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Stress concentration factors Axially loaded lugs with clearance-fit pins

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This Item was accepted for inclusion in the Stress and Strength Series by the Stress Analysis and Strength of Components Committee, which first met in 1964 and now has the following constitution:

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STRESS CONCENTRATION FACTORS AXIALLY LOADED LUGS WITH CLEARANCE-FIT PINS

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STRESS CONCENTRATION FACTORS AXIALLY LOADED LUGS WITH CLEARANCE-FIT PINS

1. NOTATION

Both SI and British units are quoted but any coherent system of units may be used.

a	distance from centre of hole to lug end (see Sketches 1.1a and 1.1b)	m	in
d	diameter of hole	m	in
e	pin-to-hole clearance as a percentage of d		
E_l, E_p	moduli of elasticity of lug and pin materials, respectively	N/m ²	lbf/in ²
f_{max}	maximum tensile stress in lug around hole perimeter	N/m ²	lbf/in ²
K'_e	stress concentration factor at e per cent clearance for lugs with t/d less than 0.5, defined by	N/m ²	lbf/in ²
$f_{max} = K'_e f_{ref}$ where $f_{ref} = \frac{P}{(W - d)t}$ (Thus $K'_{0.5}$ relates to 0.5 per cent clearance between pin and hole and K'_{100} is used for the limiting case of point loading. Note that for round-ended lugs f_{ref} remains as defined here even when $a < W/2$.)			
K''_e	value of K'_e when t/d is greater than 0.5 (see Section 2.5)		
K_s	stress concentration factor for waisted lug with flat and slot (related to K_{wf} , see Section 2.4)		
K_w	stress concentration factor for waisted lug (related to particular value of K'_e , see Section 2.4)		
K_{wf}	stress concentration factor for waisted lug with additional flat (related to a particular value of K'_e , see Section 2.4)		
L	distance between lug hole and slot in waisted lug (see Section 2.4)	m	in
P	tensile load on lug applied via pin	N	lbf
t	thickness of lug (see Sketch 1.1c)	m	in
W	width of lug (see Sketches 1.1a and 1.1b)	m	in

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w width of waisted lug (see Figures 5, 6 and 7) m in

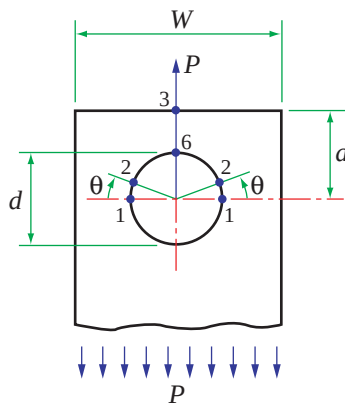
η_e correction factor for clearance e based on $K'_{0.2}$ and defined by

$$\eta_e = \frac{K'_e - K'_{0.2}}{K'_{100} - K'_{0.2}}$$

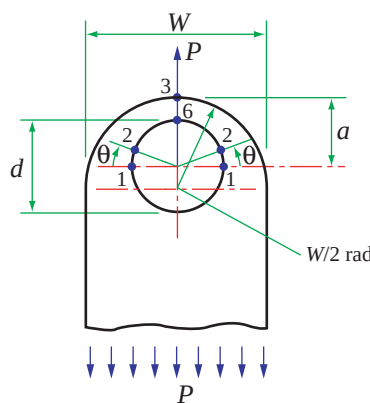
so that

$$K'_e = K'_{0.2} + \eta_e(K'_{100} - K'_{0.2})$$

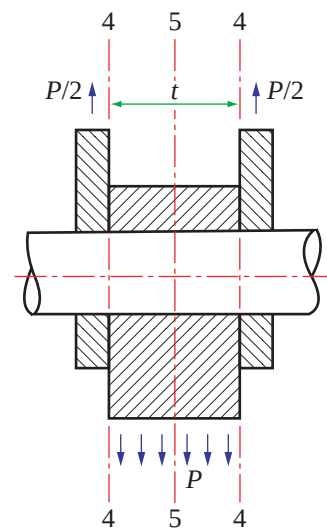
θ angle indicating position of f_{max} (see Sketches 1.1a and 1.1b) degree degree



Sketch 1.1a Square-ended lugs



Sketch 1.1b Round-ended lugs



Sketch 1.1c Section through lug assembly centre line

2. GENERAL NOTES

This Item provides the maximum elastic stress concentration factors at the perimeter of the hole in lugs loaded axially by single central clearance-fit pins. In Figures 1 to 3 data are provided for thin square- and round-ended plain lugs to which the following notes up to Section 2.3 apply. In Figures 5, 6, 7 and 8 data are given on particular examples of thin waisted round-ended lugs as guidance on the stress concentrations to be expected for such geometries. The notes in Section 2.4 qualify the use of the waisted lug data and their relationship to the data for plain lugs. In Figure 4 data on the effect of lug thickness are given, notes on the use of this figure being given in Section 2.5.

In addition to lug geometry the pin/hole clearance significantly affects the stress concentration. For both square- and round-ended lugs having perfect-fit pins the theoretical position of f_{max} is at Points 1 shown in Sketches 1.1a and 1.1b. As clearance between the pin and hole is introduced the value of f_{max} increases and its position moves. Thus for most practical good quality clearance-fits f_{max} occurs at Points 2 on the sketch for which θ is typically between 10 and 35 degrees. Section 2.3 provides data that may be used to account for pin-to-hole clearances when estimating K'_e . Note that if $(a - d/2)$ is small then significant local bending of the thin section $(a - d/2)$ wide will occur so transferring the maximum tensile stress in the lug to Point 3 on the outside of the lug. This will only occur outside the range of geometries covered by this Item.

Figures 1 and 2 provide curves for the limiting condition of $a/W = \infty$. In practice this limit applies at values of a/W in excess of about 1.5. For lugs with $t/d < 0.5$, variation in the ratio E_p/E_l between 1.0 and 3.0 has no significant effect on K'_e . See Section 2.5 for lugs with $t/d > 0.5$.

2.1 Square-ended Lugs with $t/d < 0.5$

Figure 1 provides curves of K'_e plotted against d/W for three values of a/W . Two sets of curves are provided and each set relates to a different quality pin-fit. The dashed curves relate to very small clearances between pin and hole, such as would normally only be obtained in laboratory specimens, that is by careful manufacture and individual pairing of lug-hole and pin. Typically $e < 0.1$ per cent for such cases which therefore represent a lower practical limit to the stress concentration factor. The solid curves relate to assemblies with pin clearances of about 0.2 per cent of d . These are therefore $K'_{0.2}$ values. An estimate of the stress concentration factor for the upper limit case of point loading, that is K'_{100} , may be obtained from Figure 2, see Section 2.2. (Note that point loading is strictly a line loading applied uniformly across the thickness of the lug at location 6, indicated on Sketches 1.1a and 1.1b.)

2.2 Round-ended Lugs with $t/d < 0.5$

Figure 2 provides curves of K'_e plotted against d/W for three values of a/W . The chain dotted curves relate to point loading and are therefore K'_{100} values. The solid lines relate to pin-fits having about 0.2 per cent clearance and are therefore $K'_{0.2}$ values. (The solid lines strictly relate to a sinusoidal type loading applied to the hole. Comparison of these data with Figure 1 and with experimental results shows that they approximate to 0.2 per cent clearance.)

2.3 Effect of Pin-to-hole Clearance, $t/d < 0.5$

Figure 3 provides values of η_e plotted against e . The data are based on a datum value of $K'_{0.2}$, that is, the solid curves of Figures 1 and 2, and strictly relate to round-ended lugs with $d/W = 0.5$ or 0.7 and with $a/W = 0.5$. The curve of Figure 3 may be used to provide an indication of the effect of e on the stress concentration factor for other geometries and lug forms. However, within set tolerances the effect of non-circularity coupled with surface finish effects can lead to considerable variation in η_e about the value obtained from Figure 3. This is particularly so when $e < 0.1$, that is, over the dashed portion of the curve. For this reason the dashed portion of the curve should be considered tentative. At the other end of the scale Figure 3 shows that conditions similar to point loading apply at clearances greater than about 10 per cent.

2.4 Waisted Round-ended Lugs, $t/d < 0.5$

Figures 5, 6 and 7 give the elastic stress concentration factors for the particular waisted lug geometries shown in the respective figures. They are based on the photoelastic tests of Derivation 3 supported by data from Derivation 1 in particular. While limited to $d/W = 0.5$ they give guidance on the effect that the geometrical variations shown will have on the lug stress concentrations K_w and K_{wf} for a range of a/W , and K_s for $a/W = 0.5$ (for which alone data were available).