E_{peek} = 5.366 \times 10^5 \text{psi}$

If we need to bakeout, PEEK data shows good creep resistance at 120C, but lower yield point.

$S_{y\_peek\_120C} := 50 \cdot 10^6 \text{Pa}$ $S_{y\_peek\_120C} = 7.252 \times 10^3 \text{psi}$

There will be a stress relaxation over time at this stress so prolonged bakeouts may need even lower design stress. For now we use half the yield at 120C.

Loads and dimensions

$W_{cg} := 15.30\text{lbf}$(CAD 4/24/10)) $l_{cg} = 6.457\,\text{in}$ $h_{fl} := 4.64\text{in}$ (from existing CAD model tpc-03)

Total Moment on rod/spacer assembly

$M_v := W_{cg} \cdot l_{cg}$ $M_v = 98.792\,\text{lbf} \cdot \text{in}$

Reaction Force on rods

$\Sigma M := 0$ Assume two bolts aligned horizontally on midplane. Then sum about axis on midplane, by symmetry, the problem becomes statically determinate since bottom two bolts have the same moment arm as each other and the same as top bolts. Alternate orientation will not be significantly different.

$F_h := \frac{M_v}{0.5 h_{fl}}$ $F_h = 42.6\,\text{lbf}$ for each pair of upper or lower bolts

per bolt:

$F_{h\_bolt} := 0.5 F_h$ $F_{h\_bolt} = 21.291\,\text{lbf}$

Since bottom two bolt forces are in compression, their sleeves will carry this reaction load. We need only concern ourselves with the top two bolts.
We need a certain amount of preload on sleeves to prevent shear slippage. Friction coefficient:

$\mu_{peek} := 0.5$ we should probably assume only half of this for safety

Normal force required:

$F_N := \frac{W_{cg}}{0.5 \mu_{peek}}$ $F_N = 61.2\,\text{lbf}$

This can be shared by all 6 bolts, if we assure sleeve compression is uniform, which we should do for alignment anyway. This will require nonuniform bolt tensioning.

$F_{N\_bolt} := \frac{F_N}{6}$ $F_{N\_bolt} = 10.2\,\text{lbf}$

Area required, total, in top two bolts (use 50% yield strength as maximum stress: use 3x static load for dynamic loading safety factor):

$A_{xsec\_min} := \frac{3\left(F_{h\_bolt} + F_{N\_bolt}\right)}{0.5 S_{y\_peek\_120C}}$ $A_{xsec\_min} = 0.0261\,\text{in}^2$

Bolt root diameter, minimum

$d_{min\_root} := \sqrt{\frac{4}{\pi} 0.5 A_{xsec\_min}}$ $d_{min\_root} = 0.129\,\text{in}$ use: $d_{bolt\_root} := 0.2\text{in}$

Bolt torque required for preload:

$$T_{bolt} := 0.2\cdot 3\left(F_{h\_bolt} + F_{N\_bolt}\right)\cdot d_{bolt\_roo} \quad T_{bolt} = 3.8\,lbf\cdot in$$

Bolt Safety factor:

$$FS_{bolt} := \left(\frac{d_{bolt\_root}}{d_{min\_root}}\right)^2 \qquad FS_{bolt} = 2.4$$

Displacement (sleeve compression) on tightening (assume tightening to 1.5x min preload).
assume length twice the c.g. distance from flange

$$r_o := .25in \qquad r_i := .13in$$

$$A_{sleeve} := \pi\left(r_o^{\,2} - r_i^{\,2}\right) \qquad A_{sleeve} = 0.143\,in^2$$

$$\delta := \frac{0.75\cdot F_h\cdot 2l_{cg}}{A_{sleeve}\cdot E_{peek}} \qquad \delta = 0.0054\,in$$

Check shear stress (for loose bolts (all 6 bolts carry load, if not prestressed):

$$\tau_{bolt} := \frac{W_{cg}}{3\cdot\frac{\pi}{4}\,d_{bolt\_root}^{\,2}} \qquad \tau_{bolt} = 162\,psi$$

For tight bolts (no slippage), shear stress is carried only by sleeves:

$$\tau_{sleeve} := \frac{W_{cg}}{6\cdot A_{sleeve}} \qquad \tau_{sleeve} = 17.8\,psi$$

Nut engagement required, same materials

$$d_{bolt} := 0.25in \qquad A_{root} := \frac{\pi}{4}d_{bolt\_root}^{\,2} \qquad N_t := 24in^{-1}$$

$$L_e := \frac{2A_{root}}{0.5\pi\left(d_{bolt} - .65N_t^{\,-1}\right)} \qquad L_e = 0.179\,in$$

http://www.engineersedge.com/thread_strength/thr-
ead_minimum_length_engagement.htm

Shear displacement

$$\delta_\tau := \frac{\tau_{sleeve}\cdot l_{sleeve}}{G_{peek}} \qquad l_{sleeve} := 8in \qquad G_{peek} := \frac{E_{peek}}{2\left(1 + \nu_{peek}\right)} \qquad \nu_{peek} := .3$$

$$\delta_\tau = 0.018\,mm$$