What is "Design"?

- Act of formulating a **plan** for the satisfaction of a **specific need**
- Results in the creation of a
  - Product
  - Process
  - Strategy
  - A form (shape or geometry)
  - A game

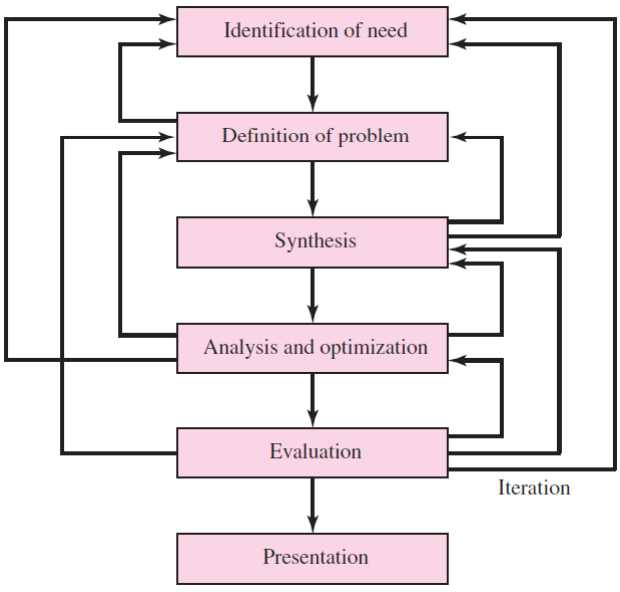
Product design

- If design leads to creation of a **product** then it should be
  - Functional
  - Safe
  - Reliable
  - Usable
  - Competitive
  - Manufacturable
  - Marketable
  - Ergonomical
- All these aspects should be therefore considered

Resources required

- Design is an **innovative** and **creative** process and involves considerable **decision making**
- Requires
  - Creativity
  - Communication skills
  - Problem solving skills
  - Analysis capabilities
  - Knowledge of first principles
- **Multi-stage process** and considerable **team work** involving experts from different disciplines

Phases in Design



Identification of need

- This step is highly related to the practical aspects and many times statements are vague
- Examples
  - Reduce vibration in an automobile
  - Reduce noise levels from the tire
  - A low cost car
  - Folding a letter for inserting in an envelope
  - Transfer a patient from operation table to stretcher with least discomfort
  - **Place a satellite in an orbit**

Definition of the problem

- More specific definition of the need is evolved through proper specifications
- Considerations
  - Input and out parameters
  - Characteristics and limitation on space, weight and cost
  - Feasibility of manufacturing
  - Available infrastructure
- Example: Weight of the satellite and orbit details

Synthesis

- Bringing out a **conceptual** design
- Different possibilities (**solutions**) are identified and explored
- These are **analyzed** at a preliminary level
- Examples:
  - A three stage versus four stage launch vehicle
  - Solid propellant or liquid propellant
  - Three cylinder versus four cylinder engine
  - Belt drive versus gear drive for speed reduction
  - Configuration: Engine in the front versus in the rear

Analysis and optimization

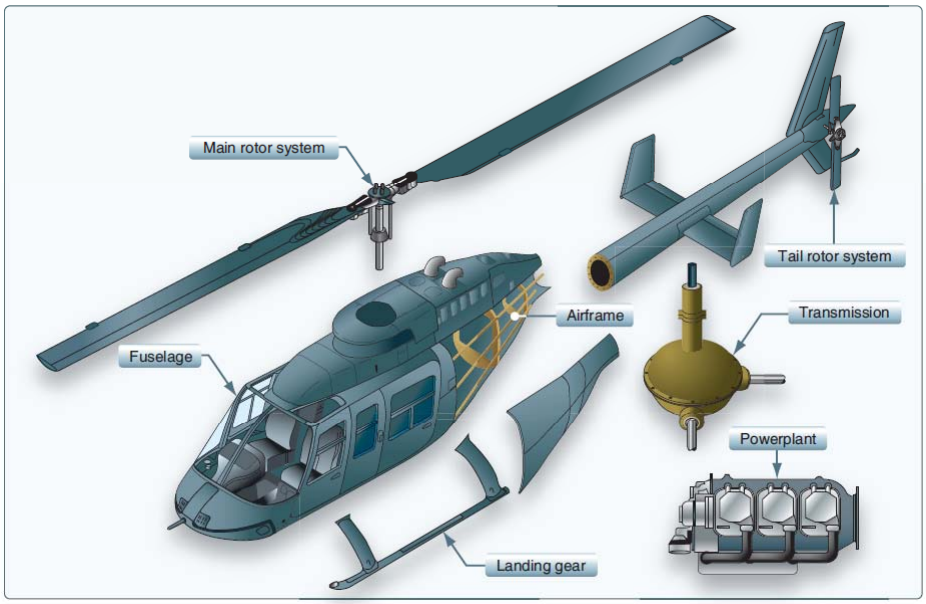
- Design of parts and components
  - Sizing of the parts so that they will not fail

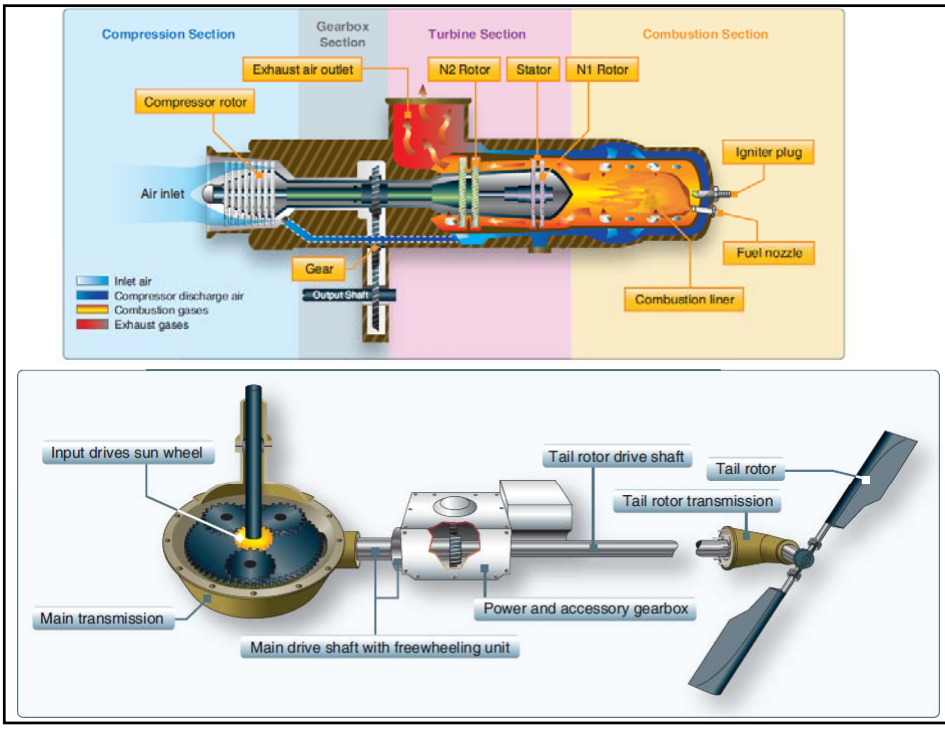
Evaluation

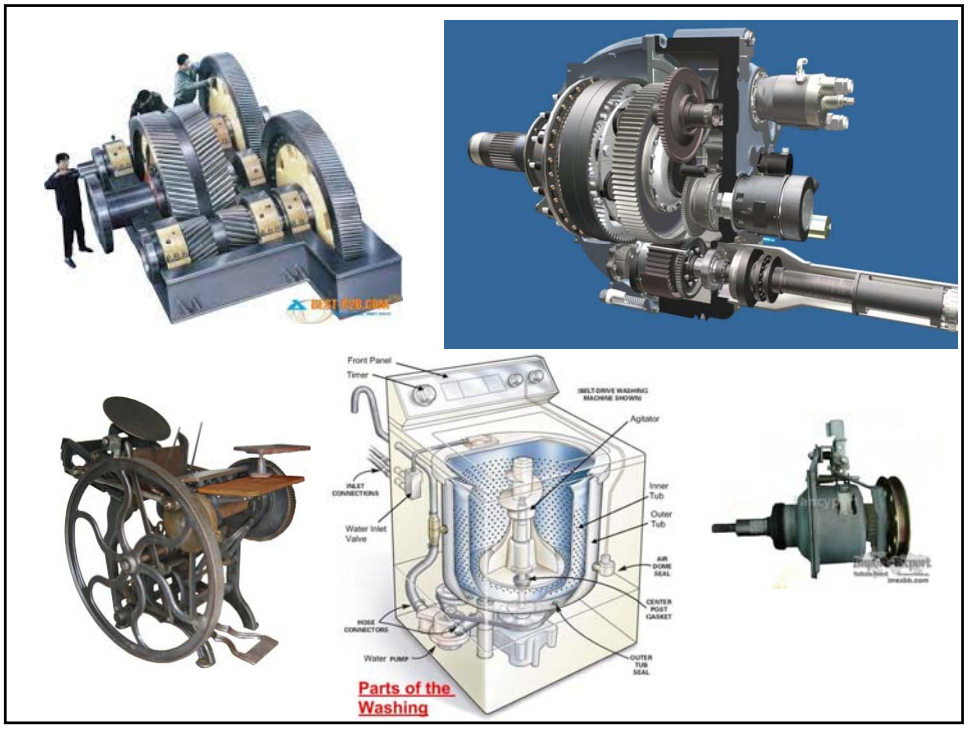
- Final proof of the successful design through
  - Testing of prototype
  - Checking the performance of the system

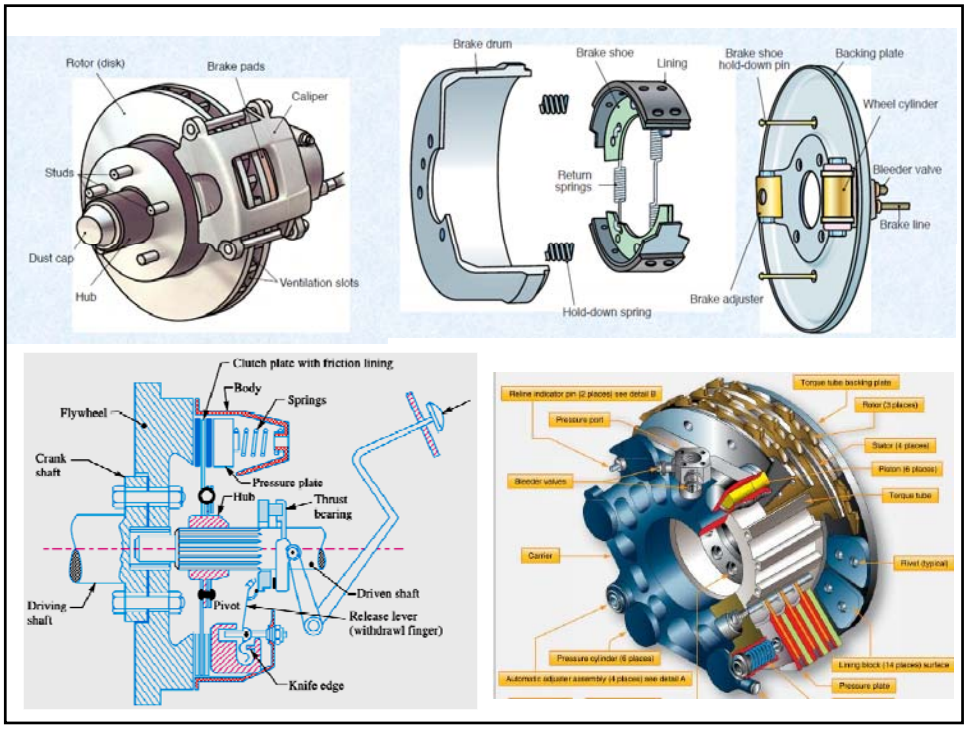
Presentation

Final step in which design is communicated to stake holders


Main rotor system
Tail rotor system
Airframe
Transmission
Fuselage
Powerplant
Landing gear


Compression Section
Gearbox Section
Turbine Section
Combustion Section
Exhaust air outlet
N2 Rotor
Stator
N1 Rotor
Compressor rotor
Igniter plug
Air inlet
Fuel nozzle
Gear
Output Shaft
Combustion liner
Inlet air
Compressor discharge air
Combustion gases
Exhaust gases
Input drives sun wheel
Tail rotor drive shaft
Tail rotor
Tail rotor transmission
Main transmission
Power and accessory gearbox
Main drive shaft with freewheeling unit


Front Panel
Timer
Agitator
Inner Tub
Outer Tub
Water Inlet Valve
Water PUMP
Parts of the Washing


Rotor (disk)
Brake pads
Caliper
Studs
Dust cap
Hub
Ventilation slots
Brake drum
Brake shoe
Lining
Return springs
Hold-down spring
Brake shoe hold-down pin
Backing plate
Wheel cylinder
Bleeder valve
Brake line
Brake adjuster
Clutch plate with friction lining
Body
Springs
Flywheel
Crank shaft
Pressure plate
Hub
Thrust bearing
Driving shaft
Pivot
Driven shaft
Release lever (withdrawl finger)
Knife edge

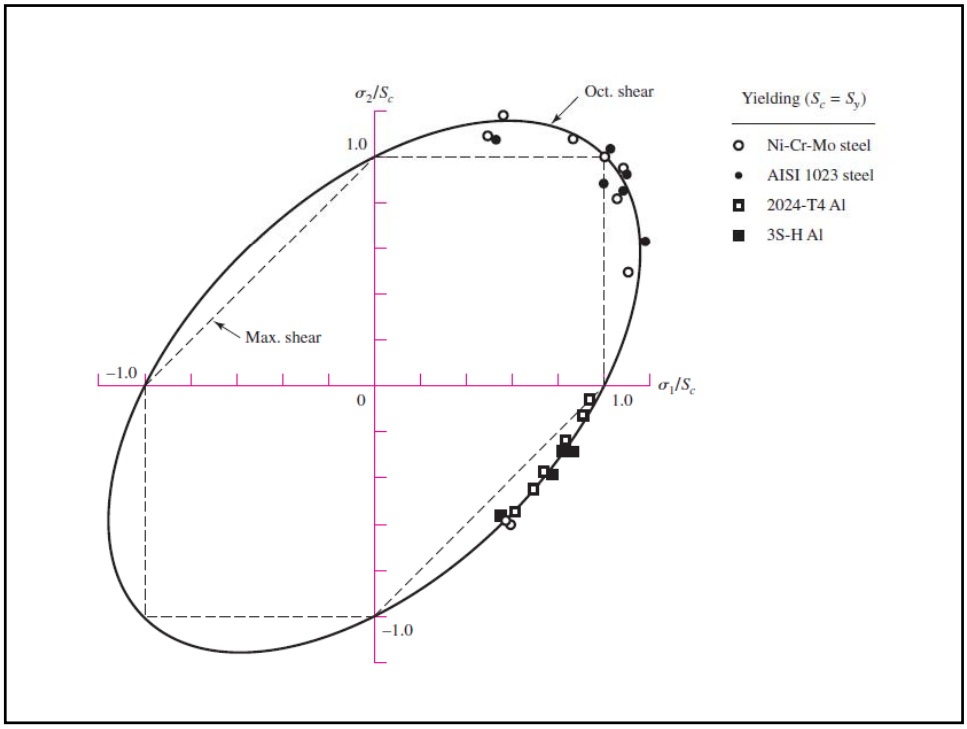
Course contents

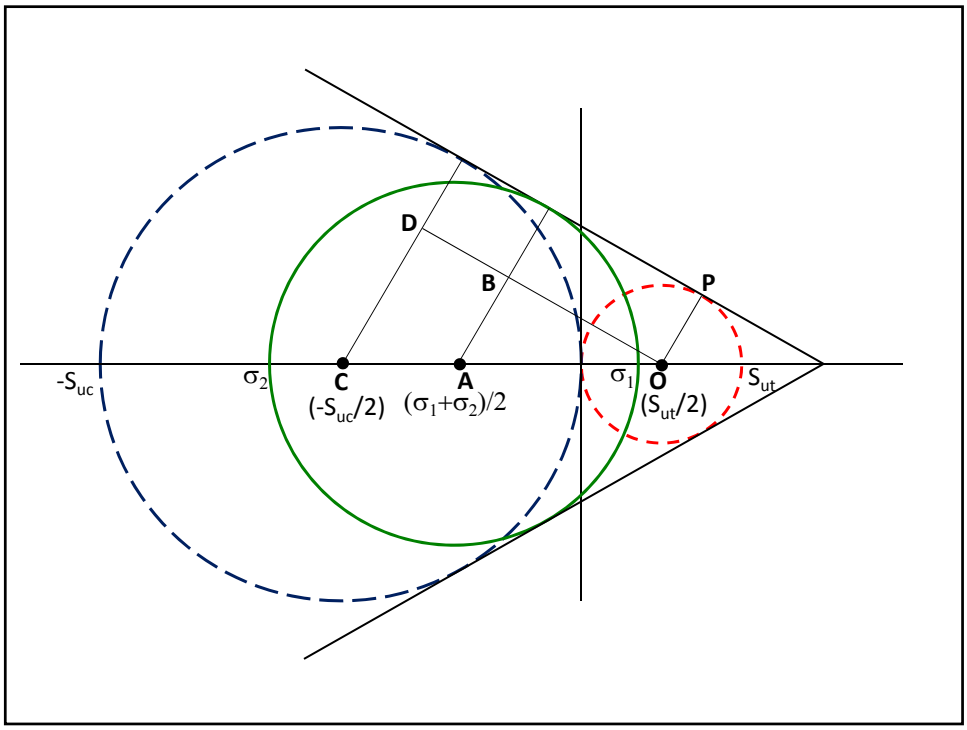
Topic
❖ Introduction to design of systems and machine elements, Modes of failure
❖ Yield criteria: Tresca, von-Mises, Mohr and modified Mohr, Stress concentration
❖ Failure by instability: Euler and Johnson Columns
❖ Fatigue failure: SN-diagram, Modification factors, Fluctuating loading, Modified Goodman, Combined loading
❖ Helical compression springs, Leaf springs
❖ Design of bolted joints and welded joints
❖ Spur and Helical gears
❖ Rolling contact bearings
❖ Shafts
❖ Probabilistic approach to design
❖ Introduction to use of techniques like FEM for design

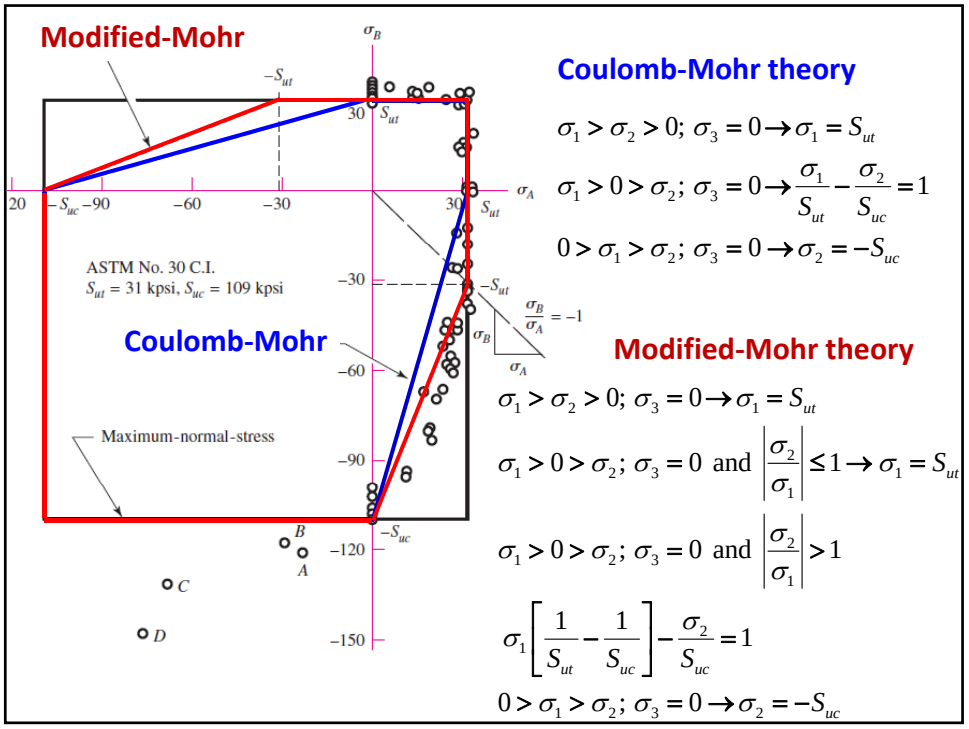
Schedule

Date	Lab/class	Topic
4-Jan	*Class*	Introduction, Bending in two planes
8-Jan	Class	Euler buckling
9-Jan	Class	Johnson buckling
11-Jan	*Class*	Failure criteria (Tresca/von-Mises)
15-Jan	Class	Failure criteria (Columb-Mhor)
16-Jan	Class	Stress concentration
18-Jan	Lab-1	Buckling + Yield criteria
22-Jan	Class	Design for Fatigue
23-Jan	Class	Design for Fatigue
25-Jan	*Class*	Design for Fatigue
29-Jan	Class	Design for Fatigue
30-Jan	Class	Design of springs
1-Feb	Lab-2	Fatigue
5-Feb	Class	Design of springs
6-Feb	Class	Design of springs
8-Feb	*Class*	Design of bolted joints
12-Feb	Class	Design of bolted joints
13-Feb	Class	Design of bolted joints
15-Feb	Lab-3	Design of springs

Date	Lab/class	Topic
5-Mar	Class	Design of bolted joints (shear)
6-Mar	Class	Design of Welded joints
8-Mar	Lab-4	Bolted Joints
12-Mar	Class	Rolling contact bearing
13-Mar	Class	Rolling contact bearing
15-Mar	*Class*	Rolling contact bearing
19-Mar	Class	Design of gears
20-Mar	Class	Design of gears
22-Mar	Lab-5	Welded Joint/Bearing selection
26-Mar	Class	Design of gears
27-Mar	Class	Design of gears
29-Mar	Lab-6	Spur Gear Design
2-Apr	Class	Brakes and clutches
3-Apr	Class	Brakes and clutches
5-Apr	Lab-7	Helical Gear Design
9-Apr	Class	Brakes and clutches
10-Apr	Class	Shaft design
12-Apr	Lab-8	Brakes and clutches
16-Apr	Class	Shaft design
17-Apr	Class	Probabilistic design
19-Apr	Lab-9	Shaft Design


σ_2/S_c
Oct. shear
Yielding ($S_c = S_y$)
Ni-Cr-Mo steel
AISI 1023 steel
2024-T4 Al
3S-H Al
1.0
Max. shear
−1.0
0
1.0
σ_1/S_c
−1.0


D
B
P
$-S_{uc}$
σ_2
C
$(-S_{uc}/2)$
A
$(\sigma_1+\sigma_2)/2$
σ_1
O
$(S_{ut}/2)$
S_{ut}



Coulomb-Mohr theory

$\sigma_1 > \sigma_2 > 0;\ \sigma_3 = 0 \rightarrow \sigma_1 = S_{ut}$

$\sigma_1 > 0 > \sigma_2;\ \sigma_3 = 0 \rightarrow \dfrac{\sigma_1}{S_{ut}} - \dfrac{\sigma_2}{S_{uc}} = 1$

$0 > \sigma_1 > \sigma_2;\ \sigma_3 = 0 \rightarrow \sigma_2 = -S_{uc}$

Modified-Mohr theory

$\sigma_1 > \sigma_2 > 0;\ \sigma_3 = 0 \rightarrow \sigma_1 = S_{ut}$

$\sigma_1 > 0 > \sigma_2;\ \sigma_3 = 0$ and $\left|\dfrac{\sigma_2}{\sigma_1}\right| \le 1 \rightarrow \sigma_1 = S_{ut}$

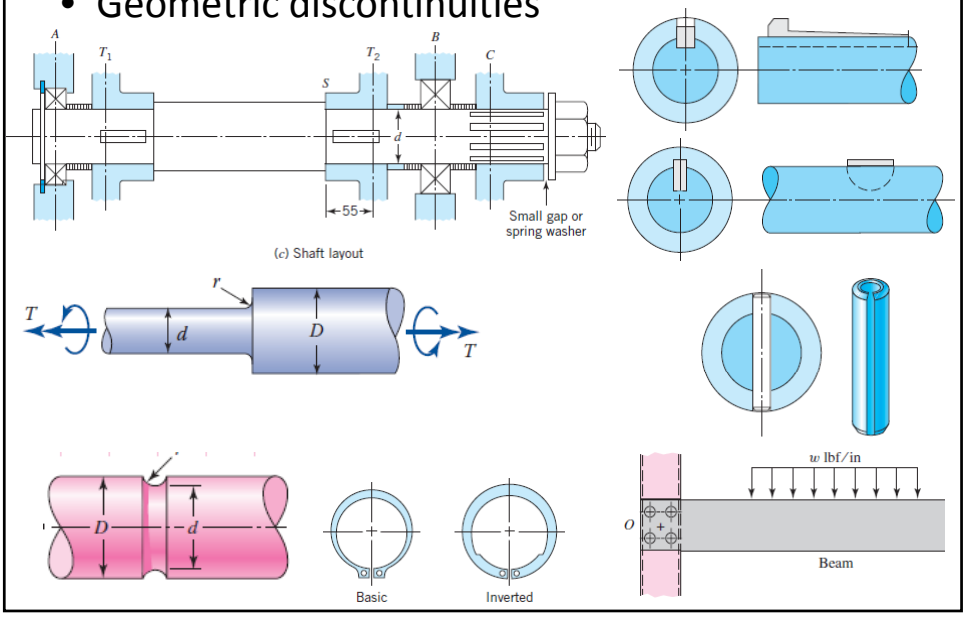
$\sigma_1 > 0 > \sigma_2;\ \sigma_3 = 0$ and $\left|\dfrac{\sigma_2}{\sigma_1}\right| > 1$

$$\sigma_1 \left[\frac{1}{S_{ut}} - \frac{1}{S_{uc}}\right] - \frac{\sigma_2}{S_{uc}} = 1$$

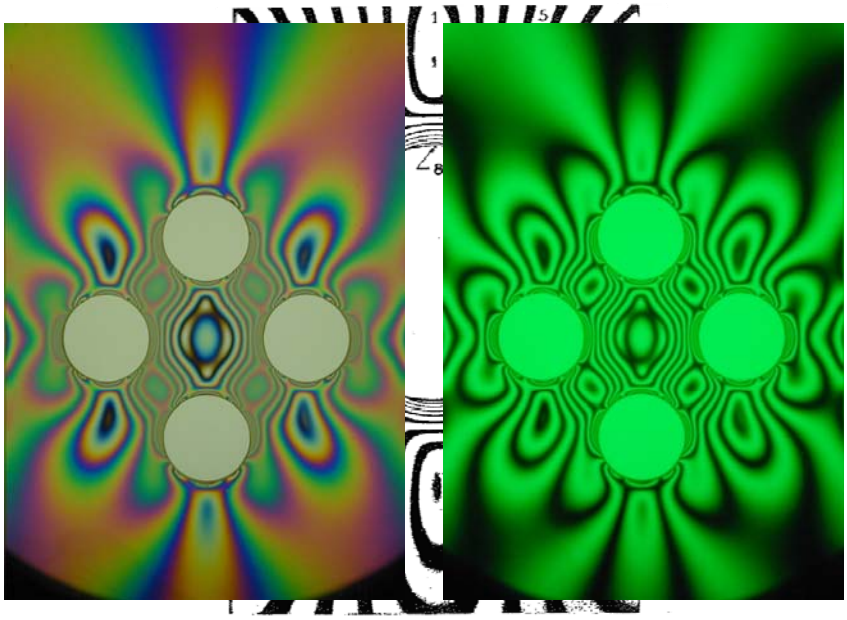
$0 > \sigma_1 > \sigma_2;\ \sigma_3 = 0 \rightarrow \sigma_2 = -S_{uc}$

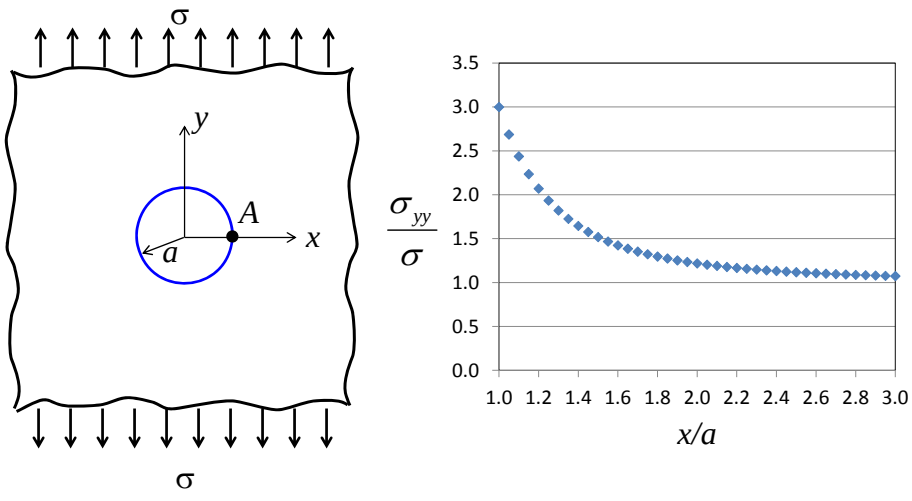
Stress concentration

- Geometric discontinuities



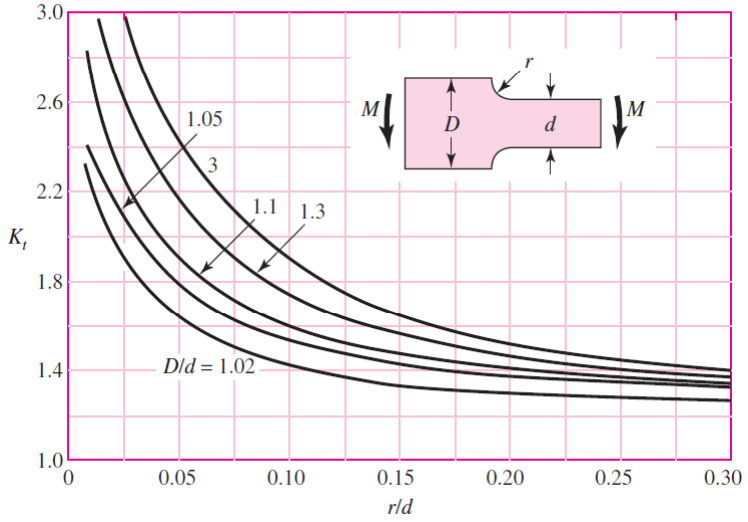
Stress concentration



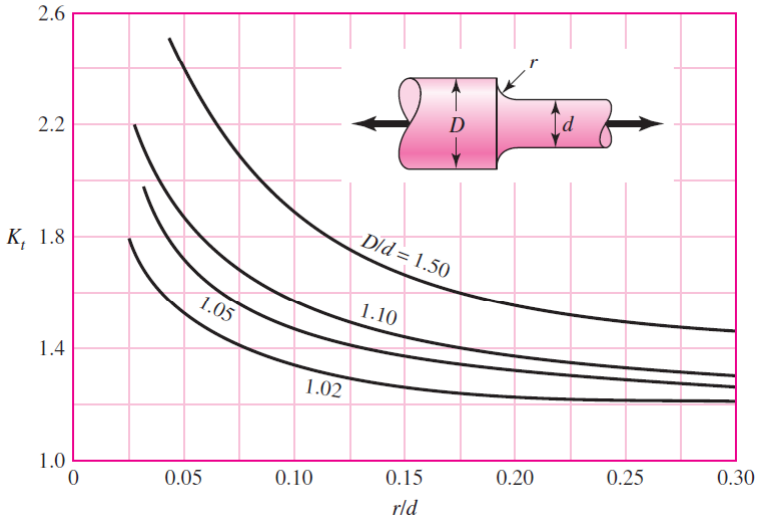


$$\frac{\sigma_{yy}}{\sigma} = \frac{1}{2}\left\{1+\frac{a^2}{x^2}\right\} + \frac{1}{2}\left\{1+3\frac{a^4}{x^4}\right\}$$

Rectangular filleted bar in bending. $\sigma_0 = Mc/I$, where $c = d/2$, $I = td^3/12$, t is the thickness.



Round shaft with shoulder fillet in tension. $\sigma_0 = F/A$, where $A = \pi d^2/4$.



Grooved round bar in bending. $\sigma_0 = Mc/I$, where $c = d/2$ and $I = \pi d^4/64$.