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

Shell Collapse by General Instability using Kendricks Equation as modified by Bryant -
Comstock, John Paul, "Principles of Naval Architecture, 1967
p. 213, Equation[33]

$SafetyFactor := 2.0$

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

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	$b := .5 \cdot in$
Ring Flange Thickness	$RFT := .5 \cdot in$

Constants:

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

Material Properties:

Youngs Modulus $\qquad E := 30 \cdot 10^6 \cdot \frac{lbf}{in^2}$

Equations:

$n := 1, 2 .. 10$

Mean Radius $\qquad R(t) := \frac{OD - t}{2}$

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

$$m(t) := \frac{\pi \cdot R(t)}{Ls}$$

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

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

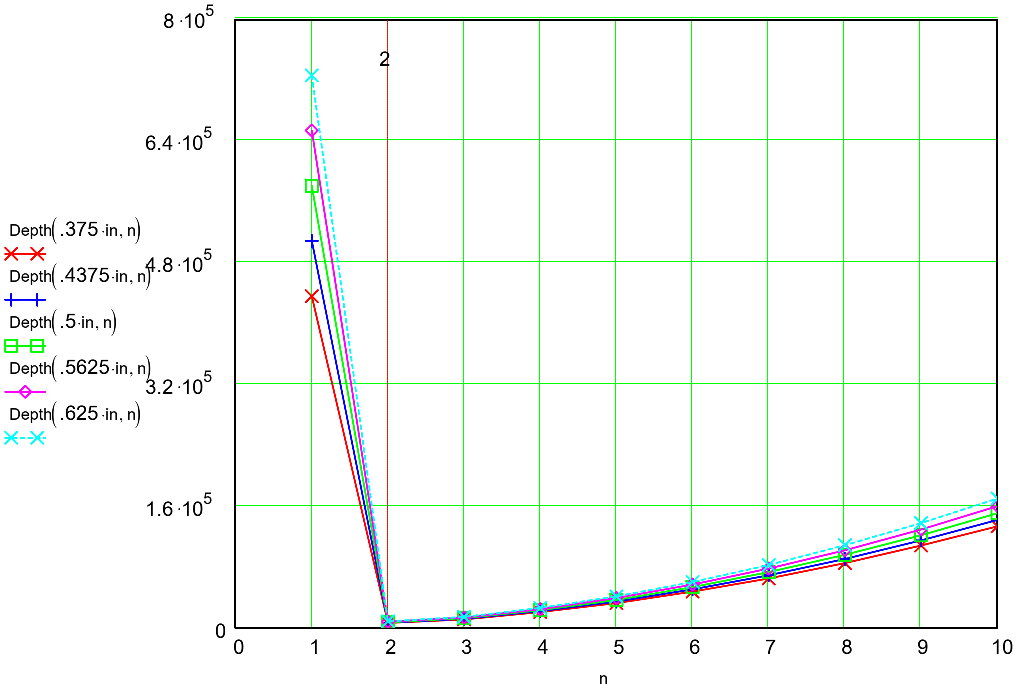
$A2 := (RD - RFT) \cdot b \qquad I2 := \frac{(RD - RFT)^3 \cdot b}{12}$

$A3(t) := t \cdot L \qquad I3(t) := \frac{t^3 \cdot L}{12}$

$$y(t) := \frac{\left(\frac{RFT}{2}\right) \cdot A1 + \left(\frac{RD - RFT}{2} + RFT\right) \cdot A2 + \left(RD + \frac{t}{2}\right) \cdot A3(t)}{A1 + A2 + A3(t)}$$

$$I(t) := I1 + I2 + I3(t) + \left(y(t) - \frac{RFT}{2}\right)^2 \cdot A1 + \left[y(t) - \frac{(RD - RFT)}{2} - RFT\right]^2 \cdot A2 + \left(RD + \frac{t}{2} - y(t)\right)^2 \cdot A3(t)$$

$$Depth(t, n) := \left[\frac{E \cdot t}{R(t)} \cdot \frac{m(t)^4}{\left(n^2 - 1 + \frac{m(t)^2}{2}\right) \cdot \left(n^2 + m(t)^2\right)^2} + \frac{\left(n^2 - 1\right) \cdot E \cdot I(t)}{R(t)^3 \cdot L}\right] \cdot \frac{1}{SeaWaterDensity}$$



$\frac{t}{in} =$

0.375
0.438
0.5
0.563
0.625

$$\frac{\mathrm{Depth}(t,2)}{ft} = \begin{pmatrix} 5989 \\ 6555 \\ 7133 \\ 7727 \\ 8344 \end{pmatrix}$$

Failue occurs at two lobes (use the minimum value)

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

$t := .5 \cdot in$

$n := 1, 2 .. 10$ Mean Radius $R(OD) := \frac{OD - t}{2}$ $Ls(OD) := \frac{1}{3} \cdot \frac{OD}{2} + Len + \frac{1}{3} \cdot \frac{OD}{2}$

$m(OD) := \frac{\pi \cdot R(OD)}{Ls(OD)}$

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

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

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

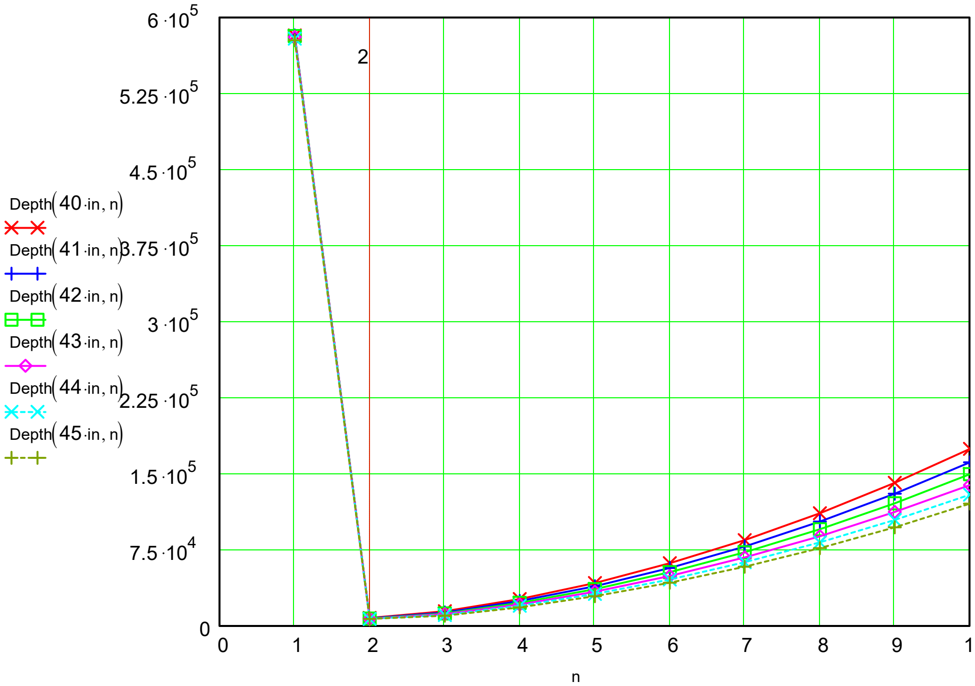
$A3(OD) := t \cdot L(OD)$ $I3(OD) := \frac{t^3 \cdot L(OD)}{12}$

$$y(OD) := \frac{\left(\frac{RFT}{2}\right) \cdot A1 + \left(\frac{RD - RFT}{2} + RFT\right) \cdot A2 + \left(RD + \frac{t}{2}\right) \cdot A3(OD)}{A1 + A2 + A3(OD)}$$

$$Ifirstpart(OD) := I1 + I2 + I3(t) + \left(y(OD) - \frac{RFT}{2}\right)^2 \cdot A1 + \left[y(OD) - \frac{(RD - RFT)}{2} - RFT\right]^2 \cdot A2$$

$$I(OD) := Ifirstpart(OD) + \left(RD + \frac{t}{2} - y(OD)\right)^2 \cdot A3(OD)$$

$$Depth(OD, n) := \left[\frac{E \cdot t}{R(OD)} \cdot \frac{m(OD)^4}{\left(n^2 - 1 + \frac{m(OD)^2}{2}\right) \cdot \left(n^2 + m(OD)^2\right)^2} + \frac{\left(n^2 - 1\right) \cdot E \cdot I(OD)}{R(OD)^3 \cdot L(OD)}\right] \cdot \frac{1}{SeaWaterDensity}$$



$\frac{OD}{in} =$

39
40
41
42
43
44
45

$$\frac{Depth(OD,2)}{ft} = \begin{pmatrix} 7897 \\ 7589 \\ 7327 \\ 7105 \\ 6919 \\ 6765 \\ 6640 \end{pmatrix}$$

Failue occurs at two lobes (use the minimum value)