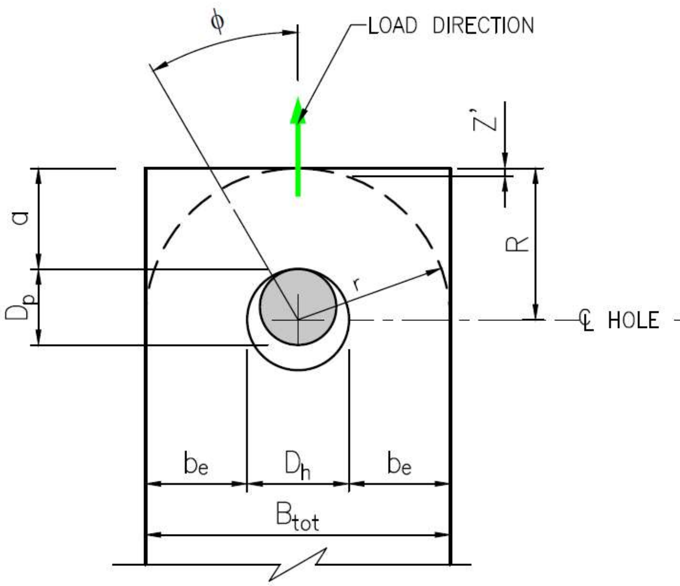
Pursuant to ASME BTH-1-2017

Big Important Client
Lifting Lug Design- Static Design Basis

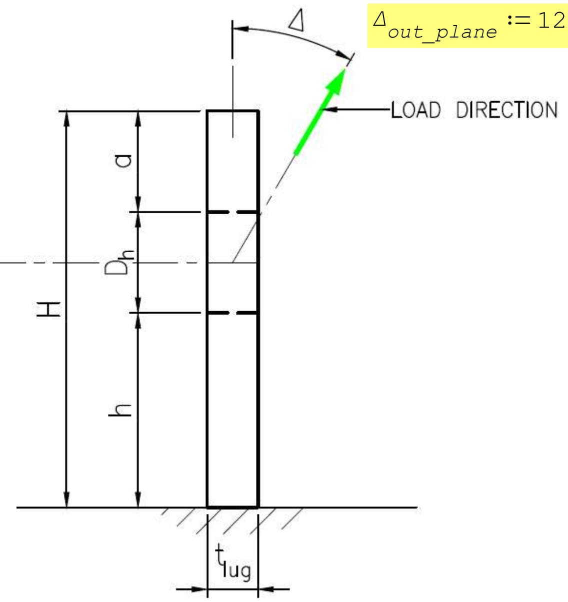
09/29/2024

Client Code: 1501-1704



Out of Plane Loading Angle

$\Delta_{out\_plane} := 12\ deg$



Material Properties

Lug Properties

Base Metal Properties

$E := 29000\ ksi$

$F_{y\_lug} := 36\ ksi$

$F_{u\_lug} := 58\ ksi$

$F_{y\_base} := 36\ ksi$

$F_{u\_base} := 58\ ksi$

Enter Nominal Design Factor for Max Allowable Stress

3-1.3.1 Nominal Design Factors. The static strength design of a below-the-hook lifting device shall be based on the allowable stresses defined in sections 3-2 and 3-3. The minimum values of the nominal design factor, N_d, in the allowable stress equations shall be as follows:

N_d = 2.00 for Design Category A lifters
= 3.00 for Design Category B lifters
= 6.00 for Design Category C lifters

Design Category: A

See ASME B30 Sec. 2-2

Nominal Design Factor: $N_d := 2$

Lug Section Geometry

Material Above Pin: $a := 2\ in$

Hole Diameter: $D_h := 2\ in$

Pin Diameter: $D_{pin} := \frac{1}{2}\ in$

Radius: $r := \frac{1}{2} \cdot D_h + a = 3\ in$

Side Material: $b_e := r - \frac{1}{2} \cdot D_h = 2\ in$

Base Total: $B_{tot} := 2 \cdot b_e + D_h = 6\ in$

Material Below Hole: $h := 2.5\ in$

Total Height: $H := h + D_h + a = 6.5\ in$

Lug Thickness: $t_{lug} := \frac{1}{2}\ in$

ϕ= Shear Plane Loading Angle

$\phi_{loading\_angle} := 15\ deg$

Shear Plane Reduction Due to Curve

See ASME B30 Eq. C-2

$$Z_{prime} := r - \sqrt{r^2 - \left(\frac{D_{pin}}{2} \cdot \left(\sin\left(\phi_{loading\_angle}\right)\right)\right)^2} = 0\ in$$

Calculate Allowable Stresses for Static Design

We are going to calculate the allowable stresses per ASME - BTH-1, and then convert those stresses into equivalent safety factors. Then, we will use AISC Allowable Stress Equations for design.

Gross Tension Yield

ASME BTH-1 Eq. 3-1 & 3-2

$$F_{t\_gross} := \frac{F_{y\_lug}}{N_d} = 18\ ksi$$

$$F_{t\_effect} := \frac{F_{u\_lug}}{1.2 \cdot N_d} = 24.2\ ksi$$

$$\Omega_{tension\_gross} := \frac{F_{y\_lug}}{F_{t\_gross}} = 2$$

Bearing Stress

ASME BTH-1 Eq. 3-53

$$F_p := \frac{1.25 \cdot F_{y\_lug}}{N_d} = 22.5\ ksi$$

$$\Omega_{bearing} := \frac{F_{y\_lug}}{F_p} = 1.6$$

Minor Axis Bending - Solid Bars

ASME BTH-1 Eq. 3-25

$$F_b := \frac{1.25 \cdot F_{y\_lug}}{N_d} = 22.5\ ksi$$

$$\Omega_{bending} := \frac{F_{y\_lug}}{F_b} = 1.6$$

Shear on Bars, Pins & Plates

See ASME B30 Sec. 3-2.3.6

$$F_v := \text{if } \frac{a}{t_{lug}} \le 2.45 \cdot \sqrt{\frac{E}{F_{y\_lug}}} \; \frac{F_{y\_lug}}{N_d \cdot \sqrt{3}} \; \text{else} \; \frac{F_y}{N_d} = 10.4\ ksi$$

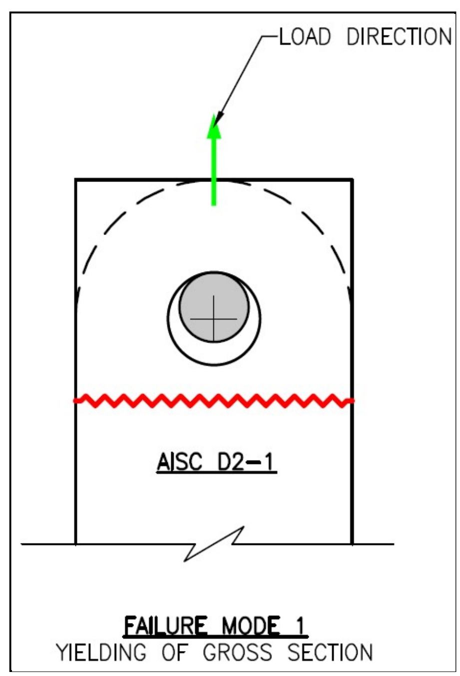
$$\Omega_{shear} := \frac{F_{y\_lug}}{F_v} = 3.5$$

Failue Mode 1 - Yielding of Gross Section

(Previously Calc'd)

$$\Omega_{tension\_gross} = 2$$

$$P_{allow\_gross\_yield} := \frac{t_{lug} \cdot B_{tot} \cdot F_{y\_lug}}{\Omega_{tension\_gross}} = 54\ kip$$



Failue Mode 2 - Tension Rupture on Effective Area

(Previously Calc'd)

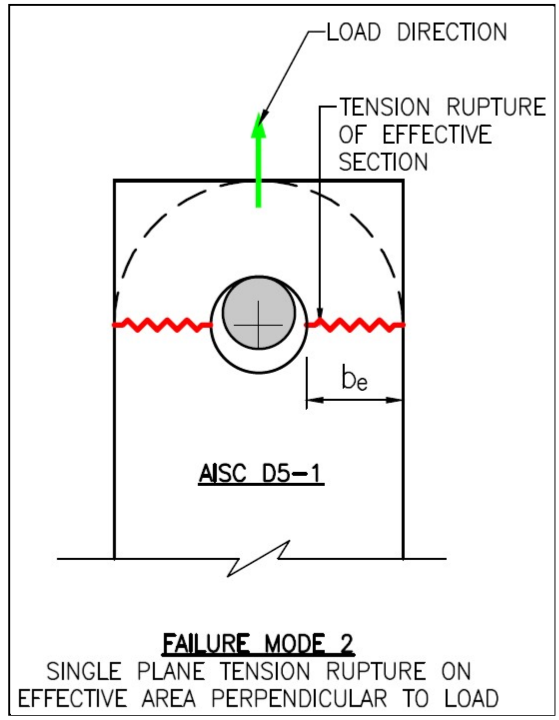
$b_e = 2\ \text{in} \quad t_{lug} = 0.5\ \text{in}$

$\Omega_{tens\_rupt} := 5$ (treat at OSHA Rigging Component)

Apply AISC Dimension limitations Sect. D5-1b

$$b_e := \min\left(\begin{bmatrix} b_e \\ 2 \cdot t_{lug} + .63\ \text{in} \end{bmatrix}\right) = 1.63\ \text{in}$$

$$P_{allow\_tens\_rupt} := \frac{F_{u\_lug} \cdot \left(2 \cdot t_{lug} \cdot b_e\right)}{\Omega_{tens\_rupt}} = 18.9\ \text{kip}$$



Failue Mode 3 - Shear Rupture on Planes Parallel to Line of Action

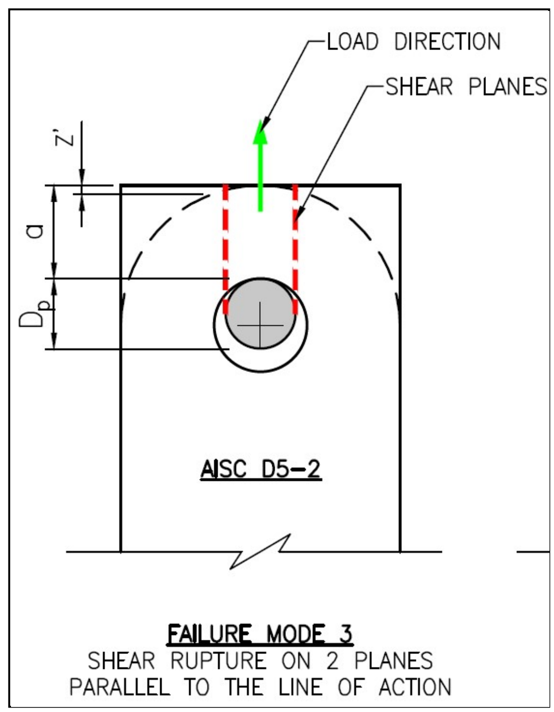
(Previously Calc'd)

$\Omega_{shear} = 3.5$

$$A_{sf} := 2 \cdot \left(a - Z_{prime} + \frac{D_{pin}}{2}\right) \cdot t_{lug} = 2.25\ \text{in}^2$$

$$P_{allow\_shear} := \frac{0.6 \cdot F_{u\_lug} \cdot A_{sf}}{\Omega_{shear}} = 22.6\ \text{kip}$$

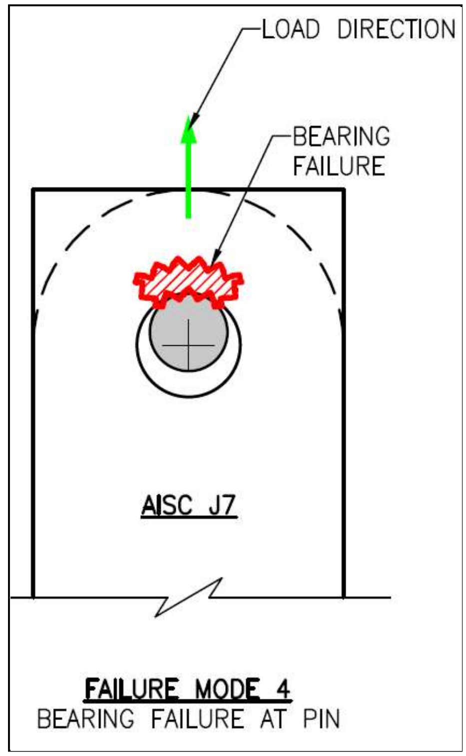
AISC EQ. D5-2



Failue Mode 4 - Bearing Failure @ Pin

$$P_{allow\_bearing} := \frac{.9 \cdot F_{y\_lug} \cdot t_{lug} \cdot D_{pin}}{\Omega_{bearing}} = 5.1 \text{ kip}$$

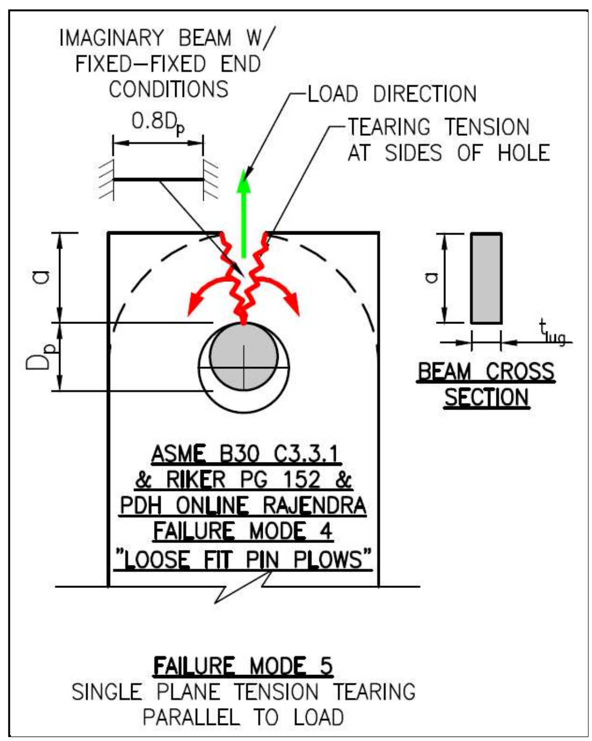
Note: We are deviating from AISC equation J7-1. Equation J7-1 applies a 1.8 coefficient to the yield stress. We have replaced that with a 0.9 coefficient based upon David Ricker's 1991 Engineering Journal recommendations. AISC assumes a tight fitting pin. For lifting operations we will have a loose fitting pin, and Ricker reports capacity is reduced.



Failue Mode 5 - Tearing Tension Along Line of Action

$$P_{allow\_Tear} = \frac{1.67 * F_{y_{lug}} t_{lug} a^2}{\Omega_{bending} D_{pin}}$$

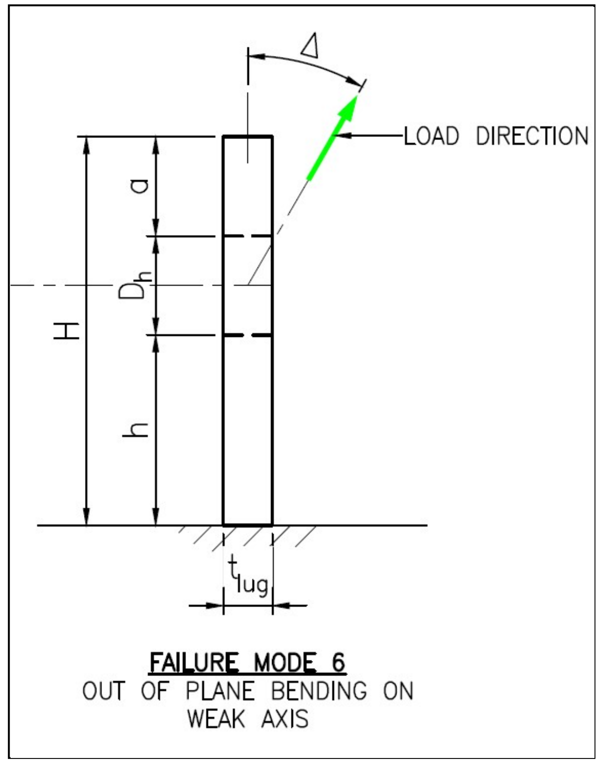
Flexural Tension on Fixed-Fixed Beam
Equation from Ricker Article pg. 152 and Figure 15
(also in Rajendra Failure Mode 4)



$$P_{allow\_tear} := \frac{1.67 \cdot F_{y\_lug} \cdot t_{lug} \cdot a^{2}}{\Omega_{bending} \cdot D_{pin}} = 150.3 \text{ kip}$$

Failue Mode 6 - Out of Plane Bending - Weak Axis

$$Z_{plastic} := \frac{1}{4} \cdot B_{tot} \cdot t_{lug}^{2} = 0.375\ in^{3}$$



$$P_{allow\_flexure} := \frac{F_{y\_lug} \cdot Z_{plastic}}{\Omega_{bending} \cdot \sin\left(\Delta_{out\_plane}\right) \cdot \left(h + \frac{D_h}{2}\right)} = 11.6\ kip$$

Summary

Failue Mode 1 - Yielding of Gross Section

Failue Mode 2 - Tension Rupture on Effective Area

Failue Mode 3 - Shear Rupture on Planes Parallel to Line of Action

Failue Mode 4 - Bearing Failure @ Pin

Failue Mode 5 - Tearing Tension Along Line of Action

Failue Mode 6 - Out of Plane Bending - Weak Axis

$P_{allow\_gross\_yield} = 54\ kip$

$P_{allow\_tens\_rupt} = 18.9\ kip$

$P_{allow\_shear} = 22.6\ kip$

$P_{allow\_bearing} = 5.1\ kip$

$P_{allow\_tear} = 150.3\ kip$

$P_{allow\_flexure} = 11.6\ kip$

$$P_{n\_allow} := \min\left(\begin{bmatrix} P_{allow\_gross\_yield} \\ P_{allow\_tens\_rupt} \\ P_{allow\_shear} \\ P_{allow\_bearing} \\ P_{allow\_tear} \\ P_{allow\_flexure} \end{bmatrix}\right) = 5.1\ kip$$