T2 Heat Exchanger Outlet

Manifold Weld Analysis

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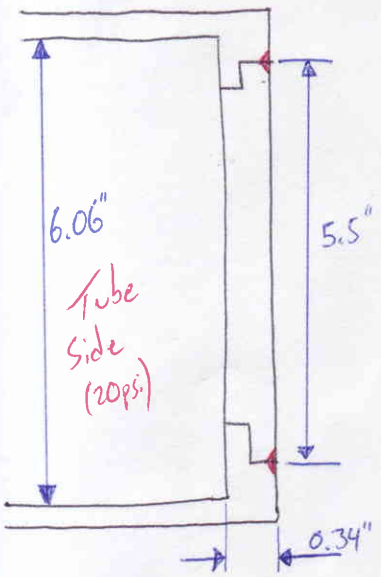
TBP0903



Assumptions

- Max pressure of tube side: 20psi
- Assume shell side vented
- Assume end cap is cut and welded at 5.5" diameter as shown
- Neglect tube stub, approximate w/ continuous end cap as shown
- Assume 0.10" butt weld
- Neglect load on original manifold section (D>5.5")
- Assume 0psi on shell side (this is worst case for weld b/c step will support end plate if pressure is higher on shell side)

Shear stress due to Direct Shear

Area: $\pi r^2 = \pi (2.25)^2 = 15.9 in^2$

Load: $(15.9 in^2)(20 psi) = 318 lbf$

Length of weld: $\ell = \pi D = \pi (5.5") = 17.3"$

Weld throat area: 

← Machine Elements 7th Ed. (Spotts, Shoup) p375

$$A = h\ell = (0.10")(17.3") = 1.73 in^2$$

$$\tau_s = \frac{F}{A} = \frac{318 lbf}{1.73 in^2} = \boxed{183.8 psi}$$

Bending Moment in thick (0.34") section of plate caused by load from 20psi internal pressure

Roark's Table 11.2, Case 10 (p488)

Uniformly distributed pressure on simply supported constant thickness circular plate:

$M_c = q a^2 L_{17}$ where a = radius = 2.25"

q = pressure = 20psi

$$L_{17} = \frac{1}{4}\left\{1 - \frac{1-\nu}{4}\left[1 - \left(\frac{r_0}{a}\right)^4\right] - \left(\frac{r_0}{a}\right)^2\left[1 + (1+\nu)\ln\frac{a}{r_0}\right]\right\}$$

$r_0 = 0$ $\therefore$ $L_{17} = \frac{1}{4}\left\{1 - \frac{1-\nu}{4}\right\} = 0.2057$

Machinery's Handbook p201 (28 Ed.) ↓ $\nu = 0.291$ for 316 SS

$M_c = (20)(2.25^2)(0.2057) = \underline{20.82}$

Normal Stress due to Bending

Table 14-14 from Machine Elements: Yield Strength of Annealed 316 SS: 30,000psi

$$\sigma_B = \frac{6M}{t^2} = \boxed{1080.6\text{psi}}$$

Resultant Stress

$$\tau = \sqrt{\tau_s^2 + \sigma_B^2} = \boxed{1096.1\text{psi}}$$

$$FOS = \frac{30{,}000\text{psi}}{1096.1\text{psi}} = \boxed{27.4}$$

Deflection of plate at center due to 20psi internal pressure

$$y_c = \frac{-qa^4}{2D}\left(\frac{L_{17}}{1+\nu} - 2L_{11}\right)$$ for simply supported plate

$$D = \frac{Et^3}{12(1-\nu^2)} = \frac{(29\times10^6)(0.34)^3}{12(1-(0.291)^2)} = 103722$$

t = thickness, E = mod. of elasticity = 29×10^6 psi (Machinery Handbook p 201)

$$L_{11} = \frac{1}{64}\left\{1 + 4\left(\frac{r_0}{a}\right)^2 - 5\left(\frac{r_0}{a}\right)^4 - 4\left(\frac{r_0}{a}\right)^2\left[2 + \left(\frac{r_0}{a}\right)^2\right]\ln\frac{a}{r_0}\right\}$$

$r_0 = 0$ $\therefore$ $L_{11} = \frac{1}{64}(1) = 0.015625$

$$y_c = \frac{-(20)(2.25)^4}{2(103722)}\left(\frac{0.2057}{1+0.291} - 2(0.015625)\right)$$

$$= \boxed{3.165\times10^{-4} \text{ inches}}$$

Plate modelled in SolidWorks and analyzed using ANSYS. Weld area fully supported.

Max von-Mises stress: ~1200 psi ok!

Max deflection: ~1.2×10^{-4} inches

↑ lower value expected because fully supported at weld