

ELASTIC STRESS CONCENTRATION FACTORS. GEOMETRIC DISCONTINUITIES IN FLAT BARS OR STRIPS OF ISOTROPIC MATERIAL

1. INTRODUCTION

This Item presents data on stress concentration effects that occur in flat bars or strips when they are loaded in tension or bending. A stress concentration factor is defined as the ratio of the highest stress to a reference stress calculable from simple two-dimensional theory.

Throughout this Item the term “bars or strips” applies to bodies having solid thin rectangular sections. Where the thickness is large in relation to the in-plane dimensions, the stress concentration factor could be slightly higher than that predicted by this Data Item, and will vary through the thickness, see Data Item No. 93030*.

The various geometries for which data are presented are listed on Table 1.1. For each geometry the cross section on which the reference stress is based is given in the appropriate section. The symbol K indicates that the reference stress is based on the gross cross section of the bar or strip, ignoring the discontinuity, and the symbol K' indicates that the reference stress is based on the net cross section at the discontinuity.

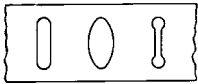
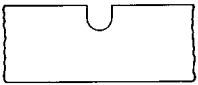
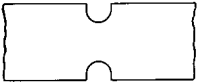
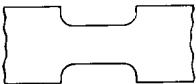
The data apply only to isotropic materials that obey Hooke's Law. However, over the practical working range most engineering materials conform substantially in these respects and for these the data may be used without significant error. If the stress concentration factor is such that the maximum stress is above the limit of proportionality of the material, the stresses will be redistributed and will give rise to residual stresses on unloading.

The notation for each section quotes both lbf in and SI Units, but any coherent system of units may be used.

Figures 5.1 to 5.5 were constructed from results of a finite element analysis and recent photoelastic work, see Derivations 28 and 29, which are in complete agreement for fillets in tension with $W/w = 2.0$ and r/w greater than 0.1. For geometries outside this range the agreement between the results decreases as r/w decreases. The stress concentration factors obtained from the recent photoelastic results can be up to 17 per cent lower than those gained from the finite element results for r/w between 0.02 and 0.2. Figures 2.1 to 4.2 and 5.6 to 5.8 were constructed from earlier photoelastic results and with the exception of Figure 2.2, theoretical results as well. The earlier photoelastic results used in this Data Item tend to give stress concentration factors up to 10 per cent lower than those of the finite element data.

* Data Item No. 93030 "Three-dimensional elastic stress concentration factors. Plain or countersunk hole in a wide plate subjected to tension, bending or pin loading".

TABLE 1.1 INDEX TO DISCONTINUITIES AND LOADING CONSIDERED

<i>Form of discontinuity</i>		<i>Loading</i>	<i>Section number</i>
Hole		Tension Bending in plane of strip Bending out of plane of strip	2
Transverse slot		Tension	3
Notch on one edge		Tension Bending	4
Notches and fillets on both edges		Tension Bending	5
		Tension Bending	5
		Tension Bending	5

2. CIRCULAR HOLES

2.1 Notation

d	diameter of hole	m	in
f_s	stress at site s	N/m ²	lbf/in ²
h	distance of centre of hole from nearer edge of bar	m	in
K_s	stress concentration factor at site s indicated defined by $f_s = K_s f_{ref}$		
	where $f_{ref} = P/Wt$ (for Figures 2.1 and 2.3)	N/m ²	lbf/in ²
	$f_{ref} = 6M/Wt^2$ (for Figure 2.2)	N/m ²	lbf/in ²
	$f_{ref} = 6M/W^2t$ (for Figure 2.4)	N/m ²	lbf/in ²
M	bending moment in bar	N m	lbf in
P	direct load in bar	N	lbf
t	thickness of bar	m	in
W	width of bar	m	in

2.2 Notes

Figure 2.1. Values of K_1 are plotted against d/W for various values of h/W for a circular hole in a flat bar or strip in tension. The tension load is uniformly distributed across sections of the bar some distance away from the hole. The maximum stress occurs at site 1 on the edge of the hole at the point nearest to the edge of the bar.

Figure 2.2. Values of K_1 and K_2 are plotted against d/W for various values of t/W for a hole centrally placed in a flat bar or strip subjected to out-of-plane bending. The maximum stress occurs at sites 1 on the edge of the hole at the points nearest to the edge of the bar.

Figure 2.3. Values of K_1 and K_2 are plotted against d/W for a hole centrally placed in a flat bar or strip in tension. The curve for K_1 is the $h/W = 0.5$ curve of Figure 2.1 and is replotted here to facilitate its use in conjunction with curve K_1 in Figure 2.4 in cases of combined loading. Similarly K_2 is presented for use with K_2 in Figure 2.4. The maximum stress occurs at sites 1 on the edge of the hole at the points nearest to the edge of the bar.

Figure 2.4. Values of K_1 and K_2 are plotted against d/W for a hole centrally placed in a flat bar or strip subjected to in-plane bending. The maximum stress occurs at sites 1, shown in the diagram, for d/W values above 0.46, and at sites 2 for lower values of d/W .

The data in Figures 2.1 to 2.4 do not apply to filled holes.

Figure 2.1 is based on Derivations 5 and 16, Figure 2.2 is based on Derivations 13 and 14, Figure 2.3 is based on Derivations 2, 9, 10, 18 and 23, and Figure 2.4 is based on Derivations 3, 12 and 18 listed in Section 6.

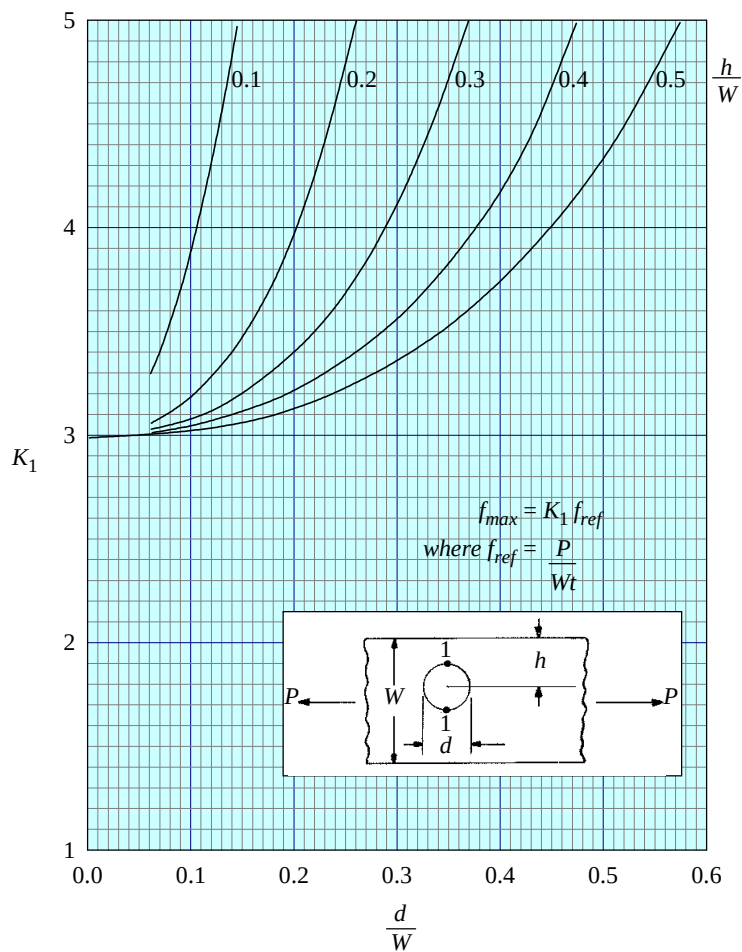


FIGURE 2.1 TENSION

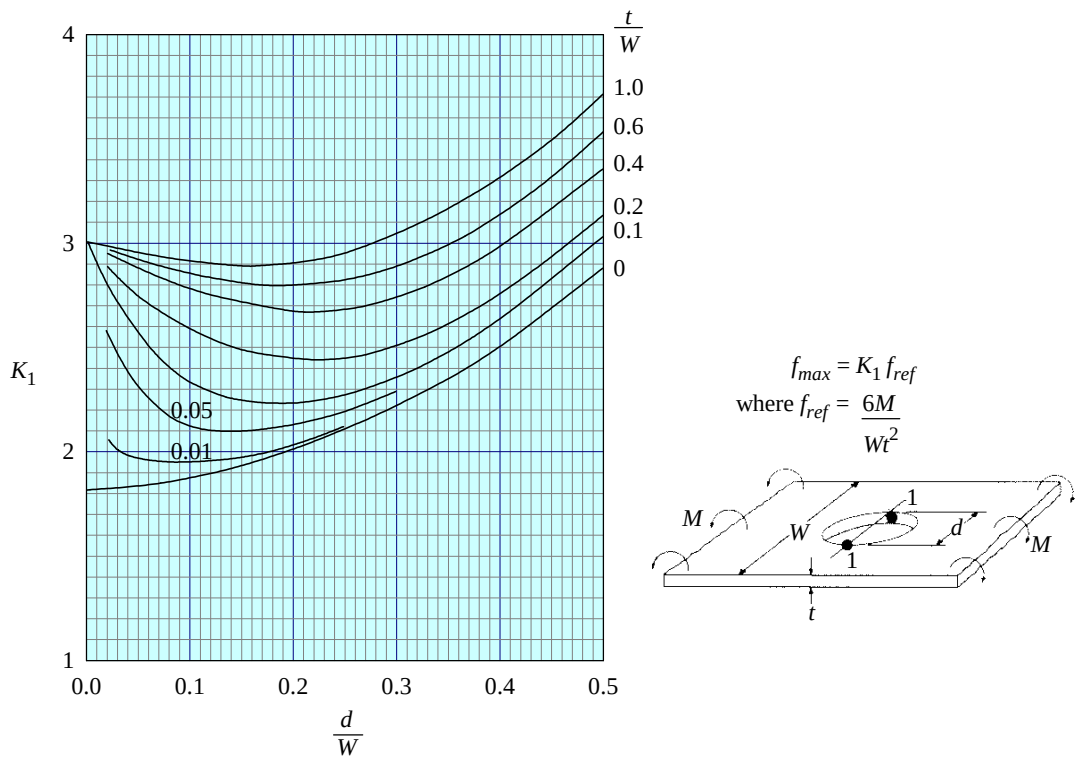


FIGURE 2.2 BENDING OUT OF PLANE

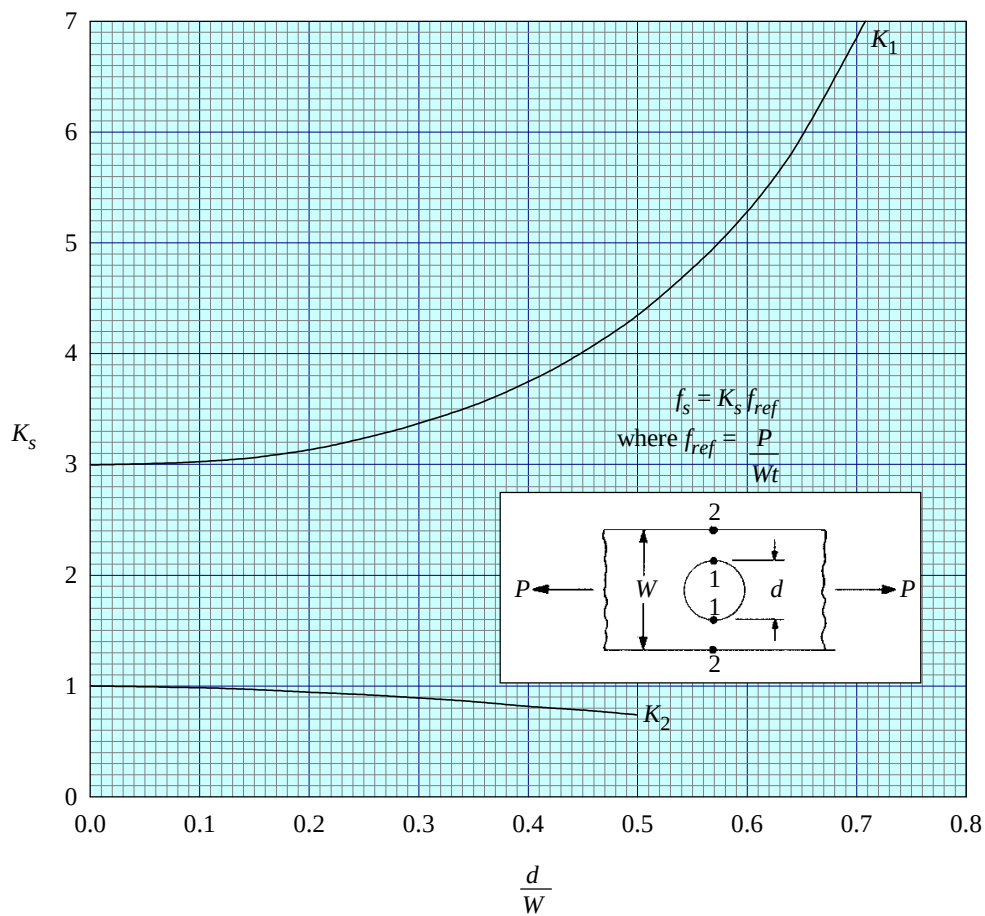


FIGURE 2.3 TENSION

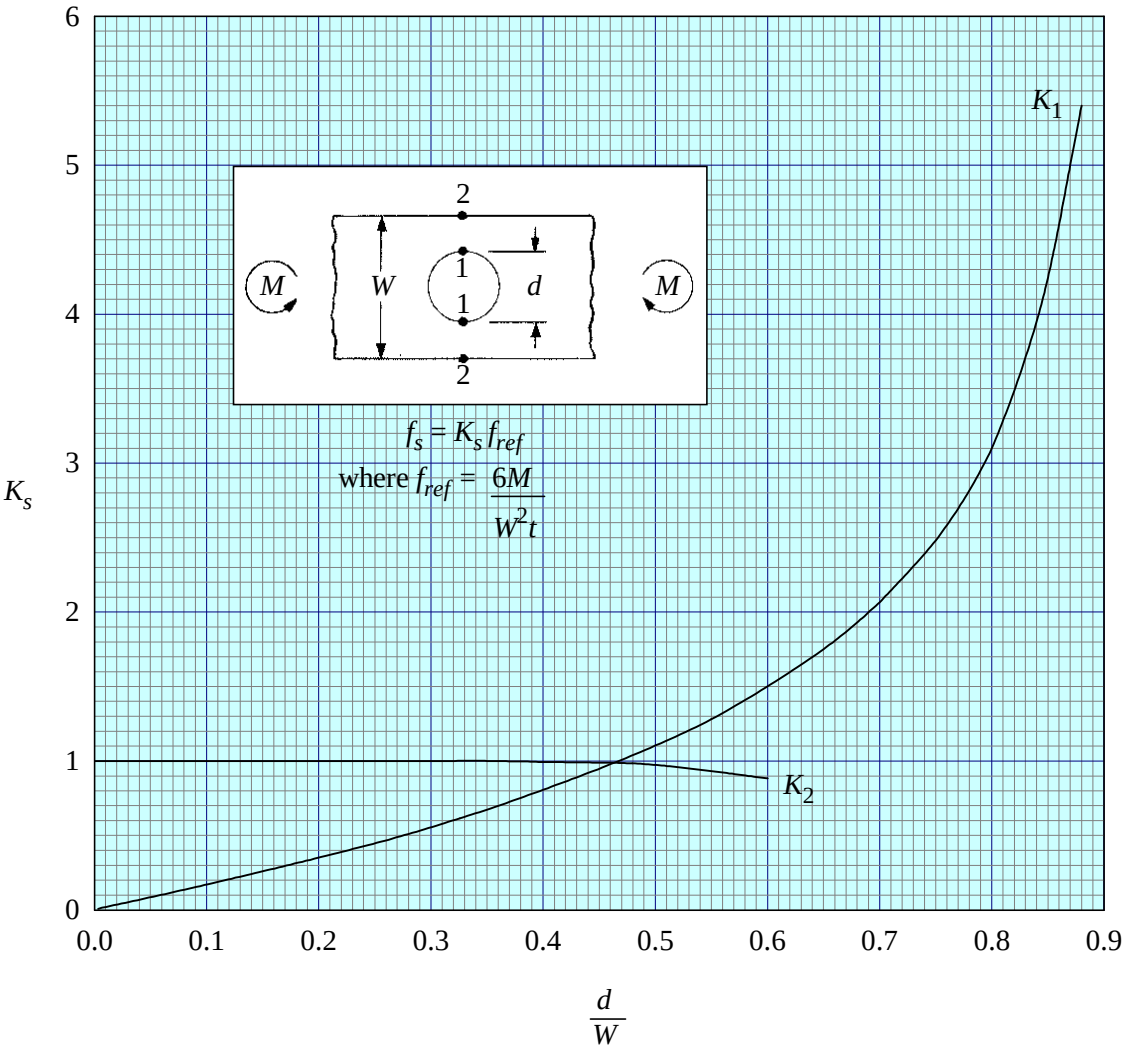


FIGURE 2.4 BENDING

3. TRANSVERSE SLOTS

3.1 Notation

f_{max}	maximum stress in bar	lbf/in ²	N/m ²
$2h$	length of slot	in	m
K'	Stress concentration factor defined by		
	$f_{max} = K' f_{ref}$ $\text{where } f_{ref} = \frac{P}{(W - 2h)t}$	lbf/in ²	N/m ²
P	direct load in bar	lbf	N
r	radius of end of slot	in	m
t	thickness of bar	in	m
W	width of bar	in	m

3.2 Notes

Values of K' are plotted against $r/2h$ for various values of $2h/W$ for a transverse slot centrally placed in a flat bar or strip in tension. The curves may be applied with sufficient accuracy for practical purposes to any of the three types of slot shown in the diagram, *i.e.* parallel-sided slot with semi-circular ends, narrow slot with circular ends and elliptical slot. In each case the maximum stress occurs at sites 1 at the ends of the slot.

The data in Figure 3.1 do not apply to filled slots.

Figure 3.1 is based on Derivations 1, 6, 17 and 26 listed in Section 6.