ME111
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Class #11
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Today's Topics

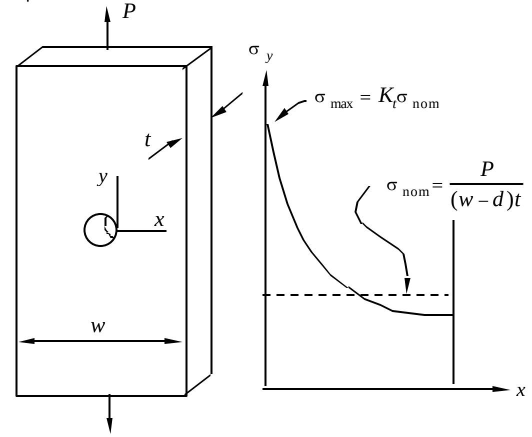
- The stress concentration phenomena and stress concentration factors.
- Avoiding stress concentrations in design.

Reading Assignment

Juvinall – Section 4.12-4.17

11.1 Stress Concentration Effects

- Changes (I.e. discontinuities) in the cross-sectional geometry of a machine element will give rise to locally high stresses that may cause failure of the part.
- Example:



- Define the nominal stress to be:

$$\sigma_{nom} = \frac{P}{A_{nom}} = \frac{P}{(w-d)t}$$

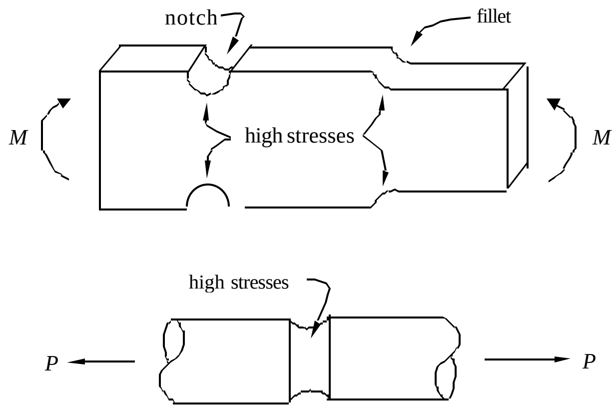
- Maximum stress near hole is:

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

where K_t is called the stress concentration factor.

11.2 Stress Concentration Effects in Design

- Many machine parts will have holes, notches, grooves, fillets, keyways and other sudden changes in geometry.
- These stress raisers can be very important in initiating failure of the part.



- Shafts can have steps, grooves and holes for the attachment of other parts -- any of these changes in the cross-sectional geometry will cause increases in the nominal stress value.

11.3 Stress Concentration Factor for Static Loads

- The stress concentration factor K_t can be determined experimentally or by using the finite element method

For normal stresses $K_t = \dfrac{\sigma_{max}}{\sigma_{nom}}$

For shear stresses $K_{ts} = \dfrac{\tau_{max}}{\tau_{nom}}$

- Use according to following guidlines:

Ductile Materials

Do not use stress concentration factor (ignore stress raiser) if:

If yielding can be allowed (this is usually the case), but base stress analysis on the net (reduced) area.

Do use stress concentration factor if:

Local yielding must be avoided for the design purpose.

Brittle Materials

Do not use stress concentration factor (ignore stress raiser) if:

If material contains internal defects and inclusions (e.g. cast iron) the full value of the stress concentration factor is not needed because the specified (I.e. published) allowable strength has already taken the irregularities into account.

Do use stress concentration factor if:

If material does not contain internal defects, use the full value of the stress concentration factor.

11.4 Stress Concentration Factor for Time-Varying Loads

-- Example: repeating or cyclic loads leadingto fatigue failure

-- The stress concentration factor should **always be applied.**

-- Needs further development (notch sensitivity factor) which we will cover later.

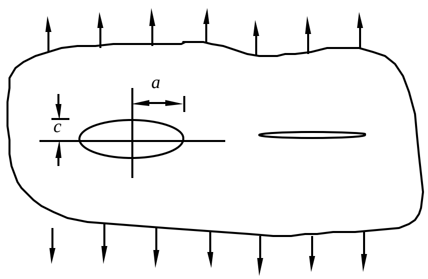
11.5 Avoiding Stress Concentrations through Design

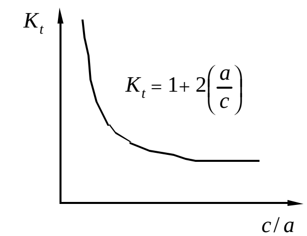
• Avoid abrupt changes in cross-section.

• Avoid sharp corners and provide the smoothest possible transitions.

11.6 Determining the Stress Concentration Factor

• Use elasticity theory (or finite element analysis)





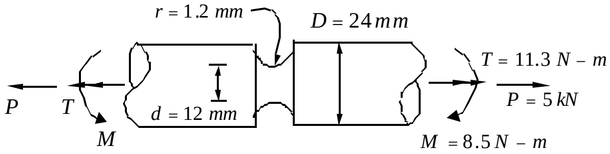
Stress concentration factor depends on:

Geometry of component

Geometry of defect

Example 11.1

Assuming that the material is not allowed to yield, determine the maximum stress that occurs in the shown element.



- Solution steps:
  (1) Brittle or ductile?
  (2) Find nominal stresses, and then apply the stress concentration factors.

(1) Although the material is ductile, we are told that yielding cannot be accepted by design, therefore the stress concentration fac tor must be applied.

(2) The nominal stresses and stress concentration factors are:

$$\frac{r}{d} = 0.1 \qquad \frac{D}{d} = 2.0$$

$$\sigma_{nom/axial} = \frac{P}{A} = 44\,MPa \qquad K_{t/axial} = 2.2$$

$$\sigma_{nom/bending} = \frac{Mc}{I} = 50\,MPa \qquad K_{t/bending} = 2.0$$

$$\tau_{nom/torsion} = \frac{Tc}{J} = 33\,MPa \qquad K_{ts/torsion} = 1.5$$

From Juvinall Fig. 4.36

The maximum stresses are:

$$\sigma_{max/axial} = K_{t/axial} * \sigma_{nom/axial} + K_{t/bending} * \sigma_{nom/bending} = 205.6\,MPa$$

$$\tau_{max/torsion} = K_{ts/torsion} * \tau_{nom/torsion} = 52.8\,MPa$$