**Check Universal Joint Fit**

All dimensions for the universal joint have been taken from drawing Ref 5.0.

| | | |
|---|---|---|
| Pin diameter | $D_{pin} = 96mm$ | |
| Jaw width | $W_{jaw} = 145mm$ | |
| Jaw length | $L_{jaw} = 265mm$ | |
| Bore center from rear of joint | $C_{bore} = 115mm$ | |
| Pulling plate bore diameter | $D_{bore} = 100mm$ | Ref. 1.0 |
| Pin clearance (Check 1) | $Check_1 = D_{bore} - D_{pin}$ | $Check_1 = 4 \cdot mm$ |
| Pulling plate thickness | $t_{plate} = 60mm$ | Ref. 1.0 |
| Boss thickness | $t_{boss} = 40mm$ | Ref. 1.0 |
| Total thickness | $t_{total} = t_{plate} + 2t_{boss}$ | $t_{total} = 140 \cdot mm$ |
| Jaw width clearance (Check 2) | $Check_2 = W_{jaw} - t_{total}$ | $Check_2 = 5 \cdot mm$ |
| Profiled radius of pulling plate | $r_{plate} = 140mm$ | Ref. 1.0 |
| Jaw length clearance (Check 3) | $Check_3 = L_{jaw} - C_{bore} - r_{plate}$ | $Check_3 = 10 \cdot mm$ |
| Universal joint fit (Evaluation 1) | $Evaluation1(X) := if\left[\sum \overrightarrow{(X < 0)}, "Unacceptable", "Acceptable"\right]$ | |
| | $Evaluation1(Check) = "Acceptable"$ | |

**Pull Load & Duty Factor**

| | | |
|---|---|---|
| Maximum HDD rig pull force | $Pull_{max} = 300tonnef$ | |
| Duty factor | $f_d = 1$ | One off use |

**Check Bearing Stress**

Check bearing stress of pin on bore through pulling plate and bosses assuming that the pin bears on 80% of the projected area

| | | |
|---|---|---|
| Bearing area | $A_{bear} = 80\% \cdot D_{pin} \cdot t_{total}$ | $A_{bear} = 10752 \cdot mm^2$ |
| Bearing stress | $\sigma_{bear} = \frac{Pull_{max}}{A_{bear}}$ | $\sigma_{bear} = 274 \cdot \frac{N}{mm^2}$ |
| Minimum yield stress - 60mm thick steel plate S355 | $\sigma_{y\_60} = 335 \frac{N}{mm^2}$ | Table 7 Ref. 4.0 |
| Allowable bearing stress (Section 5.1.6 Ref. 3.0) | $\sigma_{bear\_all} = 0.8 \cdot \sigma_{y\_60} \cdot f_d$ | $\sigma_{bear\_all} = 268 \cdot \frac{N}{mm^2}$ |
| Bearing stress as a % of allowable | $\frac{\sigma_{bear}}{\sigma_{bear\_all}} = 102 \cdot \%$ | Therefore OK |

**Check Pin For Tear-Out**

Consider the shear stress in the pulling plate and bosses generated by the load on the pin. The possible mode of failure is double shear.

| | | |
|---|---|---|
| Profiled radius of boss | $r_{boss} = 130mm$ | Ref. 1.0 |
| Shear area - pulling plate | $A_{sh\_plate} = \left(r_{plate} - \frac{D_{bore}}{2}\right) \cdot t_{plate}$ | $A_{sh\_plate} = 5400 \cdot mm^2$ |
| Shear area - boss | $A_{sh\_boss} = \left[\left(r_{boss} - \frac{D_{bore}}{2}\right) \cdot t_{boss}\right] \cdot 2$ | $A_{sh\_boss} = 6400 \cdot mm^2$ |
| Total double shear area at pin connection | $A_{sh\_total} = 2\left(A_{sh\_plate} + A_{sh\_boss}\right)$ | $A_{sh\_total} = 23600 \cdot mm^2$ |
| Shear stress at pin connection | $\sigma_{shear} = \frac{Pull_{max}}{A_{sh\_total}}$ | $\sigma_{shear} = 125 \cdot \frac{N}{mm^2}$ |

| | | |
|---|---|---|
| Allowable shear stress (Section 5.1.5 Ref. 3.0) | $\sigma_{shear\_all} = 0.37 \cdot \sigma_{y\_60}$ | $\sigma_{shear\_all} = 124 \cdot \frac{N}{mm^2}$ |
| Shear stress as a % of allowable | $\frac{\sigma_{shear}}{\sigma_{shear\_all}} = 101 \cdot \%$ | Therefore OK |

**Check Tensile Stress In Pulling Plate**

| | | |
|---|---|---|
| Tensile length | $L_{tensile} = 2 \cdot r_{plate} - D_{bore}$ | $L_{tensile} = 180 \cdot mm$ |
| Tensile area - pulling plate | $A_{ten\_plate} = L_{tensile} \cdot t_{plate}$ | $A_{ten\_plate} = 10800 \cdot mm^2$ |
| Tensile area - boss | $A_{ten\_boss} = \left(r_{boss} - \frac{D_{bore}}{2}\right) \cdot t_{boss}$ | $A_{ten\_boss} = 3200 \cdot mm^2$ |
| Total tensile area at pin connection | $A_{ten\_total} = A_{ten\_plate} + 4A_{ten\_boss}$ | $A_{ten\_total} = 23600 \cdot mm^2$ |
| Tensile stress at pin connection | $\sigma_{tensile} = \frac{Pull_{max}}{A_{ten\_total}}$ | $\sigma_{tensile} = 125 \cdot \frac{N}{mm^2}$ |
| Allowable tensile stress (Section 5.1.2 Ref. 3.0) | $\sigma_{tensile\_all} = 0.6 \cdot \sigma_{y\_60}$ | $\sigma_{tensile\_all} = 201 \cdot \frac{N}{mm^2}$ |
| Tensile stress as a % of allowable | $\frac{\sigma_{tensile}}{\sigma_{tensile\_all}} = 62 \cdot \%$ | Therefore OK |

**Check Boss Fillet Weld**

Consider tensile stress in boss fillet welds assuming that the load is transferred in proportion to plate thickness.

Length of weld in tension around boss

$$L_{ten\_weld} = 2 \cdot r_{boss} \cdot \pi \qquad L_{ten\_weld} = 817 \cdot mm$$

Maximum tensile force on weld around boss

$$F_{ten\_weld} = Pull_{max} \cdot \left( \frac{t_{boss}}{2 \cdot t_{boss} + t_{plate}} \right) \qquad F_{ten\_weld} = 841 \cdot kN$$

Allowable stress on weld around boss

$$\sigma_{all\_weld} = 144 \frac{N}{mm^2}$$

Table 18 Ref. 3.0 (Electrodes classification - E - 51B)

Required throat size around boss

$$t_{weld\_boss} = \frac{F_{ten\_weld}}{L_{ten\_weld} \cdot \sigma_{all\_weld}} \qquad t_{weld\_boss} = 7.1 \cdot mm$$

Required size of weld around boss

$$s_{weld\_boss} = \frac{t_{weld\_boss}}{0.7} \qquad s_{weld\_boss} = 10.2 \cdot mm$$

**Therefore use a 10mm fillet weld between boss and pulling plate.**

**Check Pulling Plate For Tear-Out**

The pipe section to be used for the pulling head will be 457mm outside diameter, 19.2mm wall thickness pipe. The pulling plate will be connected to the pipe by means of a full penetration weld on either side. However, for a conservative analysis limit allowable stress to that of a fillet weld.

The minimum length of weld required between for pulling plate and pipe will be found using the process of iteration.

Size of weld to be used between pulling plate and pipe

$$s_{weld\_pipe} = 10mm$$

Mathcad requires an estimate of weld length to complete the iteration.

Trail length of weld between pulling plate and pipe

$$L_{weld\_pipe} = 1000mm$$

Given

$$L_{weld\_pipe} = \frac{Pull_{max}}{s_{weld\_pipe} \cdot 0.7 \cdot \sigma_{all\_weld}}$$

Minimum allowed length of weld between pulling plate and pipe

$$L_{weld\_pipe\_min} := Find\left(L_{weld\_pipe}\right) \qquad L_{weld\_pipe\_min} = 2919 \cdot mm$$

Actual total longitudinal weld between pulling plate and pipe is approximately 3200mm. Therefore OK .