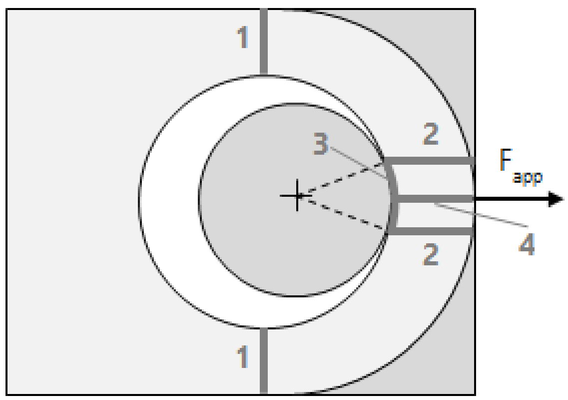
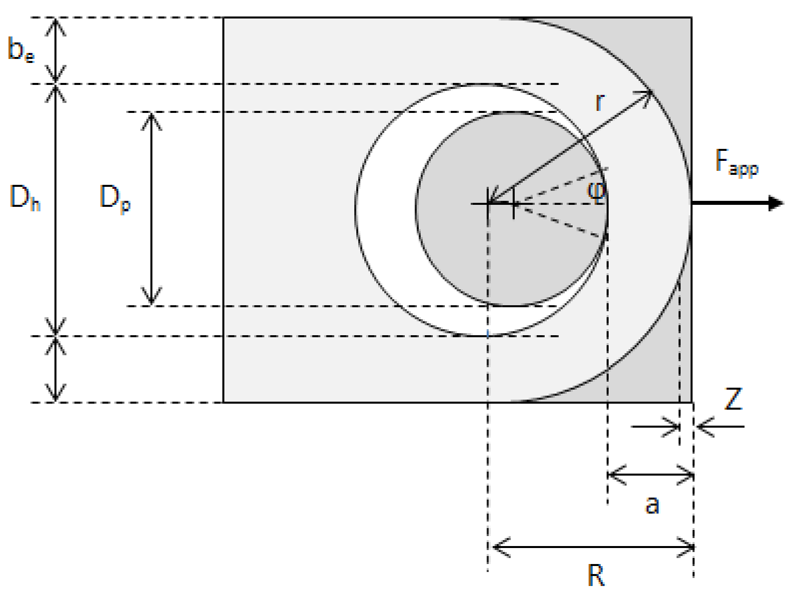
Lifting Lug Analysis

Lug analysis involves several failure modes, associated with different areas of the lug:

1. Tension failure across the net section
2. Shear failure along two planes
3. Bearing failure
4. Hoop tension failure/fraction on single plane
5. Out of plane buckling (dishing)



This application analyzes a lug according to the ASME BTH-205 method. The analysis only applies for lugs under axial loading, and does not account for the interaction between the lug and pin, or out of plane buckling (dishing)



Parameters

Thickness

$t := 0.75$

Distance from hole edge to lug edge

$a := 3.3125$

Pin diameter

$Dp := 1.375$

$be := 1.66$

Hole diameter

$Dh := 1.6875$

Curved edge

curved_edge := "Y"

Lug yield stress

$Fy := 36$

Lug ultimate stress

$Fu := 58$

Pin yield stress

$Fyp := 58$

Applied Load

$F_{app} := 40$

Correction Factors

Shear plane locating angle

Locates the two planes along which shear tear out occurs. Ratio of the pin to hole diameter such that a loose fitting pin has a smaller shear plane than a tight-fitting pin

Half angle of the portion of the pin in contact with the lug (Ref 2 eq 9)

$$phi := 55 \cdot \frac{Dp}{Dh} = 44.815$$

Design Factor and Service Class

Nd=2: Design Category A lifters (predictable loads, accurately defined or non-severe environmental conditions, no more than 20,000 load cycles)

Nd=3: Design Category B lifters (unpredictable loads, uncertain or severe environmental conditions)

Design factor

$$Nd := 2$$

Service class

$$service\_class := 0$$

Effective Width

Effective width (ASME eq 3-46) Protect against dishing failure. Ignore for stiffened lug or constrained against buckling

$$beff1 := 4 \cdot t = 3.000$$

Effective width (ASME eq 3-47 empirical)

$$beff2 := be \cdot 0.6 \cdot \frac{Fu}{Fy} \cdot \sqrt{\frac{Dh}{be}} = 1.618$$

Effective width. This should not be larger than the actual net width

$$beff := \min(beff1, beff2) = 1.618$$

Radius of curvature of edge of lug (>=R)

$$r := a + \frac{Dh}{2} = 4.156$$

Distance from hole center to lug edge

$$R := a + \frac{Dh}{2} = 4.156$$

ASME BTH-1-2005. This check can be ignored when Dp/Dh>0.9

$$DhDp := \frac{Dh}{Dp} = 1.227$$

check_all := "Y"

Strength reduction factor

$$Cr := \begin{cases} 1 & \frac{Dp}{Dh} > 0.9 \textbf{ and } check\_all = "N" \\ 1 - 0.275 \cdot \sqrt{1 - \left(\frac{Dp}{Dh}\right)^2} & \text{otherwise} \end{cases}$$

$$Cr = 0.841$$

Lug Strength

Tensile Strength

Area of net section

$$A_t := 2 \cdot t \cdot beff = 2.427$$

Ultimate tensile load that would result in tensile failure across net section

$$Ptu := Cr \cdot Fu \cdot A_t = 118.318$$

Allowable tensile load

$$Pt := \frac{Ptu}{1.2 \cdot Nd} = 49.299$$

Safety factor

$$Fs_t := \frac{Ptu}{F_{app}} = 2.958$$

$$\text{ifelse}\left(Fs_t > 1.2 \cdot Nd, \text{"pass"}, \text{"fail"}\right) = \text{"pass"}$$

Single Plane Facture Strength

Failure along plane collinear with load

Effective area

$$A_b := \left(1.13 \cdot \left(R - \frac{Dh}{2}\right) + \frac{0.92 \cdot be}{1 + \frac{be}{Dh}}\right) \cdot t = 3.385$$

Ultimate single plane fracture load

$$Pbu := Cr \cdot Fu \cdot A_b = 165.018$$

Allowable single plane fracture load (ASME eq 3-48)

$$Pb := \frac{Pbu}{1.2 \cdot Nd} = 68.758$$

Safety factor

$$Fs_b := \frac{Pbu}{F_{app}} = 4.125$$

Double Plane Fracture Strength

Loss in shear plane length due to curvature at end of lug (ASME eq C3.2). If lug is flat, r is infinity and Z=0

$$Z := \begin{cases} r - \sqrt{r^2 - \left(\frac{Dp}{2} \cdot \sin(phi)\right)^2} & curved\_edge = \text{"Y"} \\ 0 & curved\_edge = \text{"N"} \end{cases}$$

$$Z = 0.031$$

Total area of two shear planes ASME eq 3-50

$$Av := 2\cdot\left(a + \frac{Dp}{2}\cdot(1-\cos(\phi)) - Z\right)\cdot t = 5.259$$

Ultimate double plane shear load that results in shear tear out along the two planes

$$P_{vu} := 0.7\cdot Fu\cdot Av = 213.520$$

Allowable double plane shear load ASME eq 3-49

$$Pv := \frac{P_{vu}}{1.2\cdot Nd} = 88.967$$

Factor of safety

$$Fsv := \frac{P_{vu}}{F_{app}} = 5.338$$

Bearing Strength

Pin bearing area

$$A_p := Dp\cdot t = 1.031$$

Ultimate bearing load

$$P_{pu} := \begin{cases} 1.25\cdot\min(Fy, Fyp)\cdot A_p & service\_class = 0 \\ 0.63\cdot\min(Fy, Fyp)\cdot A_p & service\_class \geq 1 \end{cases}$$

$$P_{pu} = 46.406$$

Allowable bearing load (ASME eq 3-51). If the connection is subject to rotating cyclic loading, this value shall be divided by 2

$$Pp := \frac{P_{pu}}{Nd} = 23.203$$

Factor of safety

$$FS_p := \frac{P_{pu}}{F_{app}} = 1.160$$