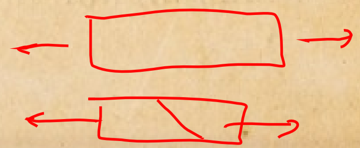
Introduction into design engineering week 11

Dr. Yukari AOKI

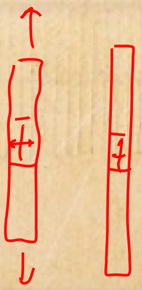
Design considerations



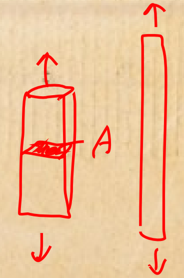
- In the preceding section learned to determine the stresses in rods, bolts, and pins under simple loading conditions.
- In engineering applications, however, the determination of stresses is seldom an end in itself.
- Rather, the knowledge of stresses is used by engineers to assist in their most important task, namely, the design of structures and machines that will safely and economically perform a specified function.

Determination of the Ultimate Strength of a Material

- An important element to be considered by a designer is how the material that has been selected will behave under a load.
- For a given material, this is determined by performing specific tests on prepared samples of the material.
- For example, a test specimen of steel may be prepared and placed in laboratory testing machine to be subjected to a known centric axial tensile force.



- As the magnitude of the force is increased, various changes in the specimen are measured, for example, changes in its length and its diameter.
- Eventually the largest force which may be applied to the specimen is reached, and the specimen either breaks or begins to carry less load.



- This largest force is called the ***ultimate load*** for the test specimen and is denoted by $\boldsymbol{P_U}$.
- Since the applied load is centric, it may be divided the ***ultimate load*** by the *original cross-sectional area* of the rod to obtain the ***ultimate normal stress*** of the material used.

$$\sigma_u = \frac{F}{A} = \frac{P_u}{A}$$

- This stress, also know as the ultimate strength in tension of the material, is

$$\sigma_U = \frac{P_U}{A} \qquad (1.23)$$

- Several test procedures are available to determine the ultimate shearing stress, or ultimate strength in shear, of a material.
- The one most commonly used involves the twisting of a circular tube.

- A most direct, if less accurate, procedure consists in clamping a rectangular or round bar in a shear tool (see in Fig.1.41) and applying an increasing load ***P*** until the ultimate load $\boldsymbol{P_U}$ for single shear is obtained.

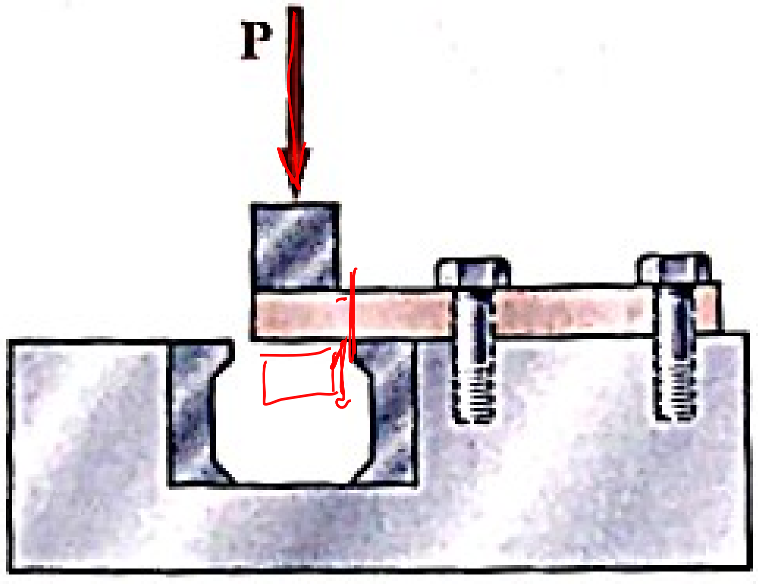
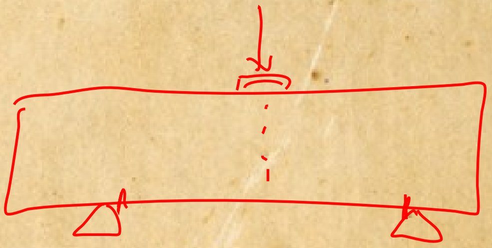


Fig. 1.41



- If the free end of the specimen rests on both of the hardened dies (see in Fig.1.42), the ultimate load for double shear is obtained.

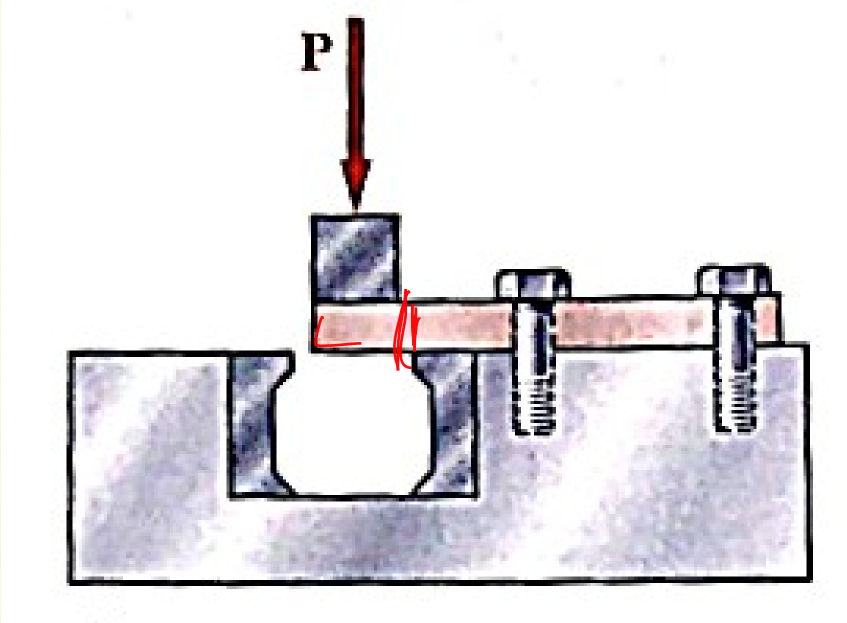


Fig. 1.41

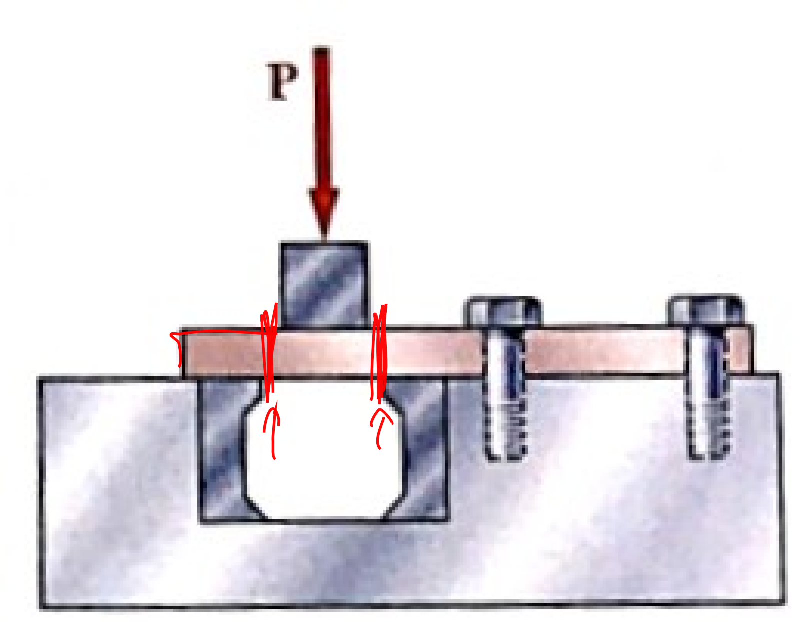


Fig. 1.42

$\sigma = \frac{F}{A}$ $\tau = \frac{F}{A}$ $\tau_u = \frac{P_u}{A}$

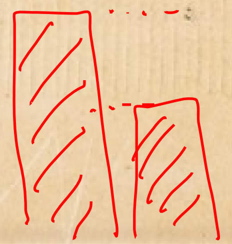
- In either case, the ***ultimate shearing stress*** τ_U is obtained by dividing the ultimate load by the total area over which shear has taken place.
- It should be recalled that, in the case of single shear, this area is the cross sectional area A of the specimen, while in double shear it is equal to twice the cross-sectional area.

$\frac{P}{2 \times A} = \frac{P/2}{A}$

Allowable load and Allowable stress; Factor of Safety.

Safety factor

- The maximum load that a structural member or a machine component will be allowed to carry under normal conditions of utilization is considerably smaller than the ultimate load.
- This smaller load is referred to as ***allowable load*** and, sometimes, as the ***working load*** or ***design load***.



- Thus, only a fraction of the ultimate-load capacity of the member is utilized when the allowable load is applied.
- The remaining portion of the load-carrying capacity of the member is kept in reserve to assure its safe performance.
- The ratio of the ultimate load to the allowable load is used to define the ***factor of safety***.

- Factor of safety is

$$Factor\ of\ safety = F.S. = \frac{ultimate\ load}{allowable\ load} \quad (1.24)$$

$\frac{500\ MPa}{200\ MPa} = 2.5$; $\frac{P_u}{P_{all}}$

- An alternative definition of the factor of safety is based on the use of stresses

$$Factor\ of\ safety = F.S. = \frac{ultimate\ stress}{allowable\ stress} \quad (1.25)$$

$\frac{\sigma_u}{\sigma_{all}}$

- Nevertheless, the ***allowable-stress method*** of design, based on the use of Eq.(1.25), is widely used.

安全率 = $\frac{\sigma_u}{\sigma_{All}}$

**In some fields of engineering, notably aeronautical engineering, the margin of safety is used in place of the factor of safety. The margin of safety is defines as the factor of safety minus one; that is,

1.5 − 1.00 = 0.5

margin of safety = F.S. - 1.00

- The two expressions given for the factor of safety in Eqs.(1.24) and (1.25) are identical when a linear relationship exists between the load and the stress.

- In most engineering applications, however, this relationship ceases to be linear as the load approaches its ultimate value, and the factor of safety obtained from Eq.(1.25) does not provide a true assessment of the safety of a given design.

Introduction into design engineering week 11

Dr. Yukari AOKI

- The two expressions given for the factor of safety in Eqs.(1.24) and (1.25) are identical when a linear relationship exists between the load and the stress.
- In most engineering applications, however, this relationship ceases to be linear as the load approaches its ultimate value, and the factor of safety obtained from Eq.(1.25) does not provide a true assessment of the safety of a given design.