

STRESS CONCENTRATIONS: INTERACTION AND STRESS DECAY FOR SELECTED CASES

1. NOTATION

a	semi-axis of ellipse parallel to x -axis	m	in
b	semi-axis of ellipse parallel to y -axis	m	in
f_{ref}	reference stress, (see appropriate figure)	N/m ²	lbf/in ²
f_{max}	maximum stress	N/m ²	lbf/in ²
f_x	direct stress acting parallel to x -axis at any point in plate	N/m ²	lbf/in ²
f_y	direct stress acting parallel to y -axis at any point in plate	N/m ²	lbf/in ²
K_t	elastic stress concentration factor (as defined on figures)		
L	centre distance between end notches in a group	m	in
P	applied tensile load	N	lbf
r	radius of notch root or hole	m	in
t	thickness of plate	m	in
W	plate width	m	in
w	ligament width between holes or notches in a plate or between notches and plate edge	m	in
x	distance from centre of ellipse (see Figures 1, 2 and 3)	m	in
z	distance from notch root (see Sketch 3.3)	m	in
ρ	radius of curvature of ellipse end	m	in

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

2. INTRODUCTION

This Item presents data on the decay of stress away from a stress concentration, and the interaction occurring between stress concentrations for selected cases. This information is particularly useful in design when it is proposed to create an additional stress concentration in the vicinity of an existing stress concentration. The extent of influence of each feature, with regard to stress, must be assessed in order to establish whether or not an interaction between them is likely to occur. Table 2.1 provides information on the features together with the loading combinations for which data are provided.

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TABLE 2.1

Feature	Loading conditions	Figure number	Derivation number
Elliptical hole in wide plate	Uniaxial stress f	1	2
	Biaxial stress f	2 and 3	1 and 2
Finite width plate with two holes	Uniaxial load P	4 and 5	6
Finite width plate with semi-circular notches	Uniaxial load P	6	3 and 4

3. GENERAL NOTES

The data apply strictly to isotropic materials that obey Hooke's law. However, over the practical working range most engineering materials conform substantially in these respects and for them the data may be used without significant error. Note that if the maximum stress at any point exceeds the elastic limit of the material, the stresses will be redistributed and will give rise to residual stresses of the opposite sign on unloading. (See either Data Item No. 75022* or 76014†).

* Data Item No. 75022 "Design against fatigue. Basic design calculations".

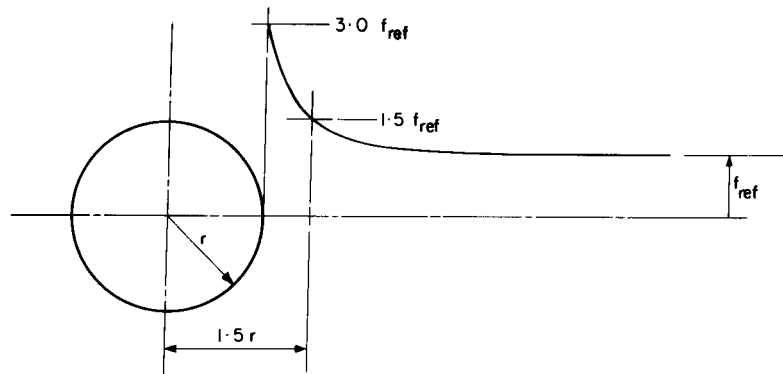
† Data Item No. 76014 "Estimation of endurance and construction of constant amplitude SN curves from related data corrected for notch and mean stress effects".

3.1 Decay of Stress Away From a Concentration

The exact form of stress decay away from a concentration will vary according to the particular feature and loading conditions involved. However, in the absence of any more detailed information it may be assumed that the stress decays to the value remote from the stress concentration along an approximately exponential curve, with the initial rate of decay being greater for higher stress concentration factors. Some general guidelines for estimating likely stress decay are given in the following examples.

3.1.1 A circular hole in a uniaxially loaded infinite plate

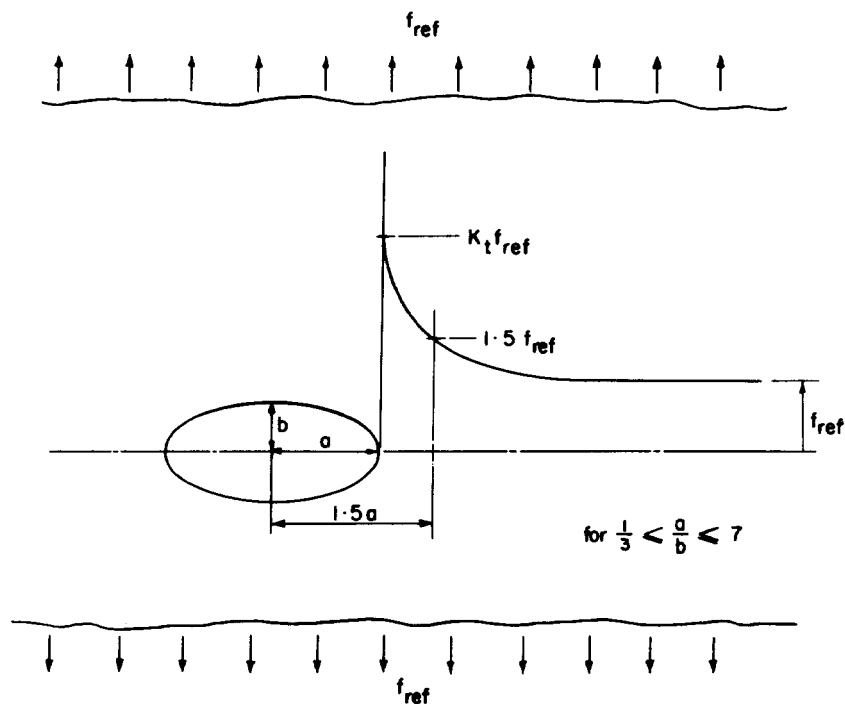
In this case the peak stress reduces from a value of $3f_{ref}$ to a value of approximately $1.5f_{ref}$ at a distance of 1.5 times the hole radius from the hole centre as shown in Sketch 3.1.



Sketch 3.1

3.1.2 An elliptical hole in a uniaxially loaded infinite plate

A similar stress decay curve arises for this case as shown in Sketch 3.2.



Sketch 3.2

3.1.3 Deep edge notches in a finite width plate

In this case an approximate solution for stress decay has been given in Derivation 5. This solution approximates to that obtained in Derivation 2 for deep hyperbolic notches. It suggests that in the region close to the notch radius, where f_y is greater than f_{ref} , the stress in the y -direction with increase in distance z from the notch root is given by

$$f_y = K_t f_{ref} \left(\frac{r}{r + 4z} \right)^{1/2}, \quad (3.1)$$

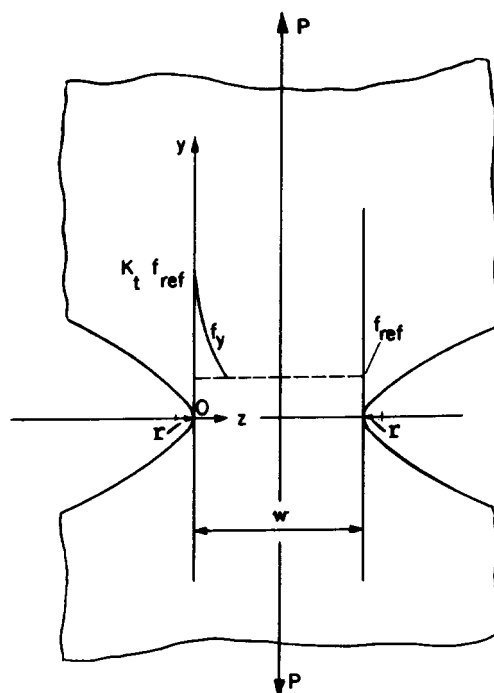
where $f_{ref} = P/(wt)$ (3.2)

and, for deep hyperbolic notches,

$$K_t = \frac{2(\gamma + 1)(\gamma)^{1/2}}{(\gamma + 1) \left\{ \arctan(\gamma)^{1/2} \right\} + (\gamma)^{1/2}}, \quad (3.3)$$

where $\gamma = (w/2r)$.

This is illustrated in Sketch 3.3.

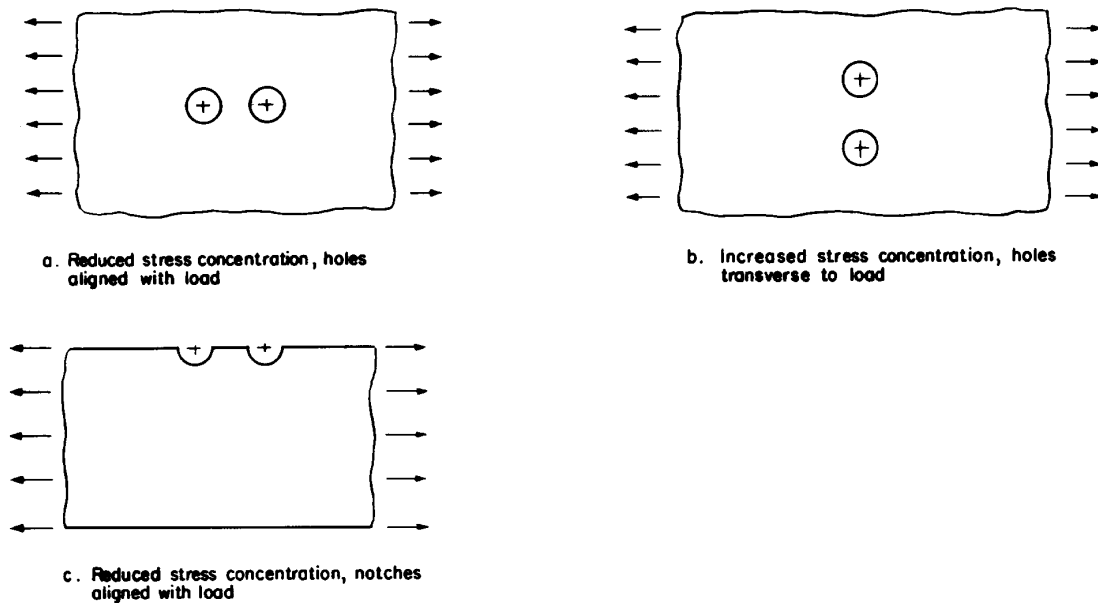


Sketch 3.3

3.2 Interaction of Stress Concentrations

When two geometrical features each of which produces a stress concentration are in close proximity the stress fields that they produce will interact. The interaction will produce a different stress pattern, which may be either more or less severe. The combined stress concentration factor is greater than or less than that for a single feature depending upon whether the stress raising features are transverse or in-line with respect

to the applied loading. Examples of these effects are shown in Sketch 3.4.



Sketch 3.4 Effect on stress concentration factor of a pair of features compared to that of a single feature

3.3 Prediction of Likely Stress Interactions

Data involving certain stress interactions are already given in some other Data Items. (Refer to Data Items Nos 67023^{*}, 69020[†] and 75007[‡].) In the absence of any definitive data an estimate of likely stress interactions between features can be made as follows.

3.3.1 Stress raising features transverse with respect to the applied loading

In this case an estimate of the likely effect of stress interactions can be made using a superposition method as illustrated in the following example. It is required to estimate the maximum stress occurring between two unequal diameter holes in a wide plate subjected to a uniaxial stress f_{ref} as shown in Sketch 3.5.

^{*} Data Item No. 67023 "Geometric stress concentrations. Two equal unreinforced circular holes in infinite flat plates".

[†] Data Item No. 69020 "Elastic stress concentration factors. Geometric discontinuities in flat bars or strips of isotropic materials".

[‡] Data Item No. 75007 "Geometric stress concentration factors: two adjacent unreinforced circular holes in infinite flat plates".