ME 314 - Engineering Design: Mechanical Components
Lecture 1

Note Title

1.1 Objective

ME 314 deals with the application of of mathematics, materials engineering, mechanics, and mechanics (or strength) of materials to the engineering design of mechanical components. Thermodynamics & Fluid Mechanics are also used in designing certain components.

Engineering Design refers to the process of applying appropriate techniques & scientific principles for the purpose of defining a device, a process, or a system (for satisfaction of some need) in sufficient detail to permit its realization.

Mechanical Components are machine elements.

Machine is (1) an apparatus with interrelated units, or
(2) a device that modifies force or motion.

1.2 A Design Process

1	Identification of need
2	Background research
3	Goal statement
4	Task specifications
5	Synthesis
6	Analysis
7	Selection
8	Detailed design
9	Prototyping and testing
10	Production

Table 1-1
A Design Process.

Writing this in my tabby

Reading Assignments: Remainder of Sections 1.2, 1.3-6, and 1.9

1.7 Factors of Safety & Design Codes

Based on the design considerations (strength, deformation, thermal properties, etc.), it is necessary to calculate one or more factors of safety.

Factor of Safety or Saftey Factor (SF) is typically the ratio of two quantities, e.g., strength/applied stress. SF is always unitless.

Choosing a SF is not easy but there are some guidelines mentioned in text where three factors F1, F2 and F3 are considered:

Information	Quality of Information	Factor
		F1
Material-property data available from tests	The actual material used was tested	1.3
	Representative material test data are available	2
	Fairly representative material test data are available	3
	Poorly representative material test data are available	5+
		F2
Environmental conditions in which it will be used	Are identical to material test conditions	1.3
	Essentially room-ambient environment	2
	Moderately challenging environment	3
	Extremely challenging environment	5+
		F3
Analytical models for loading and stress	Models have been tested against experiments	1.3
	Models accurately represent system	2
	Models approximately represent system	3
	Models are crude approximations	5+

Table 1-3
Factors Used to Determine a Safety Factor for Ductile Materials.

Design Code

A design code is a set of specifications for achieving a specified degree of safety & performance.

Standard

A standard which is a set of specs intended to achieve uniformity, efficiency, and quality.

Codes & Standards

Codes and standards are established by professional organizations: ASME, SAE, etc. (see text).

Classical, or Traditional, or Deterministic Approach to Design

A design based on SF is called the "classical", or "traditional", or "deterministic" approach to design.

Since nothing is absolute and there are many uncertainties in material properties, external loads, etc., we sometimes need to base the design on statistical considerations.

1.8 Statistical Considerations

This is referred to as reliability approach to design. This is much more costly than the deterministic approach because many tests are involved. We will discuss this a bit more later.

Chapter 2 - Materials & Processes

Material properties & manufacturing processes are reviewed in this chapter. You have had a good Materials Engineering Course & Lab (ME 240 & 241) so we are going to briefly go over some topics.

2.1 Material-Property Definitions

*** Material Properties are determined by tests on samples made from material of interest.**

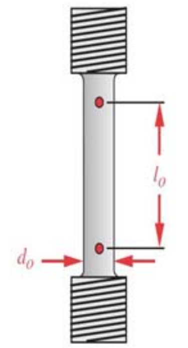
*** There are uncertainties about loading & material property so properties such as strength are treated as random variables.**

*** The American Society for Testing Materials (ASTM) defines standards for tests & material properties measurements.**

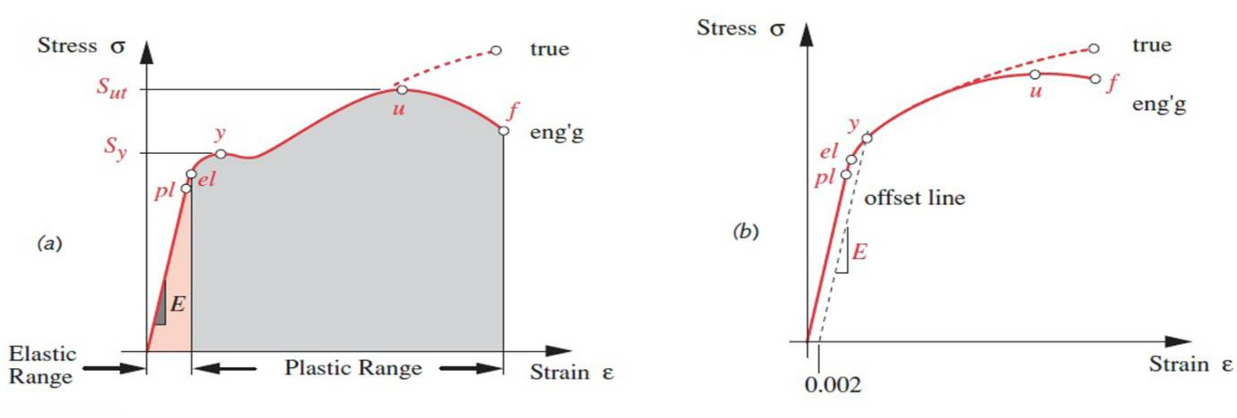
Published strength data are given as minimum values (there is a 1% chance that a sample has a strength less than the value in Tables).

The Tensile Test

The test specimen:



d_0 = 2.5 mm,6.25mm, 12.5 mm, and 0.505 in
l_0 = 10 mm, 25 mm, 50 mm, 1 in, and 2 in



For "engineering", or "nominal" stress-strain curve:

pl = Proportional Limit

From zero strain to pl, the stress-strain relationship is linear, the slope of the line is:

$$E = \sigma/\varepsilon = \text{Young's Modulus}$$

For example, for steel: E = 30 Mpsi = 30 x10^6 psi = 207 GPa

el = Elastic Limit

Beyond this point there is plastic irreversible deformation. Between pl & el we have non-linear elasticity.

y = Yield Point

Many materials undergo large strain rapidly without a corresponding increase in stress. Notice the amount of strain from ε_y to ε_f for a relatively small change in stress from S_y to S_{ut} and then S_f.

Beyond *y*, if we unload, there would be a permanent change in length. The corresponding point *a* is referred to as "permanent set". The yield point *y* is not obvious for all materials. In this case, point *a* is taken to be 0.2% or ε_a = 0.002, and then a line is drawn from *a* with a slope of E. The intersection of this line and (σ-ε) curve will determine *y*.

u = Ultimate Tensile Strength, S_{ut}

This is the maximum stress reached.

f = Fracture Point

After peak stress, S_{ut}, stress seems to fall off to a value at the fracture point *f*.

For ductile materials, the points u & f are distinct.

For brittle materials, fracture occurs while the stress is still rising so points u and f are very close and sometimes identical.

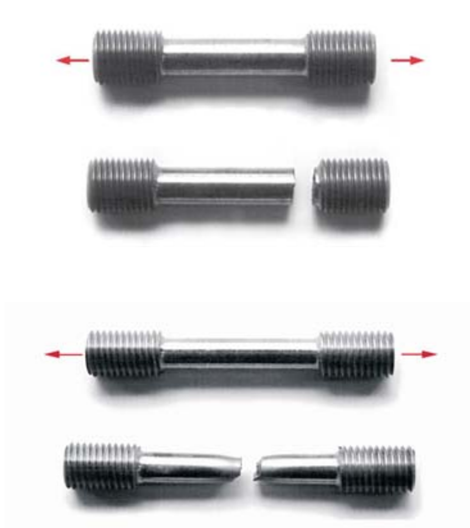


Figure 2-3
A Tensile Test Specimen of Mild, Ductile Steel Before and After Fracture.

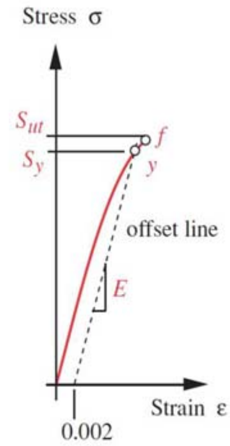


FIGURE 2-4
Stress-Strain Curve of a Brittle Material

Engineering vs True Stress-Strain Diagrams

Engineering stress and strain are not "true" values of stress and strain.

Mechanical Properties
(True Stress & True Strain)

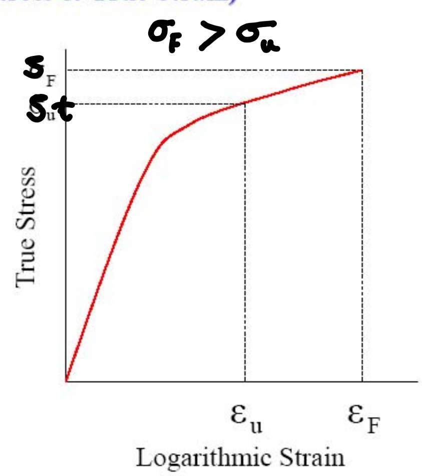
Logarithmic Strain

$$d\varepsilon = \frac{dl}{l}$$

$$\varepsilon = \int_{l_o}^{l_i} \frac{dl}{l} = \ln\frac{l_i}{l_o}$$

True Stress

$$\sigma = \frac{P}{A_i}$$



The Compression Test

If a ductile material is compressed (by running the tensile test machine in reverse) it will not fracture. It will be crushed. Most ductile materials have a stress-strain curve in compression that is similar to their tension curve. Such materials are called "even" materials. For "even" materials:

$$S_{yc} = S_{yt}$$

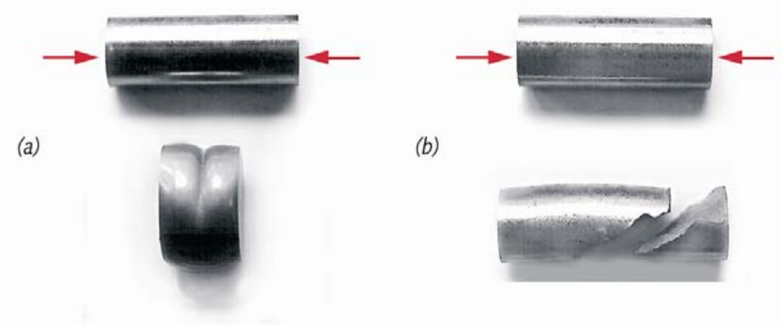


Figure 2-6
Compression Test Specimens Before and After Failure *(a)* Ductile Steel *(b)* Brittle Cast Iron.

Most brittle materials *fracture* in compression and have much greater strength in compression than in tension. Such materials are referred to as "uneven" materials. For uneven materials:

$$S_{yc} > S_{yt}$$

The Torsion Test

This is more difficult than the tensile test. The sample is as shown. It is twisted to

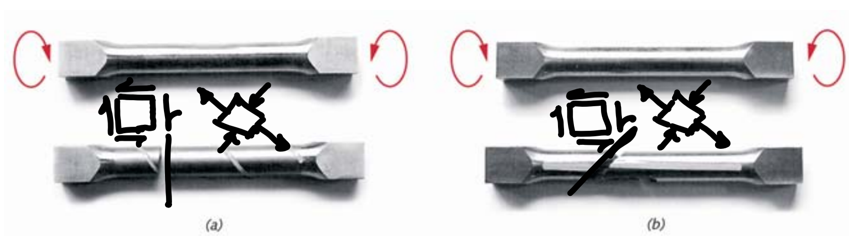
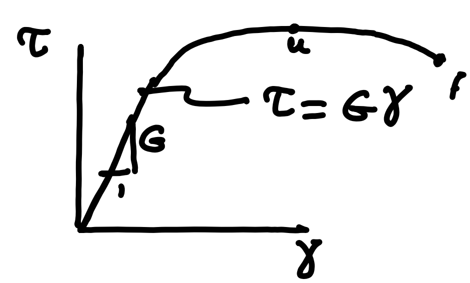


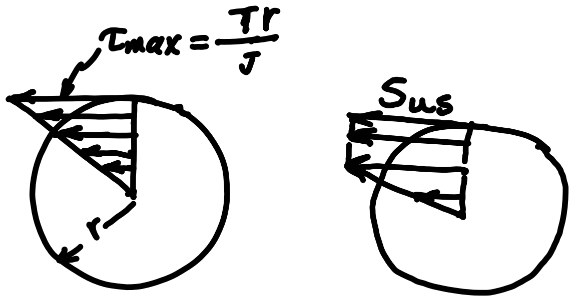
Figure 2-8
Torsion Test Specimens Before and After Failure *(a)* Ductile Steel *(b)* Brittle Cast Iron.

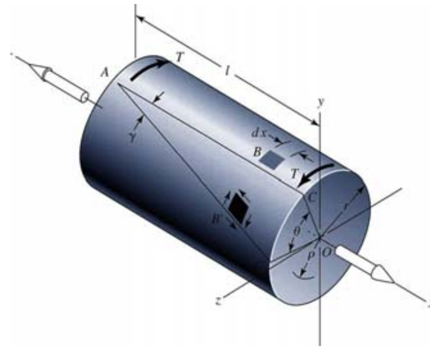
Let

τ = **Shear Stress**
γ = **Shear Strain**
G = Modulus of rigidity, or Shear modulus



G can be defined in terms of the Young 's modulus, E, and the Poisson's ratio, ν:





Other material properties representing strength:

S_{us} = Modulus of Rupture (but most refer to it as "Ultimate Shear Strength")

S_{sy} = Shear Yield Strength

If no data are available, a good approximation is obtained using tensile test data:

For steel: $S_{us} = 0.80\ S_{ut}$

For other ductile materials: $S_{us} = 0.75\ S_{ut}$ (2.5b)

For shear yield strength we will show that

$$S_{ys} = 0.577 S_y \quad (2.5c)$$

2.4 Hardness

S_{ut} of some materials, e.g., steel are highly correlated to their hardness:

$S_{ut} \approx 500\ HB \pm 30\ HB$ psi

$S_{ut} \approx 3.45\ HB \pm 0.2\ HB$ MPa (2.10)

where HB = Brinell Hardness

This is a rough (but nondestructive) estimate for low or medium strength carbon or alloy steel samples.