Design Study of a Ring Stiffened Cylinder for use as a Manned Submersible

Shell Yield using Von Sanden and Gunther's Equation - Comstock, John Paul "Principles of Naval Architecture", 1967, p. 210, Equation [21]

$SafetyFactor := 2.0$

$DesignGoal := 1320 \cdot ft \cdot SafetyFactor$ $\qquad DesignGoal = 2640\,ft$

Design Variables:

Outside Diameter	$OD := 42.0 \cdot in$
Shell Thickness	$t := .375 \cdot in, .4375 \cdot in .. .625 \cdot in$
Shell Length	$Len := 104.25 \cdot in$
Number of Rings	$num := 2$
Ring Depth	$RD := 2.5 \cdot in$
Ring Width	$RW := 2 \cdot in$
Ring Web Thickness	$b := .4375 \cdot in$
Ring Flange Thickness	$RFT := .5 \cdot in$

Constants:

$SeaWaterDensity := 64 \cdot \frac{lbf}{ft^3}$

Material Properties:

Poissons Ratio	$\mu := .3$
Yield Strength	$\sigma := 38000 \cdot \frac{lbf}{in^2}$
Youngs Modulus	$E := 30 \cdot 10^6 \cdot \frac{lbf}{in^2}$

Equations:

$$L(OD) := \frac{\frac{1}{3} \cdot \frac{OD}{2} + Len + \frac{1}{3} \cdot \frac{OD}{2}}{num + 1} - b$$

Mean Diameter $\quad D(t) := OD - t$

Mean Radius $\quad R(t) := \frac{D(t)}{2}$

$$\theta(t) := L(OD) \cdot \left[\frac{3 \cdot \left(1 - \mu^2\right)}{R(t)^2 \cdot t^2}\right]^{\frac{1}{4}}$$

$$N(t) := \frac{\cosh(\theta(t)) - \cos(\theta(t))}{\sinh(\theta(t)) - \sin(\theta(t))}$$

$$A := RFT \cdot RW + (RD - RFT) \cdot b$$

$$K(t) := \frac{\sinh(\theta(t)) - \sin(\theta(t))}{\sinh(\theta(t)) + \sin(\theta(t))}$$

$$B(t) := \frac{b \cdot t}{A + b \cdot t}$$

$$\beta(t) := \frac{2 \cdot N(t)}{A + b \cdot t} \cdot \left[\frac{1}{3 \cdot \left(1 - \mu^2\right)}\right]^{\frac{1}{4}} \cdot \left(R(t) \cdot t^3\right)^{\frac{1}{2}}$$

$$Hm(t) := -2 \cdot \frac{\sinh\left(\frac{\theta(t)}{2}\right) \cdot \cos\left(\frac{\theta(t)}{2}\right) + \cosh\left(\frac{\theta(t)}{2}\right) \cdot \sin\left(\frac{\theta(t)}{2}\right)}{\sinh(\theta(t)) + \sin(\theta(t))}$$

$$He(t) := -2\left(\frac{3}{1-\mu^2}\right)^{\frac{1}{2}} \cdot \left(\frac{\sinh\left(\frac{\theta(t)}{2}\right)\cdot\cos\left(\frac{\theta(t)}{2}\right) + \cosh\left(\frac{\theta(t)}{2}\right)\cdot\sin\left(\frac{\theta(t)}{2}\right)}{\sinh(\theta(t)) + \sin(\theta(t))}\right)$$

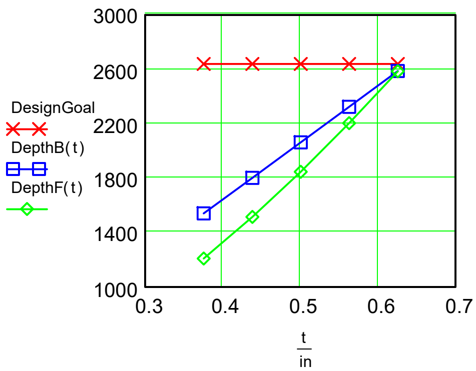
$$H(t) := Hm(t) + \mu\cdot He(t)$$

Yielding at Frame

$$DepthF(t) := \frac{\frac{2\cdot\sigma\cdot t}{D(t)}}{\left[.5 + 1.815\cdot K(t)\cdot\left(\frac{.85 - B(t)}{1+\beta(t)}\right)\right]\cdot SeaWaterDensity}$$

Yielding at Mid-Bay

$$DepthB(t) := \frac{\frac{2\cdot\sigma\cdot t}{D(t)}}{\left[1 + H(t)\cdot\left(\frac{.85 - B(t)}{1+\beta(t)}\right)\right]\cdot SeaWaterDensity}$$



$\frac{t}{in} = \begin{pmatrix} 0.375 \\ 0.4375 \\ 0.5 \\ 0.5625 \\ 0.625 \end{pmatrix}$

$\frac{DepthB(t)}{ft} =$	$\frac{DepthF(t)}{ft} =$
1540	1207
1800	1513
2061	1846
2323	2204
2586	2585

$$OD := 39\cdot in, 40\cdot in .. 45\cdot in$$

$$t := .5\cdot in$$

$$L(OD) := \frac{\frac{1}{3}\cdot\frac{OD}{2} + Len + \frac{1}{3}\cdot\frac{OD}{2}}{num + 1} - b$$

Mean Diameter $D(OD) := OD - t$

Mean Radius $R(OD) := \frac{D(OD)}{2}$

$$\theta(OD) := L(OD)\cdot\left[\frac{3\cdot\left(1-\mu^2\right)}{R(OD)^2\cdot t^2}\right]^{\frac{1}{4}}$$

$$N(OD) := \frac{\cosh(\theta(OD)) - \cos(\theta(OD))}{\sinh(\theta(OD)) - \sin(\theta(OD))}$$

$$A := RFT\cdot RW + (RD - RFT)\cdot b$$

$$K(OD) := \frac{\sinh(\theta(OD)) - \sin(\theta(OD))}{\sinh(\theta(OD)) + \sin(\theta(OD))}$$

$$B := \frac{b\cdot t}{A + b\cdot t}$$

$$\beta(OD) := \frac{2\cdot N(OD)}{A + b\cdot t}\cdot\left[\frac{1}{3\cdot\left(1-\mu^2\right)}\right]^{\frac{1}{4}}\cdot\left(R(OD)\cdot t^3\right)^{\frac{1}{2}}$$

$$Hm(OD) := -2\cdot\frac{\sinh\left(\frac{\theta(OD)}{2}\right)\cdot\cos\left(\frac{\theta(OD)}{2}\right) + \cosh\left(\frac{\theta(OD)}{2}\right)\cdot\sin\left(\frac{\theta(OD)}{2}\right)}{\sinh(\theta(OD)) + \sin(\theta(OD))}$$

$$He(OD) := -2\cdot\left(\frac{3}{1-\mu^2}\right)^{\frac{1}{2}}\cdot\left(\frac{\sinh\left(\frac{\theta(OD)}{2}\right)\cdot\cos\left(\frac{\theta(OD)}{2}\right) + \cosh\left(\frac{\theta(OD)}{2}\right)\cdot\sin\left(\frac{\theta(OD)}{2}\right)}{\sinh(\theta(OD)) + \sin(\theta(OD))}\right)$$

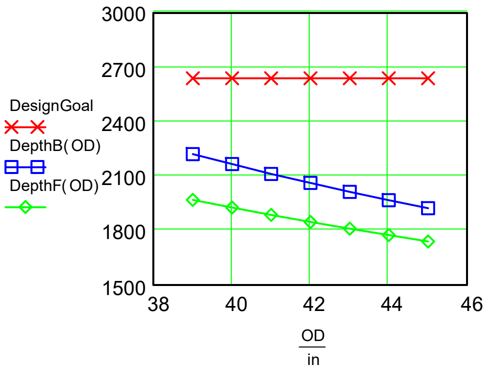
$$H(OD) := Hm(OD) + \mu\cdot He(OD)$$

Yielding at Frame

$$DepthF(OD) := \frac{\frac{2\cdot\sigma\cdot t}{D(OD)}}{\left[.5 + 1.815\cdot K(OD)\cdot\left(\frac{.85 - B}{1 + \beta(OD)}\right)\right]\cdot SeaWaterDensity}$$

Yielding at Mid-Bay

$$DepthB(OD) := \frac{\frac{2\cdot\sigma\cdot t}{D(OD)}}{\left[1 + H(OD)\cdot\left(\frac{.85 - B}{1 + \beta(OD)}\right)\right]\cdot SeaWaterDensity}$$



OD/in =	DepthB(OD)/ft =	DepthF(OD)/ft =
39	2221	1968
40	2165	1925
41	2112	1885
42	2061	1846
43	2013	1809
44	1967	1774
45	1923	1740