LIFTING LUG ANALYSIS (ASD)
Per AISC 13th Edition ASD Manual, ASME BTH-1-2008, and
"Design and Construction of Lifting Beams" by David T. Ricker

Input:

* Design Parameters :

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lug Yield Strength (Fy)</td>
<td>34.1kip = 235MPa</td>
</tr>
<tr>
<td>Lug Ultimate Strength (Fu)</td>
<td>58.0kip = 400MPa</td>
</tr>
<tr>
<td>Edge Distance (a)</td>
<td>2.56in = 65mm</td>
</tr>
<tr>
<td>Edge Distance (e)</td>
<td>1.18in = 30mm</td>
</tr>
<tr>
<td>Lug Width (b)</td>
<td>6.10in = 155mm</td>
</tr>
<tr>
<td>Rounded Edge ?</td>
<td>No</td>
</tr>
<tr>
<td>Will Pin Rotate Under Load ?</td>
<td>No</td>
</tr>
<tr>
<td>Hole Diameter (d)</td>
<td>0.98in = 25mm</td>
</tr>
<tr>
<td>Pin Diameter (dpin)</td>
<td>0.75in = 19mm</td>
</tr>
<tr>
<td>Lug Thickness (t)</td>
<td>0.75in = 19mm</td>
</tr>
<tr>
<td>AISC Factor of Safety (FS1)</td>
<td>5.0</td>
</tr>
<tr>
<td>AISC Factor of Safety (FS2)</td>
<td>3.0 (MAX(3, Fy/(Fu/FS1)))</td>
</tr>
<tr>
<td>ASME Factor of Safety (FS3)</td>
<td>3.0 (Assuming Category B lifters)</td>
</tr>
</tbody>
</table>

Results:

* Check Geometry :

Check 1: \(d - dpin > 0\), Pin fits in hole, OK
Check 2: \(a \geq \text{MAX}(0.5d, 2t)\), Plate Proportions are OK
Check 3: \(e \geq 0.67d\), Plate Proportions are OK
Check 4: \(e \leq 1.33a\), Use \(a_{\text{eff}} = \text{MIN}(a, 3e/4, 4t, dh^{1.25})\) in design

\[a_{\text{eff}} = \text{MIN}(a, 3e/4, 4t, dh^{1.25}) = 0.885 \text{ in} = 22.48 \text{ mm}\]
\[a_{\text{max}} = 2t + 0.625 = 2.125 \text{ in} = 53.98 \text{ mm}\]
\[a_{\text{use}} = \text{MIN}(a_{\text{eff}}, a_{\text{max}}) = 0.885 \text{ in} = 22.48 \text{ mm}\]

* Tensile Strength of Lifting Lug (AISC Eqn. D5-1) :

\[P_1 = \frac{2a_{\text{use}}tFu}{FS1} = 15.40 \text{kips (68.50 kN)}\]

* Bearing Capacity of Lifting Lug (AISC Eqn. J7-1) :

\[P_2 = \frac{1.8Fy^*dpin}{FS2} = \text{N/A kips (N/A kN)}\]

Per Ricker, only check bearing capacity if pin is "snug" in hole
**LIFTING LUG ANALYSIS (ASD)**

* Tearing Tension Capacity of Lifting Lug *(Ricker pg 152)* :
  
  \[ P_3 = \frac{(1.67F_yt^2e^2e)}{d} \times \frac{1}{FS_2} = 20.23 \text{ kips (89.99 kN)} \]

Per Ricker pg. 152, \( F_b \) is used instead of \( F_y \), but \( F_b = F_y/FS_2 \)

* Shear Capacity (Shear Rupture) of Lifting Lug *(AISC Eqn D5-2)* :
  
  \[ P_4 = \frac{(0.6F_u^2t^2e)}{FS_1} = 12.32 \text{ kips (54.80 kN)} \]

Per AISC Eqn. D5-2, \( As_f = 2t(e+dh/2) \), cons. to assume \( dh/2=0 \)

* Gross Section Yielding of Lifting Lug *(AISC Eqn D2-1)*:
  
  \[ P_5 = \frac{(F_yt)b}{FS_2} = 52.00 \text{ kips (231.31 kN)} \]

* Tensile Strength of Lifting Lug *(ASME Eqn. 3-45)* :
  
  \[ \alpha_{eff} = \min(a, 4t, 0.6a^2(F_u/F_y)^2(d / a)) = 1.62 \text{ in} \]

  \[ P_6 = \frac{(Cr^2t^2\alpha_{eff})}{(12^2FS_3)} = 32.22 \text{ kips (143.32 kN)} \]

* Single Plane Fracture Strength of Lifting Lug *(ASME Eqn. 3-49)* :
  
  \[ R = e+(d/2) = 1.670 \text{ in} \]

  \[ P_7 = \left[ \frac{[Cr^2Fu]}{(12^2FS_3)} \right] \times \left[ 1.13[R-(0.5d)+(0.92\alpha_{eff}/(1+a_{eff}/d))] \times t \right] = 18.85 \text{ kips (83.85 kN)} \]

* Double Plane Fracture Strength of Lifting Lug *(ASME Eqn. 3-50)* :
  
  \[ f = 55\left[(dpin / d)\right] = 42.09 \text{ deg.} \]

  \[ Z' = R - \sqrt{[R^2 - \left[(dpin/2)^2\sin(f)^2\right]]} = 0.000 \text{ in.} \]

  only applicable for rounded edges

  \[ A_v = 2(e+0.6(dpin)[1-cos(f)]-Z')t = 1915 \text{ in}^2 \]

  \[ P_8 = \frac{(0.7F_u^2Av)}{(12^2FS_3)} = 21.60 \text{ kips (96.08 kN)} \]

* Bearing Capacity of Lifting Lug *(ASME Eqn. 3–53)* :
  
  \[ P_9 = \frac{(125^2F_y^2dpin^2t)}{FS_3} = 7.99 \text{ kips (35.54 kN)} \]

(==== Controls)

* Summary / Safe Working Load of Lifting Lug :
  
  \[ \text{Pallow} = \min(P_1, P_2, P_3, P_4, P_5, P_6, P_7, P_8, P_9) = 7.99 \text{ kips = 35.54 kN} \]

* Required Weld Strength for Vertical Load :
  
  \[ P_{design} = \text{Pallow} \times 1.5 = 11.99 \text{ kips = 53.33 kN} \]

Assuming fillet weld and F.S. = 5.0 against \( F_{exx} \). Use \( P_{design} \) to design welds using \( 0.3F_{exx} \times 0.707 \times \text{weld size} \). Could also use \( \text{Pallow} \), but need to use \( 0.2F_{exx} \times 0.707 \times \text{weld size} \) for F.S. = 5.0.