Mechanics of Materials I:

Fundamentals of Stress & Strain and Axial Loading

Dr. Wayne Whiteman
Senior Academic Professional and Director of the Office of Student Services
Woodruff School of Mechanical Engineering

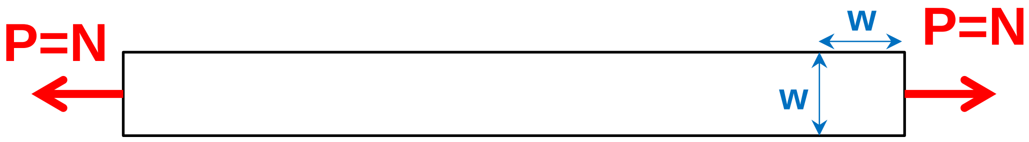
Georgia Institute of Technology

Module 27 Learning Outcomes

- Define Stress Concentrations
- Describe “Saint-Venant’s Principle”
- Employ Stress Concentration Factors to calculate maximum stresses at discontinuities in structural and machine elements

Stress Concentrations

- For axially loaded bars, we assumed average uniform stress over the cross-sectional area.
- Discontinuities in the structural or machine element (notches, holes, grooves, or other abrupt changes in geometry), disrupt the stress path.
- Stresses may be considerably higher in these areas.
- We call these areas of higher stress, “Stress Concentrations.”
- Stress Concentrations also appear at points of loading, where high stresses occur at points of application.



Width w, thickness t or diameter d [largest lateral dimension]

$$\sigma = \frac{N}{A}$$

is nearly uniform a distance w (or d) from end

This also hold true for the distance from discontinuities (notches, holes, etc.)

This is a general observation for most linearly elastic bodies and is known as “Saint-Venant’s Principle” (French mathematician, 1797-1886)

Stress Concentrations

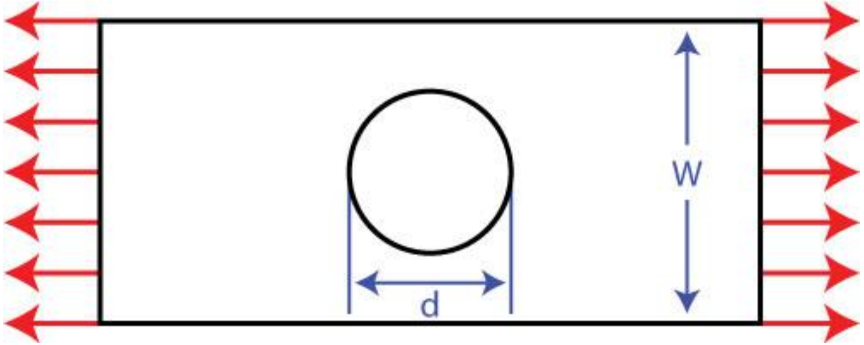
The ratio of the maximum stress to the average stress is called the "Stress Concentration Factor, K"

$$\sigma = K\left(\frac{N}{A}\right)$$

Be careful: Could be based on gross or net section area

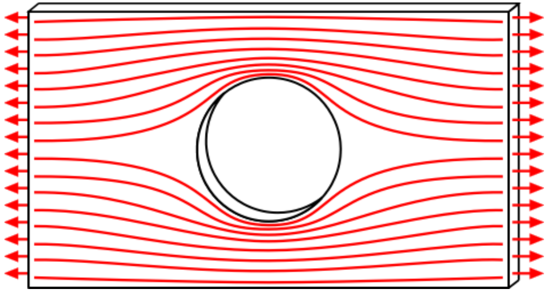
Example: Axially Loaded Bar with a Hole

$$\sigma = \frac{N}{A}$$



$$\sigma = \frac{N}{A}$$

Adapted from "Photoelastic Studies in Stress Concentration," M.M. Frocht, Mechanical Engineering, August 1936.

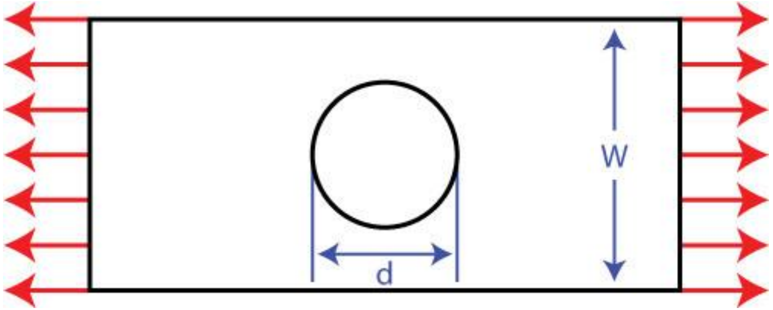


By Kaidor (Own work based on File:HoleForceLines.gif) [CC BY-SA 3.0 (http://creativecommons.org/licenses/by-sa/3.0)], via Wikimedia Commons

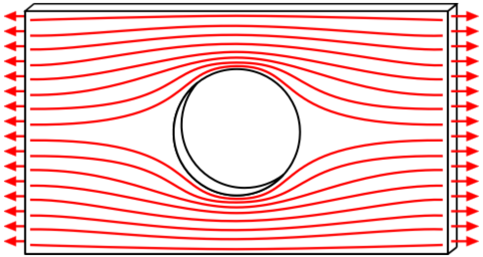
Example: Axially Loaded Bar with a Hole

Georgia Tech

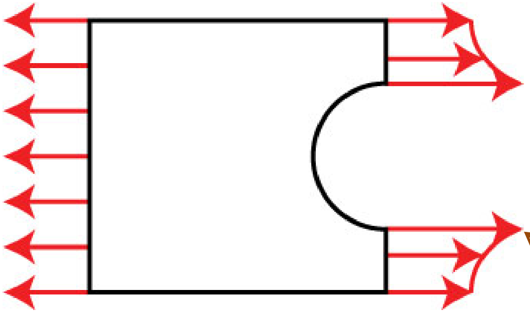
$$\sigma = \frac{N}{A}$$



$$\sigma = \frac{N}{A}$$



$$\sigma = \frac{N}{A}$$

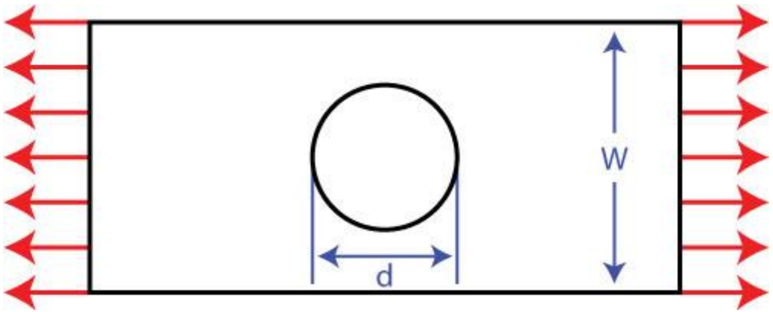


$$\sigma = K\left(\frac{N}{A}\right)$$

Max stress

Example: Axially Loaded Bar with a Hole

$$\sigma = \frac{N}{A}$$

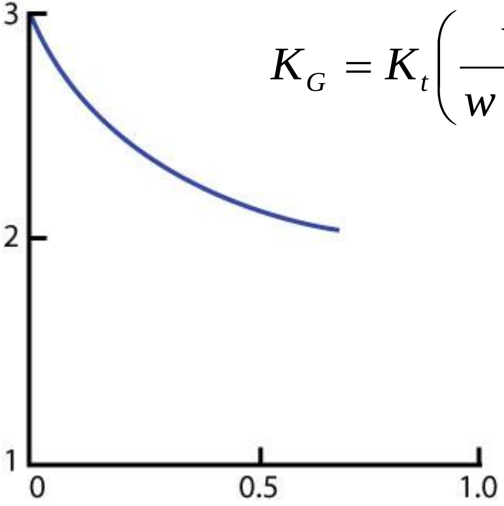


$$\sigma = \frac{N}{A}$$

$$K_G = K_t\left(\frac{w}{w-d}\right)$$

Stress Concentration Factor

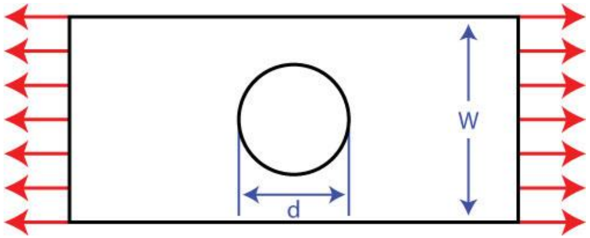
K_t



Ratio $\dfrac{d}{w}$

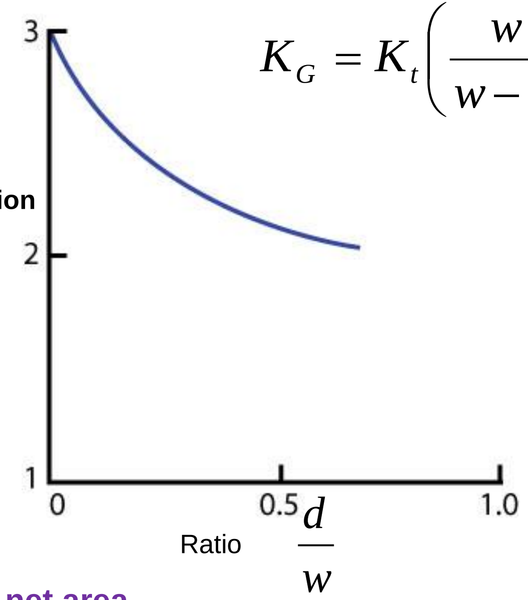
Adapted from “Photoelastic Studies in Stress Concentration,” M.M. Frocht, Mechanical Engineering, August 1936.

Example: Axially Loaded Bar with a Hole



Stress Concentration Factor

K_t

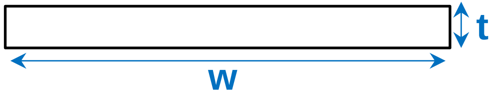


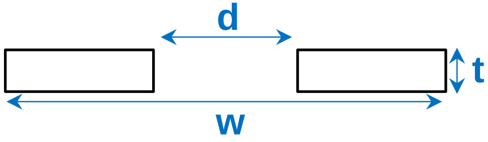
$$K_G = K_t\left(\frac{w}{w-d}\right)$$

$$K_G = K_t\left(\frac{w}{w-d}\right)$$

based on gross area

based on net area





$$A_G = t\,w$$

$$A_t = t(w-d)$$