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k = Distance from outer face of flange to web toe of fillet, in.
t = Web thickness, in.

Lifting Padeye Design

Lifting Padeye design should consider the impact from vessel motion. Load factors should be applied to the lifting weight. API RP 2A recommends that for lifts to be made at open sea, a factor of two should be applied. Most offshore lifting is performed by using four slings. It is conservative in practical design to consider that one sling will sag during lifting. The sling load P can be calculated by

$$2W = nP\cos\alpha$$
$$P = 2W/(n\cos\alpha)$$

where: α = Angle between the sling and vertical line
W = Lifting weight
n = Number of slings

The procedure of Padeye design is expressed as follows:

1. Check bearing stress.

Allowable bearing $F_p = 0.9F_y$

$$d(T + 2t)F_p \geq P$$

where: d = Pin diameter
T = Main plate thickness
t = Cheek plate thickness

$$T + 2t \geq \frac{P}{dF_p} \qquad (6\text{-}17)$$

From Equation 6-17, the thickness of the main plate and cheek plates can be properly selected.

2. Check shear stress.

Allowable shear $F_v = 0.4F_y$
$$2[T(R - r_0) + 2(r - r_0)t]F_v \geq P$$

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$$T(R - r_0) + 2(r - r_0)t \geqslant \frac{P}{2F_v} \quad (6\text{-}18)$$

where: R = Radius of main plate
r_0 = Radius of pin hole
r = Radius of cheek plates

From Equation 6-18, proper plate thickness can be selected. In most cases, the plate thickness selected from Equation 6-17 will govern the design.

3. Check welding between the main plate and cheek plates. If the welding size is w and the allowable welding stress is F_w, then (weld)

$$2\pi r \times 0.707w \times F_w \geqslant P\frac{t}{T + 2t}$$

$$w \geqslant \frac{Pt}{4.44F_w(T + 2t)r} \quad (6\text{-}19)$$

From Equation 6-19, the required welding (fillet) between the main plate and the cheek plates can be calculated.

4. Check axial and shear stress along a section cutting through the main plate. If a section is cut through the main plate at b distance from the center of the hole, the section is h units high:

Axial stress $f_a = \frac{P\cos\theta}{Th}$

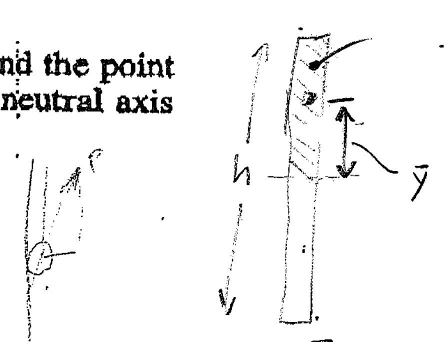
Bending stress $f_b = \frac{Mc}{I}$

Shear stress $f_v = P\sin\theta\frac{Q}{IT}$ $\frac{k \quad in^2}{in^4 \times in}$

where P = Force on padeye
θ = angle of Force on padeye from Horizontal.
T = Main plate thickness
h = Length of padeye section cut by plane distance "b" from center of hole and parallel to base of main plate
b = distance from center of pin hole to the cut-plane ∥ to padeye base.

where: θ = Angle between slings, and the horizontal
Q = Static moment of the cross-sectional area beyond the point where the shear is calculated (taken about the neutral axis of the section)

$$M = P\sin\theta \cdot b - P\cos\theta\left(\frac{h}{2} - R\right)$$



Q = Cross-hatch Area * $\bar{y}$

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The maximum bending stress $f_b = 6M/(Th^2)$

The average shear stress $f_v' = P \sin \theta/(Th)$ is calculated and the principal stress at the edge of the section can be calculated:

$$\sigma_{max} = \frac{f_a + f_b}{2} + \sqrt{\left(\frac{f_a + f_b}{2}\right)^2 + (f_v')^2} \qquad (6\text{-}20)$$

In practical design a horizontal force of 5% of the static sling load should be applied simultaneously with the sling load.

Padeye design should provide sufficient clearance for easy installation. The following clearances are recommended:

1. The Padeye pin-hole diameter should be one-quarter inch larger than the pin diameter.
2. The Padeye thickness should be one-half inch less than the jaw width of the shackle (Figure 6-6).
3. The outer radius of Padeye main plate should allow about one-quarter-inch clearance between the main plate and the sling.

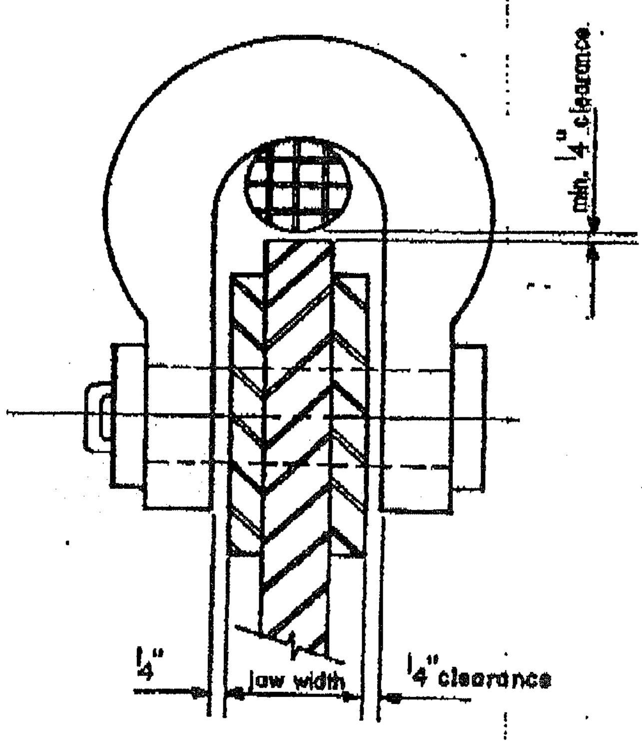

Figure 6-6. Padeye clearance.

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4. It is important to locate the Padeye such that the shackle, the pin, and slings clear the adjacent structural members.

Example 6-3

The topside structure of a offshore platform weighs 800 t. Four Padeyes are needed for the lift. Design the Padeyes.

Given: $\alpha = 30°$
$\theta = 60°$
$F_y = 42$ ksi
$d = 6$ in.

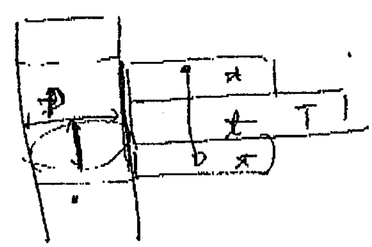
1. Calculate sling loads (consider one sling sags).

$$P = \frac{2W}{3\cos\alpha} = \frac{2 \times 1{,}600}{3 \times \cos 30} = 1{,}232 \text{ kips}$$

2. Check bearing stress.

$$F_P = 0.9F_y = 37.8 \text{ ksi}$$

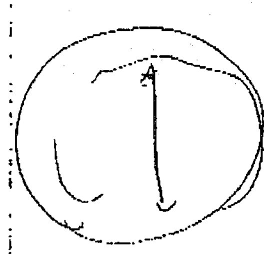
$$d(T + 2t)F_P \geqslant P$$
$$6(T + 2t) \times 37.8 \geqslant 1{,}232$$
$$T + 2t \geqslant 1{,}232/(6 \times 37.8) = 5.43 \text{ in.}$$



Try 2 in. main plate.
1.75 cheek plates
$T + 2t = 2 + 3.5 = 5.5 > 5.43$ in.

3. Check shear stress.

$$F_v = 0.4 \times 42 = 16.8 \text{ ksi}$$



Try
$R = 11$ in.
$r = 10$ in.

Use $2r_0 = d + 1/4 = 6.25$ in.
$T(R - r_0) + 2(r - r_0)t \geqslant P/(2F_v)$
$2(11 - 3.13) + 2(10 - 3.13) \times 1.75 = 39.78$

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$$\frac{P}{2F_y} = \frac{1,232}{2 \times 16.8} = 36.67 < 39.78$$

It is noted that bearing governs the design.

4. Check welding of the check plates. Assume E60 welds are used.

$$w \geqslant \frac{Pt}{4.44F_w(T + 2t)r}$$

$$w \geqslant \frac{1,232 \times 1.75}{4.44 \times 13.6(2 + 3.5) \times 10} = 0.65 \text{ in.}$$

Use three-quarter-inch fillet welds around the cheek plates.

5. Check stress at a section 11 in. from hole center.

Try h = 48 in.

$$\begin{aligned} M &= P \sin\theta\, b - P\cos\theta\,(h/2 - R) \\ &= 1232 \times 0.87 \times 11 - 1232 \times 0.5(24 - 11) \\ &= 3782 \text{ k-in.} \end{aligned}$$

$$f_a = \frac{P\cos\theta}{Th} = \frac{1232 \times 0.50}{2 \times 48} = 6.42 \text{ ksi}$$

$$f_b = \frac{6M}{Th^2} = \frac{6 \times 3782}{2 \times 48^2} = 4.92 \text{ ksi}$$

Five percent of static sling load = 0.05 × 616 = 30.8 kips

$M = 31 \times 12 = 372$ k-in.

$f_b = 6 \times 372/(48 \times 4) = 11.63$ ksi

$f = 6.42 + 4.92 + 11.63 = 22.97$ ksi

$\frac{Q}{I} = \frac{3}{4h}$

$$\text{Shear at N.A.} = \frac{VQ}{IT} = \frac{3V}{4Th} = \frac{3 \times 1,072}{4 \times 2 \times 48} = 8.38 \text{ ksi}$$

Shear stress at edge = 0

$$\text{Maximum stress} = \frac{6.42 + 11.63}{2} + \sqrt{9.03^2 + 8.38^2} = 21.35 \text{ ksi}$$

It is suggested that sufficient stiffeners be provided to reduce the lateral bending stress (11.63 ksi). The designed Padeye is shown in Figure 6-7.

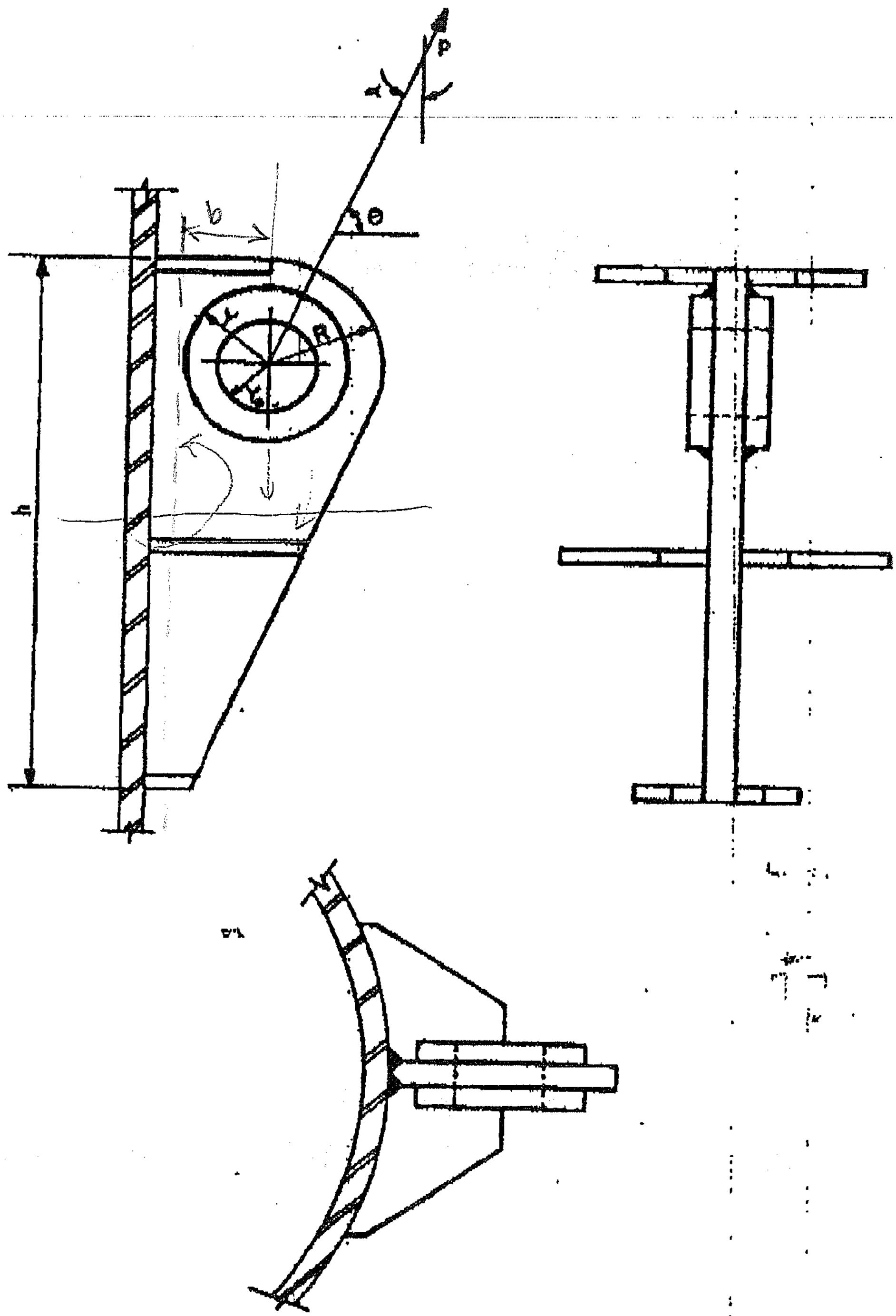
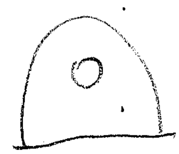


Figure 6-7. Padeye design.



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