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PAD EYE LUG DESIGN WITH A SIDE LOAD

As design engineers, it is our responsibility to make sure that our lug designs meet the latest codes before they are issued for fabrication, but due to the variables in fabrication, installation, field implementation, etc, the designs might not fit right or be used right to code. That is why we use an impact factor (IF) or a safety factor, ie, it is recommended to always use at least a 1.8 IF.

One of the ways that lifting lugs are used outside of code is when the field allows side loading in the weak axis. Very seldom are lugs designed for a side load in the weak axis, so the rule the field should go by is “Do not side load lugs in the weak axis”. This is especially detrimental and dangerous for pad eye lugs because the side load on the lug causes the weld on the load side to act as a hinge and the weld on the back side away from the load sees most of the stress. Also the QC on the welds is very critical, ie, making sure there is no porosity, weld sizes are per the drawing, etc. Over stressing the weld on the back side can cause sudden failure to occur where the pad eye lug rips off.

I have checked enough Heavy Lift Contractors (HLC) rigging drawings to know that sometimes their rigging engineers/ superintendents don’t think that a little side load in the weak axis on a lug is serious, ie, a lot of HLC use spreader bars that have inserts that bolt together to lengthen or shorten the overall length. The inserts are usually one meter or longer in length, so it is hard to make sure that the lift slings will be vertical. Fluor uses pipe spreader bars with end caps so that the inserts can be cut to length to ensure that the lift slings are vertical.

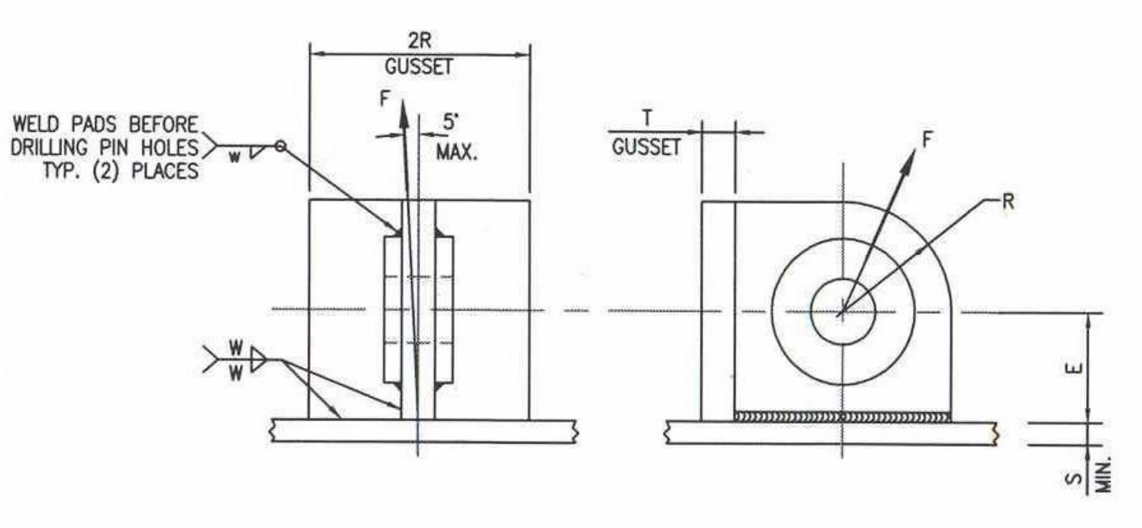
The purpose of this presentation is to show how to design a pad eye lug so that it will have reserve strength against side loading in the weak axis. Two methods will be shown:

METHOD 1:

A gusset can be added to the rear of the lug as shown in the sketch below. This will provide sufficient strength for a side load up to 5 degrees. Note that the pad eye lug program calculates lug properties where:

E = Eccentricity
F = force on the lug
R = radius of the lug
S = Min. thickness of the support base which is equal to or greater than W
T = Thickness of the lug and gusset
w = Pad weld size
W = Lug weld size

The width of the lug is 2*R
The width of the gusset is a minimum of 2*R



METHOD 2:

A pad eye lug can be designed with some reserve strength by taking into account a side load in the weak axis. The example below shows how to calculate the stresses in the lug plate and in the weld for a 40 kips side load at 10 ° in the weak axis.

The printout below shows the design for a pad eye lug without any side load, but it is the basis for calculating the additional stresses that a side load imposes on the lug plate and the weld. Note the combined stress of the lug plate and the weld size are circled in the printout.

PROGRAM TO DESIGN A PAD EYE TYPE LIFTING LUG v.02

COMPANY: Maximum Reach **PROJECT:** Pad Eye Design
ITEM NUMBER: # 25 Presentation

Crosby G2130x25 — Select a metric shackle from the lookup table based on the force on the lug or click the SHACKLE button to enter your own

2.88	in	Shackle Inside Width at Pin	
4.19	in	Shackle Eye Diameter	
2.04	in	Shackle Pin Diameter	
2.17	in	Lug Pin Hole Diameter	Recommend hole be 0.13" or > than shackle pin dia.
3.50	in	Lug Radius	
2.00	in	Lug Plate Thickness	
7.00	in	Lug Plate Width at Base	Minimum value of 2*radius of lug
0.00	in	Lug Pad Thickness	Input zero if pads are not required
0.00	in	Lug Pad Radius	Input zero if pads are not required
3.50	in	Lug Eccentricity	
39.39	kips	Force on the Lug	
60.00	deg	Angle of the Force on the Lug	Measured from the horizontal
36.00	ksi	Yield Stress of the Lug Material Fy	
14.85	kips/in	Allowable Force on the Weld	Use 10.91 for LH60 or 14.85 for LH70
1.80		Impact factor, IF	Recommend that a minimum 1.8 impact factor be used

OUTPUT:

Checking combined stress of the lug plate

14.00	in^2	Area of Lug Plate at Base
16.33	in^3	Section modulus of the lug plate at the base
7.60	ksi	Bending stress of the lug plate fb, actual
4.39	ksi	Tension stress of the lug plate ft, actual
21.60	ksi	Allowable bending and tension stress, Fb & Ft
0.55		Combined stress of the lug plate. Must be less than 1.0

Checking the lug weld size, with the weld treated as a line

14.00	in	Area of the weld
16.33	in^2	Section modulus of the weld
12.25	kips/in	Resultant Force on the weld
0.82	in	Minimum weld size

Checking bearing at the pin hole

17.38	ksi	Bearing stress of the lug without pads
0.00	ksi	Bearing stress with pads attached
32.40	ksi	Allowable bearing stress
0.00	kips	Load per pad
0.00	in	Pad weld size, min.

Checking end area of the lug across the pin hole

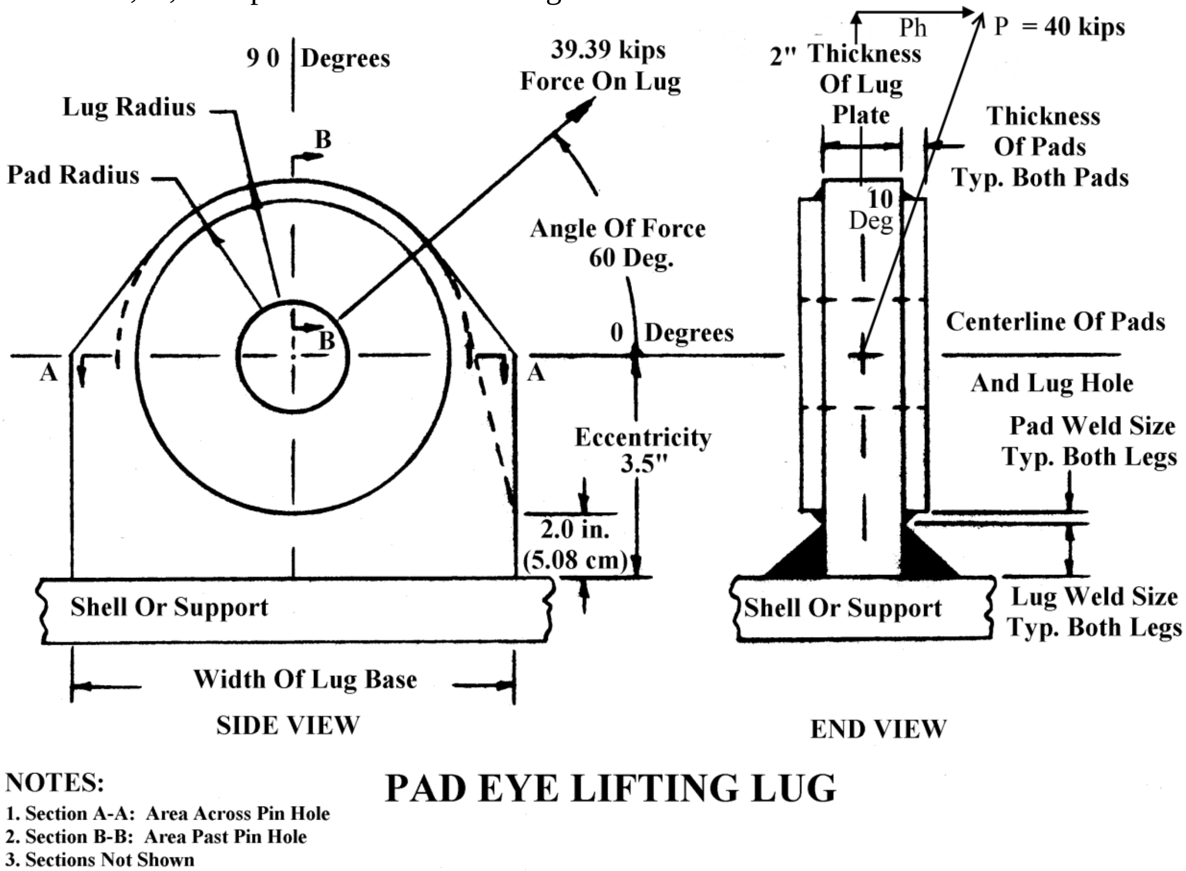
4.38	in^2	End area required across the pin hole
3.40	in	Maximum effective lug radius. Used to calculate the max. allowable end area
6.94	in^2	Maximum effective end area

Checking end area of the lug past the pin hole

2.92	in^2	Area required past the pin hole
4.83	in^2	Actual end area
4.63	in^2	Maximum allowable end area

Calculated by www.maximumreach.com 8/1/2014

The drawing below shows the details of the pad eye lug that agrees with the printout above and also shows the side load information, ie, 40 kips at a 10° side load angle.



NOW CALCULATE THE ADDITIONAL STRESS IMPOSED ON THE LUG PLATE DUE TO THE SIDE LOAD:

Refer to the printout and drawing above.

Where:

The force on the lug P at 10 deg. angle	= 40.00 kips
The horizontal component of the side load force Ph	= 6.95 kips
The force on the lug in the strong axis	= 39.39 kips
The angle of the force in the strong axis of the lug	= 60 deg.
Angle of the force in the weak axis	= 10 deg.
The eccentricity	= 3.5 inches
The allowable yield stress Fb in bending of the A36 plate = 36 ksi*.6	= 21.6 ksi
The allowable yield stress Ft in tension of the A36 plate	= 21.6 ksi
The section modulus Sx for bending in the strong axis is	
2” (thickness of the lug) * 7” (width of the lug)^2/6	= 16.33 cu. in.
The section modulus Sz for bending in the weak axis is	
7” * 2^2/6	= 4.67 cu. in.
Bending moment Mz in the weak axis is	
3.5” eccentricity *6.95 kips Ph * 1.8 (Impact factor IF)	= 43.79 k-in.
Bending stress fbz in the weak axis is	
43.79 k-in/4.67 cu.in.	= 9.38 ksi
The ratio of the the bending stress fbz to the allowable bending stress is	
9.38/21.6	= 0.43

From the printout above note that the combined stress for
the lug plate without any side load = 0.55
To get the total combined stress on the lug plate in the strong
axis and the weak axis, add 0.55 + 0.43 = 0.98 > 1.0 ==➔ Good

Therefore the lug plate is good for the 10° side load

NOW CALCULATE THE ADDITIONAL WELD REQUIRED AT THE BASE OF THE LUG PLATE DUE TO THE SIDE LOAD:

Method 1:

The section modulus Sz for the weld treated as a line in the weak direction is
2" lug thickness * 7"lug width = 14.00 sq. in.
Bending moment in the weak axis is
1.8 IF * 6.95 kips Ph * 3.5" eccentricity = 43.79 k-in
The bending stress is
M/Sz = 43.79 k-in/14.00 sq. in. = 3.13 k/in

From the printout, note that the resultant force Fr on the weld
without any side load. = 12.25 k/in

Therefore, the total resulting force on the weld = 12.25 k/in + 3.13 k/in = 15.38 k/in

The minimum required weld size using an allowable force on the weld of 14.85 k/in is

15.38 k/in / 14.85 k/in = 1.04 in

Recommend using 1 1/8" weld size

Method 2: My preferred method as it is usually more conservative.

Calculate the vertical force F that the weld on the back side of the lug will see due to the side load.

F = 43.79 k-in bending moment / 1" (½ width of lug) = 43.79 k

Now, the additional weld required due to the side load is

43.79 k/(14.85 k/in*7"width of lug) = 0.42

Therefore the total weld size required is 0.82" (from the printout) + 0.42" = 1.24 in

Recommend using a 1 1/4" weld size

COMMENTS:

1. Note that the side load was taken at the center of the lug hole. If the shackle pin is a tight fit in the lug hole, then the side lug force will occur up at the bail of the shackle (probably more to the side of the bail) instead of at the center of the lug hole and the eccentricity or moment arm should be taken from the base of the lug to bearing on the shackle bail or there about, ie, for a 25 Te shackle the eccentricity would then be +/- 8.02" + 3.5" = +/-11.52". In this example, the additional eccentricity would over stress the lug plate and would require a very large weld size. The proof of this is left up to the reader.

2. This is why it is strongly recommended that pad eye lugs not be side loaded, because if they are it is usually hard to determine the correct moment arm to use to be conservative.

END OF PAD EYE CHECK FOR A SIDE LOAD