The University of Tennessee at Martin

MARTIN School of Engineering

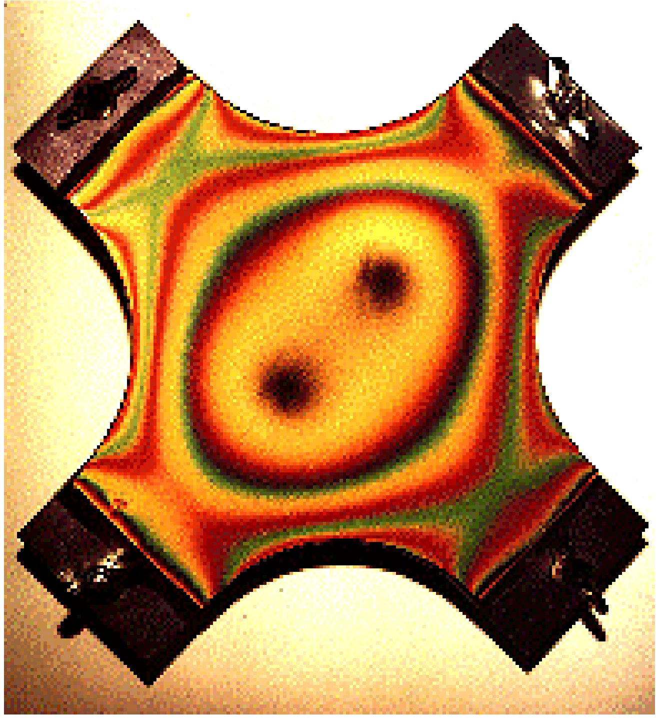
Stress Concentration Factors and Notch Sensitivity

Lecture 4

Engineering 473
Machine Design

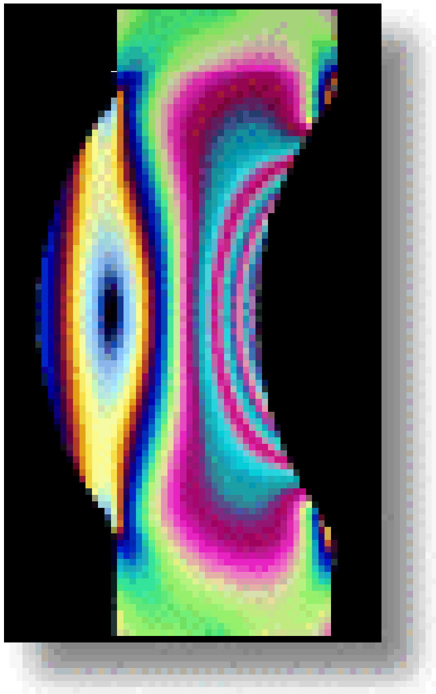
MARTIN

Photoelasticity



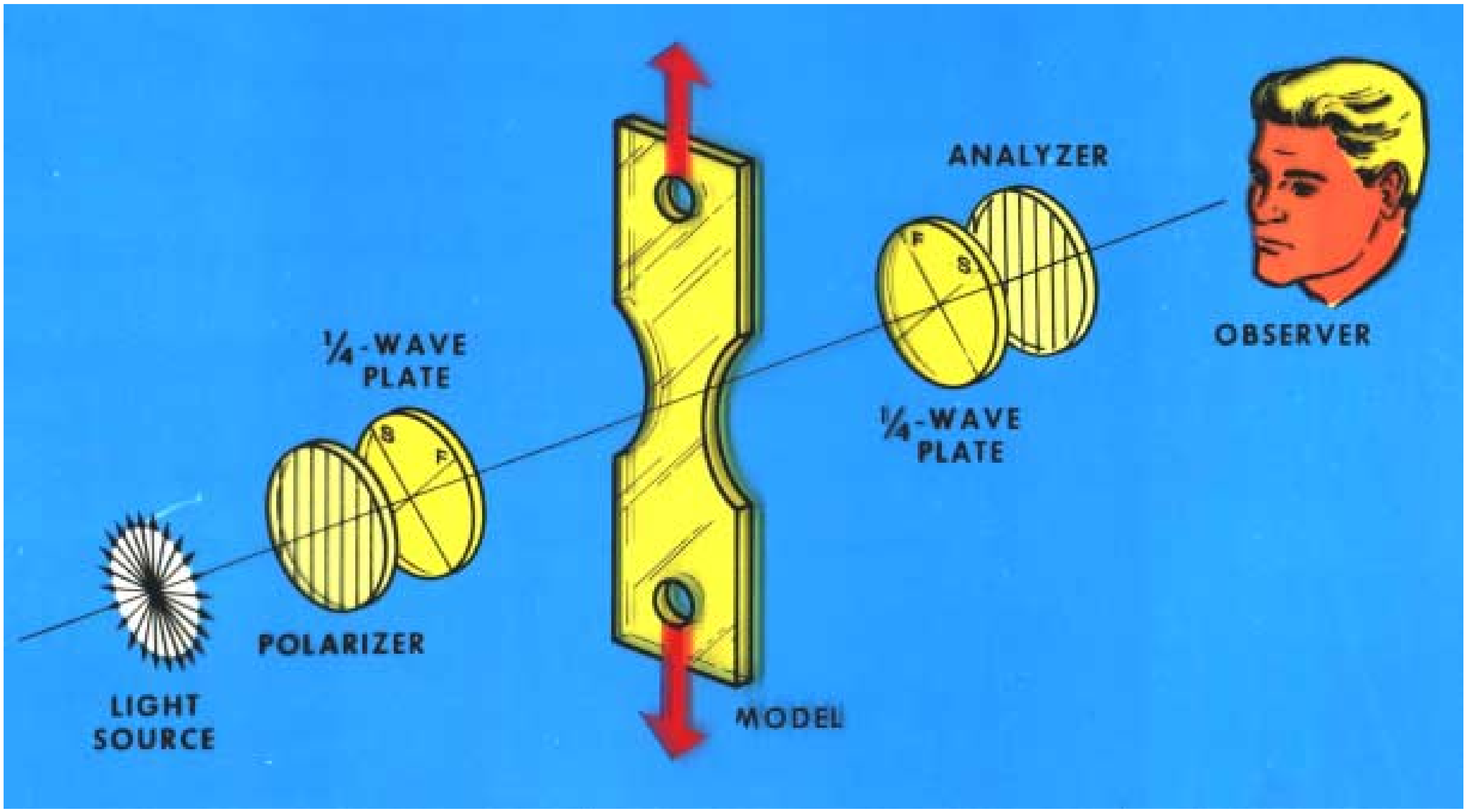
Photoelasticity is a visual method for viewing the full field stress distribution in a photoelastic material.

Photoelasticity
(Continued)



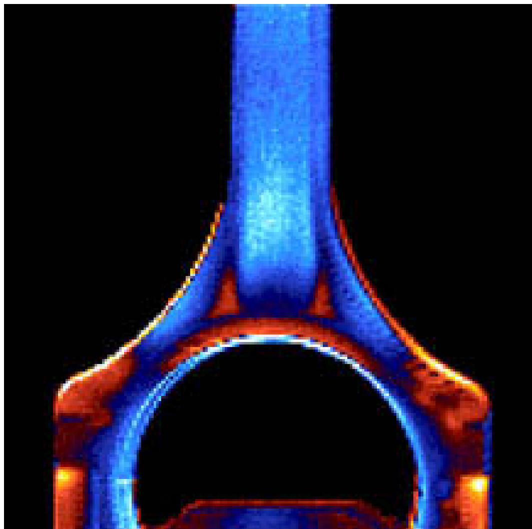
When a photoelastic material is strained and viewed with a polariscope, distinctive colored fringe patterns are seen. Interpretation of the pattern reveals the overall strain distribution.

Components of a Polariscope



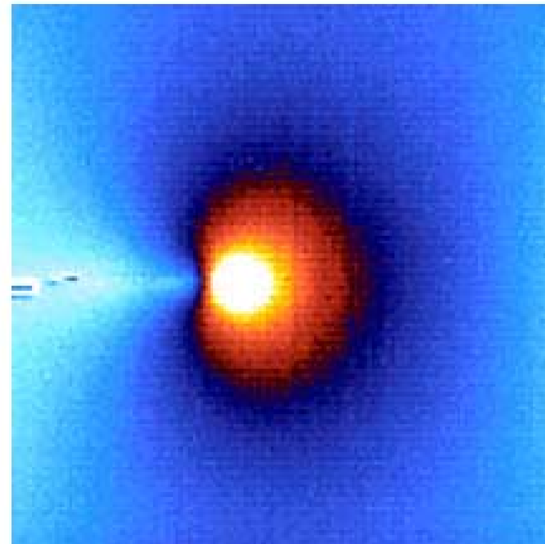
Vishay Lecture-Aid Series, LA-101

Radiometric Thermoelasticity



Automobile Connecting Rod

Hook and Clevis

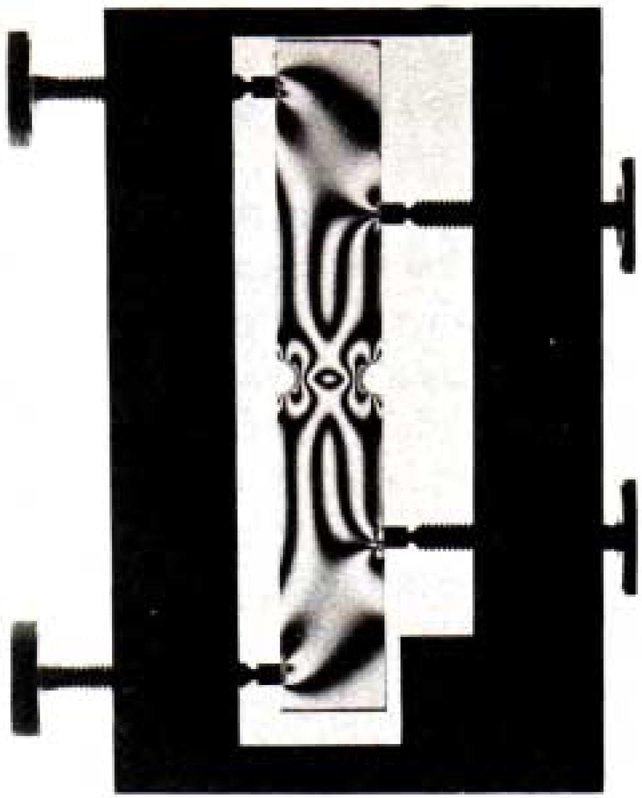


Crack Tip

When materials are stressed the change in atomic spacing creates temperature differences in the material. Cameras which sense differences in temperature can be used to display the stress field in special materials.

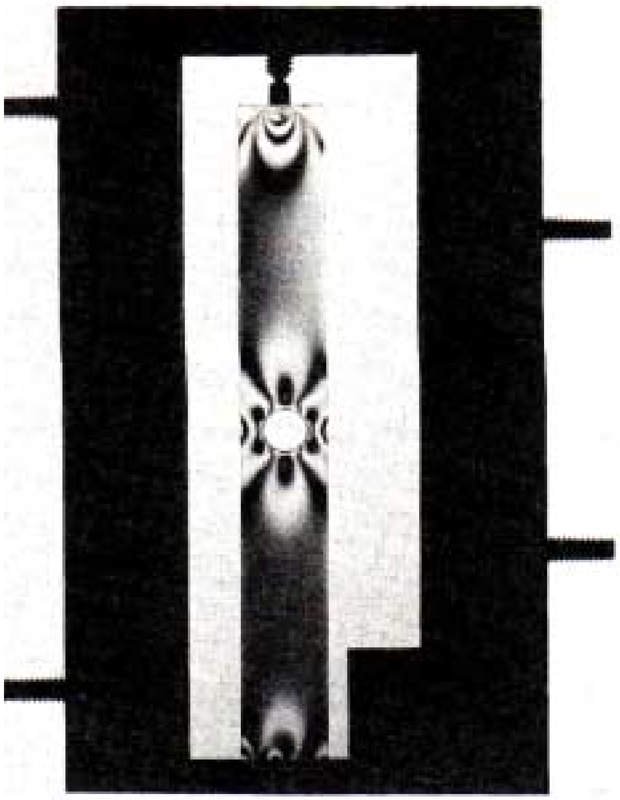
www.stressphotonics.com

Stress Distributions Around Geometric Discontinuities



(c)

Photoelastic fringes in anotched beam loaded in bending.

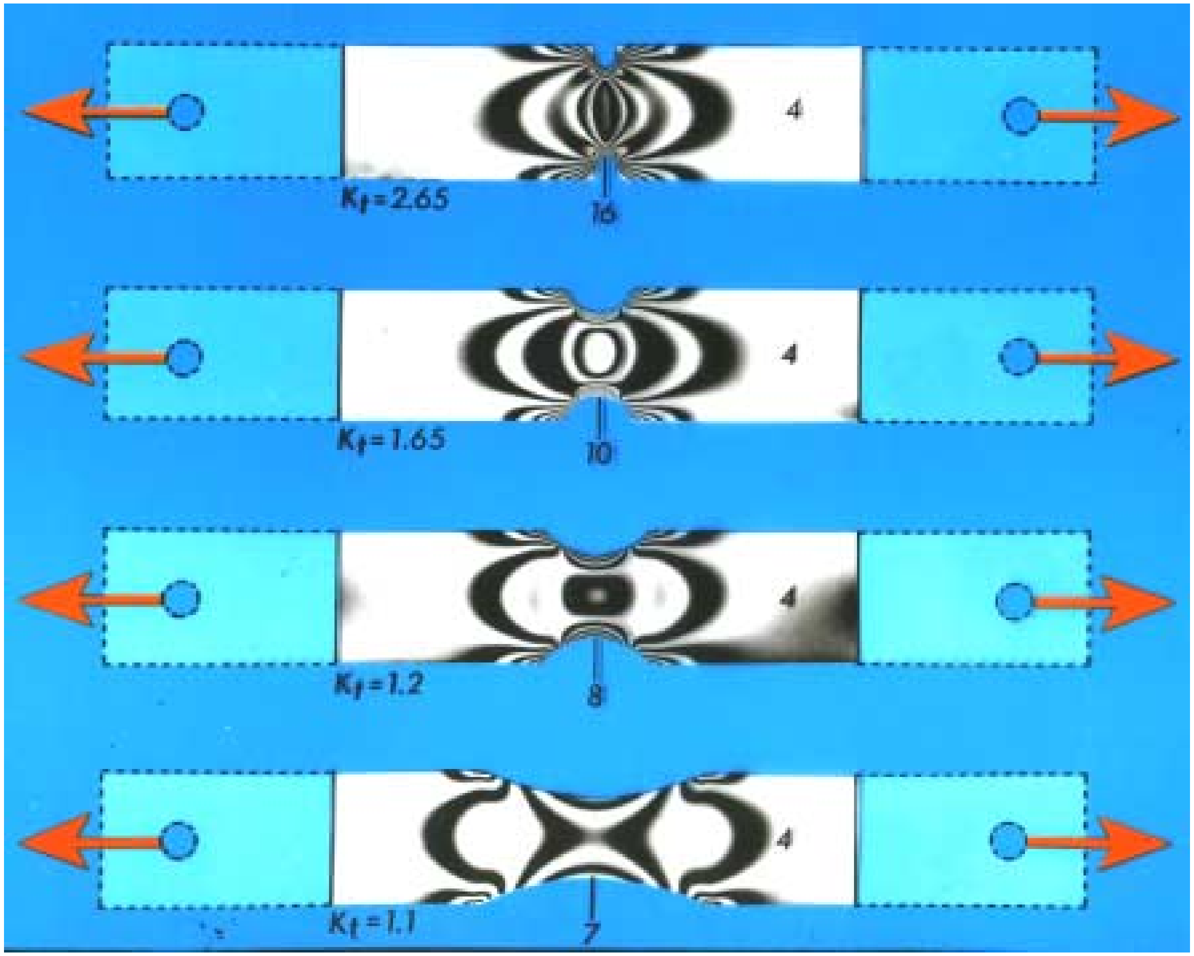


(b)

Photoelastic fringes in a narrow plate with hole loaded in tension.

Deutschman, Fig. 5-3

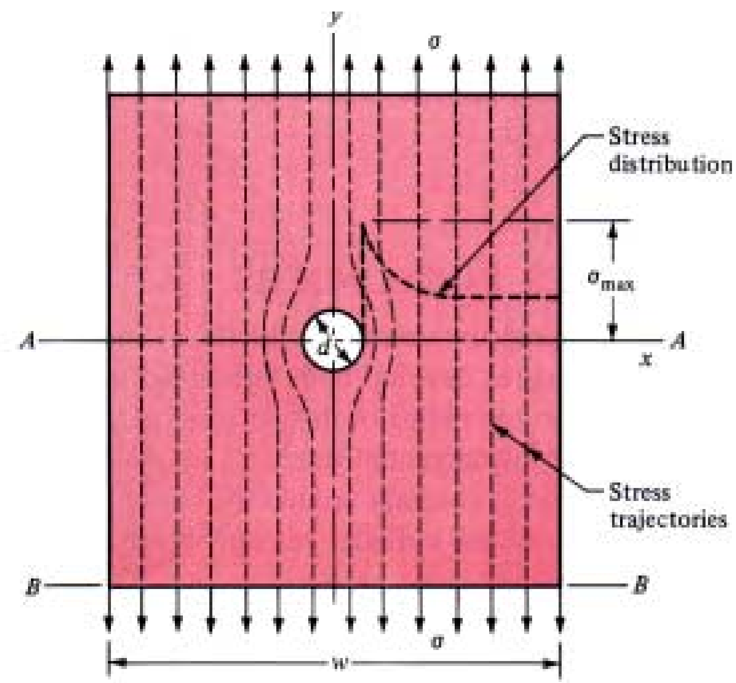
Effect of Discontinuity Geometry



The discontinuity geometry has a significant effect on the stress distribution around it.

Vishay Lecture-Aid Series, LA-101

Geometric Stress Concentration Factors



$$K_t = \frac{\sigma_{max}}{\sigma_{nom}}$$

$$\sigma_{nom} = \frac{F}{A_0}$$

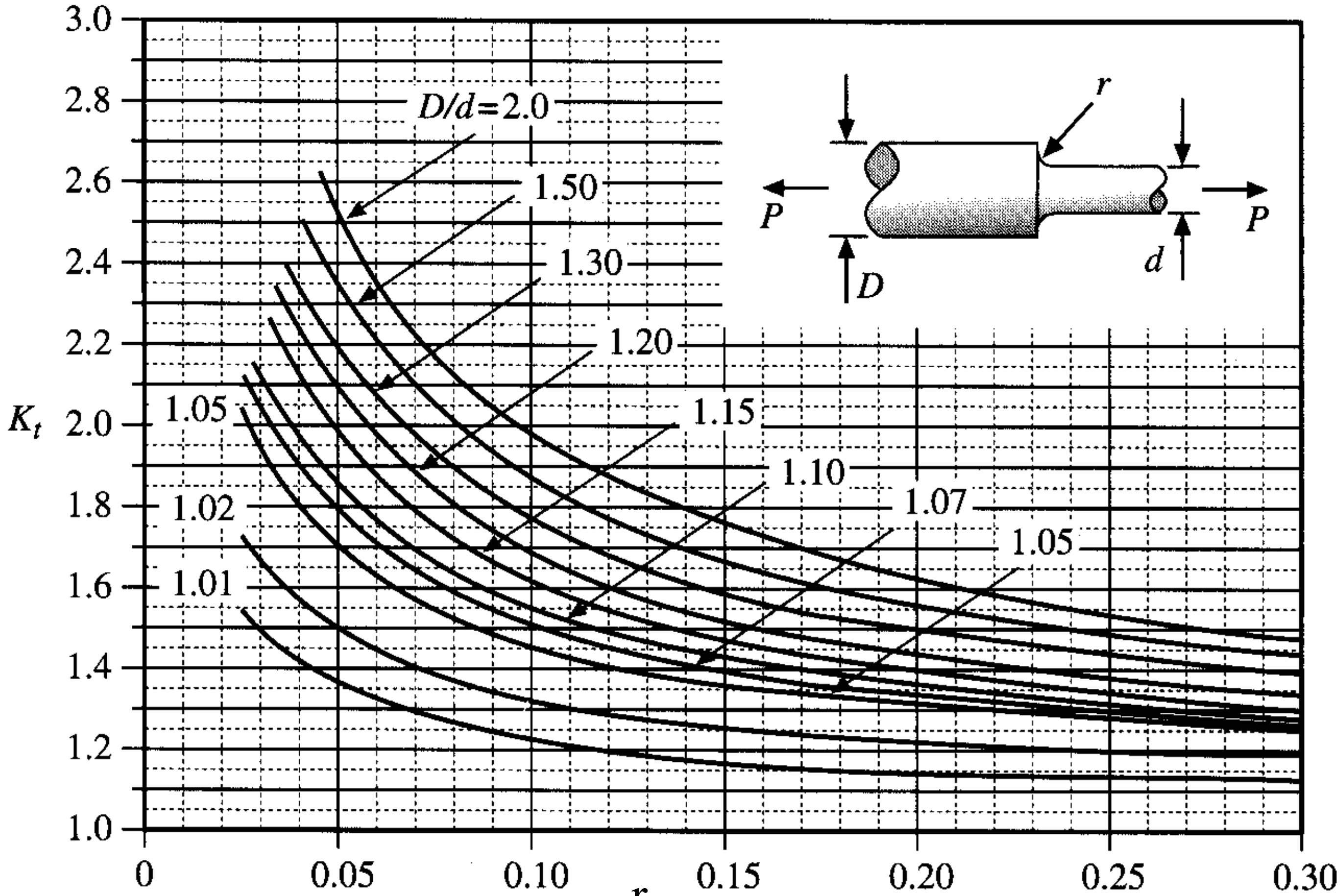
$$A_0 = (w - d)t$$

Geometric stress concentration factors can be used to estimate the stress amplification in the vicinity of a geometric discontinuity.

Shigley, Fig. 2-22

Geometric Stress Concentration Factors

(Tension Example)

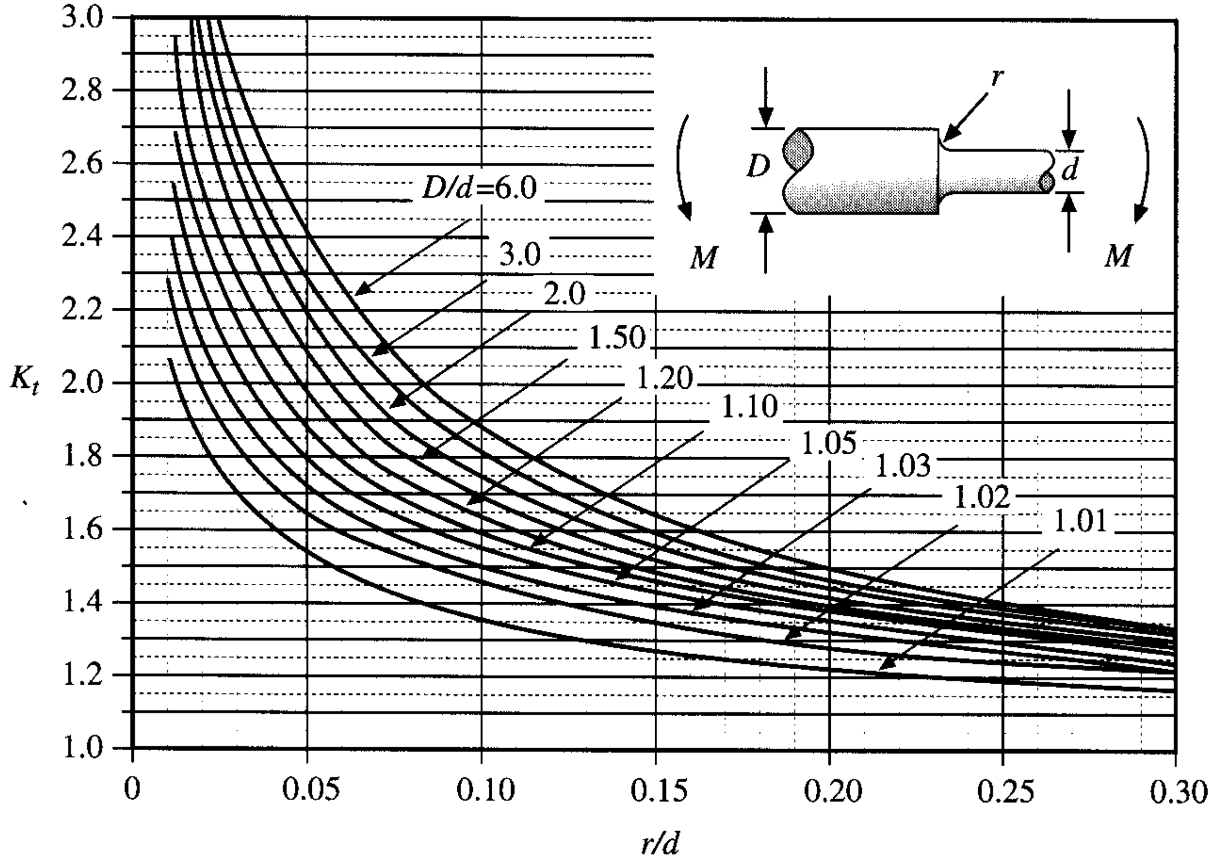


$\frac{r}{d}$

Spotts, Fig. 2-8, Peterson

Geometric Stress Concentration Factors

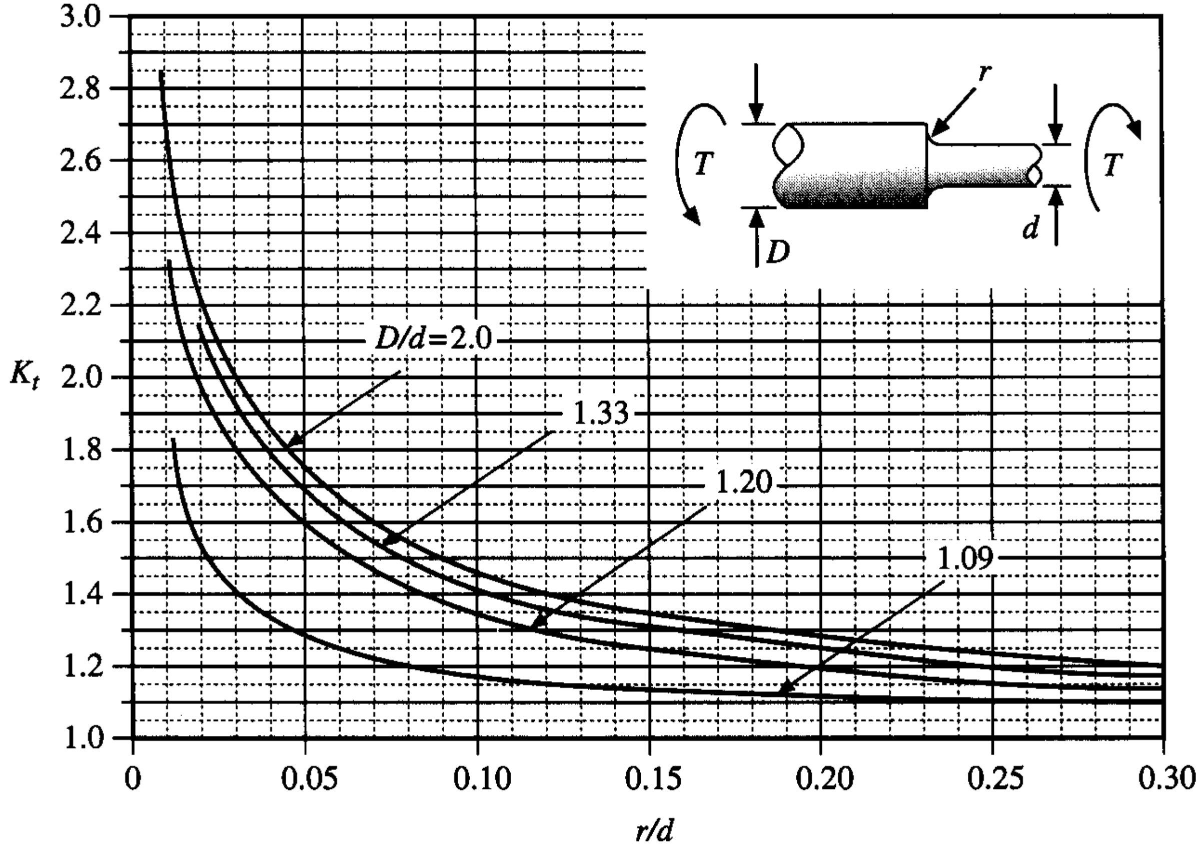
(Bending Example)



Spotts, Fig. 2-9, Peterson

Geometric Stress Concentration Factors

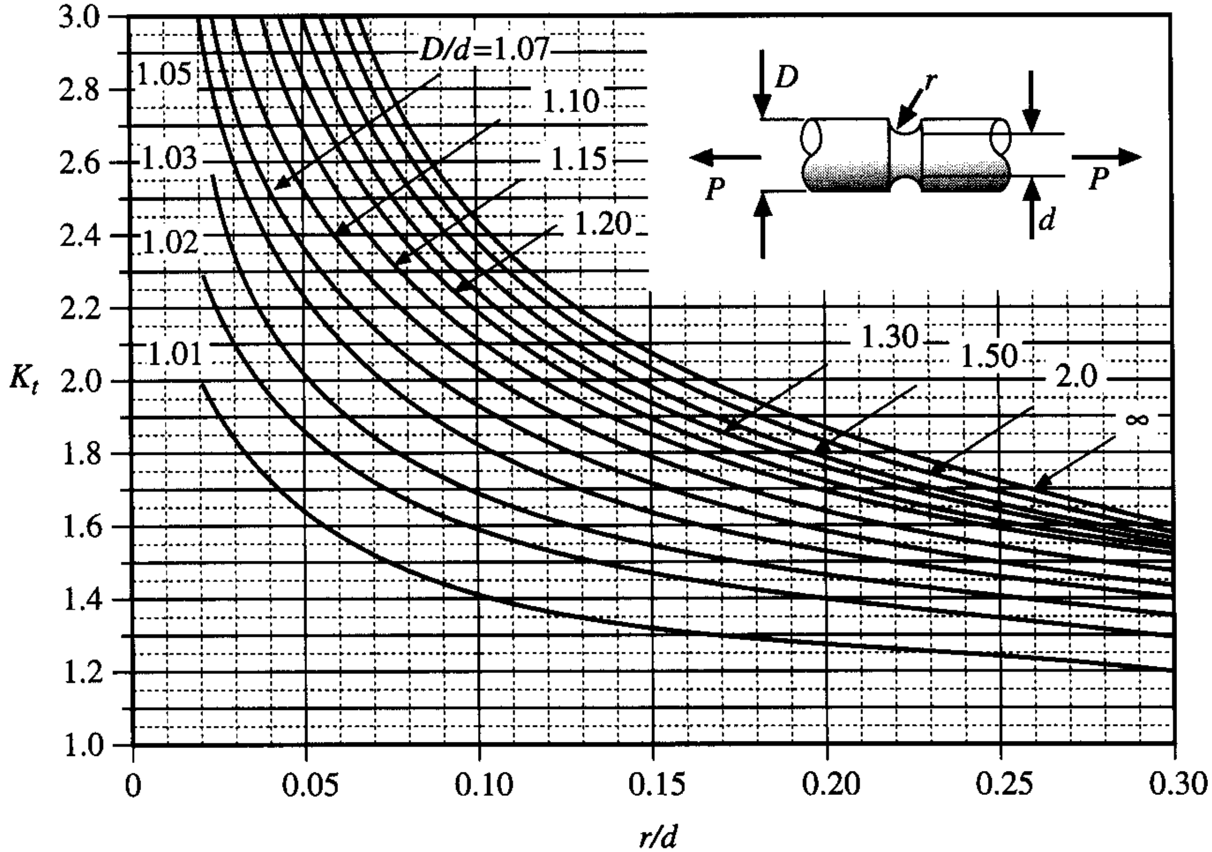
(Torsion Example)



Spotts, Fig. 2-10, Peterson

Geometric Stress Concentration Factors

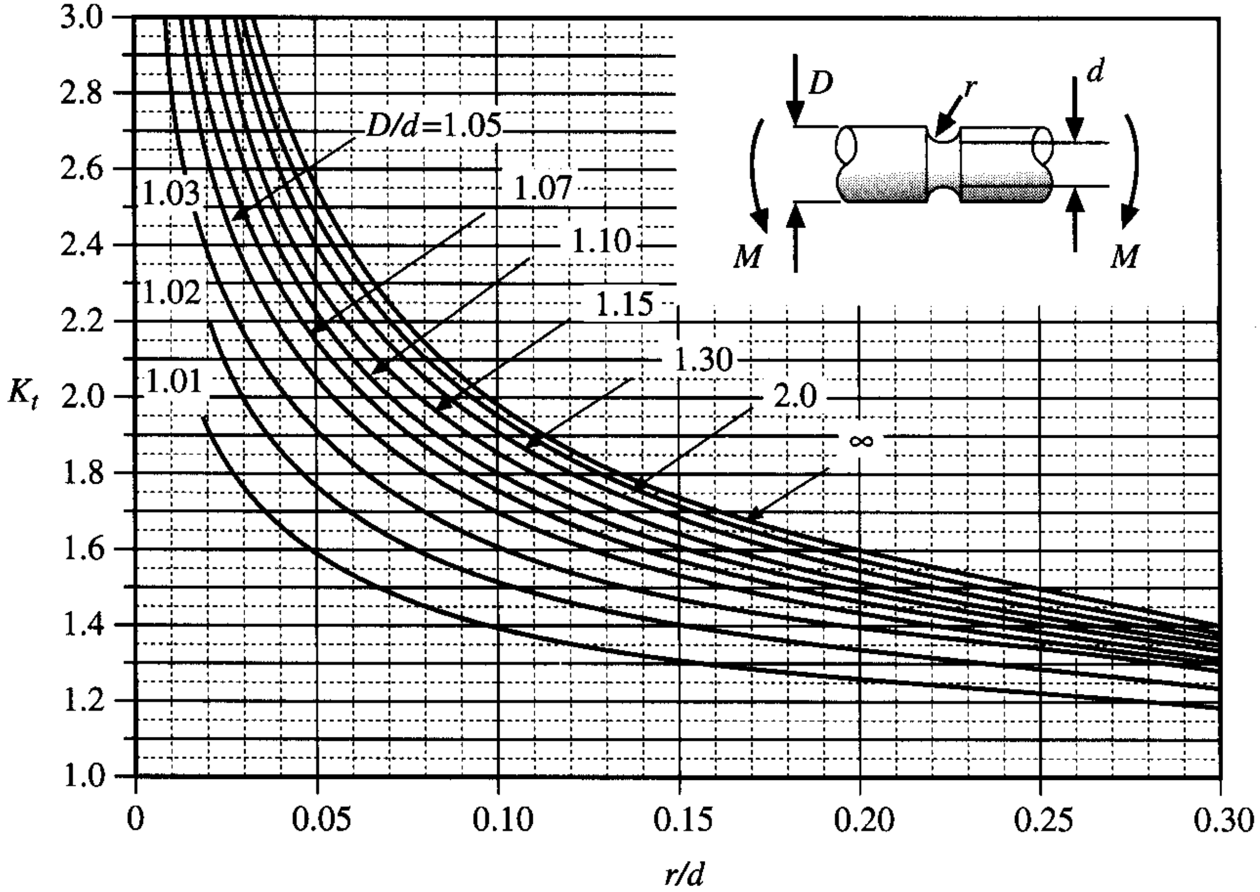
(Tension Example)



Spotts, Fig. 2-11, Peterson

Geometric Stress Concentration Factors

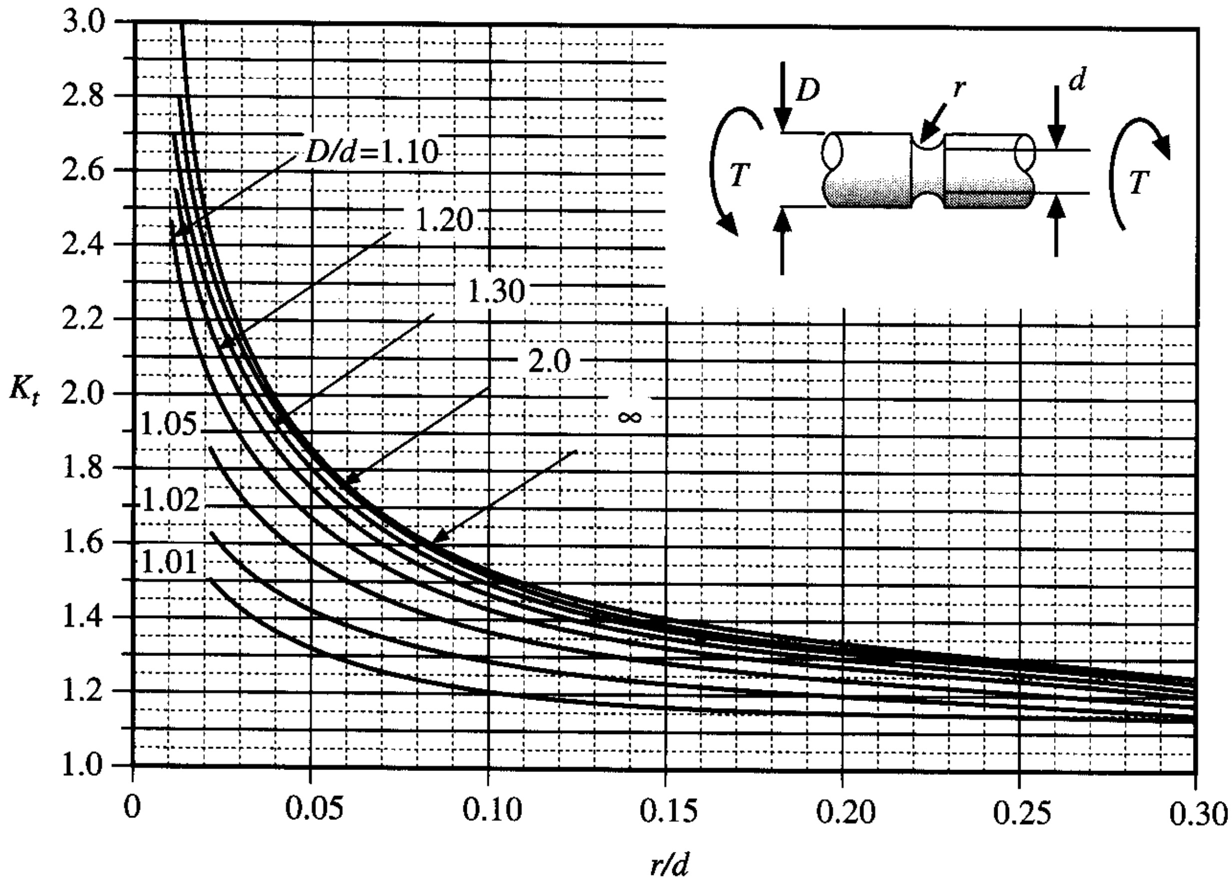
(Bending Example)



Spotts, Fig. 2-12, Peterson

Geometric Stress Concentration Factors

(Torsion Example)



Spotts, Fig. 2-13, Peterson

Geometric Stress Concentration Factors
(Summary)

K_t is used to relate the maximum stress at the discontinuity to the nominal stress.

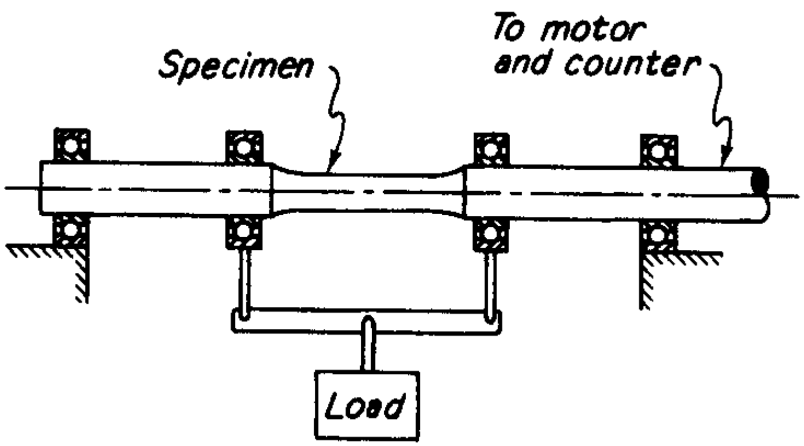
K_t is used for normal stresses

K_{ts} is used for shear stresses

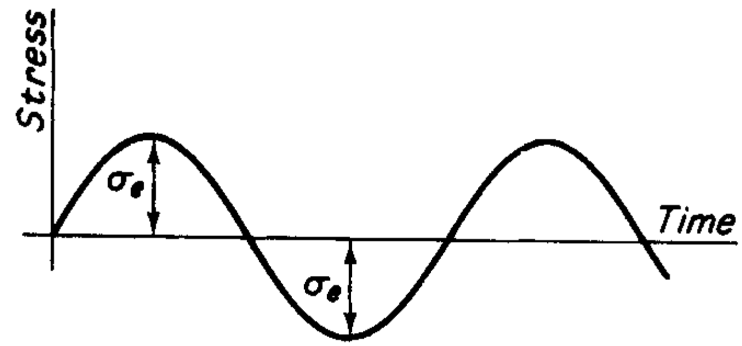
K_t is based on the geometry of the discontinuity

σ_{nom} is usually computed using the minimum cross section

Rotating Beam Fatigue Tests



(a) Machine for applying uniform bending moment to specimen

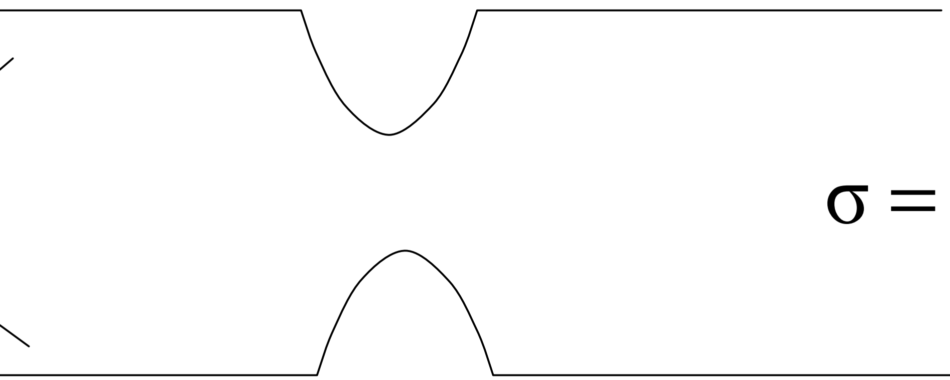


(b) Endurance limit stress is highest value of completely reversed bending stress for continuous operation

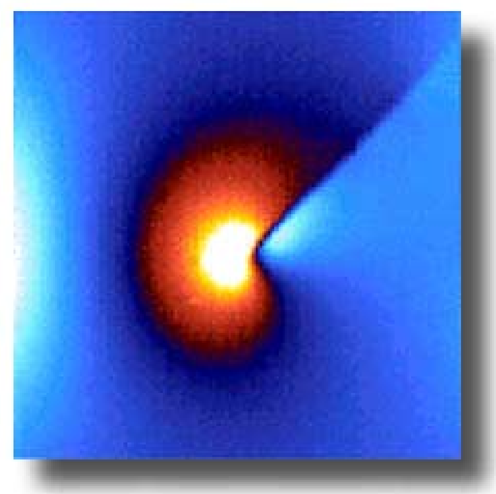
Spotts, Fig. 2-25

Un-notched and Notched Fatigue Specimens

~~$\sigma = K_t \frac{Mc}{I}$~~



$\sigma = K_f \frac{Mc}{I}$



Comparisons of fatigue test results for notched and un-notched specimens revealed that a reduced K_t was warranted for calculating the fatigue life for many materials.

www.stressphotonics.com

Fatigue Stress Concentration Factors

$$K_f = \frac{\text{Maximum stress in notched specimen}}{\text{Stress in notch - free specimen}}$$

or

$$K_f = \frac{\text{Endurance limit of a notched specimen.}}{\text{Endurance limit of a notch - free specimen.}}$$

Notch Sensitivity Factor

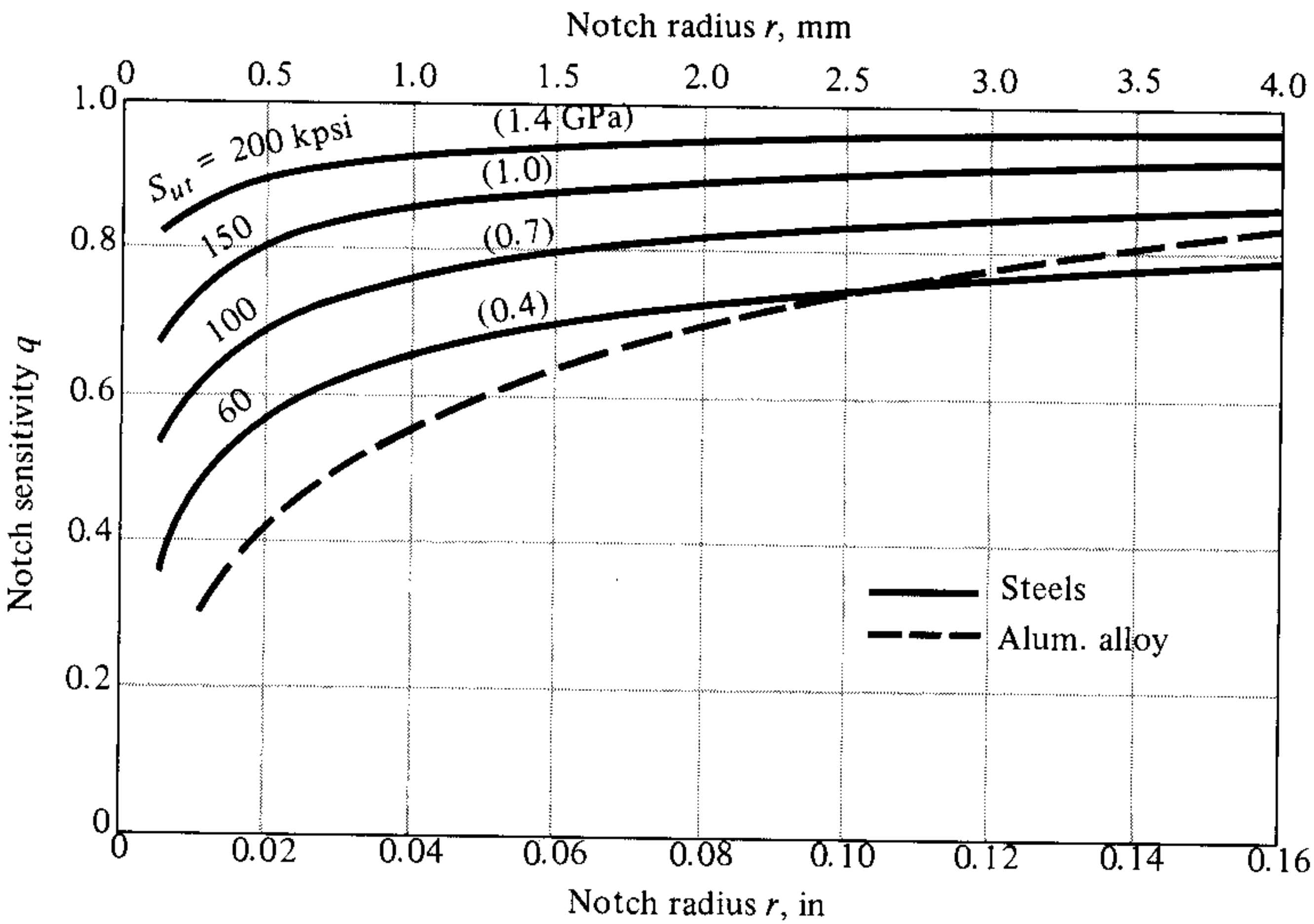
The notch sensitivity of a material is a measure of how sensitive a material is to notches or geometric discontinuities.

$$q = \frac{K_f - 1}{K_t - 1} \qquad 0 \le q \le 1$$

$$K_f = 1 + q\left(K_t - 1\right) \qquad 1 \le K_f \le K_t$$

Notch Sensitivity Factors

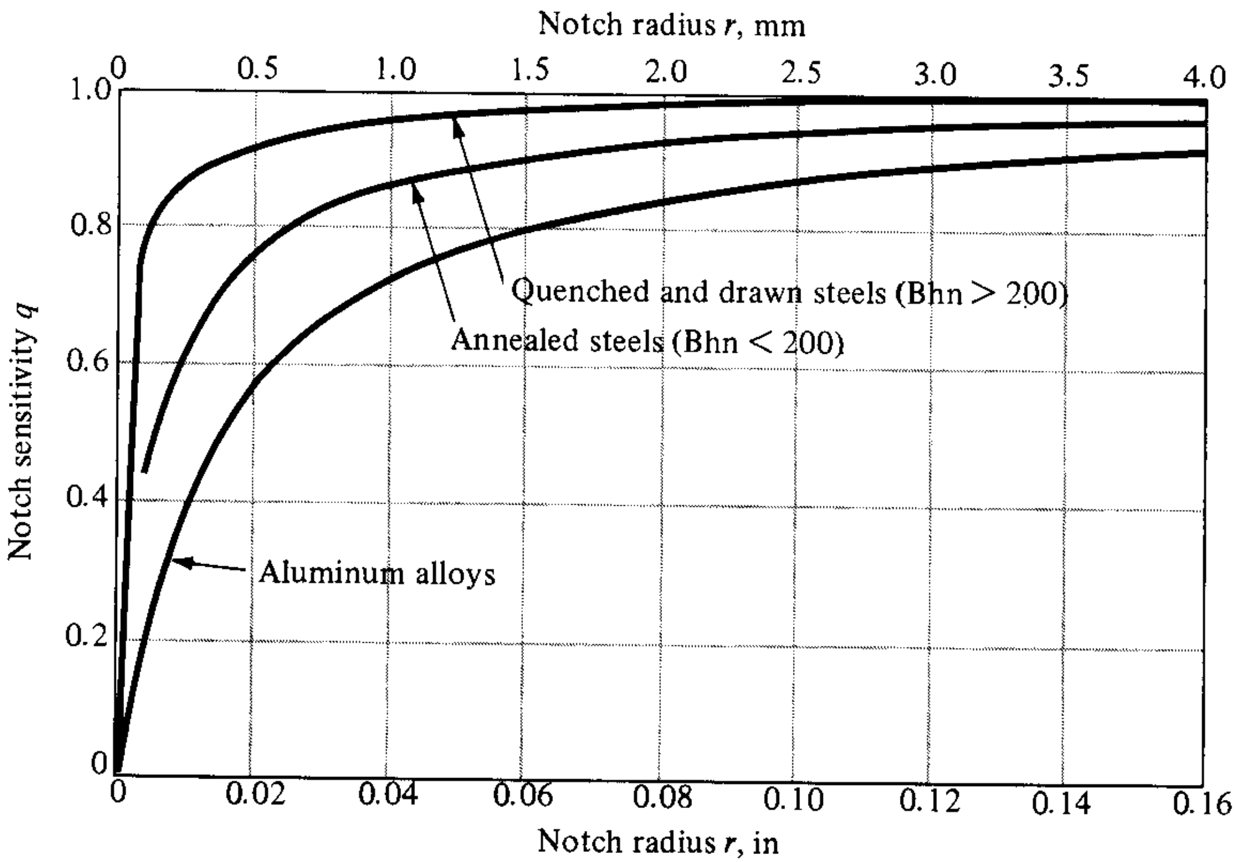
(Bending Example)



Shigley, Fig. 5-16

Notch Sensitivity Factors

(Torsion Example)



Shigley, Fig. 5-17

Fatigue Stress Concentration Factors

- K_f is normally used in fatigue calculations but is sometimes used with static stresses.
- Convenient to think of K_f as a stress concentration factor reduced from K_t because of lessened sensitivity to notches.
- If notch sensitivity data is not available, it is conservative to use K_t in fatigue calculations.

References

Deutschmann, A.D., W.J. Michels, C.E. Wilson, Machine Design: Theory and Practice, Macmillan, New York, 1975.

Peterson, R.E., "Design Factors for Stress Concentrations, Parts 1 to 5," Machine Design, February-July, 1951.

Shigley, J.E., C.R. Mischke, Mechanical Engineering Design, 5th Ed., McGraw-Hill, Inc., New York, 1989.

Spotts, M.F., Design of Machine Elements, 7th Ed., Prentice Hall, New Jersey, 1998.

www.measurementsgroup.com

www.stressphotonics.com

Assignment

1. Read – Sections 3-21 and 3-22

2. Find the most critically stressed location on the stepped shaft. Note that you will need to use the stress concentration factors contained in the lecture notes.