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

Bodily Collapse using Tokugawa's Equation - Trilling, Charles

"The Influense of Stiffening Rings on the Strength of Thin Cylindrical Shells Under External Pressure", U.S. Experimantal Model Basin Report No. 396 February 1935, p. 7, Equation [10]

$\text{SafetyFactor} := 2.0$

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

Design Variables:

Outside Diameter	$OD := 42 \cdot in$
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	$b := .5 \cdot in$
Ring Flange Thickness	$RFT := .5 \cdot in$

Constants:

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

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:

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

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

$A1 := RW \cdot RFT$ $\qquad$ $I1 := \frac{RFT^3 \cdot RW}{12}$

$A2 := (RD - RFT) \cdot b$ $\qquad$ $I2 := \frac{(RD - RFT)^3 \cdot b}{12}$

$$\nu := \frac{\left(RD - \frac{RFT}{2}\right) \cdot A1 + \left(\frac{RD - RFT}{2}\right) \cdot A2}{A1 + A2}$$

$A := A1 + A2$

$$\delta(t) := \frac{\frac{t}{2} \cdot (L \cdot t) + (t + \nu) \cdot A}{A + L \cdot t}$$

$A3(t) := t \cdot L$

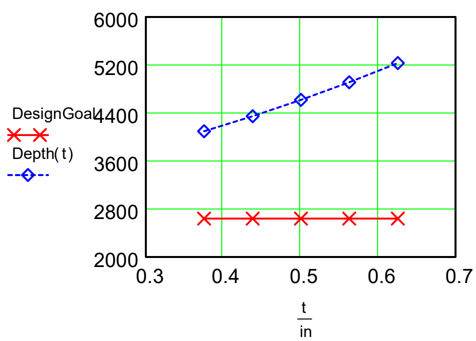
$$I := I1 + I2 + \left(RD - \frac{RFT}{2} - \nu\right)^2 \cdot A1 + \left[\nu - \frac{(RD - RFT)}{2}\right]^2 \cdot A2$$

$$i0 := \sqrt{\frac{I}{A}}$$

$$\gamma(t) := 1 + \frac{t^2}{4 \cdot i0^2} \cdot \left[\left(1 + \frac{2 \cdot \nu}{t}\right) - \left(\frac{2 \cdot \delta(t)}{t} - 1\right)\right]^2$$

$$\beta(t) := 1 + 3 \cdot \left(\frac{2 \cdot \delta(t)}{t} - 1\right)^2$$

$$Depth(t) := \frac{\beta(t) \cdot \left(\frac{2 \cdot E}{1 - \mu^2}\right) \cdot \left(\frac{t}{D(t)}\right)^3 + \gamma(t) \cdot \frac{24 \cdot E \cdot I}{D(t)^3 \cdot L}}{SeaWaterDensity}$$



$$\frac{t}{in} =$$

0.375
0.438
0.5
0.563
0.625

$$\frac{Depth(t)}{ft} = \begin{pmatrix} 4092 \\ 4346 \\ 4616 \\ 4909 \\ 5229 \end{pmatrix}$$

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

$t := .5\cdot in$

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

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

$A1 := RW\cdot RFT$ $\quad I1 := \frac{RFT^3\cdot RW}{12}$

$A2 := (RD - RFT)\cdot b$ $\quad I2 := \frac{(RD - RFT)^3\cdot b}{12}$

$$\nu := \frac{\left(RD - \frac{RFT}{2}\right)\cdot A1 + \left(\frac{RD - RFT}{2}\right)\cdot A2}{A1 + A2}$$

$A := A1 + A2$

$$\delta(OD) := \frac{\frac{t}{2}\cdot(L(OD)\cdot t) + (t + \nu)\cdot A}{A + L(OD)\cdot t}$$

$A3(OD) := t\cdot L(OD)$

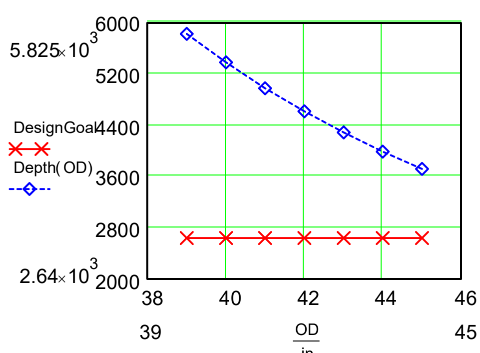
$$I := I1 + I2 + \left(RD - \frac{RFT}{2} - \nu\right)^2\cdot A1 + \left[\nu - \frac{(RD - RFT)}{2}\right]^2\cdot A2$$

$$i0 := \sqrt{\frac{I}{A}}$$

$$\gamma(OD) := 1 + \frac{t^2}{4\cdot i0^2}\cdot\left[\left(1 + \frac{2\cdot\nu}{t}\right) - \left(\frac{2\cdot\delta(OD)}{t} - 1\right)\right]^2$$

$$\beta(OD) := 1 + 3\cdot\left(\frac{2\cdot\delta(OD)}{t} - 1\right)^2$$

$$Depth(OD) := \frac{\beta(OD)\cdot\left(\frac{2\cdot E}{1 - \mu^2}\right)\cdot\left(\frac{t}{D(OD)}\right)^3 + \gamma(OD)\cdot\frac{24\cdot E\cdot I}{D(OD)^3\cdot L(OD)}}{SeaWaterDensity}$$



$\frac{OD}{in} =$
39
40
41
42
43
44
45

$$\frac{Depth(OD)}{ft} = \begin{pmatrix} 5825 \\ 5380 \\ 4979 \\ 4616 \\ 4288 \\ 3989 \\ 3717 \end{pmatrix}$$