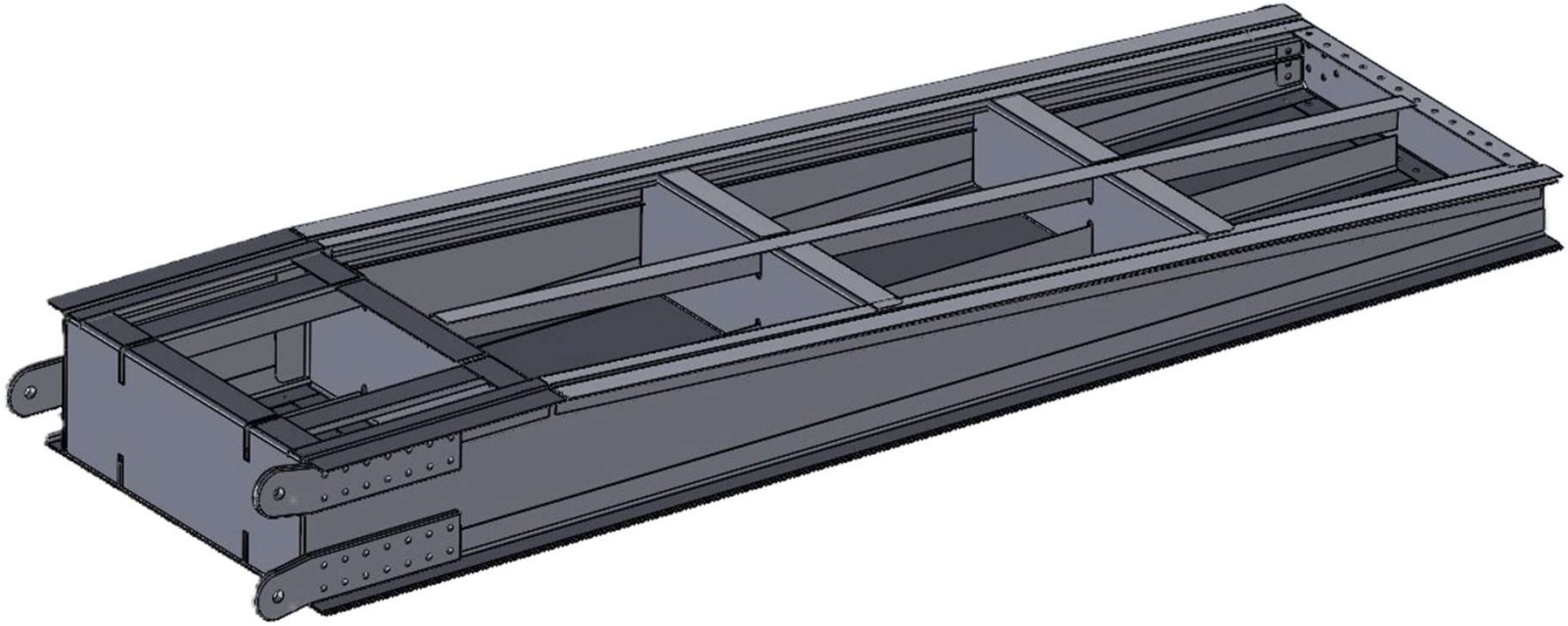
Critical Design Review

Group 7



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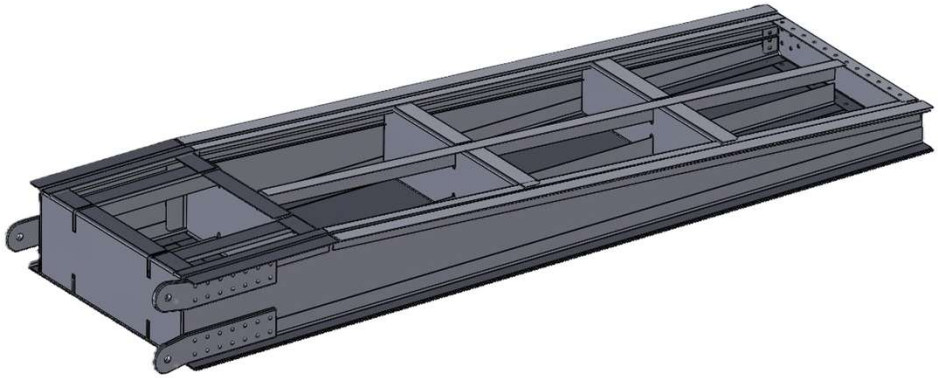
Component Summary

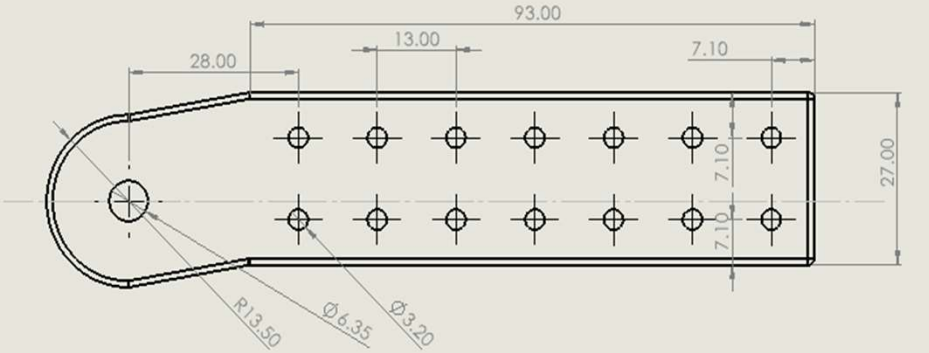
Component	QTY
Lug A/B	2
Lug C	1
Lug P	1
Spars	2
Ribs	5
Spar Caps	4
Stringers	6
Skins	2
Total Mass	**1112 grams**



Final Drawings of Fittings

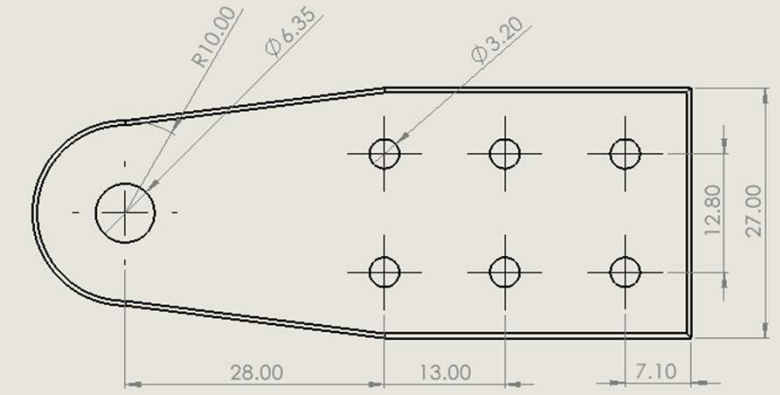
A & B Lug Design

- 14 x MS20470AD Aerospace Rivets, 13mm Spacing
- 4.83mm thick
- Bolt Critical MoS: 0.33 (Shear-Bearing Failure @ Load Case 1)
- Rivet Critical MoS: 0.10 (Shear-Bearing Failure @ top left rivet)



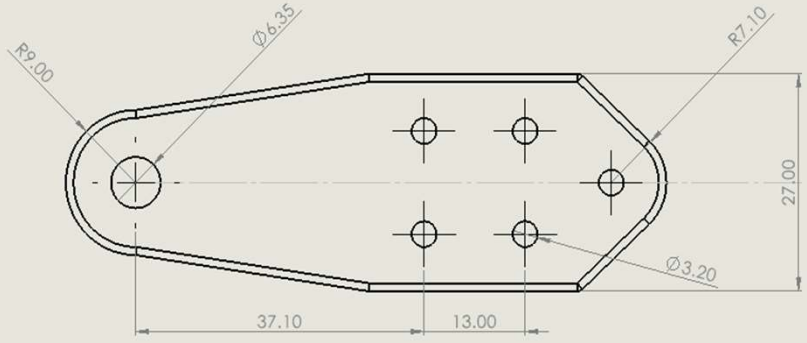
C Lug Design

-6 x MS20470AD Aerospace Rivets, 13mm Spacing
- 4.83mm thick
- Bolt Critical MoS: 0.87 (Transverse Failure @ Load Case 3)
- Rivet Critical MoS: 0.11 (Shear-Bearing Failure @ bottom right rivet)



P Lug Design

- 5 x MS20470AD Aerospace Rivets, 13mm Spacing
- 4.83mm thick
- Bolt Critical MoS: 0.91 (Transverse Failure @ Load Case 3)
- Rivet Critical MoS: 0.20 (Shear-Bearing Failure @ far right rivet)

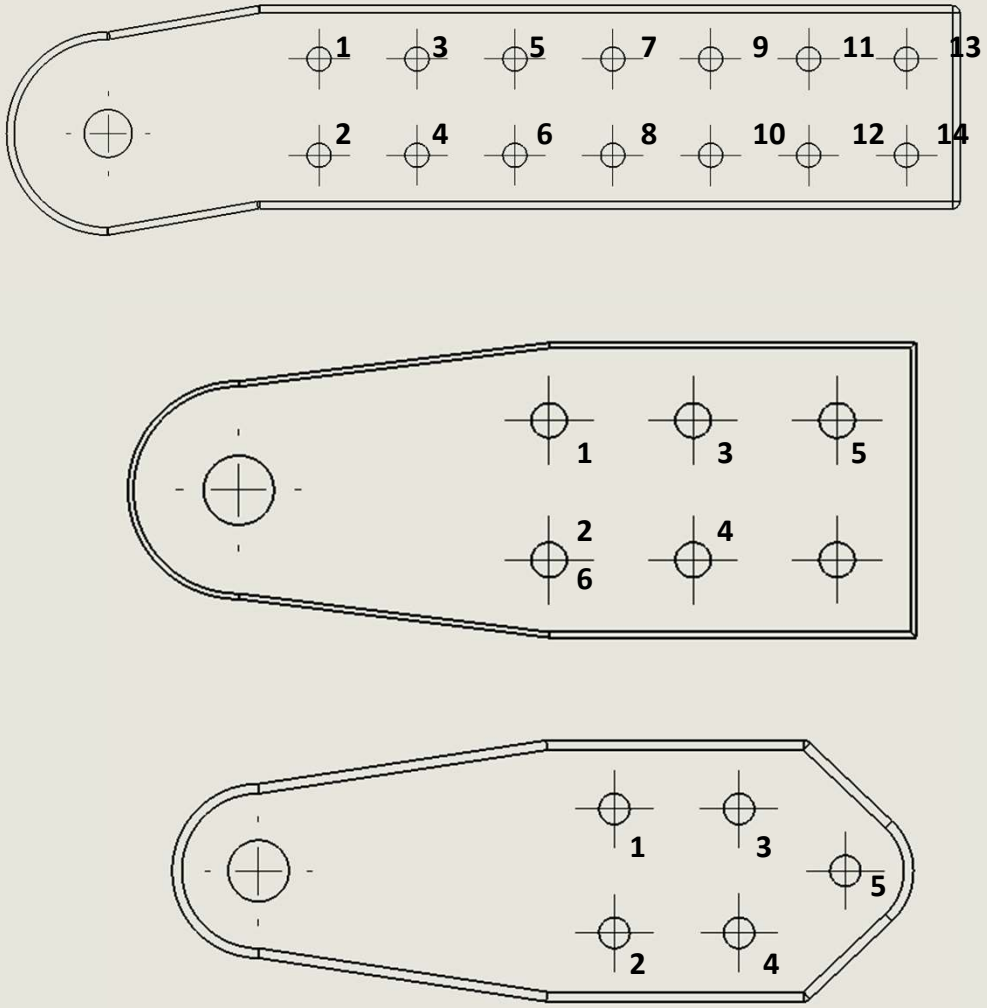


Stress Analysis of Fittings and Fastners

Lug A and B	Force (N)
1	796.88
2	840.97
3	790.09
4	834.55
5	785.89
6	830.57
7	784.30
8	829.06
9	785.34
10	830.05
11	789.01
12	833.52
13	795.26
14	839.44

Lug C	Force (N)
1	472.89
2	545.50
3	280.34
4	390.55
5	786.40
6	832.09

Lug P	Force (N)
1	513.25
2	549.65
3	539.10
4	573.86
5	770.38



Fitting MoS Summary

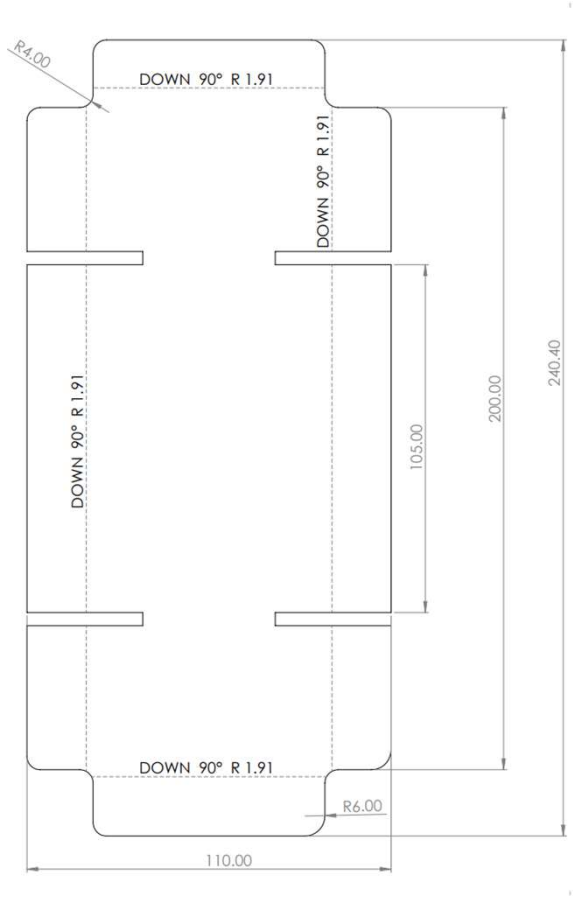
Bolts:

Lug	Critical Failure Mode	MoS
A	Shear Bearing	0.33
B	Shear Bearing	0.33
C	Transverse	0.87
P	Transverse	0.91

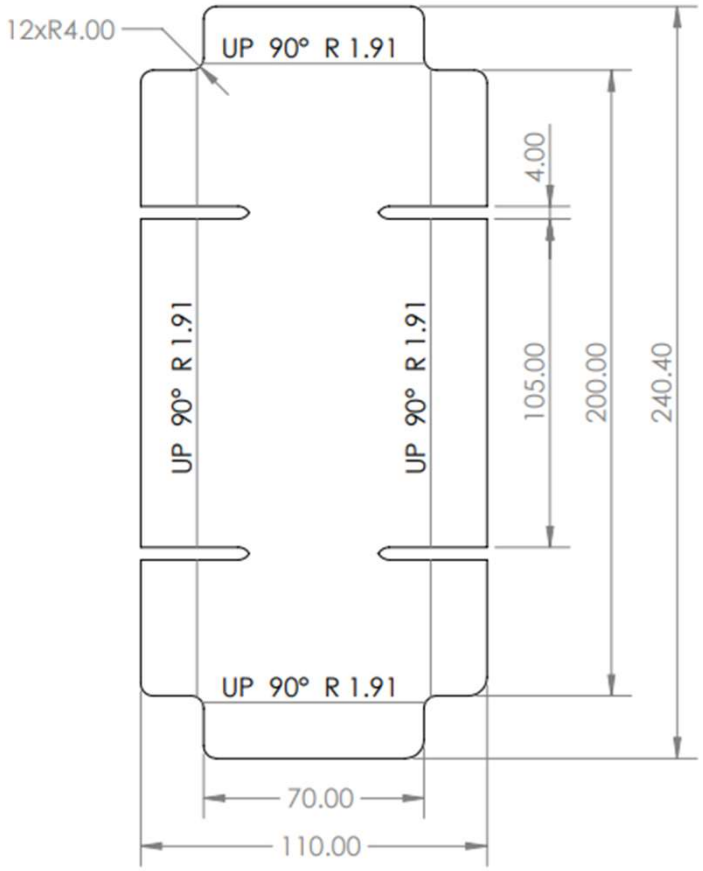
Rivets:

Lug	Critical Failure Mode	MoS
A	Shear-Bearing Failure	0.10
B	Shear-Bearing Failure	0.10
C	Shear-Bearing Failure	0.11
D	Shear-Bearing Failure	0.20

Rib Drawings

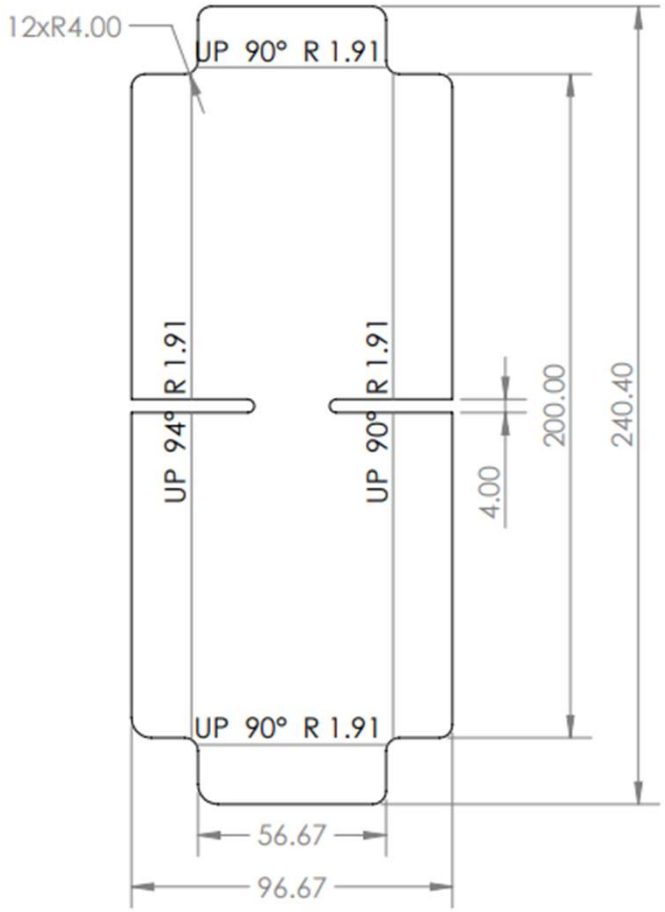


Rib 1

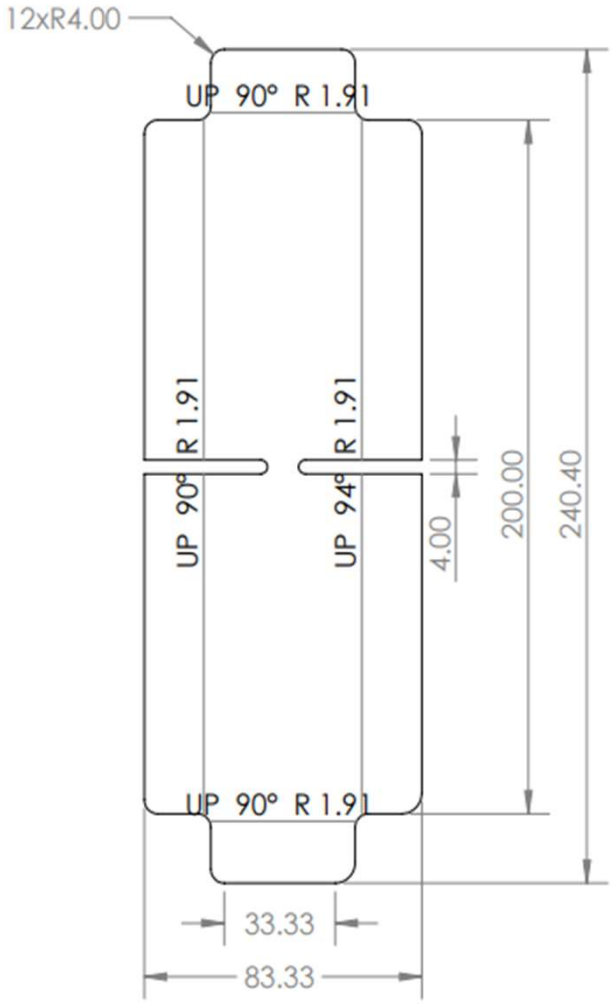


Rib 2

Rib Drawings

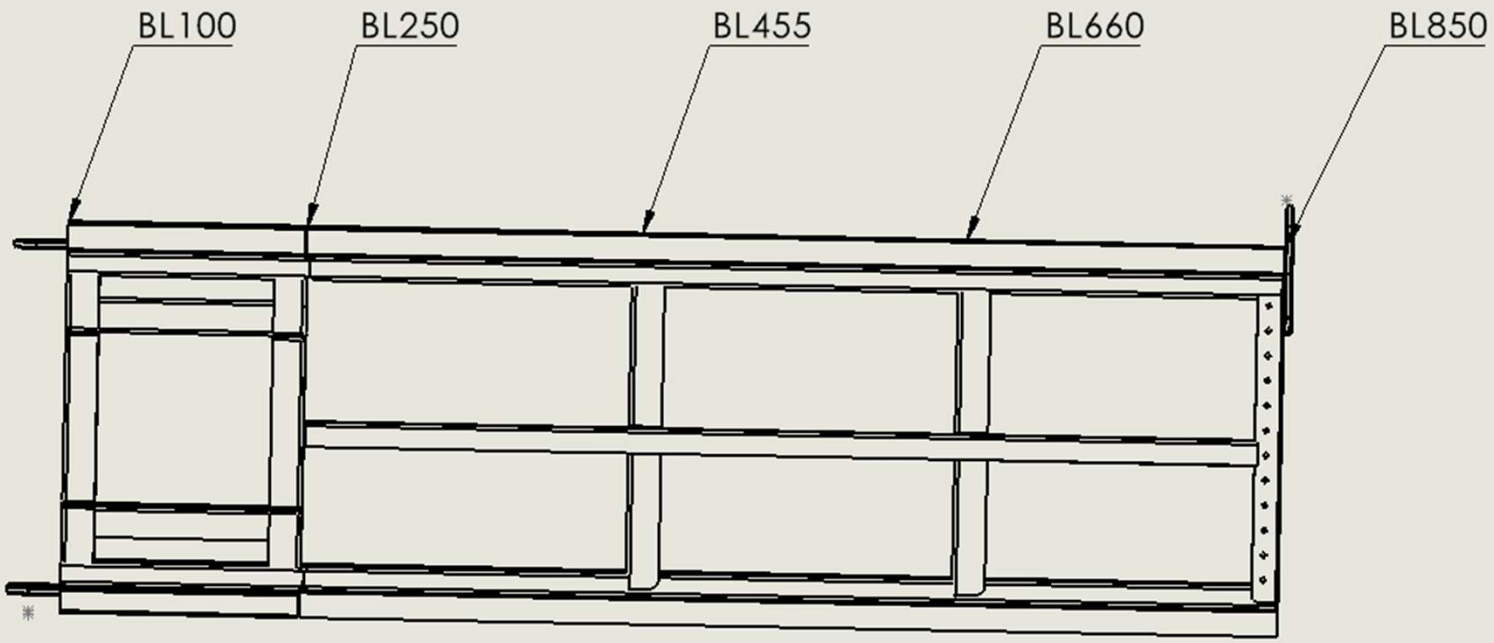


Rib 3



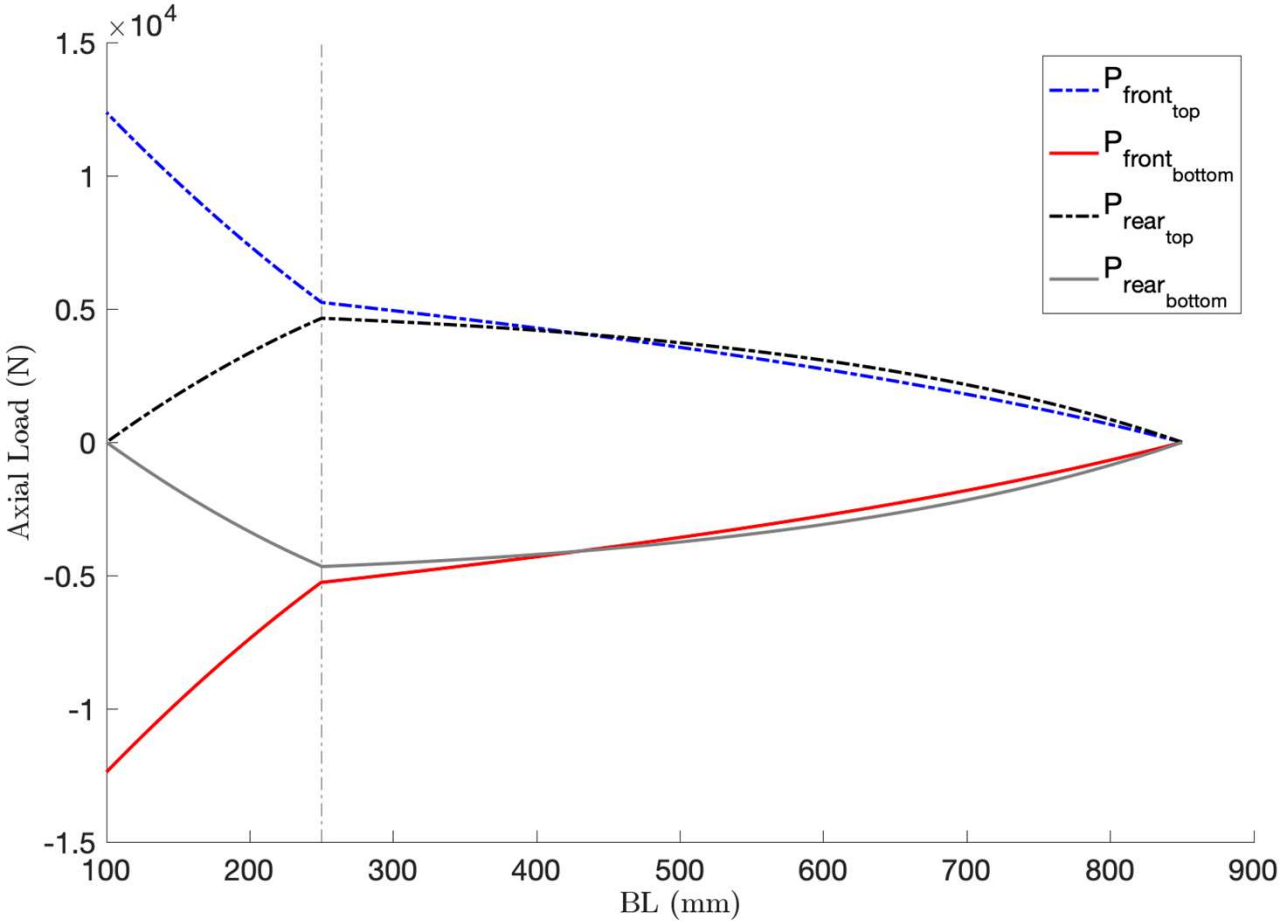
Rib 4

Layout of TPB



Box 1 Box 2 Box 3 Box 4

Calculations of Cap Loads



- Assumed idealised structure, no defects in material properties across the TPB
- Booms take only axial loads
- Skins and spar webs take shear load

$$P = \frac{\mathrm{M}}{\mathrm{h}}$$

$$\boldsymbol{P_{h_f}(\xi) = \frac{V\xi}{h}(1-\lambda)}$$

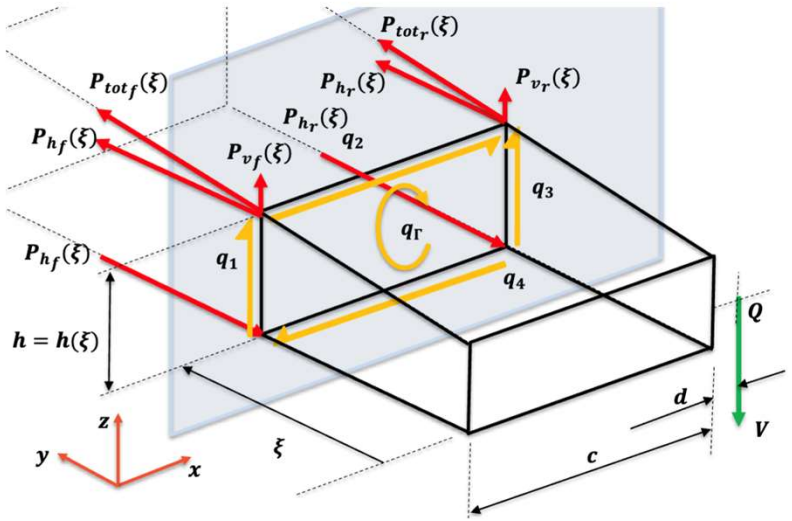
$$\boldsymbol{P_{h_r}(\xi) = \frac{V\xi}{h}(\lambda)}$$

$$\boldsymbol{P_{tot_*}(\xi) = P_{h_*}(\xi)/cos(\theta)}$$

$$\boldsymbol{P_{v_*}(\xi) = P_{h_*}(\xi) \cdot tan(\theta)}$$

Calculations of Shear Flows

$$\lambda = \begin{cases} 0.57 - 0.1\left(\frac{\xi}{500}\right), 0 \le \xi < 500 \\ 0.47 - 0.47\left(\frac{\xi - 500}{250}\right), 500 \le \xi \le 750 \end{cases}$$



$$q_1 = \frac{V_{\text{tot}} \cdot (1 - \eta(\xi)) - P_{v,\text{front}}}{h(\xi)} \qquad q_2 = q_4 = q_\gamma \qquad q_3 = \frac{V_{\text{tot}} \cdot \eta(\xi) - P_{v,\text{rear}}}{h(\xi)}$$

$$q_\gamma = \frac{-\left[\left(q_1 \cdot h(\xi) + P_{v,\text{front}}\right)(c + d)\right] - \left[\left(q_3 \cdot h(\xi) + P_{v,\text{rear}}\right)d\right] - (q_2 + q_4) \cdot c \cdot 0.5 \cdot h(\xi)}{2c \cdot h(\xi)}$$

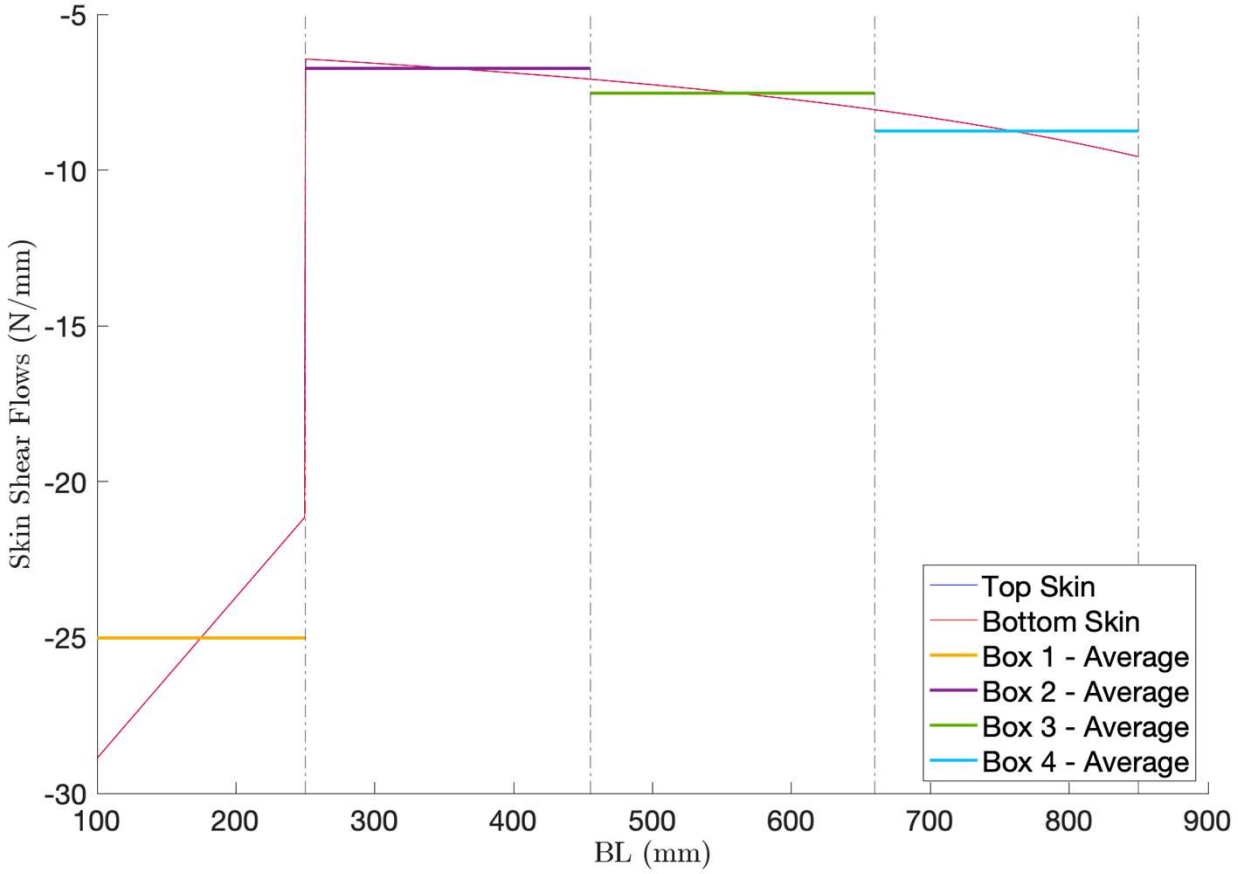
$$P_{h_f}(\xi) = \frac{V\xi}{h}(1 - \lambda)$$

$$P_{h_r}(\xi) = \frac{V\xi}{h}(\lambda)$$

$$P_{tot_*}(\xi) = P_{h_*}(\xi)/cos(\theta)$$

$$P_{v_*}(\xi) = P_{h_*}(\xi) \cdot tan(\theta)$$

Skin Shear Flow and Buckling Ratio



Panels are treated as **simply supported**, with **no edges clamped** for skin panels

The critical Buckling Ratio was determined to be in Box 1, with a BR of **4.13**

$$K = 4.84 + 6.86\left(\frac{a}{b}\right)^2$$

$$\mathrm{P_{cr}} = \eta \mathrm{KE}\left(\frac{a}{b}\right)^2$$

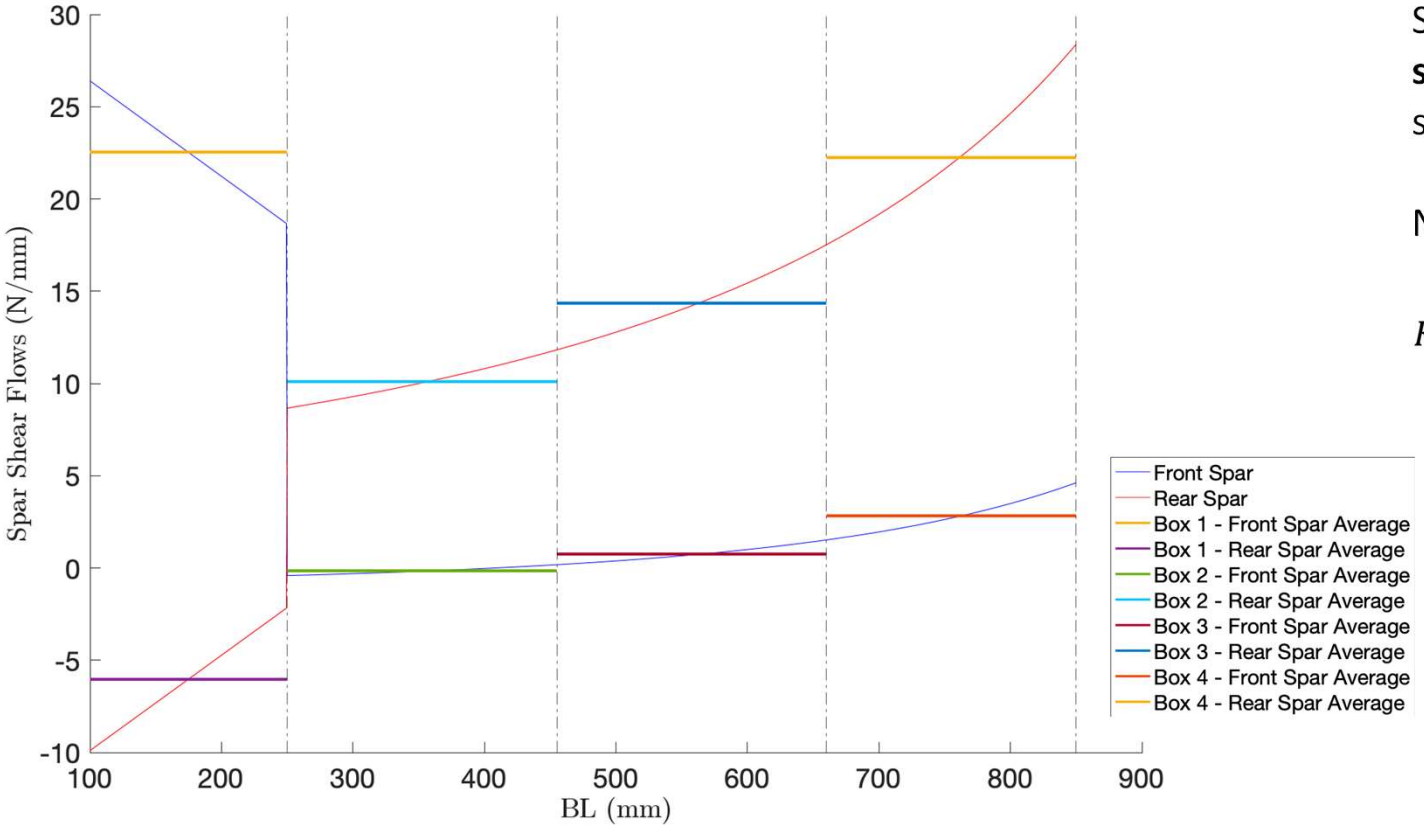
$$\tau = \left(\frac{\mathrm{q}}{\mathrm{t}}\right) \mathrm{x}\, 10^6$$

$$\mathrm{BR} = \frac{\tau}{\mathrm{P_{cr}}}$$

Skin Shear Flow and Buckling Ratio

Box #	Skin Panel	Shear Flow (N/mm)	Buckling Ratio
1 (BL100 to BL250)	Top	-25.013	**4.13**
	Bottom	-25.013	4.13
2 (BL250 to BL455)	Top	-6.737	2.44
	Bottom	-6.737	2.44
3 (BL455 to BL660)	Top	-7.532	2.72
	Bottom	-7.532	2.72
4 (BL660 to BL850)	Top	-8.748	3.09
	Bottom	-8.748	3.09

Spar Web Shear Flow and Buckling Ratio



Spar Webs are treated as **simply supported**, with **two edges clamped** for skin panels

None of these BR are critical.

$$K = 4.84 + 3.55\left(\frac{a}{b}\right)^2$$

Spar Web Shear Flow and Buckling Ratio

Box #	Spar Web Panel	Average Shear Flow (N/mm)	Buckling Ratio
1 (BL100 to BL250)	Front	22.5380	0.0974
	Rear	-6.0380	0.7235
2 (BL250 to BL455)	Front	-0.1551	0.0414
	Rear	10.1003	0.7235
3 (BL455 to BL660)	Front	0.7517	0.0122
	Rear	14.3517	0.7042
4 (BL660 to BL850)	Front	2.8252	2.1936
	Rear	22.2447	0.4796

Spar Caps Calculations

1. Crippling Stress (for each element)

$$F_{cs} = C_e \frac{\sqrt{E F_{cy}}}{\left(\frac{b'}{t}\right)^{0.75}}$$

2. Temporary Crippling Load

$$P_{c_{tmp}} = \sum_{i=1}^{n} A_i * F_{cs_i}$$

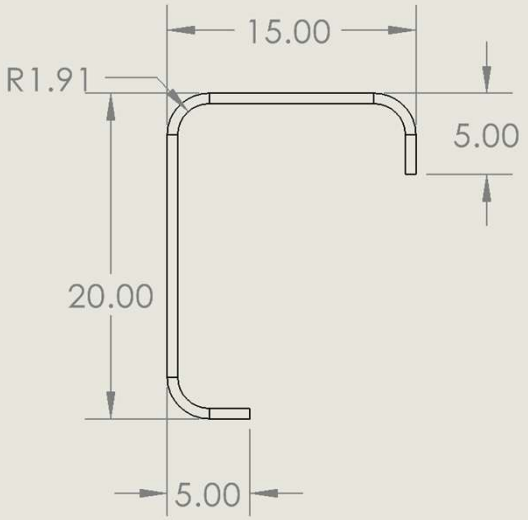
3. Final Crippling Stress

$$F_c = \frac{P_{c_{tmp}}}{\sum A_i}$$

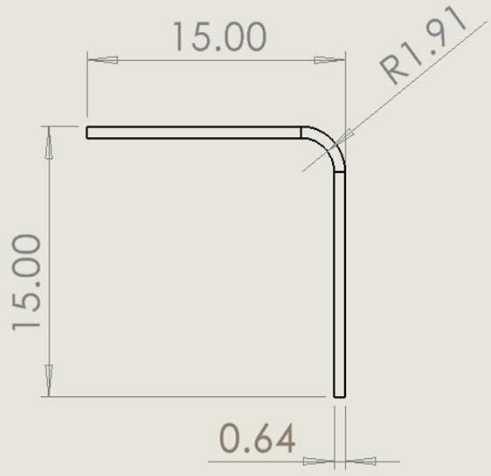
4. Final Crippling Load

$$P_{c_{true}} = F_c * A_{true}$$

Standard Spar Cap



Reinforcement Spar Cap



Spar Caps Calculations

5. Effective Skin Width

$$w_{eff} = w = 1.70t\sqrt{\frac{E}{F_{cs}}}$$

$$w_{eff\_edge} = w_1 = 0.60t\sqrt{\frac{E}{F_{cs}}}$$

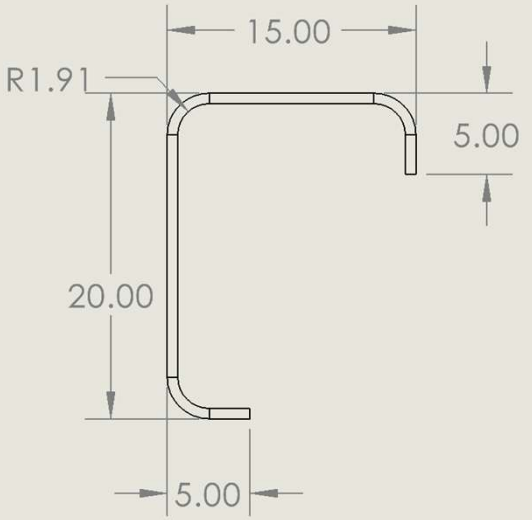
6. Total Crippling Load

$$P_{tot} = P_{cap} + P_{eff}$$

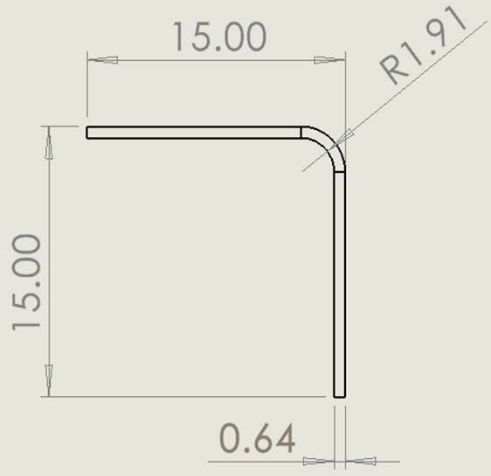
7. Inter Rivet Buckling

Using Universal Head Rivet,
FIR > Fcs, no adjustment

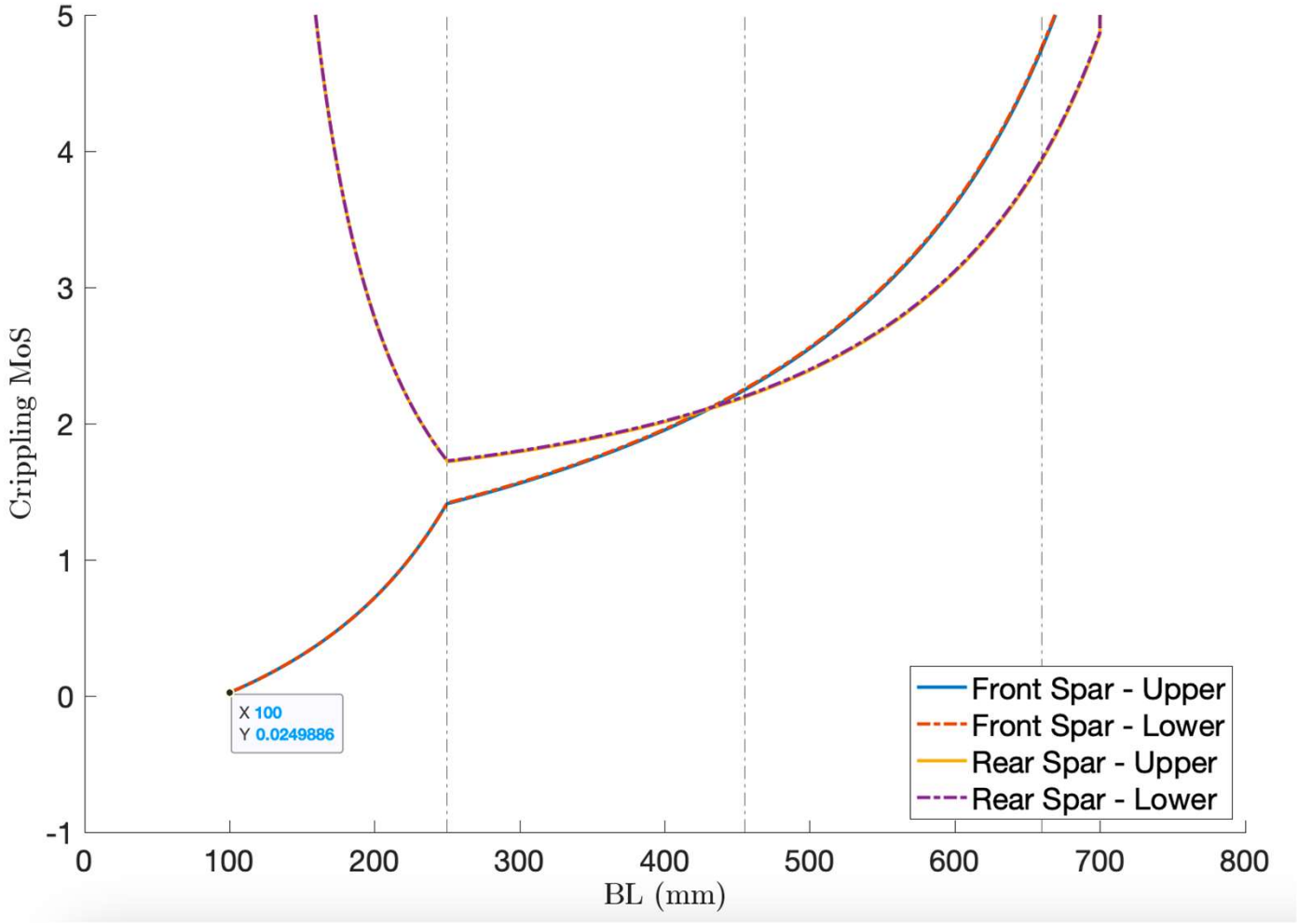
Standard Spar Cap



Reinforcement Spar Cap



Spar Caps Crippling



Critical MOS	
Front Spar Upper and Lower	0.025

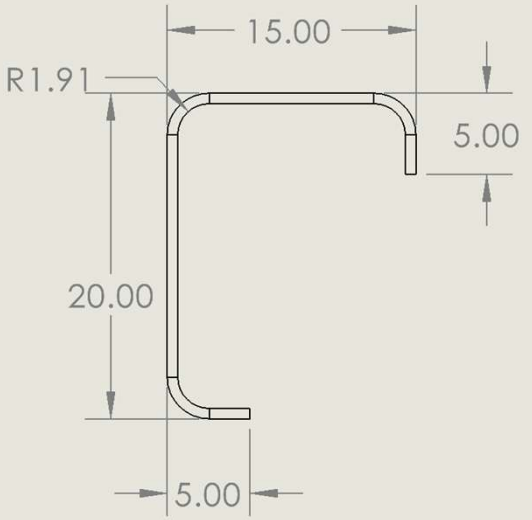
Diagonal Tension Calculations

1. Panel Direct Load $w = kq$

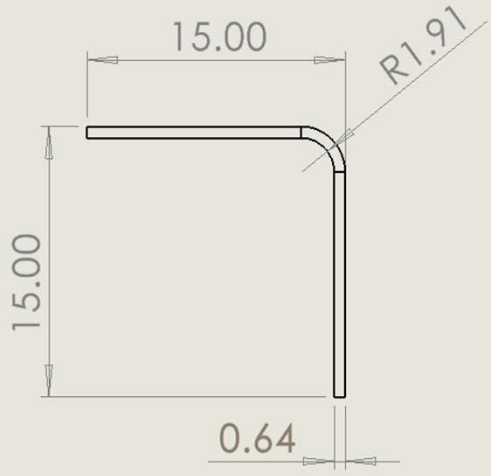
2. Maximum Bending Moment $M_{max} = \frac{kqb^2}{12}$

3. Total stress (including diagonal) $\sigma = \frac{B}{A_{cap}} + \frac{kqb^2}{12} * (\frac{c_{cap}}{I_{yycap}})$

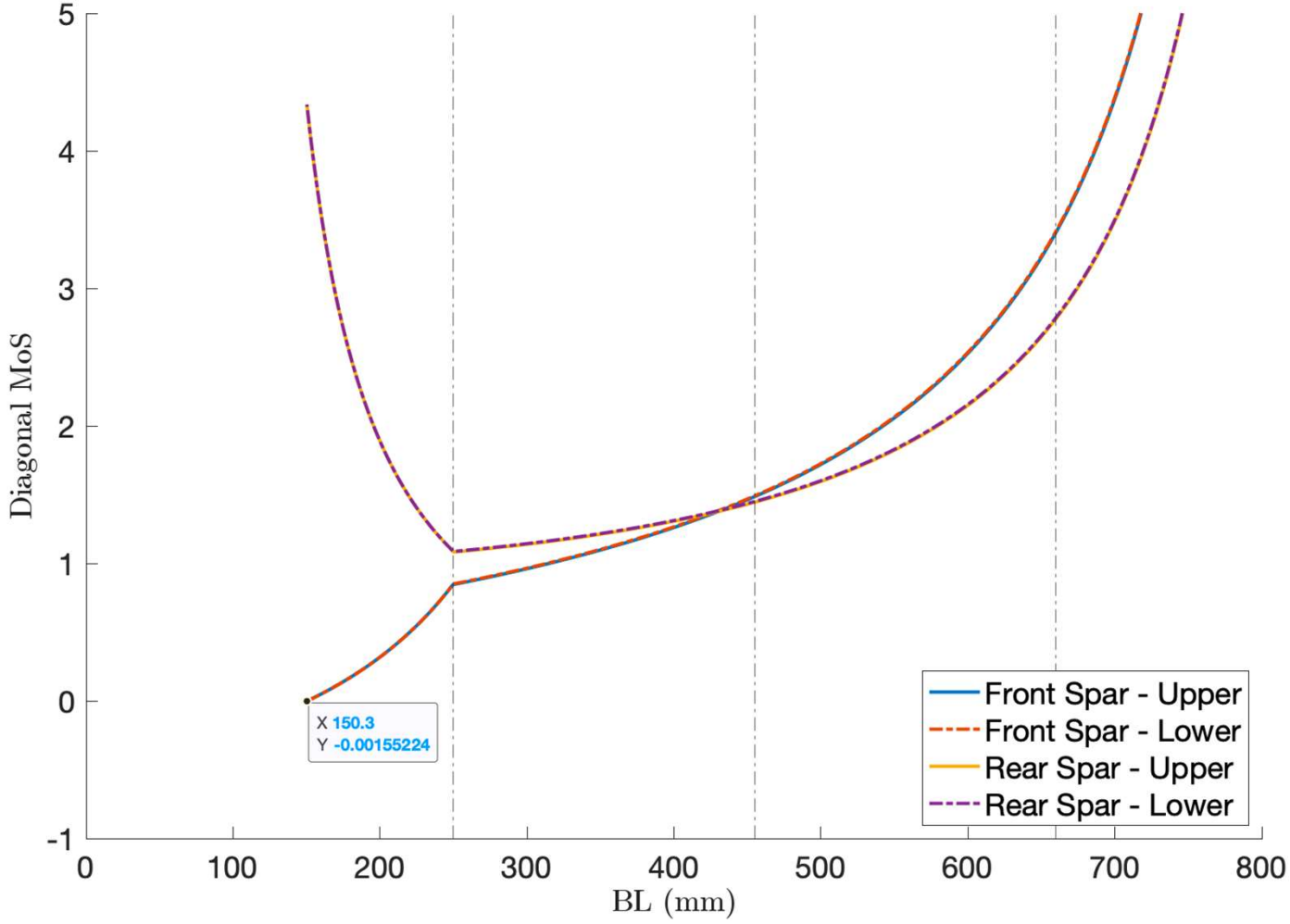
Standard Spar Cap



Reinforcement Spar Cap



Diagonal Tension



Critical MOS	
Front Spar Upper and Lower	-0.00

MOS Summaries

Component	Failure Type	MoS
Lug A	Bolt – Shear Bearing	0.33
Lug A	Rivets – Shear Bearing	0.10
Lug B	Bolt – Shear Bearing	0.33
Lug B	Rivets – Shear Bearing	0.10
Lug C	Bolt – Transverse	0.87
Lug B	Rivets – Shear Bearing	0.11
Lug P	Bolt - Transverse	0.91
Lug P	Rivets – Shear Bearing	0.20
Top Skin	Buckling	0.21
Bottom Skin	Buckling	0.21
Spar Web Fore	Buckling	1.28
Spar Web Aft	Buckling	1.28
Spar Cap	Diagonal Tension	-0.00