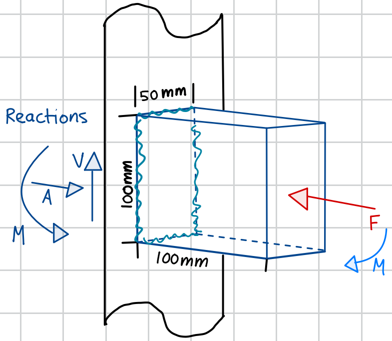
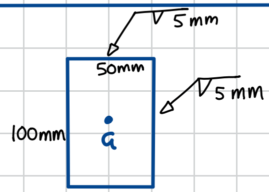
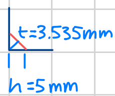
EGB316 ASS 2 - Fatigue stress

Distance leaf spring pin to weld = 100mm.







Total weld

$l = 300\text{mm}$

$\bar{x} = 0.025\text{m}$

$\bar{y} = 0.05\text{m}$

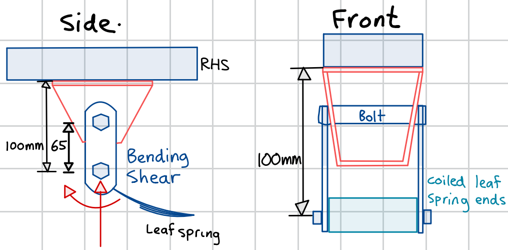
$t = 0.707 \times (5\times10^{-3}) = 0.003535 \text{ mm}$

$J_u = \frac{(b+d)^3}{6} = \frac{(0.05+0.1)^3}{6}$

$I_u = \frac{d^2(3b+d)}{6} = \frac{0.05^2(3(0.1)+0.05)}{6}$

$J_u = 5.625\times10^{-4}$

$I_u = 1.46\times10^{-4}$



Loading Cases and Stress

1) Static loading

Trailer is stationary. The rear shackle hangs vertically ($\theta = 0°$). Load vector therefore has only vertical loading, creating zero bending.

$F_{static} = \left(\frac{750 \cdot 9.81}{4}\right) = 1840\text{N}$ (750 Kg atm, 4 weld groups)

$\tau = \frac{V}{tl} = \frac{1840}{(0.003535)(0.3)}$ $= 1.74 \text{ MPa}$

$\sigma_b = 0 \ (\theta \approx 0°)$

$\sigma_{VM} = \sqrt{\sigma_b^2 + 3\tau^2} = \sqrt{0^2 + 3(1.74)^2}$

$\sigma_{VM} = 3.01 \text{ MPa}$

2) Dynamic loading (standard road loading: 2.0g)

Represents the primary high-cycle fatigue event.
The stiff leaf spring deflects slightly under a 2g load.
Rear shackle is pushed backward as leaf spring compresses to maximum safe dynamic angle of $\theta = 15°$.

Vertical load:

$F_y = 2(1840) = 3680\text{N}$

Horizontal Vector:

$F_x = 3680 \times \tan(15°) = 986\text{N}$

Direct shear (vertical)

$\tau = \frac{V}{tl} = \frac{3680}{(0.003535)(0.3)}$ $= 3.47 \text{ MPa}$

Bending Stress

$\sigma_b = \frac{Mc}{tI_u} = \frac{(986\times0.1)(0.025)}{(0.003535)(1.46\times10^{-4})}$ $= 4.78 \text{ MPa}$

Von Mises

$\sigma_{VM} = \sqrt{\sigma_b^2 + 3\tau^2}$ $\quad \sigma_{VM} = \sqrt{4.78^2 + 3(3.47)^2}$

$\sigma_{VM} = 7.68 \text{ MPa}$

3) Impact of hitting a pothole (Severe impact 3g)

Represents a low-cycle yield threat. Leaf spring experiences maximum deflection, pushing the rear hanger 65mm shackle to a conservative limit $\theta = 20°$.

Vertical load:

$F_y = 3(1840) = 5520\text{N}$

Horizontal Vector:

$F_x = 5520 \times \tan(20°) = 2009\text{N}$

Direct shear (vertical)

$\tau = \frac{V}{tl} = \frac{5520}{(0.003535)(0.3)}$ $= 5.2 \text{ MPa}$

Bending Stress

$\sigma_b = \frac{Mc}{tI_u} = \frac{(2009\times0.1)(0.025)}{(0.003535)(1.46\times10^{-4})}$ $= 9.73 \text{ MPa}$

Von Mises

$\sigma_{VM} = \sqrt{\sigma_b^2 + 3\tau^2}$ $\quad \sigma_{VM} = \sqrt{9.73^2 + 3(5.2)^2}$

$\sigma_{VM} = 13.26 \text{ MPa}$

4) Cornering (Lateral acceleration 0.3g):

Cornering creates a load perpendicular to the leaf pin. Creates torsional twist on weld group.

Lateral force:

$F_{cornering} = 1840 \times 0.3 = 552\,N$

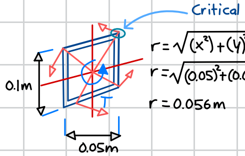
Torsional shear:

Maximum for loaded trailer

$T = 552 \times 0.1m = 55.2\,Nm.$

$\tau_{torsion} = \frac{Tr}{t\,J_u}$

$\tau_{torsion} = \frac{(55.2)(0.056)}{(5.625\times10^{-4})(0.003535)}$



$r = \sqrt{(x^2)+(y)^2}$

$r = \sqrt{(0.05)^2+(0.025)^2}$

$r = 0.056m$

$\tau_{torsion} = 1.55\,MPa$

$\tau_{total} = \sqrt{(\tau_{static})^2+(\tau_{torsion})^2} = \sqrt{(1.74)^2+(1.55)^2}$

$\tau_{total} = 2.33\,MPa$

Von Mises

$\sigma_{VM} = \sqrt{(\sigma_{b,static})^2+3(\tau_{total})^2} = \sqrt{(0)^2+3(2.33)^2}$

$= 4.04\,MPa$

5) Braking

Braking force is not considered for the rear weld group. Front hanger is assumed to bear 100% longitudinal forces as the rear has free rotation.

Fatigue analysis

Assumptions:

σ_{min}: empty trailer, parked

σ_{max}: dynamic 2g loading

Minimum Stress:

Tare Mass: 260 Kg

$F_{y,min} = \frac{260\times9.81}{4} = 637.7\,N$

$\tau_{min} = \frac{F_{y,min}}{t \cdot l} = \frac{637.7}{(0.0035)(0.3)} = 0.6\,MPa$

Von Mises

$\sigma_b = 0\ (\theta \approx 0°)$

$\sigma_{VM} = \sqrt{\sigma_b^2+3\tau^2} = \sqrt{0^2+3(0.6)^2}$

$\sigma_{VM,min} = 1.04\,MPa$

$\sigma_{max} = \sigma_{VM,dynamic} \times K_f$

$= 7.68 \times 2.7 = 20.74\,MPa$

$\sigma_{min} = \sigma_{VM,empty} \times K_f$

$= 1.04 \times 2.7 = 2.81\,MPa$

$\sigma_m = \left(\frac{\sigma_{max}+\sigma_{min}}{2}\right) = \left(\frac{20.74+2.81}{2}\right) = 11.78\,MPa$

$\sigma_A = \left(\frac{\sigma_{max}-\sigma_{min}}{2}\right) = \left(\frac{20.74-2.81}{2}\right) = 8.97\,MPa$

Endurance limit modifier

$S_n = S_n' C_L C_G C_S C_T C_R$

$S_n' = 0.5 S_{ut} = 0.5\times430 = 215$

(assuming grade C300 standard structural)

$C_L = 1$ (von-mises)

$C_G = 0.8$ (all welds)

$C_S = 0.53$ (as-forged)

$C_T = 1$ ($\leq 450°c$)

$C_R = 0.753$ (assuming 99.9% reliability)

$S_n = 215 \times 1 \times 0.8 \times 0.53 \times 1 \times 0.753$

$S_n = 68.64\,MPa$

Goodman criteria

$\frac{\sigma_a}{S_n} + \frac{\sigma_m}{S_{ut}} = \frac{1}{N}$

$\frac{8.97}{68.64} + \frac{11.78}{430} = \frac{1}{N} \rightarrow N = 6.33$

Yield criteria ($S_y = 300\,MPa$)

$\left|\frac{\sigma_a}{S_y}\right| + \left|\frac{\sigma_m}{S_y}\right| = \frac{1}{N}$

$\left|\frac{8.97}{300}\right| + \left|\frac{11.78}{300}\right| = \frac{1}{N} \rightarrow N = 14.46$

$\therefore$ Goodman is more conservative

Yield check of 3g event

$FoS = \frac{S_y}{\sigma_{VM,3g}} K_f = \frac{300}{13.26}(2.7) = 8.38$