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DESIGN OF MACHINE MEMBERS UNDER SIMPLE STRESS

Stress

Stress is "*force per unit area*" - the ratio of applied force *F* to cross section area A- defined as "force per area".

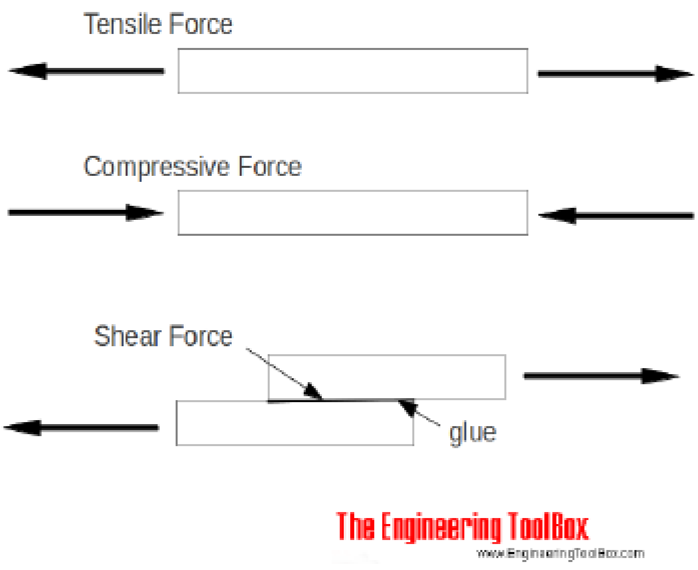
Recall the normal stresses of tension St and compression Sc

St = F/A and Sc = F/A

Tensile stress - stress that tends to stretch or lengthen the material - acts normal to the stressed area.

Compressive stress - stress that tends to compress or shorten the material - acts normal to the stressed area.

Shearing stress - stress that tends to shear the material - acts in plane to the stressed area at right-angles to compressive or tensile stress.



Simple stress: Stress is the intensity of force inside a solid. The basic unit of stress is the Pascal (Pa) which is Newton per square metre. In engineering it is more convenient to measure as the force (N) per square mm. This gives the common engineering unit of stress, MPa.

Ultimate tensile strength (UTS): Often shortened to tensile strength (TS), ultimate strength, is the capacity of a material or structure to withstand loads tending to elongate, as opposed to compressive strength, which withstands loads tending to reduce size. In other words, tensile strength resists tension (being pulled apart), whereas compressive strength resists compression (being pushed together). Ultimate tensile strength is measured by the maximum stress that a material can withstand while being stretched or pulled before breaking.

Yield strength: A yield strength or yield stress is the material property defined as the stress at which a material begins to deform plastically whereas yield point is the point where nonlinear (elastic + plastic) deformation begins. Prior to the yield point the material will deform elastically and will return to its original shape when the applied stress is removed. Once the yield point is passed, some fraction of the deformation will be permanent and non-reversible.

Factors of safety (FOS): also known as safety factor (SF), is a term describing the load carrying capacity of a system beyond the expected or actual loads. Essentially, the factor of safety is how much stronger the system is than it usually needs to be for an intended load. Safety factors are often calculated using detailed analysis because comprehensive testing is impractical on many projects, such as bridges and buildings, but the structure's ability to carry load must be determined to a reasonable accuracy.

Many systems are purposefully built much stronger than needed for normal usage to allow for emergency situations, unexpected loads, misuse, or degradation (reliability).

Structural members or machines must be designed such that the working stresses are less than the ultimate strength of the material.

$$FS = \text{Factor of safety}$$

$$FS = \frac{\sigma_u}{\sigma_{all}} = \frac{\text{ultimate stress}}{\text{allowable stress}}$$

$$\text{FS} = \frac{\textit{Loading that would cause failure}}{\textit{Actual loading on part}}$$

N.B: For the time being we shall use the design factor N or factor of safety to define a design stress Sd; thus, for the ultimate stress Su and yield stress Sy criteria, we have

$$S_d = \frac{Su}{N} \quad \text{and} \quad S_d = \frac{Sy}{N}$$

Factor of safety considerations:

• uncertainty in material properties

• uncertainty of loadings

• uncertainty of analyses

• number of loading cycles

• types of failure

• maintenance requirements and deterioration effects

• importance of member to structures integrity

• risk to life and property

• influence on machine function

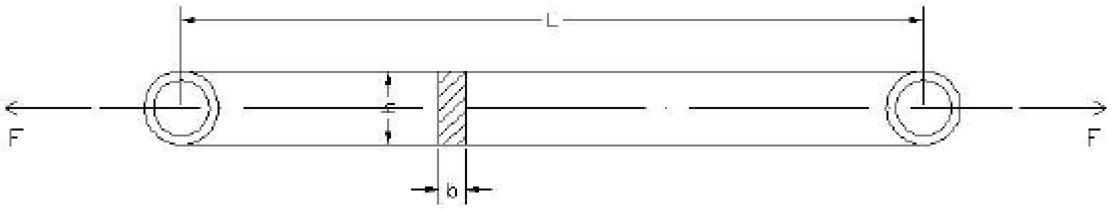
Elongation

 The action or process of lengthening something.

$$\text{Elongation, } \delta = \frac{FL}{AE}$$

Problem-1:

The link shown, made of AISI C1045 steel, as rolled, is subjected to a tensile load of 8000 lb. Let $h = 1.5b$. If the load is repeated but not reversed, determine the dimensions of the section with the design based on (a) ultimate strength, (b) yield strength. (c) If this link, which is 15 in. long., must not elongate more than 0.005 in., what should be the dimensions of the cross section?



Solution:

For AISI C1045 steel, as rolled (Table AT 7)

$s_u = 96\ ksi$

$s_y = 59\ ksi$

$E = 30\times10^6\ psi$

$$s_d = \frac{F}{A}$$

where

$F = 8000\ lb$

$A = bh$

but

$h = 1.5b$

therefore $A = 1.5b^2$

(a) Based on ultimate strength

N = factor of safety = 6 for repeated but not reversed load (Table 1.1)

$$s_d = \frac{s_u}{N} = \frac{F}{A}$$

$$\frac{96{,}000}{6} = \frac{8000}{1.5b^2}$$

$$b = 0.577 \; in \;\; \text{say} \;\; \frac{5}{8} \, in \, .$$

$$h = 1.5b = \frac{15}{16} \, in$$

(c) Elongation = $\delta = \frac{FL}{AE}$

where,

$\delta = 0.005\ in$

$F = 8000\ lb$

$E = 30\times10^{6}\ psi$

$L = 15\ in$

$A = 1.5b^{2}$

then,

$$\delta = \frac{FL}{AE}$$

$$0.005 = \frac{(8000)(15)}{(1.5b^{2})(30\times10^{6})}$$

$$b = 0.730\ in \text{ say } \frac{3}{4}\ in.$$

$$h = 1.5b = 1\frac{1}{8}\ in$$

(b) Based on yield strength

N = factor of safety = 3 for repeated but not reversed load (Table 1.1)

$$s_d = \frac{s_u}{N} = \frac{F}{A}$$

$$\frac{59{,}000}{3} = \frac{8000}{1.5b^{2}}$$

$$b = 0.521\ in \text{ say } \frac{9}{16}\ in.$$

$$h = 1.5b = \frac{27}{32}\ in$$